TRB Standing Committees

ANB10 – Transportation Safety Management

ANB20 – Safety Data, Analysis and Evaluation

ANB25 – Highway Safety Performance

Synthesis Report on Safety-Related Papers

presented at the 98th TRB Annual Meeting

Prepared by

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TRB Standing Committee ANB10 – Transportation Safety Management

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

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

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TRB Standing Committee ANB20 – Safety Data, Analysis and Evaluation

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

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

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TRB Standing Committee ANB25 – Highway Safety Performance

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

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

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Contents

1 Introduction

This report is mainly aimed at facilitating access to Committees ANB10-ANB20-ANB25 related presentations and events at the 98th Annual TRB meeting. With this aim, papers sponsored by the Committees ANB10 – Transportation Safety Management, ANB20 – Safety Data, Analysis and Evaluation, and ANB25 – Highway Safety Performance have been split into subthemes and the abstracts reproduced. For each subtheme, a brief comment on the methodological and application perspectives of the presented papers is reported. Further, some papers sponsored by other Interacting Committees which are within the scopes of ANB10[1], ANB20[2], and ANB25[3] have been identified and classified in order to promote better interaction between ANB10, ANB20, ANB25 and these other Committees. Indeed, highway safety is a worldwide major social challenge which requires synergic research in several strategic areas and an effective cooperation between the TRB Committees is crucial to contribute to enhance roadway safety.

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

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

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

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

a) Crash Data and Data Analysis (130 papers);
b) Network Screening (9 papers);
c) Safety Performance Functions (52 papers);
d) Crash Severity Prediction (52 papers);
e) Crash Modification Factors (15 papers);
f) Surrogate Measures of Safety (35 papers); and
g) Transportation Safety Management (27 papers).

[1] The committee will be concerned with the development and coordination of integrated safety management programs to reduce death and injury on transportation systems. Areas of concern include: 1) the advancement of safety management systems, 2) research and technology to improve safety, and 3) models of safety delivery systems.
[2] This committee is concerned with the study of roadway safety. This includes the collection, maintenance and use of crash records and related roadway, road user, and vehicle data; the development of theories, analytical techniques, and evaluation methodologies for improving the understanding of roadway safety; and the application of these theories, techniques and methods to identify road user, vehicle and/or roadway-based treatments that will enhance roadway safety.
[3] This Committee deals with the advancement, integration and institutionalization of quantitative highway safety information to support transportation decision-making at all levels. The function of this committee is to foster the continual development, validation and increased knowledge of science-based methods, procedures and measures that will increase the safety of the nation's highways and roadways.

Table 1 ANB 10, ANB20, and ANB25 Committee Meetings

Time	Title	Location
Tuesday, 1:30PM – 5:30PM	Safety Data, Analysis and Evaluation Committee, ANB20	Marriott Marquis, Ballroom Salon 12 (M2)
Wednesday, 8:00AM – 12:00PM	Transportation Safety Management Committee, ANB10 https://sites.google.com/site/trbcommitteeanb10/news-events	Marriott Marquis, Ballroom Salon 12 (M2)
Wednesday, 2:30PM – 6:00PM	Highway Safety Performance Committee, ANB25	Marriott Marquis, Ballroom Salon 10 (M2)
Thursday, 8:00AM – 12:00PM	Highway Safety Performance Committee, ANB25	Marriott Marquis, Liberty JK (M4)

Table 2 ANB 10, ANB20, and ANB25 Subcommittee Meetings

Time	Title	Location
Monday, 10:15AM – 12:00PM	Roadway Safety Culture Subcommittee, ANB10(1)	Marriott Marquis, Supreme Court (M4)
Monday, 10:15AM – 12:00PM	Bicycle and Pedestrian Safety Analysis, ANB20(4), Joint Subcommittee of ANB20, ANF10, ANF20, ANB25	Marriott Marquis, Ballroom Salon 14 (M2)
Monday, 1:30PM – 3:15PM	Surrogate Measures of Safety Subcommittee, ANB20(3)	Marriott Marquis, Supreme Court (M4)
Monday, 7:30PM – 9:30PM	Intersections, (AHB65(1), Joint Subcommittee of AHB65, AFB10, AHB70, and ANB20	Marriott Marquis, Supreme Court (M4)
Monday, 3:45PM – 5:30PM	Toward Zero Deaths Goal Subcommittee, ANB10(9)	Marriott Marquis, Ballroom Salon 14 (M2)
Monday, 3:45PM – 5:30PM	Highway Safety Performance International Research Subcommittee, ANB25(5)	Marriott Marquis, Judiciary Square (M3)
Monday, 6:00PM – 7:30PM	Transportation Safety Planning Subcommittee, ANB10(3)	Marriott Marquis, Ballroom Salon 14 (M2)
Tuesday, 10:15AM – 12:00PM	Global Road Safety Subcommittee, ANB10(8)	Marriott Marquis, Supreme Court (M4)
Tuesday, 10:15AM – 12:00PM	Future Directions in Safety Analysis, ANB20(1), Joint Subcommittee of ANB20, ANB25	Marriott Marquis, Ballroom Salon 16 (M2)
Tuesday, 1:30PM – 3:15PM	Rural Road Safety Policy, Programming, and Implementation, ANB10(7), Joint Subcommittee of ANB10, AFB30, ANB20	Marriott Marquis, Ballroom Salon 4 (M2)
Tuesday, 3:45PM – 5:30PM	Highway Safety Workforce Development Subcommittee, ANB10(4)	Marriott Marquis, Ballroom Salon 10 (M2)
Tuesday, 6:00PM – 7:30PM	School Transportation Subcommittee, ANB10(6)	Marriott Marquis, Ballroom Salon 14 (M2)
Wednesday, 8:00AM – 9:45AM	Animal-Vehicle Collisions Subcommittee, ANB20(2), Joint Subcommittee of ANB20, ADC30	Marriott Marquis, Ballroom Salon 8 (M2)
Wednesday, 10:15AM – 12:00PM	Traffic Speed and Safety - Cross-cutting Issues, ANB20(5), Joint Subcommittee of ANB20, AHB65, ANB10	Marriott Marquis, Ballroom Salon 8 (M2)
Wednesday, 10:15AM – 12:00PM	Emergency Response, ABR30(1), Joint Subcommittee of ABR30, ANB10, ANB40, AHB10	Marriott Marquis, Independence C (M4)

Time	Title	Location
Wednesday, 12:15PM – 2:15PM	Highway Safety Performance User Liaison and Technology Facilitation Subcommittee, ANB25(3)	Marriott Marquis, Ballroom Salon 12 (M2)
Wednesday, 6:15PM – 7:15PM	Highway Safety Performance Policy and Legal Aspects Subcommittee, ANB25(1)	Marriott Marquis, Ballroom Salon 16 (M2)
Wednesday, 7:30PM – 9:30PM	Combined Highway Safety Performance Research Subcommittees Meeting	Marriott Marquis, Ballroom Salon 10 (M2)

Table 3 ANB 10, ANB20, and ANB25 Workshops

Time	Title	Location
Sunday, 9:00AM - 12:00PM	(1010) Enterprise GIS-T: Lessons Learned and Discussion of Noteworthy Practices in Standardization	CC, 143B
Sunday, 9:00AM - 12:00PM	(1039) From Silos to Safe Systems: An Integrated Response to the Global Road Safety Crisis	CC, 103A
Sunday, 1:30PM - 4:30PM	(1065) Planning for a Comprehensive Update of AASHTO's "A Policy on Geometric Design of Highways and Streets, 8th Edition"	CC, 208
Sunday, 1:30PM - 4:30PM	(1082) National Toward Zero Deaths Strategy: Roadmap to Implementation	CC, Salon A
Sunday, 1:30PM - 4:30PM	(1084) Uncontrolled Crosswalks: What's New, What's Needed	CC, 102B

Table 4 ANB 10, ANB20, and ANB25 Lectern Sessions

Time	Title	Location
Monday, 8:00AM – 9:45AM	(1098) Transportation Workforce Planning and Development Strategies (NCHRP Synthesis 20-05 Topic 49-10)	CC, 150B
Monday, 8:00AM – 9:45AM	(1109) Practical Applications in Rural Road Safety Research	CC, 143C
Monday, 8:00AM – 9:45AM	(1126) Safety Management Policies and Decision-Support Frameworks—Hybrid Session	CC, Salon B
Monday, 10:15AM – 12:00PM	(1173) Doctoral Student Research in Transportation Safety—Hybrid Session	CC, Salon B
Monday, 1:30PM – 3:15PM	(1274) Building Systems into a Safe System: From Theory to Practice	CC, 102B
Tuesday, 8:00AM – 9:45AM	(1412) Safety Data, Analysis, and Evaluation: Research in Four Acts	CC, 103A
Tuesday, 8:00AM – 9:45AM	(1413) Highway Safety Performance Data-Driven Analyses: When It Counts	CC, 102B
Tuesday, 8:00AM – 9:45AM	(1416) Motorcycle Crash Causation Study: Early Results and Future Directions	CC, 103B
Wednesday, 10:15AM – 12:00PM	(1735) Using the Highway Safety Manual in the Real World	CC, 102B
Wednesday, 2:30PM – 4:00PM	(1759) Emergency Response: Why Is Data a Roadblock?	CC, 152A
Thursday, 8:00AM – 12:00PM	(1788) Emergency: Saving Our Responders	CC, Salon B

Table 5 ANB 10, ANB20, and ANB25 Poster Sessions

Time	Title	Location
Monday, 8:00AM – 9:45AM	(1160) From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety	CC, Hall A
Monday, 8:00AM – 9:45AM	(1161) Applying New Data to Old Questions and Seeing Old Data in a New Light	CC, Hall A
Monday, 8:00AM – 9:45AM	(1162) Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk	CC, Hall A
Monday, 1:30PM – 3:15PM	(1306) Case Studies in Performance-Based Analysis of Geometric Design	CC, Hall A
Monday, 3:45PM – 5:30PM	(1366) Gaining Insight into Highway Safety and Risk Through Improved Methods and Models	CC, Hall A
Monday, 3:45PM – 5:30PM	(1438) Transportation Safety Management from Start to Finish	CC, Hall A
Monday, 3:45PM – 5:30PM	(1439) School Transportation Safety	CC, Hall A
Wednesday, 8:00AM – 9:45AM	(1706) Highway Safety Performance	CC, Hall A

2 Crash Data and Data Analysis

Mohamad Banihashemi, GENEX Systems

Crash Data and Data Anaysis contained many papers in wide variety of subjects in highway safety this year. Of papers submitted to the 2019 Annual Meeting, there are more than 130 papers that fit in this major category, with several sub-categories into which these papers could be split.

Pedestrians, Bicyclists, Motorcycles and School Buses Safety: There are about 25 papers related to these subjects in the Annual Meeting.

Three sessions, “School Transportation Safety” (1439), “From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety” (1160), and “Motorcycle Crash Causation Study: Early Results and Future Directions” (1416) exclusively present papers related to these subjects. Mueller, S. et al. (19-01218), C. G. Lizarazo Jimenez et al. (19-03108), and C. Morency et al. (19-04044) present their research about school bus safety in session 1439. Rahman, S. et al. (19-00055), J. Liu and S. Jones (19-00598), J. Liu et al. (19-01140), J. Wang and H. Huang (19-02726), H. Guo et al. (19-05050), Z. Chen and W. Fan (19-02356), Y. Li and W. Fan (19-02385), O. Abu Kazem et al. (19-00054), J. Liu et al. (19-01147), and R. Schneider and X. Qin (19-05271) present their research on vulnearable road users safety in session 1160. Hassan, H. et al. (19-03104), B. Wali et al. (19-05159) and (19-05185), H. Chawla et al. (19-05819), and J. Ouellet (19-05186) present their researches on motorcycle safety in session 1416.

Hagen, J evaluates the first systematic traffic calming program in a major city in US (19-03775). Doggett, S. et al. evauate the underreported pedestrian and bicyclist crashes (19-05465). Al Mahammed, F et al. (19-03034) analyse pedestrian and bicyclist crashes at the corridor level. And Goughnour, E et al. (19-04607) and R. Srinivasan et al. (19-05379) evaluate the effect of left-turn signal and pedestrian countdown signals on pedestrian safety.

Besides the above papers, Y. Wang (P19-21854) and F. Al Mahammed (P19-21856) present their doctoral research results during session 1173.

Human Factors Affecting Safety: There are 10 papers related to this sub-category. Wang, X. et al. (19-03855) and K. Tang et al. (19-05279) use naturalistic driving study data to study the risky and aggressive behavior of drivers. Zhao, S. et al. (19-02580) evaluate the effect of grouping drivers in studying crashes. Fatmi, M and M. Habib (19-03367), M. A. Rahman (19-02387), and M. Gillis et al. (19-04185) present different researches on distracted driving. Li, Y. et al. (19-00736) and Y. Wei et al. (19-00990) use trajectory data to study the safety effect of lane-changing behavior and critical decision events at mixed-flow conditions, respectively. Tavakoli, A. et al. (19-05204) study the effect of environment on emotions that affect driving.

Besides the above papers, P. Bakhit (P19-21865) presents his doctoral research results on distracting driving during session 1173.

Crash Data Collection and Sources Including SHRP 2 Data: There are 10 papers related to this sub-category. Keaus, E et al. (19-03622) use a roadway data extraction tool to produce data matching MIRE specification. Gu, X. et al. (19-00286) use aerial data to analyse crash risk at interchange merging areas. Farhan, A. et al. (19-00573) reports the results of their study on local roads crashes. Merlin, L. A. et al. (19-03017) present the effect of residential accessability on crashes. Newmark, G. et al. (19-03962) present the possibility of predicting crash severity using censor data.

SHRP2 data are used in several researches. Banihashemi, M. et al. (19-00471) use the SHRP2 RID linked with NPMRDS data to study the speed-safety relations. Kamrani, M. et al. (19-01980) and R. Arvin (19-01981) present their research on relations between speed and safety using SHRP2 NDS data. Khattak, A. et al. (19-05054) use SHRP2 NDS to study the relations between drivers violations and safety events. G. Ashley et al. (19-05934) use the SHRP2 NDS to study the effect of driver, vehicle, and road related factors on crashes.

Besides the above papers, M. Atiquzzaman (P19-21863) presents his doctoral research results on this subject during session 1173.

Calibration and Transferability of Crash Prediction Models: There are 10 papers related to this sub-category. Majority of these papers are presented in poster session 1706. These are the comparison of calibration methods for improving the transferability of safety performance functions by X. Wang et al. (19-04352), transferability of safety performance functions for freeways of the US and China by M. Feng et al. (19-04898), comparing calibration to newly developed SPFs by D. Chimba et al. (19-00228), transferability of macro-level safety performance functions of US and Italy by J. Lee et al. (19-02530), transferability of highway safety manual safety performance function for two lane highways in Brazil by K. C. Rodrigues Silva and A. C. Pinto Ferraz (19-02949), calibration of HSM freeway models for Kansas by I. Matarage and S. Dissanayake (19-02869), transferability of crash modification factors via graphical causal models by G. Davis and J. Gao (19-03007), and calibration of the HSM unsignalized intersection crash prediction models in Kansas by R. Karmacharya and S. Dissanayake (19-02897).

Besides the above papers, Parvinashtiani, N. and O. Smadi (19-03130) investigate the relationship between US road assessment program and iRAP star rating. S. Dadvar et al. (P19-21495) present an alternative method to calibrate the HSM crash prediction models.

Emergency Medical Services and Identifying Safety Hotspots: There are 5 papers related to this sub-category. Li, J. and X. Wang (19-01591) present their model for hotspot identification in meso-level. Gu, X. et al. (19-03519) use Empirical Bayes and Bayesian Hierarchial models in hotspot identification.

Session 1759 has three posters related to emergency response subject. Gallagher, P. (P19-21448) presents the impact of secondary crashes on transportation resiliency, J. Runge (P19-21449) prsents the connection of EMS data to the roadway, and P. Jodoin from FHWA (P19-21450) provides an insight of the traffic incident management in the context of EDC.

Spatial Data and Safety Analysis: There are 9 papers related to this sub-category. Rouhana, F. et al. (19-05591) present their work on geospatial statistical analysis of crashes. Bao, J. et al. (19-04439) present the use of data from several sources including GPS data to predict short-term crash risk. Bell, M. et al. (19-03053) present their effort in creating a risk map, to identify wildlife-vehicle collisions (WVCs). T. Kim et al. (19-01850) use geographically weighted structural equation modeling to study crashes. W. Chen et al. (19-02686) conducted a sensitivity analysis on bayesian semiparametric spatial crash frequency models. H. Zhou et al. (19-03389) incorporated spatial effects into temporal dynamic of traffic fatality risks study. T. Liu et al. (19-03963) use spatial and temporal correlations in support vector machine in real-time crash prediction.

Speed and Safety and Secondary Crashes: There are 9 papers related to this sub-category. Ghasemzadeh, A. and Mohamed Ahmed (19-03306) present their modeling approach to analyze speeding behavior using SHRP2 NDS data. Warner, J. et al. (19-03113) present the results of their study on relationship between traffic safety and speed limits. Z. Pu et al. (19-03134) use full bayesian models to analyze safety effects of variable speed limits. S. Stapleton et al. (19-02361) present speed-related characteristics contributing to vehicle-deer crashes.

Kitali, A. et al. (19-02583) present their approach on detecting secondary crashes. Zhang, X. et al. (19-05748) use text mining techniques to identify secondary crashes. A. Huq and P. Alluri (19-01780) make a review of secondary crash studies. A. Kittali et al. (19-02788) use penalized logistic regression model to identify secondary crash risk factors. C. Xu et al. (19-04725) use zero-inflated ordered probit regression to predict secondary crashes.

Connected and Automated Vehicles Safety: There are 7 papers related to this sub-category. Arvin, M. et al. (19-00602) present the use of connected vehicle data to study rear-end and head-on crashes. Khattak, Z. H. et al. (19-04570) present their work on studying the effect of disengagement on safety in autonomous vehicles. C. Xu et al. (19-01662) investigate the characteristics of connected and autonomous vehicle involved crashes. A. Boggs et al. (19-05567) use bayesian binary logit model to analyze automated vehicle crashes.

Besides the above papers, S. Wang (P19-21860), M. Ardiansyah (P19-20861) and M. Sharikur Rahman (P19-21862) present their doctoral research results on this subject during session 1173.

New Approaches including Crash Cost Analysis: There are 35 papers related to this sub-category. Almost half of these papers are presented in the poster session 1366. These are the appliocation of extreme value theory for before-after studies by L. Zhang and T. Sayed (19-00438), comparison of empirical bayes and propensity score methods by H. Li et al. (19-

00565), appliocation of random effects negative binomial models with clustered dataset by H. Gong et al. (19-00817), incorporating route safety in the pathfinding problem by N. Hoseinzadeh et al. (19-01433), application of correlated random parameter probit model by C. Villa et al. (19-01791), using spectral analysis in the determination of optimal segment length by X. Zhao (19-02342), using a time-series count data to model the effect of snow on daily crashes by B. Dutta Ayon et al. (19-03285), using long short-term memory recurrent neural network by J. Yuan et al. (19-03414), conducting real-time crash risk analysis by J. Yuan and M. Abdel-Aty (19-03593), evaluating Restricted Crossing U-turns (RCUT) by X. Sun et al. (19-03728), using multilayer perceptron based machine learning method by C. Li et al. (19-04002), analyzing temporal stability of factors in work-zone crashes by M. Islam and C. Lee (19-04235), analyzing displaced left turn intersections by Y. Qi et al. (19-04385), applications of measurement error correction approaches in road safety analysis by A. Musunuru and R. Porter (19-04990), comparing simulation-based multivariate model with copula-based multivariate model by T. Bhowmik et al. (19-05507), using possibility theory-based classification by S. Nazemi et al. (19-05823), and economic analysis of some crash avoidance technologies by C. D. Harper et al. (19-01100).

Wang, L. et al. (19-02313) use vehicle trajectory in real-time safety analysis. Jiang, C. et al. (19-04169) present the factors contributing in miss-and-run crashes. Ma, Y. et al. (19-01569) present their work on using traffic conflict technique and microscopic simulation in estimating crash risk. Xue, Q. et al. (19-04355) present their work on estimating rear-end crashes using rapid recognition method of driving patterns based on vehicle trajectory data. A. Theofilatos et al. (19-01388) compare machine learning and deep learning methods for real-time crash prediction. S. Katicha et al. (19-03895) use multiresolution haar wavelet method to evaluate road safety. K. Yang et al. (19-039210 use recurrent neural-networks to predict real-time crashes. N. Dutta and M. Fontaine (19-03693) use hourly flow parameters to develope freeway crash prediction models. B. Carlos et al. (19-02139) present a seasonal crash prediction model for urban intersections. B. Henderson and D. Chimba (19-00124) study the effects of traffic control type, functional class and spatial distributions on intersections safety. Y. Chen et al. (19-04098) use random-effect models to predict crashes on cross-river tunnels. K. Velez et al. (19-04991) use a methodology to identify locations of high-risk crshes in wet conditions. And, A. Hachey et al. (19-04233) evaluate the monetary benefits of safety countermeasures.

Besides the above papers, J. Wang (P19-21855) and L. Qin (P19-21864) present their doctoral research results on this subject during session 1173.

Below, for each of the 130 papers involving crash data and data analysis, the following information is provided: authors, sponsporing committee, session numer, session title, paper number, paper title, and abstract.

Authors	Jia Li, Beijing University of Technology Xuesong Wang, Tongji University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-01591
Paper Title	Hotspot Identification of Urban Arterials at the Meso Level
Abstract	Urban arterials form the main structure of street networks. They typically have high traffic volume and high crash frequency. Hotspot identification (HSID) is the first step for traffic safety management process and often utilizes crash prediction models. The classical crash prediction models investigate the relationship between arterial characteristics and traffic safety at micro level, since they treat road segments and intersections as isolated units. This micro-level analysis has limitations when examining urban arterial crashes because: 1) signal spacing is typically short for urban arterials in dense street network, and there are interactions between intersections and road segments that classical models do not accommodate; 2) in practical engineering, a hotspot consists of several adjacent intersections and road segments instead of a single intersection or road segment. Taking these into account, a meso-level unit that combined signalized intersections and their adjacent road segments as a whole was adopted. To investigate the suitable research unit and method for urban arterial HSID, this study identified hazardous micro-level (intersections or road segments) and meso-level units at the same time using crash frequency, empirical Bayesian (EB), potential for safety improvement (PSI), and full Bayesian (FB) methods. Consistency was tested to evaluate the performance of the HSID methods. The results showed that 1) meso-level units performed better than micro-level units regardless of which HSID method was adopted; 2) EB and PSI performed better than the other methods no matter for which research unit; 3) there was a big difference between the identified hazardous micro- and meso-level units.

Authors	
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-02802
Paper Title	**Assessing Collaboration Processes and Performance Outcomes: An Analysis of Regional Safety Coalitions**
Abstract	Development and implementation of a local road safety plan (LRSP) has recently been adopted as a proven safety countermeasure. Yet little knowledge exists about how to effectively engage safety-related partners in a process of collaboration and coordination that results in an implementable local road safety plan. This research investigated one state's effort to develop a regional approach to safety plan development using regional safety coalitions. Evaluating ongoing efforts to develop regional safety plans is useful because of the potential to identify risks and opportunities for the development of local road safety plans. An embedded case study of nine regional safety coalitions was used to highlight opportunities for improving the collaborative processes used to engage coalition members. A survey was developed and disseminated to coalition members to assess perceptions of the collaboration process, and to identify member perceptions of each coalition's performance. The results from this research contribute to a broader understanding of safety plan development models currently in use by highlighting a regional approach. Additionally, this research outlines a process for evaluating efforts at the regional scale that may be adapted and implemented by local partners in the development of a local road safety plan.

Authors	Amin Mohamadi Hezaveh, University of Tennessee, Knoxville Christopher Cherry, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-02874
Paper Title	**Likelihood of Involvement in Traffic Crashes: Introducing Home-Based Approach**
Abstract	It is well-known that the crash rate varies across countries, one may question that how does crash rate of individuals who lives in a certain geographic area vary within a country in a fine geographic level; to the best of authors' knowledge, no study has explored this issue. The predominant approach of road safety analysis attributes focuses on the location of traffic crashes, which makes measuring individuals' likelihood of involvement in traffic crashes (e.g., crash rate) challenging. In this study, we established Home-Based Approach (HBA) definition to complement the traditional definition of the road safety that focuses on the residential location, i.e., the expected number of crashes that road users who live in a certain geographic area have during a specified period. We use the addresses of the individual who had a direct role in traffic crashes to evaluate road safety at the zonal level. Census tract and police report crashes were used to extract the location of the traffic crashes and home-address of road users in Tennessee, and accompanying socioeconomics. Findings indicate that a mixed-effect negative binomial model was more suitable than a fixed-effect model for HBA crash frequency. Findings indicate that education, age cohorts between 16-42, and 43-60 years, share of motorized transport mode to work, portion of individuals with college-degree, and vehicles per capita have positive associations with HBA crash frequency. Instead, median household income and percent of White race have a negative association with HBA crash frequency. Findings are discussed in line with road safety countermeasures.

Authors	Amin Mohamadi Hezaveh, University of Tennessee, Knoxville Amin Mohamadi Hezaveh, University of Tennessee, Knoxville Christopher Cherry, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03258
Paper Title	**Comprehensive Cost of Traffic Crashes at Zonal Level**
Abstract	Global road safety records demonstrated the spatial variation of comprehensive cost of traffic crashes; to the best of our knowledge, no study has explored the variation of this matter at a fine geographical level. This study proposes a method to estimate the comprehensive crash cost at zonal level by using person injury cost unit. The current metric of road safety attributes safety to the location of the crash, which makes it challenging to assign the crash cost to the origin of the individuals who were involved in traffic crashes. To overcome this limitation, we introduced Home-Based Approach as the expected number of crashes by severity that road users who live in a certain geographic area have during a specified period. Home addresses of individuals who were involved in traffic crashes in Tennessee were assigned to their corresponding census tract. The average comprehensive crash cost per capita (CCCPC) at the census tract level was $11932. Poisson and Geographically Weighted Poisson Regression (GWPR) models were used to analyzing the data. The GWPR model was more appropriate compared to the global model to capture the spatial heterogeneity. Findings indicate population under 16-year-old and over 60-year-old, the proportion of residents that use non-motorized transportation, household income, population density, household size and metropolitan indicator have a negative association with CCCPC. Alternatively, VMT, vehicle per capita, percent educated over 25-year-old, the proportion of minority races and individuals who use a motorcycle have a positive association with CCCPC. Findings are discussed in line with road safety literature.

Authors	Nadia Naqvi, Loughborough University Mohammed Quddus, Loughborough University Marcus Enoch, Loughborough University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03653
Paper Title	**Do Higher Fuel Prices Help Reduce Road Traffic Accidents?**
Abstract	Road traffic accidents have decreased in most developed nations over the last decade. This has been attributed to improvement in vehicle and road design, medical technology as well as driver education and training. Recent evidence however indicates that fuel price changes have a significant impact on road traffic accidents through other mediating factors such as more fuel-efficient driving behaviours, less car travel through changing modes and speed reduction on high-speed roads. However, there is a lack of evidence to support the effects of changes in fuel prices on road traffic accidents in the UK which is the focus of this paper. For this purpose, weekly time series of fuel prices (between 2005-2015) have been used to study the effects on road traffic accidents using Prais-Winsten model of first order autoregressive (AR1) and the Box and Jenkins seasonal autoregressive integrated moving average models (SARIMA). This study is designed to quantify the effects of fuel price on road traffic accidents frequency through changes and adjustments in travel behaviour. The findings provide the evidence that the relationship between fuel prices and fatal road accident is negative, with every 1% increase in fuel price there is a 0.4% reduction in the fatal road traffic accidents frequency. However, with recent government plans to ban petrol and diesel vehicles by 2040, wiping away benefits from high fuel prices through reducing fatal accidents, to gain environmental benefits, transport policy makers need reviewing their policy to reduce road accident externality in the absence of road fuel prices.

Authors	Jonas Hagen, Columbia University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03775
Paper Title	**Humps, Circles and Chicanes: Policy Transfer of 20-MPH Zones From London to New York City**
Abstract	New York City's Neighborhood Slow Zones program, the first systematic area-wide traffic calming program in a major US city, was inspired by London's Slow Zones. However, while London's zones were associated with statistically significant reductions in traffic casualties, the zones in New York were not. In this paper, I use a policy transfer framework to determine if street design contributed to the insignificant traffic safety impacts of area-wide traffic calming in New York. I use both quantitative and qualitative data on the traffic calming devices implemented in 20-mph zones in both cities. While speed humps were the only device used to slow traffic in New York City, London's 20-mph zones used a much broader range of traffic calming devices. Further, the quantity of traffic calming devices was much higher in London. The large difference in the street designs used in 20-mph zones in each city suggests that New York's more skeletal version of area-wide traffic calming contributed to the disappointing results in that city. Barriers to a more complete transfer of street designs for 20-mph zones include the cost of, and public opposition to, more robust traffic calming measures, in addition to the emergence of other traffic safety priorities in New York. Despite the NSZ program's shortcomings, I argue that the program was a partial success.

Authors	Sarah Doggett, University of California, Berkeley David Ragland, Safe Transportation Research and Education Center Grace Felschundneff, Safe Transportation Research and Education Center
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-05465
Paper Title	**Evaluating Research on Data Linkage to Assess Underreporting of Pedestrian and Bicyclist Injury in Police Crash Data**
Abstract	Traffic safety decisions are based predominantly on information from police collision reports. However, a number of studies suggest that such reports tend to underrepresent bicycle and pedestrian collisions. Underreporting could lead to inaccurate evaluation of crash rates and may under- or overestimate the effects of road safety countermeasures. This review examined ten studies that used data linkage to explore potential underreporting of pedestrian and/or bicyclist injury in police collision reports. Due to variations in definitions of reporting level, periods of study, and study locations, it was difficult to directly compare the studies. Even among the six studies using the hospital link definition, estimates of reporting levels ranged from 44 to 75 percent for pedestrian crashes, and from 7 to 46 percent for bicycle crashes, suggesting a severe underreporting problem. However, few of the studies provided estimates of the error around their reporting level estimates, and as a result, it is difficult to determine the true level of underreporting. It may be that bicycle and pedestrian crashes appear in both police and hospital datasets but are less likely to be linked. Due to linkage error, link rate can only be used to estimate reporting level. Without the variance of that estimate, the effect of underreporting on traffic safety analyses cannot be accurately determined. Future studies should include estimates of the error present in their data linkage process for greater accuracy of the underreporting in police data. Datasets should be designed for easier linkage with hospital data and other datasets.

Authors	Francesco Rouhana, University of Notre Dame Dima Jawad, University of Notre Dame, Louaize Maya Atieh, University of Notre Dame, Louaize
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-05591
Paper Title	**GEOSPATIAL STATISTICAL ANALYSIS OF ROAD TRAFFIC ACCIDENTS AND MORTALITY**
Abstract	According to the World Health Organization, global road fatalities remain at an alarming rate of 1.25 million fatalities per year besides 50 million injuries with 90% of these fatalities happening in developing countries. Hence, road safety has moved up to the top of priorities to be tackled. Identifying high-risk road segments is one of the indispensable steps in establishing any road safety program. Operational road infrastructure interventions can be implemented to address road safety problems. These interventions aim at reducing the probability of a crash. Particular interventions can almost abolish death and serious injury while others provide more limited improvements. In this paper, an approach is put forward for identifying high-risk road segments taking into consideration the existing road crashes records in the context of developing countries where poor crash-related data can be a major impediment in developing any pressing road safety program. The proposed approach is implemented in the country of Lebanon after identifying the most critical governorate in terms of road fatalities.The available road crashes data are analyzed through detecting accident hot spots using complex spatial analysis in Geographic Information System based on statistics by Moran's I for Spatial Autocorrelation, Getis-Ord Gi* for Hot Spot, Clusters and Outliers analysis, and High/Low Clustering analysis. The main objective of hot spots and risk evaluation of road network is to distinguish high-risk road segments and aid in identifying cost-effective mitigation measures that can be implemented to enhance the safety programs in abating the index of mortality due to road accidents.

Authors	Timothy Harmon, VHB Frank Gross, VHB Geni Bahar, NAVIGATS Inc.
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-06067
Paper Title	**Crash Costs in Practice**
Abstract	Crash costs represent a monetary estimate of the impacts of highway crashes. Crash costs are used in all stages of the project development process and allow analysts to monetize changes in highway safety performance. Analysts use crash costs in estimating the return on investment for projects that affect road user safety. To assure safety analyses are accurate, crash cost values should match the units, year, and region to which they are applied. States independently select, modify, and apply their own crash costs in safety analysis. Based on a questionnaire sent to Federal Highway Administration Division Offices, states use widely varied crash costs from three major sources and apply them in different ways. For example, crash cost values applied to fatal crashes in safety analysis varied from $190,200 to $10,100,000, which reflects different cost components, estimation methods, weighting, injury scales, analysis year, and units. The questionnaire also indicated that crash costs are not always applied correctly in analysis, likely stemming from a lack of documentation on the topic. This paper examines the crash cost practices across state Departments of Transportation and formalizes calculations to adjust and transform crash costs for analysis. The methods presented in this paper can help agencies improve analysis accuracy, completeness, and consistency when applying crash costs in the safety management process. Keywords: Crash Costs, Safety Management, Economic Analysis, Safety Benefit

Authors	Niloo Parvinashtiani, Institute of Transportation Engineers Omar Smadi, Iowa State University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03130
Paper Title	**An Investigation of Relationship Between the United States Road Assessment Program Star Rating and Crash Experience**
Abstract	Over the recent decades, the International Road Assessment Program (iRAP) has been widely used as a systemic safety management tool. iRAP uses the risk-based non-crash measure of Road Protection Score (RPS) for assessing the level of safety of the roads on a 1 to 5 Star Rating scale. Given that few published studies exist in this area, one of the most significant current research needs is the validation of the relationship between the crashes and Star Ratings. Moreover, the previous validation studies have been mostly limited only to the descriptive comparison of crash rate and Star Rating averages and have failed to establish a comprehensive statistical relationship. In order to investigate such a relationship, this study develops a crash prediction model using a sample of two lane rural roads in North Carolina. The crash frequency was estimated as a function of Road Protection Score and Annual Average Daily Traffic using a negative binomial model. The results of this study showed that the crash frequency consistently increases with Road Protection Score. The developed safety performance function showed that moving from a 3-star road to a 2-star road would result in 47% more crashes. These findings confirm that Star Rating is a valid risk measure for crash frequency on two lane rural roads. Keywords: iRAP, Systemic Safety, Safety Performance Function, Validation, Data, Star Rating

Authors	Edgar Kraus, Texas A&M Transportation Institute Robert Pollack, Office of Safety Federal Highway Administration
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03622
Paper Title	**MIRE Safety Data Integration Using Roadway Data Extraction Tool**
Abstract	The Model Inventory of Roadway Elements (MIRE) is a guideline of roadway and traffic data elements developed and published by FHWA to help state and local transportation agencies with the development of a comprehensive roadway data inventory useful for safety data analysis. Beginning with MIRE 1.0, FHWA developed a subset of MIRE data elements called the fundamental data elements (MIRE FDEs) as required by MAP-21 and the FAST Act. States are required to have access to the MIRE FDEs on all public roads by September 30, 2026. This paper summarizes the results of two pilot implementation projects at the Washington State DOT and the Missouri DOT conducted by the FHWA Roadway Data Extraction Technical Assistance Program (RDETAP). The focus of the projects was the implementation of a Roadway Data Extraction (RDE) Tool to extract and integrate roadway data from existing DOT and local transportation sources. Both pilot implementation projects resulted in an improvement of each DOT's roadway dataset towards expansion of current roadway inventory databases and improving compliance with the federal FDE requirement. The paper documents how the RDE Tool was adapted to meet the needs of the agencies participating in the pilots, and summarizes several lessons learned that will be of interest to transportation agencies involved with improving roadway data inventories through data extraction, sharing, and integration.

Authors	Sven Mueller, Karlsruhe University of Applied Sciences Lucia Mejia-Dorantes, Hoschule Karlsruhe
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1439
Session Title	School Transportation Safety
Paper Number	19-01218
Paper Title	**Analysis of active school transportation in hilly urban environments: The Dresden Case Study**
Abstract	This paper analyses how students travel to school and discusses the influence of the ur-ban environment to shape their travel patterns. More specifically, it analyses how topo-graphic changes affect the likelihood to prefer cycling as modal choice. As a case study, we present the case of Dresden, an important city in Germany, which has significant topographic changes. It is an important educational and cultural pole in the country and it is known as one of the greenest cities in Germany. The results show that transport choice modelling is improved by using nested logit models. Topographic changes con-tribute to shape the transport patterns of scholars. Transport policy in the city should foster environmentally friendly transport choices for scholars and preferably active transportation, which provides the greatest benefits for the society as a whole.

Authors	Cristhian Guillermo Lizarazo Jimenez, Purdue University Thomas Hall, Purdue University Andrew Tarko, Purdue University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1439
Session Title	School Transportation Safety
Paper Number	19-03108
Paper Title	**Evaluating the Effectiveness of Safe Routes to School Interventions in Indiana**
Abstract	The Safe Routes to School (SRTS) program apportions funding for safety interventions aimed at encouraging walking and bicycling to school. Initially, the SRTS program (2006-2012) allocated over $20 million to schools throughout Indiana for infrastructure- and non-infrastructure-related safety interventions. Under the continuation of the SRTS program, many states (including Indiana) do not provide special consideration for SRTS using federally allocated funds. Nevertheless, there are provisions for non-infrastructure projects to be funded through the program. This paper examines the initial implementation of SRTS to gauge the effectiveness of infrastructure and non-infrastructure safety interventions using econometric modeling techniques. The impact of SRTS interventions on child (6-17 years) pedestrian and bicyclist crashes nearby schools was evaluated over time using a panel data structure that included SRTS and control group (no interventions) schools in Indiana. In the period before implementing the SRTS interventions, the schools selected for the program experienced higher crash frequencies than the control group, thus supporting their inclusion in the program. After the program's implementation, infrastructure interventions were found to be effective in reducing child pedestrian and bicyclist crashes, while non-infrastructure interventions showed a nonsignificant impact. Covariates such as vehicle miles travelled (VMT), school enrollment, median age of residents, median income of household head, and average annual precipitation also influenced safety in the region surrounding the studied schools. Based on the results of this study, SRTS programs including infrastructure-related safety interventions appeared to be most promising in improving safety for child pedestrians and bicyclists.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1439
Session Title	School Transportation Safety
Paper Number	19-04044
Paper Title	**Allocation of Street Space Between Road Users and the Quality of Routes to School**
Abstract	Children who walk to school in their early years have a better chance of using active transportation in their adult life. Hence, creating walkable environments around schools plays an important role in the mode choice of children. This paper uses space allocation algorithms to measure the land area allocated to each road user. The estimation is conducted for the road network of the city of Laval, a suburb of Montréal, Canada. With the help of open and government-owned datasets representing the street surfaces and roadway characteristics, a typology of urban streets is developed using the space allocation results. A focus is then set on the pedestrian itineraries to school: using a school registration database of all elementary-level students, itineraries are calculated for all home—school pairs in the study area. This allows the characterization of shortest routes to school according to the types of street segments encountered along the way. Results show that for almost 20 % of schools, itineraries are concentrated on streets with little dedicated pedestrian infrastructure. Hence, the structure of students' itineraries shows that not all paths to school can be carried out on residential streets with sidewalks, not even in the denser neighborhoods. To take the shortest path to school, students must often resort to using either multimodal arterials, which usually provide sidewalks but might end at dangerous intersections, or car-oriented streets. Further research efforts will work towards improving the detection and classification of public street space, notably by integrating information on parking spaces.

Authors	Pat Gallagher, Parsons Corporation
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Lectern Session 1759
Session Title	Emergency Response: Why Is Data a Roadblock?
Paper Number	P19-21448
Paper Title	**Impact of Secondary Crashes on Transportation Resiliency**
Abstract	No Abstract

Authors	Jeffrey Runge
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Lectern Session 1759
Session Title	Emergency Response: Why Is Data a Roadblock?
Paper Number	P19-21449
Paper Title	**Connecting EMS Data to the Roadway**
Abstract	No Abstract

Authors	Paul Jodoin, Federal Highway Administration (FHWA)
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Lectern Session 1759
Session Title	Emergency Response: Why Is Data a Roadblock?
Paper Number	P19-21450
Paper Title	**Everyday Counts in Traffic Incident Management**
Abstract	No Abstract

Authors	Md. Sharikur Rahman, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Samiul Hasan, University of Central Florida Qing Cai, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-00055
Paper Title	**Applying Data Mining Techniques to Analyze the Pedestrian and Bicycle Crashes at the Macroscopic Level**
Abstract	This paper presents different data mining techniques to analyze the vulnerable road user (i.e., pedestrian and bicycle) crashes by developing crash prediction models at macro-level. In this study, we developed data mining approach (i.e., decision tree regression (DTR) models) for both pedestrian and bicycle crash counts. To author knowledge, this is the first application of DTR models in the growing traffic safety literature at macro-level. The empirical analysis is based on the Statewide Traffic Analysis Zones (STAZ) level crash count data for both pedestrian and bicycle from the state of Florida for the year of 2010 to 2012. The model results highlight the most significant predictor variables for pedestrian and bicycle crash count in terms of three broad categories: traffic, roadway, and socio demographic characteristics. Furthermore, spatial predictor variables of neighboring STAZ were utilized along with the targeted STAZ variables in order to improve the prediction accuracy of both DTR models. The DTR model considering spatial predictor variables (spatial DTR model) were compared without considering spatial predictor variables (aspatial DTR model) and the models comparison results clearly found that spatial DTR model is superior model compared to aspatial DTR model in terms of prediction accuracy. Finally, this study contributed to the safety literature by applying three ensemble techniques (Bagging, Random Forest, and Boosting) in order to improve the prediction accuracy of weak learner (DTR models) for macro-level crash count. The model's estimation result revealed that all the ensemble technique performed better than the DTR model and the gradient boosting technique outperformed other competing ensemble technique in macro-level crash prediction model.

Authors	Jun Liu, University of Alabama Steven Jones, University of Alabama
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-00598
Paper Title	**Behavioral pathways in bicycle-motor vehicle crashes: From contributing factors, pre-crash actions, to injury severities**
Abstract	Bicyclists are more vulnerable than motorists in bicycle-motor vehicle crashes. There is a behavioral pathway, from contributing factors, pre-crash actions to injury severities, in crashes, which has been underexplored. This study performed a path analysis to uncover the behavioral pathways in bicycle-motor vehicle crashes. We build models to investigate more than 7,000 bicycle-motor vehicle crashes in North Carolina between 2007 and 2014. Pre-crash actions investigated in the study include "bicyclist failed to yield", "motorist failed to yield", "bicyclist overtaking motorist" and "motorist overtaking bicyclist". Model results show significant correlates of pre-crash actions and bicyclist injury severity. For example, young bicyclists (18 years old or younger) are more likely to fail to yield to motor traffic prior to the event of a crash than elder bicyclists. The "bicyclist failed to yield" action is associated with increased bicyclist injury severity than other actions. The path analysis highlights contributing factors related to risky pre-crash actions that lead to severe injuries. For example, intoxicated bicyclists are found to be more likely to involve the "bicyclist failed to yield" action which often results in severe injuries. The path analysis can also identify factors (e.g., intersection) that are not directly but indirectly correlated to injury severity through pre-crash actions. This study offers a methodological framework to quantify the behavioral pathways in bicycle-motor vehicle crashes. The findings are expected to be useful for bicycling safety recommendations from the perspective of bicyclist and motorist behavior, such as the educational program for students in school.

Authors	Jonas Hagen, Columbia University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-00939
Paper Title	**Not Slow Enough? Traffic Casualties and New York City's 20-Mph Zones**
Abstract	New York City's Neighborhood Slow Zones (NSZ) program was created as part of an effort to increase pedestrian safety. This paper examines whether New York City's Neighborhood Slow Zones (NSZs) are associated with reductions in traffic casualty rates for vulnerable users (pedestrians and cyclists), motor vehicle occupants, and total casualties. It employs a quasi-experimental, before/after research design with a comparison group. The paper first conducts a "simple" analysis (without controls), and then two controlled analyses that employ a difference-in-differences approach. While the simple analysis finds statistically significant reductions, the two analyses that include control zones do not find the NSZs to be associated with significant reductions in traffic casualty rates. Pedestrians and cyclists experienced the smallest reductions in casualty rates in all analyses, suggesting that the zones may be particularly ineffective for vulnerable users.

Authors	Jun Liu, University of Alabama Alexander Hainen, University of Alabama Shashi Nambisan, University of Alabama
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-01140
Paper Title	**Pedestrian injury severity in motor vehicle crashes: An integrated spatio-temporal modeling approach**
Abstract	Traffic crashes are outcomes of human activities interacting with the diverse cultural, socio-economic and geographic contexts, presenting a spatial and temporal nature. This study employs an integrated spatio-temporal modeling approach to untangle the crashed injury correlates that may vary across the space and time domain. Specifically, this study employs Geographically and Temporally Weighted Ordinal Logistic Regression (GTWOLR) to tackle the correlates of pedestrian injury severity in motor vehicle crashes. The method leverages the space- and time-referenced crash data and powerful computational tools. This study performed non-stationarity tests to verify whether the local correlates of pedestrian injury severity from GTWOLR have a significant spatio-temporal variation. Results showed that some variables passed the tests, indicating they have significantly varying relationships with pedestrian injury severity. These factors include pedestrian age, pedestrian position, crash location, motorist age and gender, DUI, motor vehicle type and the crash time in a day. The spatially and temporally varying correlates of pedestrian injury severity are valuable for researchers and practitioners who develop pedestrian safety improvement solutions. For example, results showed that DUI crashes in the city of Charlotte and Asheville are more likely to cause severe pedestrian injuries than same crashes in other areas; and DUI crashes are associated with an increasing likelihood of causing severe pedestrian injuries. Therefore, DUI may be a near-future focus for pedestrian safety improvements in North Carolina and especially for the city of Charlotte and Asheville. More implications can be drawn from the modeling results.

Authors	Jie Wang, Central South University Helai Huang, Central South University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-02726
Paper Title	**Mixed Logit Analysis of Pedestrian Red-Light Violations and Injury Severity in Pedestrian Crashes at Signalized Crossings**
Abstract	Pedestrian red-light violations at signalized crossings are an important traffic safety concern. We aimed to quantitatively investigate factors associated with pedestrian red-light violations and injury severity resulting from pedestrian–motor vehicle crashes at signalized crossings. Mixed logit models are used to account for individual-specific heterogeneity that arises from a set of unmeasured factors related to traffic conditions and the pedestrians' physical and mental status. Data for the analysis are based on the historical crash record maintained by the Hong Kong Transport Department. Children younger than 11 years are not only associated with a higher likelihood of pedestrian red-light violations but also tend to have a higher probability of fatal or serious injuries. Factors including summer, dual carriageways with a central traffic island, and pedestrian age of 12 to 25 years are solely related to a higher likelihood of pedestrian red-light violations; meanwhile, variables solely associated with a higher probability of fatal or serious injuries include crashes that occur between 22:00 and 06:59, crashes occurring in rainy weather, crashes involving pedestrians older than 46 years, and bus crashes. Based on identified statistically significant factors, appropriate countermeasures are recommended to curb pedestrian red-light violations and to reduce the severity of pedestrian crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-05050
Paper Title	**Method for Quantifying Risky Behaviors in the Context of the Road Environment: Case Study Using a Crosswalk**
Abstract	Driver related factors such as speeding and driver inattention contribute greatly to motor vehicle crashes. These risky behaviors can be identified in the context of the road environment so that countermeasures can be better tailored for the situation. In this study, we propose a method to quantify the riskiness of driver behaviors. A real-world example using crosswalk data from a naturalistic driving study, the Safety Pilot Model Deployment (SPMD), was used. The probabilities of encountering an activated Rectangular Rapid Flash Beacon (RRFB) and a pedestrian was considered in the computation of a risk rating score for each driver. The proposed model is adaptable for other risky behaviors and additional drivers as they become available.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-02356
Paper Title	**Modeling pedestrian injury severity in pedestrian-vehicle crashes in rural and urban areas: mixed logit model approach**
Abstract	Pedestrian-vehicle crashes are more likely to result in severe pedestrian incapacitating injuries and fatalities. In this study, mixed logit models are developed to investigate and identify significant contributing factors to the pedestrian injury severity in pedestrian-vehicle crashes in both rural and urban areas in North Carolina, U.S.A. Pedestrian-vehicle crash data from Highway Safety Information System (HSIS) database from 2005 to 2012 are collected and used in this study. Crash injury severities are classified into five categories: no injury (property damage only), injury class 3 (possible injury), injury class 2 (evident injury), injury class 1 (disabling injury), and fatality. The estimation results show that factors such as bad driver's physical condition, heavy trucks, dark light condition, speed limit between 35-50 mph and speed limit above 50 mph will significantly increase pedestrian injury severities in both rural and urban areas. The developed model and analysis results provide insights on developing effective countermeasures to reduce pedestrian injury severities in pedestrian-vehicle crashes and improve traffic system safety performance.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-02385
Paper Title	**Pedestrian-Injury Severities in Pedestrian-Vehicle Crashes and the Partial Proportional Odds Logit Model: Accounting for Age Difference**
Abstract	This study investigates factors that significantly contribute to the severity of pedestrian injuries resulting from pedestrian-vehicle crashes. Multinomial logit (MNL) models, mixed logit (ML) models, and ordered logit/probit models have been widely used in modelling crash injury severities, including pedestrian injury severities in pedestrian-vehicle crashes. However, both MNL and ML models treat injury severity levels as non-ordered, ignoring the inherent hierarchical nature of crash injury severities, and the data used in ordered logit models need to be strictly subjected to the proportional odds (PO) assumption. In this study, a partial proportional odds (PPO) logit model approach is employed to explore the issues of pedestrian safety associated with each age group: young (ages under 24), middle-aged (ages 25-55), and older pedestrians (ages over 55). Data used in this study are police reported pedestrian crash data collected from 2007-2014 in North Carolina. A variety of motorist, pedestrian, environmental, and roadway characteristics are inspected. Results from Likelihood Ratio tests statistically show the better performance of developing separate injury severity models for each age group compared to estimating a single model utilizing all data. Relevant parameter estimates and associated marginal effects are used to interpret the results, followed by recommendations made in the conclusion section.

Authors	Omar Abou Kasm, New York University Ziyi Ma, New York University Joseph Chow, New York University Ali Diabat, New York University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-00054
Paper Title	**Quantifying the Effect of Cyclist Behavior on Bicycle Crashes and Fatalities**
Abstract	This paper is dedicated to quantifying the effect of cyclist riding behavior in bicycle crashes, injuries and fatalities. The motivation of the paper comes from the New York City (NYC) Vision Zero program and moreover aims to fill the literature gap that misses the consideration of cyclist behavior in existing crash models. The quantification is done by the introduction of three regression models for Manhattan in NYC. The first two relate cyclist behavior to crash counts and crash rates; the third relates behavior to fatality equivalent counts. Results show that riding counter flow in a bicycle lane is the largest cause of crashes while riding in a lane other than the bike lane or the one adjacent to it is the largest cause for fatality equivalent counts. Other measures are also quantified, namely the use of helmets and area specific effects. The latter shows that crashes are more likely to happen in the area around the Central Park (Upper West and Upper East Manhattan), whereas the built environment in Midtown is very safe for bikes. Moreover, a helmet-use sensitivity analysis is presented showing that helmets can aid in decreasing fatality equivalent counts by up to 60% from current use. Finally, the use of the quantifications for severity-based fine pricing is introduced.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-01147
Paper Title	**Examining non-stationary correlates of bicyclist injury severity in traffic crashes: A spatial approach for geo-referenced crash data**
Abstract	This study employed a spatial modeling approach to uncover non-stationary correlates of bicyclist injury severity in traffic crashes. The approach is Geographically Weighted Ordinal Logistic Regression (GWOLR), extended from the regular ordered logistic regression (OLR) by incorporating the spatial perspective of traffic crashes. The GWOLR modeling approach allows the relationships between injury severity and its contributing factors vary across the spatial domain, to account for the spatial heterogeneity. This approach makes use of geo-reference data. This study explored more than 7,000 geo-referenced bicycle-motor vehicle crashes in North Carolina. Results from GWOLR show local (rather than global) relationships between contributing factors and bicyclist injury severity. This study performed a series of non-stationarity tests to identify local relationships that vary substantially across the spatial domain. Contributing factors that were identified to have a significant non-stationary relationship with bicyclist injury severity include bicyclist age, bicyclist intoxication status, bicycle direction (as relative to the traffic), bicycle position, driver age, driver intoxication status, vehicle speed, vehicle type, pre-crash action and traffic volume. Researchers and practitioners may use GWOLR to prioritize cycling safety countermeasures for specific regions. For example, GWOLR modeling estimates in the study highlighted the west part (from Charlotte to Asheville) in North Carolina for extra increased bicyclist injury severity due to the intoxication of road users including both bicyclists and drivers. Therefore, if a countermeasure is concerned with the road user intoxication, there may be a priority for the region from Charlotte to Asheville (relative to other areas in North Carolina).

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-05271
Paper Title	**How do Intersection Characteristics Relate to High Pedestrian Crash Rates? Quantifying Fundamental Relationships**
Abstract	Pedestrian safety is receiving renewed attention in the US as annual pedestrian fatalities increased by 46% in just seven years. This underscores the need for fundamental pedestrian safety research, such as understanding how a broad range of intersection characteristics relate to pedestrian crash risk. We explore this issue by analyzing 59 pairs of High-Risk Intersections and Comparison Intersections in Milwaukee, Wisconsin. We use principal component analysis to identify three main components, or groups of correlated intersection variables: “Crossing Roadway Size” (crossing roadway number of through lanes, number of left-turn lanes, presence of centerline median, and curb-to-curb crossing distance), “Mainline Roadway Size” (mainline roadway traffic volume, posted speed limit, number of through lanes, number of left-turn lanes, and curb-to-curb crossing distance), and “Intersection Complexity” (signal control, presence of a marked crosswalk on the mainline roadway, presence of a marked crosswalk on the crossing roadway, and presence of a bus stop near the intersection). Conditional logistic regression shows that that all three components have a significant positive association with the likelihood of being a High-Risk Intersection. Despite some limitations, our study addressed several shortcomings of previous research. We attempted to control for the influence of pedestrian exposure on intersection pedestrian crashes using a matched-pairs structure and conditional logistic regression analysis. We studied a wide range of intersection characteristics and addressed the challenge of highly-correlated variables using principal component analysis. This helped us provide useful information about pedestrian risk factors at urban intersections.

Authors	Xin Gu, Southeast University Mohamed Abdel-Aty, University of Central Florida Qiaojun Xiang, Southeast University Qing Cai, University of Central Florida Jinghui Yuan, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-00286
Paper Title	**Analyzing Crash Risk at Interchange Merging Areas using Aerial Data**
Abstract	The interchange merging area suffers from a high crash risk in the freeway system, which is greatly related to the intense mandatory merging maneuvers. Recently, the availability of unmanned aerial vehicles (UAV) provide an opportunity to collect individual vehicle’s data to conduct traffic analysis at the microscopic level. Hence, this paper contributes to the literature by proposing a new framework to analyze crash risk at freeway interchange merging areas considering drivers’ merging behavior. The analysis framework is conducted based on individual vehicle data from UAV videos. A multilevel random parameters logistic regression model is proposed to investigate each driver’s merging behavior in the acceleration (auxiliary) lane. The model could identify the impact of different factors related to traffic and drivers on the merging behavior. Then, the crash risk between the merging vehicle and surrounding vehicles is calculated by incorporating the time-to-collision (TTC) and the output of the estimated merging behavior’s model. The results suggest that the proposed method provides more valuable insights about the crash risk at interchange merging areas by simultaneously considering the merging behavior and the safety measure. It is concluded that the merging speed, driving ability (e.g., lane change confidence, lane-keeping instability), and the merging location can affect the crash risk. These results can help traffic engineers propose efficient countermeasures to enhance the safety of the interchange merging area. The results also have implications to the design of merging areas and the advent of connected vehicles’ technology.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-00602
Paper Title	**Instantaneous Driving Behavior at Intersections: Insights on Rear-End and Head-On Crash Frequencies Using Connected Vehicles**
Abstract	Connected and automated vehicles have enabled researchers to use big data for development of new metrics that can enhance transportation safety. Emergence of such big data coupled with computational power of modern computers have enabled us to obtain deeper understanding of instantaneous driving behavior by applying the concept of "driving volatility" to quantify variations in driving behavior. Since rear-end and head-on crashes are the most frequent and severe unsafe outcome at intersections, this paper brings in a methodology to quantify variations in vehicular movements utilizing longitudinal and lateral volatilities. More than 125 million real world Basic Safety Message data were analyzed and integrated with historical crash and road inventory data at 167 intersections in Ann Arbor, MI. To capture variations in vehicle movement, we quantified and used 24 measures of driving volatility by using speed, longitudinal and lateral acceleration. Rigorous statistical models including fixed parameter, random parameter, and geographically weighted Poisson regressions were developed. The results revealed that controlling for intersection geometry and traffic exposure, and accounting unobserved factors longitudinal volatility is highly correlated with the frequency of rear-end crashes. When it comes to head-on crashes, speed, longitudinal and lateral acceleration volatilities are highly associated with the frequency of crashes. Intersections with high lateral volatility have higher risk of head-on collisions due to risk of deviation from the centerline leading to head-on crash. The developed methodology and volatility measures can be used to proactively identify hotspot intersections where frequency of rear-end/head-on crashes is low but longitudinal/lateral driving volatility is high.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-03855
Paper Title	**Assessing the Relationship Between Self-Reported Driving Behaviors and Driver Risk Based On Naturalistic Driving Study**
Abstract	Drivers are prone to overlook their risky behaviors and bad habits during daily driving. These behaviors and habits may be associated with their risk of crash involvement. Safety countermeasures can be more effectively developed if the relationships between risky behaviors and crash risk are better understood, but the low incidence of crashes has limited the accuracy of most research. The objectives of this study are therefore: 1) to determine the extent to which driver involvement in both crashes and near crashes (CNCs) is related to driving behavior, and 2) to assess the relationship between each type of risky behavior and individual driver CNC risk. Driver and crash data were required from the Shanghai Naturalistic Driving Study (SH-NDS), and a k-mean cluster method was adopted to classify the drivers into three CNC groups (high-, moderate- and low-risk drivers). Drivers self-reported their driving behaviors and bad driving habits by completing the Manchester Driver Behavior Questionnaire (DBQ). Principal component analysis of the 24 DBQ items led to a five-component structure including aggressive violations, ordinary violations, lapses, inattention errors, and inexperience errors. Two logistic regression models were developed to investigate the correlation between the five DBQ components and drivers' CNC levels. Conclusions are as follows: 1) High-risk drivers were more likely to have inattention errors (e.g., miss "yield" rule) and ordinary violations (e.g., run a red light) than the other drivers, 2) aggressive violations (e.g., race against others) and ordinary violations were positively related to the probability of being a high- or moderate-risk driver.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-04439
Paper Title	**A Spatiotemporal Deep Learning Approach for Citywide Short-Term Crash Risk Prediction with Multi-source Data**
Abstract	The primary objective of this study is to investigate how the deep learning approach contributes to citywide short-term crash risk prediction by leveraging multi-source datasets. This study uses data collected from Manhattan in New York City to illustrate the procedure. The following multiple datasets are collected: crash data, large-scale taxi GPS data, road network attributes, land use features, population data and weather data. A spatiotemporal convolutional long short-term memory network (STCL-Net) is proposed for predicting the citywide short-term crash risk. A total of nine prediction tasks are conducted and compared, including weekly, daily and hourly models with 8×3, 15×5 and 30×10 grids, respectively. The results suggest that the prediction performance of the proposed model decreases as the spatiotemporal resolution of prediction task increases. Moreover, four commonly-used econometric models (ARIMA, Random-parameter model, Random-effects model and GWR), and four state-of-the-art machine-learning models (CNN, LSTM, ANN, and GBRT) are selected as benchmark methods to compare with the proposed STCL-Net for all the crash risk prediction tasks. The comparative analyses suggest that in general the proposed STCL-Net outperforms the benchmark methods for different crash risk prediction tasks in terms of lower MSE, MAE and MAPE. The results verify that the proposed spatiotemporal deep learning approach performs better at capturing the spatiotemporal characteristics for the citywide short-term crash risk prediction. In addition, the comparative analyses also reveal that econometric models perform better than machine-learning models in weekly crash risk prediction tasks, while they exhibit worse results than machine-learning models in daily crash risk prediction tasks. The results can potentially guide transportation safety engineers to select appropriate methods for different citywide crash risk prediction tasks.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-02580
Paper Title	**Evaluation of Not-At-Fault Assumption In Quasi-Induced Exposure Method Using Traffic Crash Data at Varied Geographical Levels**
Abstract	Acquiring real-world driver distribution data on roadways is a challenge. The quasi-induced exposure (QIE) method is a promising alternative as it only requires the available crash data. The question to be answered through this study is whether the not-at-fault driver assumption of the QIE still holds when the population is broken down to smaller geographical levels, such as counties, towns, or routes. This is important because the result will provide statistical support to choose for or against the application of QIE at disaggregate levels. In this study, the distributions of driver gender, age and vehicle type between four groups of drivers in the crash data were examined, using data obtained from the state of Connecticut from 2015 to 2017. Namely, they are the not-at-fault drivers and at-fault drivers in two-vehicle crashes (NF2 and AF2) and the not-at-fault drivers and at-fault drivers in three-or-more vehicle crashes (NF3 and AF3). Chi-square tests and Wilcoxon Mann–Whitney tests were used to provide statistical evidence of whether the driver groups come from the same population. The evidence shows that there are no statistical differences between the distributions of NF2 and NF3. The QIE assumption of not-at-fault drivers is valid at all tested geographical levels. Driver characteristic distribution in the NF2 (and NF3) groups in the crash data should be a good representation of the driving population. The results also revealed the similarities of distributions between AF2 and AF3 and the significant differences between the not-at-fault drivers (NF2 and NF3) and at-fault-drivers (AF2 and AF3).

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-02583
Paper Title	**Impact of Primary Incident Spatiotemporal Influence Thresholds on the Detection of Secondary Crashes**
Abstract	Incident management agencies are investing substantial amount of resources to devise strategies to mitigate secondary crashes (SCs). Nevertheless, detection of SCs is not a straightforward process since the definition itself is subjective; identification of SCs depends on how the impact area of the primary incident (PI) is defined. Both static and dynamic methods, the two most common approaches used to define the impact area of the PI, have serious limitations that restrict their practical applications. While the dynamic method is proven to yield accurate results, applying it requires real-time traffic data which are only available on limited locations. On the other hand, the static method's one-size-fits-all approach of using fixed spatiotemporal thresholds do not yield reliable results. This study investigated the impact of PI spatiotemporal influence thresholds on the detection of SCs. To implement the study objective, both static and dynamic approaches were developed. The static method was based on predefined spatiotemporal thresholds while the dynamic method was based on prevailing traffic speed data from BlueToad® paired devices. Comparison of SC-frequencies identified using the static and dynamic methods showed that the static method consistently under and overestimated SC-frequencies for smaller and larger spatiotemporal thresholds, respectively. The prevailing traffic conditions were found to play a crucial role in instigating SCs as more than 75 percent of SCs occurred during congested traffic conditions. Use of varying spatiotemporal thresholds depending on the prevailing traffic conditions is expected to reduce the biases associated with the subjective thresholds used in the static method.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-03367
Paper Title	**Modeling Vehicle Collision Injury Severity Involving Distracted Driving: Assessing the Effects of Land Use and Built Environment**
Abstract	This paper presents the findings of vehicle occupant injury severity model, particularly focusing on the collisions involving distracted driving. The study develops latent segmentation-based logit (LSOL) model for analyzing crash injury severity utilizing police reported collision data from 2007-2011 in Nova Scotia, Canada. A segment allocation model is estimated to capture latent heterogeneity based on individual victims and drivers' profile, and collision attributes including vehicle type, vehicle trajectory, collision object, and collision type. The segment allocation model results suggest the existence of a high-risk and a low-risk injury severity segments. This study extensively tests the effects of built environment characteristics. The model results suggest that rain, curved road, freeway, and mid-block collisions aggravate vehicle occupant injury severity; whereas, higher land use mix, longer length of sidewalk, and higher population density mitigate injury severity. Significant heterogeneity is found across the high and low-risk segments. For instance, straight road alignment is found to yield higher injury severity in the high-risk segment and lower severity in the low-risk segment. Moreover, the model unveils the interplay between built environment and distraction type. Driver distracted by communication device increases injury severity at a curved road intersection. Additionally, distraction due to inattentiveness increases injury severity. The findings of this study assist road safety engineers and planners to identify effective countermeasures and awareness programs on reducing the crash injury severity/consequence of vehicle occupants.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-00471
Paper Title	**Using Linked SHRP2 RID and NPMRDS Data to Study Speed-Safety Relationships on Urban Interstates and Major Arterials**
Abstract	Although speed is widely recognized as having serious safety impacts, these effects are complex and only partially understood. This research investigates relationships between posted and operating speed and severity of crashes on urban interstates and major arterials. Travel speeds derived from the National Performance Management Research Dataset (NPMRDS) (1) were conflated with roadway and crash data from the SHRP2 Roadway Information Database (RID) (2) for portions of Washington State. Non-congested speed was estimated from NPMRDS travel times, and relationships of crash occurrence and severity with speed differentials were investigated. Regression models were developed to estimate 85th-percentile and average speeds during non-congested periods, as a function of Posted Speed and "Weighted Average Degree of Curvature." Crash severity was represented by the ratio of fatal and injury (FI) crashes to total crashes, and the relationships of this crash severity measure with different speeds and speed differentials were examined. The results suggest that as the operating vs. posted speed differential increases, the ratio of FI crashes to total crashes decreases. While this finding appears to be counterintuitive, it can be explained as follows. The operating vs. posted speed differentials are greater on sections with lower posted speeds. Higher speeds generally result in more severe crashes; therefore, an expectation is that crashes are relatively less severe at lower speeds. Since greater speed differentials correspond to lower posted speeds, then the FI to total crash ratio could be lower on those sections compared to sections with smaller speed differentials (i.e., sections with higher posted speeds).

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-00573
Paper Title	**Collision Models of Local Roads: Impacts of Zonal Attributes and Transit Fare Sensitivity**
Abstract	The problem of collisions on local roads has received little specific attention despite the considerable number of such collisions that occur each year. This study examines collision frequency on local roads at the traffic analysis zone (TAZ) level. The City of Calgary is used as a case study, where we focus on the impacts of land use, demographic characteristics, and travel characteristics. We also investigate the effects of some key transportation planning parameters for which there have been very limited studies, including the number of personal and commercial trips and the employment numbers in various categories. This study examines the impact of the number of trips made by automobile versus more sustainable transport modes like transit, walking, and biking for personal travel. It also examines the impact of commercial truck movement on the number of collisions on local roads in a TAZ. The impact of transit-oriented development zone initiatives is explored, as is the relationship between the predominant land use type (e.g., residential, commercial, industrial) and the number of collisions on local roads. Using a Regional Transportation Model (RTM) and calibrated Crash Prediction Models (CPMs), this study uses sensitivity analysis to explore how changes in transit fares impact the collision count on local roads. Results provided some important insights for policy level implications.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-02387
Paper Title	**Prediction of Distracted Driving Crash Severity With Multinomial Logistic Regression and Data Mining Algorithm**
Abstract	While the ongoing developments of autonomous vehicles show a great promise to reduce fatalities and injuries, the full implementation will take years to become a reality. Due to the escalating usage of cell phone and social networking, distracted driving is and will remain as one of the most serious problems faced by the Departments of Transportation (DOTs) and law enforcement agencies. Although crash data is underreported and there have been many advanced and expensive technologies to identify and measure distracted driving behaviors, crash data is still an important resource for identification of factors related to distracted driving. Louisiana is one of the worst states in road safety performance in the United States while distracted driving remains a key source of road crashes. In terms of severity, three types of distracted driving related crashes are discussed — Fatal (K) and Severe (A) Injury; Moderate (B) and Complaint (C) Injury; Property-damage only (PDO). One statistical method was used for prediction — 'multinomial logistic regression'; one data mining algorithms were used — 'random forest'. Sensitivity and specificity were used to compare the predicted results. Higher speed limit, curved road, head-on crashes were identified among the key factors. Data mining algorithms performs better in prediction compared to the multinomial logistic regression. The prediction of severity models is expected to help transportation authorities and enforcement agencies to identify underlying factors behind distracted driving crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-03053
Paper Title	**Risk Mapping Wildlife-Vehicle Collisions across the State of Montana**
Abstract	Over the past few decades, road ecologists and transportation engineers have been exploring new methods to adapt to the environmental and driver safety concerns involving wildlife-vehicle collisions (WVCs). There are over one-million crashes every year in the U.S. that result in substantial property damage and personal injuries. Recent studies modeling WVCs identify clusters of points, and landscape and road characteristics that influence the likelihood of a collision occurring. This study takes a new approach to look at known and unknown influential variables on a large geographic scale, the state of Montana. The goal is to create a predictive model that will estimate the risk of a WVC as a driver travels across multiple ecosystems. This model is the base for creating a risk map to identify potential wildlife hazards for drivers and transportation agencies. A negative binomial regression was used to estimate wildlife-vehicle collisions. Models were created and simulated to test accuracy with the root mean square error. The model application was tested by running the original data through the model and transposing a color gradient onto the transportation network for Montana. The response variable was also divided into seasons to see if this method of modeling can detect seasonal changes in collision risk. There is high potential for the use of this type of modeling in assisting in creating innovative warning systems and future mitigating infrastructure.

Authors	Ali Ghasemzadeh, University of Wyoming Mohamed Ahmed, University of Wyoming
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-03306
Paper Title	**A Multi-Level Modeling Approach to Analyze Driver Speeding Behavior Considering Regional Heterogeneity Using Trajectory-Level SHRP2 Naturalistic Driving Data**
Abstract	Driver-behavioral factors, specifically speeding behavior, which is a critical aspect of traffic safety, have received less attention in case of analyzing the impact of local characteristics on driver-behavioral choices that might increase the risk of crashes. In recent years, evolving data from the connected and automated vehicles as well as similar second-by-second trajectory level data from naturalistic driving studies worldwide, considering the impact of local characteristics on various driver behaviors is even more important. In fact, neglecting mentioned impact might lead to erroneous inferences due to the disparities in socioeconomic characteristics in different regions. Therefore, this paper, for the first time, utilized multilevel logistic regression modeling approach to evaluate the effect of driver's locality-related factors on driver speeding behavior using naturalistic driving data collected from the SHRP2 project in six US states. The methodology and the results from this study can pave the road for future human factor studies utilizing trajectory-level data from different geographical locations to reduce the heterogeneity and increase the transferability of the results without introducing a bias in inferences.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-04185
Paper Title	**Exploration of the concordance between state-reported estimates and actual driving behavior of drivers in the city of Riverside**
Abstract	ABSTRACT With the introduction of new technology and increased dependence on cell phones, distracted driving has become a serious threat to public health. The purpose of this study was to observe driving behaviors in the city of Riverside, California. Driving behaviors were obtained by recording individuals driving in the City of Riverside, California. This data was then compared to data collected by the California Office of Traffic Safety (COTS). This research serves to either validate or challenge the COTS data, and shed light on driving behaviors as observed in motion compared with driving behaviors observed at traffic signals. Hypotheses: State reported data on cellphone use while driving does not accurately depict behavior. Females were more likely to use their cellphone while driving, when compared to males. Methods: A camera mounted to an SUV was used to record video on driver behaviors. Vehicles were observed for distracted driving behaviors: holding phone to ear with hand, talking on headset or bluetooth, manipulating hand-held device, or talking on a handheld device. Results: A Chi-Square Goodness of Fit test of was used to analyze the observational data on distracted driving and found no significant difference between observational data and COTS percentage of distracted driving. A Chi-Square test of independnce was used to analyze gender differences in distracted driving and no significant difference was found. A Chi-Square test of independence was conducted to analyze distracted driving while in motion and stationary and found a significant difference. Keywords: Distracted Driving, Motor Vehicles, Behavioral Research

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-05748
Paper Title	**Identifying Secondary Crashes Using Text Mining Techniques**
Abstract	Reducing secondary crashes has been a priority for many transportation agencies. However, it has been a challenging task to collect accurate secondary crash data. To assist this effort, a text mining approach is proposed to extract and analyze crash narratives and identify secondary crashes. Due to the unstructured nature of text narratives, they are first transformed into numeric vectors suitable for machine learning algorithms following a four-step process. Four classification models including Logistic Regression, Random Forest, Naïve Bayes, and Support Vector Machine are developed with transformed vectors. The performance of four models are evaluated and compared, and it is determined that Logistic regression outperforms other models in terms of overall classification accuracy and F1 score. The effect of tokenization is also evaluated. The results show that the uni-gram scheme provides comparative performance compared to more complicated schemes and is suggested for future implementation. Detailed investigation is performed on the classification results. It is found that the model is very effective in identifying key words that characterize secondary crashes. The model performance can also be influenced by other less frequent words unrelated to secondary crashes. It is recommended to include more narratives in the analysis to mitigate the issue. Additionally, subjectivity in reviewer's interpretation and potential mislabeling also contribute to some false classifications. Overall, the text mining approach provides satisfactory performance and shows great potential for the task of secondary crash identification.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-03017
Paper Title	**Residential Accessibility's Relationships with Crash Rates per Capita**
Abstract	This paper examines the relationship between residential accessibility, i.e. accessibility at a person's home address, and their likelihood of being in a crash over a three-year period. Two relationships with accessibility are explored. The first relationship is that persons who live in high destination accessibility areas may drive less and therefore are less likely to be in vehicular crashes where they are driving. The second relationship is that persons who live in high population accessibility areas may be exposed to higher levels of traffic in their regular activity space. Examining traffic analysis zones in Knoxville, TN, this paper finds some evidence for each of these theoretical effects. These oppositely directed effects have dominant influence within different travel time thresholds. The first relationship between destination accessibility and fewer crashes is found for 10-minute auto accessibility, whereas the second relationship between population accessibility and more crashes is found to be strongest for 30-minute auto accessibility.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-00736
Paper Title	**Evaluating the Rear-end Collision Risks of Mandatory Lane-Changing Behaviors Using Trajectory Data**
Abstract	Mandatory lane-changing behaviors increase crash risks significantly. Particularly in a weaving section of highways, vehicles driving into and out the main lane have to search for acceptable gaps and perform lane-changing maneuvers, resulting in high risks of crash occurring. This study aimed to evaluate the rear-end collision risks of two type of mandatory lane-changing behaviors using trajectory data. The two type of lane-changing behaviors were first introduced. Then, a dataset from NGSIM project was used to extract trajectory data. A risk evaluation algorithm was developed based on a novel crash risk index (CRI) to collect lane-changing vehicles' trajectory and quantify rear-end collision risks. Statistics of the key variables were compared and two logistic regression models were developed and specified to investigate impacts of various factors. The Results indicate that for both driving into and out highway situations, the following vehicle on the target lane has significant impacts on collision risks. However, the front vehicle has more influence on crash risks when the subject vehicle drives into the main lane. The leading vehicle has remarkable effects when the subject vehicle exit off the highway. The speed differences between the subject lane-changing vehicle and surrounding vehicles are the dominating factor affecting the rear-end collision risks. Results of logistic regression models demonstrate the validation of the proposed risk evaluation algorithm. Findings of this study provide useful information for lateral control strategy designs of CAVs in the future.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-00990
Paper Title	**Trajectory-based Identification of Critical Instantaneous Decision Events at Mixed-Flow Signalized Intersections**
Abstract	Mixed-flow intersections are prevailing in many developing countries such as China and India. At mixed-flow intersections, there is no clear lane discipline or regular trajectories within the intersection, especially for the non-motorized traffic. This leads to more interactions and encounters between the motorized traffic and the non-motorized traffic. Hence, critical instantaneous decision events, such as abrupt accelerating, decelerating, jerking, swerving, and swinging, may occur more frequently, resulting in traffic conflicts and crashes. This study presents a methodology based on the entropy theory and vehicle trajectory data to identify critical instantaneous decision events at the mixed-flow signalized intersections. A three-dimensional cube searching algorithm is firstly proposed to extract general events by examining the proximity between trajectories. A novel model incorporating Vehicle Kinematics and Permutation Entropy is then developed to identify critical events by quantifying driving volatility based on the time-serial trajectory data. Next, 1,205 vehicle trajectories and 384 bicycle trajectories with a resolution of 0.12 s are collected at a signalized intersection in Shanghai and used to demonstrate the proposed method. Results show that the proposed method is capable of identifying all the critical instantaneous decision events and tends to produce a higher identification ratio compared with the conventional method solely using kinematic thresholds. A sensitivity analysis is also conducted to investigate the effects of model parameters on the performance of the proposed model. This work could be applied for traffic safety assessment, real-time driving alert systems, and early diagnosis of risk-prone road users at mixed-flow intersections.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-01980
Paper Title	**The Role of Aggressive Driving and Speeding in Road Safety: Insights from SHRP2 Naturalistic Driving Study Data**
Abstract	By harnessing the rich information available from naturalistic driving study data, this paper studies the impact of detailed driving behavior and recently developed measures of driving volatility on crash and near-crash risks. Building on previous efforts in developing of driving volatility measures, highly correlated measures with crash risk are identified and then driving behaviors contributing to driving volatilities and crash risk are explored. The paper incorporates driver, vehicle and infrastructure data collected in a naturalistic setting into the analysis along with studying the near-crash risks. In particular, both direct and indirect effects (through driving volatility) of aggressive driving and speeding on crash and near-crash risks are investigated through structural equation modeling (SEM). According to the results, aggressive driving is associated with increased risk of near-crash and crashes by 35% and 6% respectively. Speeding also was found to be correlated to increased chance of near-crash and crash events by 16% and 9% respectively. The findings are beneficial in two ways. First, they are helpful in identifying dangerous driving behaviors in order to reduce crash risk directly by avoiding them. Second, avoiding such behaviors will lead to reduced driving volatility which in turn, is effective in crash risk reduction.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-01981
Paper Title	**Examining the Role of Speed and Driving Stability on Crash Severity Using SHRP2 Naturalistic Driving Study Data**
Abstract	While the cost of crashes nears $1 Trillion a year in the U.S., the availability of high-resolution naturalistic driving data provides an opportunity for researchers to conduct in-depth analysis of crash contributing factors, and design appropriate interventions. The SHRP2 Naturalistic Driving Study (NDS) is a unique dataset that allows new insights due to detailed information on driver behavior in normal pre-crash and near crash situations, in addition to trip characteristics, and vehicle performance characteristics. NDS data are used to investigate not only the vehicle movements in space but also the speed and stability of vehicles prior to crash and their contribution to severity using path analysis. A subset of the data containing 617 crash events with around 180,000 temporal trajectory data are analyzed. To quantify driving stability, microscopic variations or volatility in vehicular movements before a crash is analyzed. Specifically, nine measures of pre-crash driving volatility are calculated and used to explain crash severity. While most of the measures are significantly correlated with severity, substantial positive correlations are observed for two measures representing speed and deceleration volatilities. Additionally, the average speed prior to a crash is highly correlated with severity outcomes, as expected. Interestingly, distracted and aggressive driving are highly correlated with driving volatility, and have substantial indirect effects on crash severity. With volatile driving serving as a leading indicator of crash severity, given the crashes analyzed in this study, early warnings and alerts for the subject vehicle driver and proximate vehicles can be helpful when volatile behavior is observed.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-02313
Paper Title	**Vehicle-Trajectory-based Real-time Safety Analysis**
Abstract	There have been plenty of segment-based real-time safety, in which it is considered that the occurrence of a crash is because of segment conditions, including traffic, geometric, and weather. However, the moving of a vehicle is continuously from upstream to downstream. Thus, the crash occurrence of a vehicle might also because the traffic conditions along its trajectory. Under this idea, the study about the vehicle-trajectory-based real-time safety is proposed. To find vehicles' trajectories, the exact crash time was identified by observing significant speed drops, and the vehicle trajectory was distinguished by using the data from HERE. The traffic information along with the trajectories is from Microwave Vehicle Detection System. A Bayesian matched-case-control logistic regression model was built to explore the impacts of traffic parameters along the vehicle trajectory on real-time crash risk. The results showed that the segmental speed difference and segmental volume difference along the vehicle trajectory in the 0 to 4 minutes interval before crash occurrence all had significant positive impacts on crash risk. Meanwhile, the truck volume difference and average segmental speed in the 0 to 1 minute interval before crash also have positive impacts on real-time crash likelihood. The findings of this study have the potential to be applied to improve the safety of Connected and Autonomous Vehicles (CAV). A CAV continuously collects the traffic information along its trajectory and calculate the crash risk. When the hazardous traffic condition happens, measurements can be taken by CAV to prevent crash occurrence.

Authors	Chenming Jiang, Shanghai Maritime University Linjun Lu, Shanghai Jiao Tong University Yichuan Peng, Tongji University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-04169
Paper Title	**Miss-and-Run: Factors Contributing to Two-Vehicle Phantom Vehicle Crashes in Florida**
Abstract	Phantom vehicle crashes (PVCs), or miss-and-run crashes are a topical issue in car insurance coverage because of controversies over testimony and compensation. However, no peer-reviewed literature has specialized in the perception and deliberations involved in this infrequent type of car crash. A novel taxonomy of roadway traffic crashes is proposed in this study on the basis of whether physical collisions did occur (hit or miss) and whether the perpetrators stayed at the crash scene (stay or run). In this way, this study poses the issue of the PVCs (miss-and-run crashes) within the scope of traffic safety research, and aims to investigate the statistically significant factors that are likely to induce PVCs. A binary logistic regression method was adopted to model the probability and occurrence of two-vehicle PVCs (TV-PVCs) in Florida. Data that derived from the Crash Analysis Reporting system in 2013 consisted of 14,776 two-vehicle crashes in which 440 ones (2.98%) were confirmed as positive TV-PVCs. Sixteen factors with 50 variables on crash information, roadway characteristics and environmental conditions were included in the original consideration of the TV-PVC model. The results indicated that a two-vehicle crash is more likely to be a PVC when the crash happens on weekends, on roadways with no traffic control or full access control, on curving and sloping roadways, on slag/gravel/stone roadways. Relative to no violation, alcohol involvement in a two-vehicle crash is more likely to result in a hit-and-stay crash than a PVC. The motorists of uninsured vehicles would indeed be more likely to be the victims of PVCs because they have the propensity to avoid physical collisions for potential self-paid loss. Several conclusions for better understanding the occurrence of a PVC are proposed for traffic management departments and car insurers.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-04570
Paper Title	**An Exploratory Investigation of Disengagements and Crashes in Autonomous Vehicles**
Abstract	Autonomous Vehicles (AVs) have a large potential to improve traffic safety but also pose some critical challenges. While AVs may help reduce crashes caused by human error, they still may experience failures of technologies and sensing, as well as decision-making errors in a mixed traffic environment. The California Department of Motor Vehicles (DMV) mandated that manufacturers testing AVs make both disengagements and crash reports publicly available. An AV transitioning control from autonomous systems to the trained test driver is termed a disengagement. This study provides a first attempt to combine both crashes and disengagements and analyze them using a rigorous modeling approach. A nested logit model was calibrated using three different outcomes: (1) disengagement with a crash, (2) disengagement with no crash, and (3) no disengagement with a crash, to analyze the safety effects of AVs. The results show that factors related to other roadway participants are more likely to lead to a disengagement without a crash. Furthermore, AVs were observed to disengage less often as the technology matured over time. For this reason, crash proportions between more recent and older tests were compared, but no statistically significant change in crash proportions over the two periods was observed. The results thus suggest that disengagements are a part of AVs' safe performance and disengagement alerts may need to be triggered in order to avoid certain failures with current technology. Since this analysis examined early generation testing, the crash data needs to be revisited as the technology matures and more data becomes available.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-05279
Paper Title	**On-line Aggressive Driving Identification Based on In-Vehicle Kinematic Parameters under Naturalistic Driving Conditions**
Abstract	Aggressive driving, amongst all driving behaviors, is largely responsible for leading to traffic accidents. With the objective to improve road safety, this paper develops an on-line approach for vehicle running state monitoring and aggressive driving identification, using kinematic parameters captured by the in-vehicle recorder under naturalistic driving conditions. To characterize the roads in reality, a novel road conceptual model is proposed. It accounts for not only the curve on the horizontal plane but also the slope on the vertical plane, as well as the cross slope. For each position where the vehicle is driving, the vehicle motion is decomposed into two circular motions on the horizontal and vertical planes. On each plane, the vehicle maneuver is first identified. Then, aggressive driving is identified according to the limit equilibrium of driving safety or comfortability. Based on the proposed method called "three-elements", the vehicle maneuver, radius and slope angle on the vertical plane can be solved in an on-line manner. The novel approach is an elaborate analytical model with clear physical meaning but small computation load, and therefore is potential to be implemented in the mobile devices for real-time aggressive driving identification and labeling. The developed approach is applied to a real case on the curved and sloped route in Nanjing, China. Empirical results of extensive experiments, based on the kinematic parameters collected from the in-vehicle data recorder under naturalistic driving conditions, demonstrate that aggressive driving behaviors are mostly found on the pavements with curve and slope, and can be identified by the developed approach.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-03113
Paper Title	**An Analysis of Rural Interstate Fatality Rates in Consideration of Recent Increases in Maximum Statutory Speed Limits**
Abstract	The relationship between traffic safety and speed limits has been an area of significant research. Since the repeal of the National Maximum Speed Law in 1995, states have full autonomy in establishing maximum statutory speed limits. Since 2001, at least 25 states have increased their maximum limits to speeds as high as 85 mph. This study examines changes in rural interstate fatalities from 2001 to 2016 in consideration of such increases. Speed limit policy data include the maximum speed limit for each state-year combination, as well as the proportion of rural interstate mileage posted at each speed limit in each state. Random parameter negative binomial models are estimated to control for unobserved heterogeneity, as well as time-invariant effects unique to each state. The results show that increasing the mileage of rural interstates posted at 70, 75, or 80 mph by one percent is associated with fatality increases of 0.2%, 0.5%, and 0.6%, respectively. These increases are more pronounced than when considering only the maximum statutory limits in each state. The study also examines the influence between these higher limits and the frequency of fatal crashes involving speeding and driver distraction. At the highest limits of 75 and 80 mph, the increases among these subsets of crashes are greater than the increases in total fatalities. Ultimately, this study provides important empirical evidence in support of continuing speed limit policy discussions, in addition to identifying salient analytical concerns that should be considered as a part of longitudinal analyses of state-level fatality data.

Authors	Synthia Tagar, University of North Carolina, Charlotte Srinivas Pulugurtha, University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-01403
Paper Title	**Modeling and Identifying Characteristics Influencing Merging Speed-Change Lane Crash Risk by Interchange Type**
Abstract	The objective of this research is to model and identify the influence of freeway traffic and geometry, ramp traffic and geometry, driver, and environmental characteristics on merging speed-change lane crash severity by interchange type. Data for merging speed-change lanes along I-85, I-77, I-277, and I-485 in the city of Charlotte, North Carolina (NC) were considered for modeling and identifying characteristics. Traffic information and crash data were obtained from the North Carolina Department of Transportation (NCDoT) and Highway Safety Information System (HSIS), for five-years, from 2011 to 2015 and used in this research. Two different Multinomial Logit (MNL) models were developed for examining the relative risk of crash severity by interchange type. Among the predictor variables, freeway annual average daily traffic (AADT), speed-change lane length, ramp average daily traffic (RADT), speed difference between freeway and ramp, the number of lanes on the freeway and the ramp, weather condition, driver age, upstream and downstream ramp type, and upstream and downstream ramp distance were observed to be significant characteristics to model fatal and injury crash risk. The risk of crash severity is relatively higher for freeway sections with less than six lanes, multiple merging ramps, and depends on closely located downstream ramp near a diamond interchange. In case of cloverleaf interchanges, adult-age drivers (41 – 55 years), multi-lane ramps, and upstream ramp distance elevate crash risk.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-01569
Paper Title	**Crash Risk Prediction Model for Expressway Diverging Areas Based on Traffic Conflict Technique and Microscopic Simulation**
Abstract	This paper investigated the influential factors for traffic crashes in the expressway diverging areas based on traffic conflict technique and microscopic simulation. The hourly conflict risk index (HCRI) was defined to establish a crash rish prediction model for the expressway diverging area. The unmanned aerial vehicle (UAV) was used to collect interchange data, and observers were trained to identify conflict severity, and Tracker 5.0 was used to calculate the time to collision (TTC) for rear-end and lane-change collision, respectively. Based on the value of direct economic losses, the traffic risk index for traffic conflict of different types and severities is established, and the severity of traffic conflict was characterized by HCRI. The number of traffic conflicts under different conditions was derived from VISSIM simulation data and imported into surrogate safety assessment model (SSAM). The multivariate linear regression model was adopted to analyze the relationship between HCRI and various influential factors. A comparison between hourly conflict ratio (HCR) model and HCRI model showed that the HCRI model is better. Finally, it was found that the mainline traffic volume, the ramp traffic volume and the proportion of heavy vehicles are positively associated with HCRI, while the acceleration lane length is negatively associated with HCRI. The study results can be used to improve the safety performance of expressway diverging areas.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-03962
Paper Title	**Can Sensor Data Predict Crash Severity?**
Abstract	Road safety continues to be a major global concern. One untapped resource to both understand conditions leading to severe crashes and intervene to prevent them is the ongoing investment in traffic monitoring technology. This research explores harnessing the torrent of traffic data generated from these sensors and employing them in concert with crash reports, road geometry, and weather information to predict when a crash is likely to be severe. This research describes the process of gathering, cleaning, and integrating these diverse data streams into a no-SQL database and estimating a binomial logit model of crash severity for each data source separately and in combination. The models estimated identified Sundays, the month of April, and outdoor temperatures as positively associated with crash severity and the hours between 8:00 and 9:00 pm, highway median widths, and lane volumes as negatively associated with crash severity. Despite identifying these statistically significant predictors, the model was unable to improve the estimation of crash severity on a reserved test data set. These findings are suggestive of the potential of big data from traffic sensors to understand road safety, but also point to the need for continued research to best apply these emerging methodologies for policy interventions.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-04355
Paper Title	**Rapid Driving Pattern Recognition Based on Rear-End Collision Risk**
Abstract	Rear-end collision crashes is one of the most common accidents in road transportation. Rapid and accurate pattern recognition for rear-end collision risk is crucial to design useful driver assistance systems and vehicle control systems. The purpose of this study is to develop a rapid recognition method of driving patterns based on vehicle trajectory data from the Next Generation Simulation (NGSIM). First, three features, Inversed Time to Collision (ITTC), Time-Headway (THW) and Modified Margin to Collision (MMTC), are selected to evaluate the rear-end collision risk of individual vehicles. The histogram results of three features are used to find the threshold values of driving risk level. Then the vehicle trajectory segments separated by threshold values are clustered by K-means algorithm into three types: safe, moderate and risky driving pattern. Finally, Multi-Class Supporting Vector Machine (MCSVM) classifier is applied to recognize the driving patterns based on the labeled drivers. The vehicle trajectory features and collision risk features are respectively adopted to facilitate the driving pattern recognition. The "leave-one-out" method is used to validate the performance and effectiveness of the proposed method. The results show that the combination of ITTC, THW, and MMTC achieves 89.1% accuracy, the highest of all collision risk features, while the combination of vehicle trajectory features achieves 83.2% accuracy.

Authors	Jie Wang, Central South University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1173
Session Title	**Doctoral Student Research in Transportation Safety—Hybrid Session**
Paper Number	P19-21855
Paper Title	**Urban Road Crash Prediction Model by Integrating Macro and Micro Risk Factors**
Abstract	

Authors	Farah Al-Mahameed, University of Wisconsin, Milwaukee
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1173
Session Title	**Doctoral Student Research in Transportation Safety—Hybrid Session**
Paper Number	P19-21856
Paper Title	**Identifying Vulnerable Road Users Safety Issues along Street Corridors**
Abstract	

Authors	Song Wang, University of Louisville
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1173
Session Title	**Doctoral Student Research in Transportation Safety—Hybrid Session**
Paper Number	P19-21860
Paper Title	**Quantifying Distraction and Modeling its Interaction with Safety in Connected Vehicle Safety Application and Automated Vehicle Environment**
Abstract	

Authors	Muhammad Ardiansyah, National Chiao Tung University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1173
Session Title	**Doctoral Student Research in Transportation Safety—Hybrid Session**
Paper Number	P19-21861
Paper Title	**A Paradigm for Advanced Driver Assistant System Effectiveness Evaluation Using Survival Analysis**
Abstract	

Authors	Md. Sharikur Rahman, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1173
Session Title	**Doctoral Student Research in Transportation Safety—Hybrid Session**
Paper Number	P19-21862
Paper Title	**Assessing the Safety Benefits Under Connected and Automated Vehicle Technologies: Platooning, Level of Automation and Market Penetration**
Abstract	

Authors	Md Atiquzzaman, Auburn University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1173
Session Title	**Doctoral Student Research in Transportation Safety—Hybrid Session**
Paper Number	P19-21863
Paper Title	**Modeling the Risk of Wrong-Way Driving at the Freeway Exit Ramp Terminals**
Abstract	

Authors	Lingqiao Qin, University of Wisconsin, Madison
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1173
Session Title	**Doctoral Student Research in Transportation Safety—Hybrid Session**
Paper Number	P19-21864
Paper Title	**Using a Driving Simulator for Virtual Road Safety Audits**
Abstract	

Authors	Peter Bakhit, Louisiana State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1173
Session Title	**Doctoral Student Research in Transportation Safety—Hybrid Session**
Paper Number	P19-21865
Paper Title	**Crash/Near-Crash: Impact of Secondary Tasks and Real-Time Detection of Distracted Driving**
Abstract	

Authors	Lai Zheng, Harbin Institute of Technology Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-00438
Paper Title	**Application of extreme value theory for before-after road safety analysis**
Abstract	Because of well-recognized quality and quantity problems associated with the historical crash data, traffic conflict techniques have been increasingly used in the before-after safety analysis in recent years. This study proposes to use extreme value theory (EVT) approach to conduct the traffic conflict-based before-after analysis. The capability of providing confident estimation of extreme events by the EVT approach drives the before-after analysis to shift from normal traffic conflicts to more serious conflicts, which are relatively rare but have more in common with actual crashes. The approach is applied to evaluate the safety effects of converting channelized right-turn lanes to smart channels, based on traffic conflicts defined by time to collision (TTC) collected from three treatment intersections and one control intersection in the city of Penticton, British Columbia. Odds ratios and treatment effects are calculated from extreme-serious conflicts, the frequencies of which are estimated from the Generalized Pareto distributions of traffic conflicts with TTC≤0.5s. The results show approximately 34% reduction in total extreme-serious conflicts (i.e., combining merging conflicts and rear-end conflicts), indicating overall a remarkable safety improvement following the smart channel treatment. This finding is consistent with the analysis result based on traffic conflicts with TTC≤3.0s. It is also found that the reduction in extreme-serious merging conflicts is small and insignificant. This is caused by the fact the TTC values of merging conflicts become smaller after the treatment, and it is possibly because drivers get more aggressive with the better view of approaching cross-street traffic provided by the smart channel.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-00565
Paper Title	**Comparison of Empirical Bayes and Propensity Score Methods for Road Safety Evaluation: a Simulation Study**
Abstract	The evaluation of the effects of road safety measures on road accidents has gained continuous attention among researchers in recent years. Besides the common used empirical Bayes (EB) approach, the propensity score (PS) methods have been widely employed in road safety evaluation studies. However, the conditions under which these methods can provide valid estimates of treatment effects are not well understood. We conduct a simulation-based comparison study to provide insight into the performance of the EB and PS methods in settings with and without violation of the key assumptions of the EB and PS methods. The models investigated include the EB, inverse probability weighting (IPW), and the doubly robust (DR) methods with different model specifications and data conditions. The results suggest that most of the methods can provide unbiased estimates of the treatment effect when the models are correctly specified, although the bias of the effect estimates increases slightly for all IPW models and most DR models with a small data sample, indicating that the propensity score methods are “data hungry”. The DR method is less affected by the omission of covariates and consistently provides unbiased estimates even in the scenarios with incorrect model specification, indicating its superiority to other two methods.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-00817
Paper Title	**Application of Random Effects Negative Binomial Models with Clustered Dataset for Vehicle Crash Frequency Analysis**
Abstract	For the past few years, vehicle crash frequency analysis has been one of the study areas of great interests in highway safety research. One of the major challenges is how to deal with the unobserved heterogeneity of crash data. While statistical models of crash frequency analysis based upon single probability distributions are constantly improving, several researchers discovered that multiple distribution models might better describe crash frequency data and capture more unobserved heterogeneity. Based upon the hypothesis that total crash counts occurring at an intersection may be affected by different unique sets of contributing factors, this research proposes a two-step approach to study the crash contributing factors at intersections in Mississippi Coast which is one of the most frequent crash areas in the State of Mississippi. In this study, the crash data are first clustered into subpopulations with the application of a hierarchical clustering method, and then a Random Effects Negative Binomial model is applied to each component at the intersection level. A model with no data clustering is also estimated to serve as the comparison benchmark. The analysis results show that this two-step approach can reveal more information about crash contributing factors and have increased predictive power and goodness of fit.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-01100
Paper Title	**Net-social and Net-private Benefits of Some Existing Vehicle Crash Avoidance Technologies**
Abstract	Most light-duty vehicle crashes occur due to human error. Many of these crashes could be avoided or made less severe with the aid of crash avoidance technologies. These technologies can assist the driver in maintaining control of the vehicle when a possibly dangerous situation arises by issuing alerts to the driver and in a few cases, responding to the situation itself. This paper estimates the social and private benefits and costs associated with three crash avoidance technologies, blind-spot monitoring, lane departure warning, and forward-collision warning, for all light duty passenger vehicles in the U.S. for the year 2015. The three technologies could collectively prevent up to 1.6 million crashes each year including 7,200 fatal crashes. In this paper, the authors estimate the net-social benefits to the overall society from avoiding the cost of the crashes while also estimating the private share of those benefits that are directly affecting the crash victims. For the first generation warning systems, net-social benefits and net-private benefits are positive. Moreover, the newer generation of improved warning systems and active braking should make net- benefits even more advantageous.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-01433
Paper Title	**Incorporating Route Safety in the Pathfinding Problem Using Big Data**
Abstract	With the emergence of the internet of things, pathfinding problems have recently received a significant amount of attention. Various commercial applications provide automated routing by considering travel time, travel distance, fuel consumption, complexity of the road, etc. Unfortunately, many of these prospective applications do not consider route safety. Because connected vehicles (CV) generate enriched "Big Data", researchers have opportunities to develop new transportation methods. The goal of this study is to address safety aspects in pathfinding problems by developing a methodological framework that simultaneously considers safety and mobility. To reach this goal, the concept of "driving volatility" is utilized as a surrogate safety performance measure. The proposed framework uses CV big data and real-time traffic data to obtain calculate safety indices and travel times. Measured safety indices include 5-year crash history, route speed and acceleration volatility, and driver volatility. Travel time and safety shape a cost function called "route impedance". The algorithm has the flexibility for the user to predefine the weight for safety consideration. It also uses driver volatility to automatically increase weights of safety considerations for volatile drivers. In order to illustrate the algorithm, an origin-destination pair in Ann Arbor Michigan is selected and more than 42 million CV observations from around 2,800 CVs from the Safety Pilot Model Deployment were analyzed. Finally, this paper shows suggested routes for multiple scenarios to demonstrate the outcome of the study. The results revealed that the algorithm might suggest different routes when considering safety indices and not just travel time.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-01662
Paper Title	**Investigating the Characteristics of Connected and Autonomous Vehicle Involved Crashes**
Abstract	This study aimed to investigate the characteristics and patterns of the connected and autonomous vehicle (CAV) involved crashes. The crash data were collected from the reports of CAV involved crash submitted to the California Department of Motor Vehicles between 2015 and 2018. The descriptive statistics analysis was employed to investigate the characteristics of CAV involved crashes in terms of crash location, weather conditions, driving mode and vehicle movement before crash occurrence, vehicle speed, collision type, crash severity and damage locations of involved vehicles. The bootstrap based binary logistic regressions were then developed to investigate the factor contributing to the collision type and severity of CAV involved crashes. The results suggested that the CAV driving mode, collision location, roadside parking, rear-end collision, and one-way road are the main factors contributing to the severity level of CAV involved crashes. The CAV driving mode, CAV stopped or not, CAV turning or not, normal vehicle turning or not, and normal vehicle overtaking or not are the factors affecting the collision type of CAV involved crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-01780
Paper Title	**A Comprehensive Review of Secondary Crash Studies**
Abstract	Secondary crashes (SCs) could have resulted from primary incidents for their complex interaction between roadways, vehicles, traffic and environmental conditions. However, several researchers are still in doubt whether the principal cause of SCs are from primary incident or from recurring congestion. Compared to primary crashes, there have been very few studies that focused on SCs. This review paper focuses the existing literatures on SCs occurred on freeways and identify possible influential risk factors associated with these crashes. The current practices to identify SCs are first discussed in detail. Static, dynamic, and spatial analysis tools are discussed particularly. The models to predict the probability of secondary crash occurrences are presented next. Finally, a thorough investigation has been done to identify influential risk factors associated with SCs. The lessons learned from this comprehensive literature are eventually presented a number of research gaps with recommendations for manifesting potential mechanisms in analyzing SCs.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-01791
Paper Title	**Hit and Run Crashes: An Application of Correlated Random Parameter Probit Model Using Real-Time Crash Data**
Abstract	The issue of unobserved heterogeneity in crash data has been highlighted by many recent traffic safety studies. The safety literature has demonstrated the capability of the full random parameters approach to address the issue of unobserved heterogeneity. However, such approach has been mostly restricted to the investigation of general crash frequency models. The current study provides the application of this approach to a concerning crash behavior of Hit and run (HR) by extending the conventional random parameter model to allow the correlation between parameters. This study also focuses on utilizing the real-time traffic data to predict the HR crash risk. Additionally, three other models are developed, representing the current safety literature, to compare the performance of the proposed correlated random parameter model. The results from the posterior model estimates demonstrated the evidence of parameters varying with observations. The model fit results illustrated the worst performance for the traditional probit model while the random parameters model was relatively superior. However, the model with correlated random parameters exhibited the best performance, potentially due to its advantage to replicate the realistic scenario where the explanatory variables may act as confounding factors due to their interactions. The results for model performance based on predictive accuracy were monitored by using ROC (receiver operating characteristic) curves. The results corroborated the model fitness trends and revealed that the accommodation of correlations for random parameters improved the model prediction performance, especially at threshold levels generally adopted by safety practitioners. Keywords: correlated random parameters, hit and run, real-time, probit

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-01850
Paper Title	**Spatial Local Effect Analysis of Traffic Accident Size Using Geographically Weighted Structural Equation Modeling**
Abstract	Considering spatial factors in the analysis of data is an approach that can better reflect the real world. In fact, there have been studies on spatial analysis using spatial metric model and structural equation models, but each approach has limitations; the effect of specific independent variables on dependent variables does not reflect differences in regions. For example, at two points with perfectly identical point properties, certain events can occur at different levels. This difference is defined as a spatial local effect in this study, and previous research has grappled with such effects. In this study, we aimed to develop a complementary model, and propose a new approach combining a spatial metric model and a structural equation model. Through this model, we can move away from interpreting only the global effect, which is the effect of certain factors on the total system. In other words, it is possible to identify differences in the influence of certain factors on specific area and to develop customized actions for that areas. In this context, we confirmed its applicability by applying it to traffic accident data of Korea. In particular, the effect of spatial factors on the size of the traffic accidents was analyzed. Through this, this study will identify what factors should be controlled to reduce size of traffic accidents at specific points and help to establish appropriate measures for each point.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-02342
Paper Title	**Determining Optimal Segment Lengths for Traffic Safety Analysis Based on Spectral Analysis**
Abstract	The Highway Safety Manual (HSM) presents a variety of methods for quantitative network segmentation. Existing approaches to determine segment lengths for safety analysis require engineering judgement and are subject to a lack of standard metrics for assessing segmentation performance. This paper presents a novel methodology that determines optimal segment lengths and innovates network segmentation methods for reliable safety analysis. The methodology is based on spectral analysis of crash density in the spatial frequency domain (SFD) in which low frequency components represent trends while high frequency components represent details and randomness. By proposing the one-dimensional spatial frequency domain analysis (SFDA), this paper discovered the characteristic of power spectral concentration within the low frequency band. Based on this finding, this paper further proposes the power spectral segment length (PSSL) for determine optimal segment lengths and the power spectral percentage (PSP) for assessing the segmentation performance. The methodology extended the knowledge of network segmentation and aggregation of crash data from a non-traditional perspective. It leads to the low-pass filtering method that outperforms the sliding window method, and an improved wavelet-based method that identifies high-risk segments properly.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-02686
Paper Title	**Sensitivity Analysis of Bayesian Semiparametric Spatial Crash Frequency Models**
Abstract	This study focused on the sensitivity analysis of Bayesian semiparametric spatial models which combine the strengths of spatially structured random effects and the Dirichlet mixture to account for the unobserved heterogeneity of crash counts. The three-year bicycle crash data from the city of Irvine in California aggregated at the transportation planning level of Traffic Analysis Zones (TAZ) were utilized for model development. Various evaluation criteria were employed to compare the performance of models with varying spatial weight matrices and precision parameters (alpha). The results demonstrate that there exists strong correlation among the posterior number of clusters (K), alpha, the fraction of variation explained by the spatial random effect, and different evaluation criteria. Even though the increased upper bound value of alpha does not necessarily lead to the enhanced model performance, the models with the full flexibility to choose the desirable amount of clustering tend to perform better than those with limited flexibility due to smaller allowable mass components. Compared with the precision parameter, no obvious trend is illustrated for the different evaluation criteria along the varying spatial weight matrices. However, the existence of significant performance variation among the models suggests the need to explore various spatial neighboring structures for the potential better modeling results.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-02788
Paper Title	**Identification of Secondary Crash Risk Factors using Penalized Logistic Regression Model**
Abstract	Secondary Crashes (SCs) have increasingly been recognized as a major problem leading to reduced capacity and additional traffic delays. However, the limited knowledge on the nature and characteristics of SCs has largely impeded their mitigation strategies. There are two main issues with analyzing SCs. First, relevant variables are unknown, while at the same time, most of the variables considered in the models are highly correlated. Second, only a small proportion of incidents results in SCs, making it an imbalanced classification problem. This study aims to develop a reliable SC risk prediction model using the Least Absolute Shrinkage and Selection Operator penalized logistic regression model with Synthetic Minority Over-sampling TEchnique-Nominal Continuous. The proposed model is considered to improve the predictive accuracy of the SC risk model since it accounts for the asymmetric nature of SCs, performs variable selection, and removes correlated variables. The study data were collected on a 35-mile I-95 section for three years in Jacksonville, Florida. SCs were identified based on real-time speed data. The results indicated that real-time traffic variables and primary incident characteristics significantly affect the likelihood of SCs. The most influential variables included mean of detector occupancy, coefficient of variation of equivalent hourly volume, mean of speed, primary incident type, percent of lanes closed, incident occurrence time, shoulder blocked, number of responding agencies, incident impact duration, incident clearance duration, and roadway alignment. The study results can be used by agencies to develop SC mitigation strategies, and hence improve the operational and safety performance of freeways.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03134
Paper Title	**Before-After Analysis of Safety Effects of Variable Speed Limit System Using Full Bayesian Models**
Abstract	Variable speed limits (VSL) have been increasingly used to improve traffic safety on freeway mainlines. The primary objective of this study was to evaluate the safety impacts of the VSL system implemented on Interstate 5 in Seattle, United States since 2010. A Full Bayesian (FB) before-after analysis was conducted based on 9,787 crashes that occurred in a 72-month study period. The analysis was conducted for all crashes, crash severity levels, crash types and crash causes. The FB before-after results implied that the total crash count was reduced by 32.3% with a standard deviation of 3.58% after the implementation of VSL system on the target freeway. The decrease in number of no injury crashes is greater than the decrease in crashes with severe injury and possible injury. The effect with respect to reducing head-on, face and leading-end crashes was with the most beneficial among all crash types, while the effect on rear-end crash was the least. The study also compared the traffic speed features in the before and after periods in order to fully evaluate the impacts of the VSL system on traffic operations. The result indicated that, the difference in speed was apparently reduced with the VSL system deployed The results of this study are particularly valuable for policy making and cost-benefit evaluation associated with VSL system implementations.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03285
Paper Title	**Modeling the Effects of Lake-Effect Snow Related Weather Conditions on Daily Traffic Crashes: A Time Series Count Data Approach**
Abstract	Winter weather in many parts of North America is characterized by heavy snowfall that affects traffic safety. Lake Effect Snow (LES) in the Great Lakes region exacerbates the problem by increasing snowfall totals and severity of winter weather locally. Past studies investigating the effects of winter weather on traffic crashes have mainly focused on site-specific weather conditions and overlooked mesoscale meteorological phenomena. Therefore, the primary objective of this paper is to develop a crash count model establishing the relationship between LES and winter traffic crashes. Daily crash data, traffic exposure data and meteorological data from State of Michigan are modelled to examine the impact of meteorological characteristics behind LES formation on the observed counts. Additionally, this paper introduces a relatively new class of time series models known as Negative Binomial Integer-valued Generalized Autoregressive Conditional Heteroscedastic (NB-INGARCH) model. NB-INGARCH offers an alternative to the integer-valued time series models and accounts for the overdispersion, non-negativity, and time interdependencies. The performance of the NB-INGARCH model is compared with Poisson INGARCH model using the Probability Integral Transformation (PIT) histogram, marginal calibration plot and scoring rules. The resultant models were quite similar in terms of coefficient estimates and goodness of fit. The results suggest that several predictor variables for LES formation are significantly related to crash data. However, NBINGARCH model exhibits better predictive performance than Poisson INGARCH by addressing overdispersion and unobserved heterogeneity issues.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03389
Paper Title	**Incorporating Spatial Effects into Temporal Dynamic of Traffic Fatality Risks: A Case Study on Lower States of the USA, 1975-2015**
Abstract	Road traffic fatality rate has long served as a regular indicator to evaluate and compare road safety performances for different administrative divisions. This article introduced a novel method known as spatial Markov chains model to incorporate the spatial effects into the temporal dynamic of the fatality rates. Comparing with the traditional Markov chains model, the proposed spatial Markov chains model can quantify the influence of neighboring sites explicitly in the transition process. A case study using a long time span dataset from 1975 to 2015 in the 48 lower states of the United Sates was conducted to illustrate the proposed model. The fatality rates were measured as the number of traffic fatalities per 100 million vehicle miles or per 10,000 residents. Our results show that the probability of transition for one state between different levels of traffic fatality risks depends largely on the context of its surrounding neighbors. Another important finding is that relative to the estimates of traditional Markov chains model, states surrounded by neighborhoods with relatively low fatality rates takes a longer time to transform to a higher level of fatality risk in the spatial Markov chains model, whereas those with high risk neighborhoods takes less time to deteriorate. These findings confirm that it is imperative to incorporate spatial effects when modeling the temporal dynamic of safety indicators to assess and monitor the safety trends of the areas of interests.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03414
Paper Title	**Real-Time Crash Risk Prediction Using Long Short-Term Memory Recurrent Neural Network**
Abstract	With the help of widely deployed traffic detectors along arterials and intersections, real-time traffic data are collected and updated in a very short time period, which enables us to conduct real-time analysis at signalized intersections. Among them, real-time crash risk prediction is one of the most promising and challenging research topics. This study attempts to predict real-time crash risk by considering time series dependency with the employment of Long Short-Term Memory Recurrent Neural Network (LSTM-RNN) algorithm. Also, the Synthetic Minority Over-Sampling Technique (SMOTE) was utilized in this study to generate a balanced training dataset for algorithm training. In comparison, a conditional logistic model was developed based on matched case control design. It is worth pointing out that both models were evaluated based on the real-world unbalanced test dataset rather than artificially balanced dataset. The comparison results indicate that the LSTM-RNN with SMOTE outperforms the conditional logistic model. The methods and findings of this study attempt to verify the feasibility of real-time crash risk prediction by using LSTM-RNN with over-sampled dataset (SMOTE).

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03593
Paper Title	**Real-Time Crash Risk Analysis for Signalized Intersections**
Abstract	This study attempts to investigate the relationship between crash occurrence at signalized intersections and real-time traffic, signal timing, and weather characteristics based on 23 signalized intersections in Central Florida. The intersection and intersection-related crashes were collected and then divided into two types, i.e., within intersection crashes and intersection entrance crashes. Bayesian conditional logistic models were developed for these two kinds of crashes, respectively. For the within intersection models, the model results showed that the through volume from "A" approach (the traveling approach of at-fault vehicle), the left turn volume from "B" approach (near-side crossing approach), and the overall average flow ratio (OAFR) from "D" approach (far-side crossing approach), were found to have significant positive effects on the odds of crash occurrence. Moreover, the increased adaptability for the left turn signal timing of "B" approach and more priority for "A" approach could significantly decrease the odds of crash occurrence. For the intersection entrance models, average speed was found to have significant negative effect on the odds of crash occurrence. The longer average green time and longer average waiting time for the left turn phase, higher green ratio for the through phase, and higher adaptability for the through phase can significantly improve the safety performance of the intersection entrance area. These results are important in real-time safety applications at signalized intersections in the context of proactive traffic management and adaptive signal control.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03728
Paper Title	**Improving Intersection Safety with RCUT: Louisiana Experience**
Abstract	The safety of intersections on major corridors is always a concern because of the high-risk vehicle maneuvers intertwined with a high operating speed. It is especially a problem for intersections with a two-way stop-sign control where vehicles on a low-speed minor roadway must cross multiple lanes and the median before merging into the path of high-speed traffic. To improve the intersection safety, Restricted Crossing U-turns (RCUT) has been constructed in Louisiana since 2011. Because of the short history of the RCUT implementation, there are limited studies available that address the RCUT safety effectiveness. This paper evaluates the safety benefit of six RCUTs in Louisiana including five intersections in urban and suburban areas. Unlike the previous studies, this investigation covers both the RCUT intersection only and RCUT system (consisting of the intersection, two U-turns and segments in between). The crash analysis shows a 100% reduction in fatalities, 41.5% in injuries and 22.3% in property damage only crash for the RCUT intersection only, and less impressive reductions for the RCUT system. The review of the original crash reports greatly benefits the investigation on why the crashes increased at few locations, thus, provides the valuable information on how to correct these crash problems through the detailed design and traffic control. The safety improvement plus the high ratio of benefit to cost strongly demonstrate that the RCUT is an effective and economically justified countermeasure on high-speed roadways in both rural and urban areas.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03963
Paper Title	**Enhancing Real-Time Crash Risk Prediction Performance Considering Spatial and Temporal Correlations in Support Vector Machine**
Abstract	Unobserved heterogeneity in crash data could affect the predicting accuracy of crash risks. Such effects can be considered within the spatial and temporal correlation to improve the model prediction performance. This study aims at proposing an enhanced support vector machine (SVM) model that involves the spatial and temporal weight features in the model structure to address the spatial and temporal proximity in the real-time crash risk predictions. A total of 254 crash data on the Interstate 80 were obtained. Traffic flow data 5 min before the occurrence of each crash were extracted to be the case database. Non-crash traffic flow data were randomly extracted from the collision free periods to be the control database. The Receiver Operating Characteristics (ROC) curves were drawn to evaluate and compare the prediction performance of different models. The results showed that by incorporating the spatial and temporal correlations in the SVM, the model fitness was improved: the predicting accuracy was increased from 79.8% to 86.5% as compared to the basic SVM model. Two weight matrixes of spatial and temporal correlation in the SVM were tested, and the models with the 0-1 first order weight feature had the highest predicting accuracy. We also tested the modeling accuracy for different ratios of training and testing sample sizes. Findings of this study suggest that the proposed SVM model with the spatial and temporal correlation can effectively improve the predicting accuracy of real-time crash risks based on the traffic variables from loop detector stations.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-04002
Paper Title	**Examining Multilayer Perceptron Based Machine Learning Method to Predict Imbalanced Sample of Traffic Crash**
Abstract	This paper combined a data processing method with imbalanced sample distribution and a machine learning method based on multi-layer function approximator was employed to deal with the prediction of crash severity, especially when the sample size of the crashes is small. Severe injury and caused to death crashes are needed to be dedicated to avoid. However, few study focused on improving the prediction accuracy of the few but more devastating severe injury crashes. The purpose of this research is to improve the prediction accuracy of each level of severity of crashes. It can effectively reduce the severity of crashes and mitigate the harm caused by traffic crashes by combining the prediction results to take effective countermeasures. This research first analyzed the distribution of the severity of traffic crash injuries in California State in 2010. Seventeen important influencing factors were selected through spearman's correlation analysis. After that, the data was equalized and the multi-layer neuron network was applied to predict the severity of the crashes. Finally, the prediction results were compared with Support Vector Machine. It was shown from modeling results that the utilized sample distribution balancing processing method and multi-layer function approximators based machine learning method can be more efficient in predicting the severity of crash injuries.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-04235
Paper Title	**An Empirical Analysis on Temporal Stability of Factors in Work-Zone Crashes in Florida: A Random Parameters Heterogeneity-in-Means Approach**
Abstract	Work-zone crashes in Florida have increased recently, particularly from 2012 to 2017. This study investigates factors leading to work-zone crashes in Florida in two distinct economic time periods in Florida—the recession-induced period (2012–2014) and the post-recession period (2015–2017). The main focus of this study is to estimate two separate time period models focusing on injury severity of work-zone crashes with mixed logit model incorporated with a heterogeneity-in-means approach. The study examines the temporal stability of contributing factors in work-zone crashes considering two time periods with a log likelihood test. Marginal effects of individual parameter estimates on work-zone crash severity were assessed to study the temporal stability of the effect of individual parameters on the likelihood of work-zone crash severity. The variables extracted from Florida's Crash Analysis Reporting System (CARS) encompass a wide variety of factors related to crash, vehicle, roadway geometry, traffic volume, driver demographics, spatial and temporal characteristics affecting the injury severity of work-zone crashes. The model results indicate significant temporal instability resulting from a possible complex interaction with macroeconomic conditions over the years from larger-scope and higher-budgeted work-zone projects in Florida with evolving driving behavior, traffic volume, and crash reporting practice in traditional state crash data. Mixed logit models on injury severity with a heterogeneity-in-means approach on work-zone crashes open a promising frontier of future research. This novel effort recognizes the possibility of uncovering complex interactions from underlying extensive and multiple data sources that otherwise expose the limitations of traditional crash databases and their management.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-04385
Paper Title	**Safety Performance of Displaced Left Turn Intersections Case Studies in San Marcos, Texas**
Abstract	Intersections with the displaced left turn (DLT) design are innovative intersections that are designed to increase the mobility of vehicles by relocating the left turn lane (lanes) to the far-left side of the road upstream of the main signalized intersection. Since DLT is a relative new design and very limited crash data are available, previous studies have focused mainly on analysis of the design's operational performance rather than its safety performance. To fill this gap, in this study we investigated the safety performance of two DLT intersections located in San Marcos, Texas. Crash data from 2011 to April 2018 were extracted from the TxDOT Crash Record Information System (CRIS). These crash data were analyzed using two different approaches, i.e., 1) statistical analysis and 2) collision diagram based analysis. The results of this study indicated that the DLT design has reduced conflicts related to left turns significantly. Also, some safety problems associated with traffic signage, geometric design, and access management of the DLT design also were identified. As a result of these analyses, recommendations were provided for safe implementation of the DLT design in the future.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-04725
Paper Title	**Predicting the Frequency of Secondary Crashes Caused by One Primary Crash Using Zero-Inflated Ordered Probit Regression**
Abstract	This paper aimed to investigate the effects of real-time traffic flow conditions on the frequency of secondary crashes caused by one primary crash on freeways. The zero inflated ordered probit (ZIOP) regression model was developed to link the probability of multiple secondary crashes after the occurrence of one primary crash with real-time traffic flow, geometric, weather and primary crash characteristics. The ZIOP regression model analyzed the probability of secondary crash frequency after one primary crash by separating it into two states. One is a secondary-crash-free state that determines whether the occurrence of a crash will lead to one or more secondary crashes, and the other is a secondary-crash-prone state that determines the secondary crash frequency caused by one primary crash. The average speed, average traffic volume, and the difference between the numbers of on-ramp and off-ramp are the significant variables in the secondary-crash-free state. In the secondary-crash-prone state, the significant variables affecting the probability of multiple secondary crashes include average detector occupancy, rainy weather, primary crash severity, and hit-and-run primary crash. The ROC curves were used to test predictive performance of the ZIOP model. The test results suggested that the ZIOP model provide reasonably good predictive accuracy of multiple secondary crashes caused by one primary crash.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-04990
Paper Title	**Applications of Measurement Error Correction Approaches in Statistical Road Safety Modeling**
Abstract	Road safety modelers frequently use average annual daily traffic (AADT) as a measure of exposure in regression models of expected crash frequency for road segments and intersections. Recorded AADT values at most locations are estimated by state and local transportation agencies with significant uncertainty, often by extrapolating short-term traffic counts over time and space. This uncertainty in the traffic volume estimates, often termed in a modeling context as measurement error in right-hand-side variables, can have serious effects on model estimation, including: 1) biased regression coefficient estimates, and 2) increases in dispersion. The structure and magnitude of measurement error in AADT estimates are not clearly understood by researchers or practitioners, leading to difficulties in explicitly accounting for this error in statistical road safety models, and ultimately in finding solutions for its correction. This study explores the impacts of measurement error in traffic volume estimates on statistical road safety models by employing measurement error correction approaches, including Regression Calibration and Simulation Extrapolation. The concept is demonstrated using crash, traffic, and roadway data from rural, two-lane horizontal curves in the State of Washington. The overall results show that the regression coefficient estimates with a positive coefficient were larger and a negative coefficient were smaller (i.e., more negative) when the measurement error correction methods were applied to the regression models of expected crash frequency. Future directions in applications of measurement error correction approaches to road safety research are provided.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-05054
Paper Title	**A Taxonomy of Naturalistic Driving Errors and Violations and Its Variations Across Different Land-Use Contexts – A Path Analysis Approach**
Abstract	Driver errors and violations are highly relevant to the safe systems approach as human error tends to dominate crash occurrence, contributing to a good 80% to 90% of crashes. To understand errors and the contexts in which errors and violations occur, this study harnessed unique data from the Naturalistic Driving Study (NDS)-SHRP2. A systematic taxonomy is first developed to classify driver errors and violations based on their presence during the perception-reaction process and to analyze their contribution in safety critical events. The NDS data provides a unique opportunity to observe pre-crash behaviors of drivers in diverse spatio-temporal contexts. Given safety critical events such as crashes and near-crashes, recognition errors were predominant in almost all types of locations. A rigorous multinomial logit and ordered probit based path analysis technique is applied to conceptualize the direct relationships between key built-environment factors and crash propensity, as well as the indirect relationships between built environment factors and crash propensity through the mediating errors and violations. The empirical framework allows us to explore certain land-use and roadway environments associated with different types of errors along with their direct and indirect effects on crash propensity. Detailed results are discussed in the paper, along with implications.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-05204
Paper Title	**A multimodal approach for monitoring driving behavior and emotions**
Abstract	Studies have indicated that emotions can significantly be influenced by environmental factors; these factors can also significantly influence driver's emotional state and, accordingly, driving behavior. Furthermore, as the demand for autonomous vehicles is expected to significantly increase within the next decade, a proper understanding of the driver/passenger(s)' emotions, behavior, and preferences will be needed in order to create an acceptable level of trust with humans. This paper proposes a novel semi-automated approach for understanding the effect of environmental factors on driver's emotions and behavioral changes through a naturalistic driving study. This setup includes a frontal road and facial camera, smart watch for tracking physiological measurements, and a Controller Area Network (CAN) serial data logger. The results suggest that the driver's emotion is highly affected by the type of road, presence of a passenger, and weather condition, which potentially can change the driving behaviors. For instance, by defining emotions metrics as valence and engagement, there exist significant differences between human emotion in different weather conditions and road types. Participant's engagement was higher in rainy and clear weather compared to cloudy weather. Moreover, his engagement was higher in city streets and highways compared to one lane roads and two lane highways. In addition, presence of a passenger increases the amount of engagement of the driver.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-05507
Paper Title	**Alternative Model Structures for Multivariate Crash Frequency Analysis: Comparing Simulation-based Multivariate Model with Copula-based Multivariate Model**
Abstract	In safety literature, there are two ways to incorporate the potential correlation between multiple crash frequency variables: (1) simulation-based approach and (2) analytical closed form approach. The current research effort proposed a comparison between simulation-based multivariate model and copula-based closed form approach to analyze zonal level crash counts for different crash types. The empirical analysis is based on traffic analysis zone (TAZ) level crash count data for both motorized and non-motorized crashes from Central Florida for the year 2016. A comprehensive set of exogenous variables including roadway, built environment, land-use, traffic, socio-demographic and spatial spillover characteristics are considered for the analysis. The resulting data fit and prediction performance offered by the copula-based approach clearly highlights the copula-based approach's superiority over the simulation-based multivariate model. The applicability of the model for hot zone identification is illustrated by generating plots identifying hot and cold zones by crash type in the Central Florida region.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-05567
Paper Title	**Analyzing Automated Vehicle Crashes in California: Application of a Bayesian Binary Logit Model**
Abstract	Automated vehicles (AVs) represent an opportunity to reduce the number of crashes by eliminating driver error as safety studies reveal human error contributes in 94% of crashes. However, existing literature lacks an understanding of the contributing factors of AV crashes. To provide insights on these crashes, this study created a unique database from California Department of Motor Vehicles (DMV) 66 manufacturer-reported Traffic Collision Reports (OL 316). The gathered information includes text mining of narratives in the reports and answers to close-ended crash questions. Results indicate that AV technology was faulty once of the 66 crashes (1.52%); the most frequent AV crash type is rear-ended (58%; N=38)—but in all cases, except one manually driven AV, the AV was struck by a conventional vehicle. This noteworthy outcome motivated us to analyze rear-end collisions by estimating assorted Bayesian models rigorously. The results indicate that most AV collisions occurred in the fully automated mode (65.2%), and the odds of AVs being struck were higher compared to vehicle takeover before impact and conventionally driven vehicles. Furthermore, the odds of an AV being rear-ended were substantially higher at an intersection than any other location, owing to the complexity of movements and conflicts at intersections. Given a crash, AV-involved rear-end crashes were more likely on one-way streets and when AVs were in motion. Within the constraints of the available data, the results highlight risk factors, given AV-involved crashes on public roadways. This study helps us understand the interactions of AVs and human-driven conventional vehicles in complex urban environments.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-05823
Paper Title	**Determination of the Driver At-fault Using Possibility Theory-based Classification**
Abstract	With the advent of driving assistant systems and the emerging capabilities for analyzing large amounts of data, various driving-related problems are revisited in the past decade. Determining the driver at-fault is one aspect that has traditionally been handled based on expert evaluations and state laws. However, integrating expert knowledge with the information available in measurements from driving experiments make it possible to exploit both sources of information simultaneously. In this study, a possibility theory-based classifier, namely possibility rule-based classifier using function approximation, is employed to capture the uncertainty in expert knowledge due to incompleteness. In this approach, a model is inferred from the 100-Car naturalistic driving dataset that demonstrates the uncertainty which is inherent in making decisions based on expert evaluations. In this experiment, the objective is to predict a degree to which each driver is at-fault in rear-end collision events. It is shown that the proposed approach can efficiently utilize the expert information and provide a graded fault evaluation for each driver engaged in the accident. This graded evaluation can either be used for further interpretations by an expert or utilized to determine the most plausible prediction.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-05934
Paper Title	**Investigating The Effect of Driver, Vehicle, and Road Related Factors on Location-Specific Crashes Using Naturalistic Driving Data**
Abstract	According to NHTSA, traffic accidents cost the country billions of U.S. dollars each year. Intersection accidents alone account for 23% of the 32,675 motor crash deaths in 2014. With the advent of the largest naturalistic driving dataset in the US collected by the SHRP2 NDS project, this study performs a crash-only analysis to identify driver, vehicle and roadway-related factors that affect the driving risk at different location types using a machine learning tool. The second objective is to analyze the most important factors obtained from the machine learning analysis to identify how it affects crash risk. The results showed that the order of importance of variables was driver behavior, locality, lane occupied, alignment and through travel lanes. Also, drivers who violated traffic signals were 4 times more likely to be involved crash than drivers who did not. Those who violated stop signs were 2 times more likely to be involved in crashes than those who did not. Drivers performing visual-manual tasks at uncontrolled intersections were 2.7 times more likely to be involved in crashes than those who did not engage in these tasks. At non-intersections, drivers who performed visual-manual tasks were 3.4 times more likely to be involved in crashes than drivers who did not. These findings add to the evidence that the institution of safety awareness programs geared towards intersection safety is imperative.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1412
Session Title	Safety Data, Analysis, and Evaluation: Research in Four Acts
Paper Number	19-01388
Paper Title	**COMPARING MACHINE LEARNING AND DEEP LEARNING METHODS FOR REAL-TIME CRASH PREDICTION**
Abstract	While there are numerous studies examining the impact of real-time traffic and weather parameters on crash occurrence in freeways, to the best of our knowledge there were no studies which compared the prediction performances of Machine Learning (ML) and Deep Learning (DL) models. The present study adds to current knowledge by comparing and validating Machine Learning and Deep Learning methods to predict real-time crash occurrence. To achieve the aims of the study, real-time traffic and weather data from Attica Tollway in Greece were utilized and linked with historical crash data. The total dataset was split into training/estimation (75%) and validation (25%) subsets, which were then standardized. Firstly, the ML and DL prediction models were trained/estimated using the training dataset. Afterwards, the models were compared on the basis of their performance metrics (accuracy, sensitivity, specificity and area under curve) on the test set. The models considered were the following: k-Nearest Neighbors, Naïve Bayes, Decision Trees, Random Forests, Support Vector Machines, Shallow Neural Network and lastly a Deep Neural Network. Overall, the Deep Learning model seems to be more appropriate, because it outperformed all other candidate models. More specifically, the DL model managed to achieve a balanced performance among all metrics compared to other models (total accuracy=68.95%, sensitivity=0.521, specificity=0.77, AUC=0.641). It is surprising though that the Naïve Bayes model, achieved a good performance, although being far less complex than other models. The findings of the study are particularly useful, because they provide a first insight on performance of ML and DL models.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1412
Session Title	Safety Data, Analysis, and Evaluation: Research in Four Acts
Paper Number	19-03034
Paper Title	**Analyzing Pedestrian and Bicyclist Crashes At The Corridor Level: A Structural Equation Modeling Approach**
Abstract	Pedestrian and bicycle crashes have been increasing at an alarming pace in recent years. Between 2009 and 2016, annual US pedestrian fatalities increased 46 percent, and bicyclist fatalities increased 34 percent. Crashes involving pedestrians and bicyclists, or vulnerable roadway users (VRUs), are negatively correlated with roadway factors, and positively correlated with environmental and socioeconomic factors. However, specific variables representing these factors are often correlated, making it difficult to accurately characterize relationships between individual variables and pedestrian and bicyclist safety. Our study used the structural equation model (SEM) technique to overcome this problem. We collected pedestrian and bicyclist crash frequency and more than 60 explanatory variables for 200 highway corridors in Wisconsin. We tested the interrelationships between observed “manifest” variables and unobserved “latent” variables. Our results suggest that the most important latent variables influencing the crash frequency of VRUs are bicycle/pedestrian-oriented roadway design (e.g., paved shoulders, sidewalks, and bike lanes), exposure (e.g., walking and biking activity, and employment density), and low social status (e.g., educational level, and wage percentage). The benefits of this study may help community planners, transportation researchers and policymakers with a better understanding of the intricate interrelationship of the influential factors contributing to VRUs road crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1412
Session Title	Safety Data, Analysis, and Evaluation: Research in Four Acts
Paper Number	19-02361
Paper Title	**Speed-Related Characteristics Contributing to Vehicle-Deer Crashes on Rural Two-Lane Roadways**
Abstract	Deer-vehicle crashes (DVCs) continue to be a problem in the United States, with 1.2 million such crashes occurring annually. DVCs are particularly an issue on two-lane rural highways in Michigan, accounting for more than 60 percent of all crashes. Such a high proportion of DVCs limits the transferability of existing safety models, including those found in the HSM, that are often based on data from states with considerably lower proportions of deer crashes. To counter this, a cross-sectional analysis of deer crashes was performed using data from the state of Michigan. Four categories of rural, two-lane two-way highway segments were analyzed separately, including: state-maintained, county federal aid paved, county non-federal aid paved, and county unpaved (i.e., gravel) surfaces. Negative binomial regression models with spatial and temporal random effects were generated. The results showed that speed-related factors, including lane width and horizontal curvature, had a significant effect on vehicle deer crashes occurring on rural two-lane two-way roadway segments in Michigan. Wider lanes were associated with a greater occurrence of deer crashes, perhaps due to higher prevailing travel speeds. Conversely, the presence of curves with design speeds lower than the statutory speed limit was associated with fewer deer crashes, perhaps due to lower travel speeds on curved segments. Wider shoulders, which afford greater separation between the travel lanes and the roadside, were found to significantly reduce deer crash occurrence. Unfortunately, the concentration of hunting licenses, a potentially useful predictor for deer crashes, did not appear to have a consistent influence on DVCs.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1416
Session Title	Motorcycle Crash Causation Study: Early Results and Future Directions
Paper Number	19-03104
Paper Title	**Examining Contributing Factors to Motorcycle Crashes using Matched Case-Control Logistic Regression**
Abstract	Unlike reduction in fatalities from motor-vehicle crashes over the years, statistics showed that the number of motorcyclist crash-related fatalities has nearly doubled in the US from 1994 to 2014 [1-3]. This paper aims to thoroughly examine the factors that affect the occurrence of motorcycle crashes and to identify the relative crash risk for each contributing factor. Data on 351 motorcycle crashes that occurred in Orange County, California, and 702 non-crash control cases were acquired from the Federal Highway Administration (FHWA) and used in the analyses. Matched Case-Control logistic regression was developed to identify the contributing factors that led to the occurrence of fatal motorcycle crashes while controlling for other confounding factors such as crash time, traffic and roadway conditions. The results indicate that percent of time for wearing helmet, amount of sleep in last 24 hours, motorcycle riding experience and number of recent traffic convictions were the factors that significantly affected the occurrence of fatal motorcycle crashes. The findings also suggest that the likelihood of motorcycle crash occurrence can be reduced if motorcyclists avoid committing certain aberrant driving behaviors such as speeding without adjusting to road conditions (i.e., curved segments), taking drugs, alcohol or medications before driving, having insufficient sleep before driving, not wearing a helmet, indulging in lateral movement pre-impact, compensation failure that contributes to crash, and not choosing a proper evasive action prior to crash. Considering the findings of this study, possible countermeasures to improve safety of motorcyclists are provided and discussed.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1416
Session Title	Motorcycle Crash Causation Study: Early Results and Future Directions
Paper Number	19-05159
Paper Title	**A Heterogeneity Based Case-Control Analysis of Motorcyclist's Injury Crashes: Evidence from Motorcycle Crash Causation Study**
Abstract	This study explores how different "policy-sensitive" factors are associated with risk of motorcycle injury crashes, while controlling for rider-specific, psycho-physiological, and other observed/unobserved factors. The analysis utilizes data from a matched case-control design collected through the FHWA's Motorcycle Crash Causation Study. In particular, 351 cases (motorcyclists involved in injury crashes) are analyzed vis-à-vis similarly-at-risk 702 matched controls (motorcyclists not involved in crashes). Unlike traditional conditional estimation of relative risks, the paper presents heterogeneity based statistical analysis that accounts for the possibility of both within and between matched case-control variations. Overall, correlations between key risk factors and injury crash propensity exhibit significant observed and unobserved heterogeneity. The results of best-fit random parameters logit model with heterogeneity-in-means show that riders with partial helmet coverage have significantly lower risk of injury crash involvement. Lack of motorcycle rider conspicuity captured by dark (red) upper body clothing is associated with significantly higher injury crash risk. Importantly, rider's motorcycle-oriented lower clothing (e.g., cannot easily get stuck in the machinery) significantly lowers odds of injury crash. Moreover, formal motorcycle driving training in recent years was associated with lower injury crash propensity. Finally, riders with less sleep prior to crash/interview had higher odds of crash involvement. Methodologically, conclusion is that correlations of several rider, exposure, apparel, and riding history related factors with crash risk are not homogeneous (vary in magnitude and direction). The study results indicate the need to develop appropriate countermeasures, such as refresher motorcycle training courses, prevention of sleep-deprived/fatigued riding, and riding under influence of alcohol/drugs.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1416
Session Title	Motorcycle Crash Causation Study: Early Results and Future Directions
Paper Number	19-05185
Paper Title	**Modeling Injury Severity Score as a More Precise Measure of Motorcyclist Injuries: A Correlated Random Parameter Corner Solution Framework**
Abstract	To analyze key risk factors in motorcycle crashes, this study quantifies how different "policy-sensitive" factors correlate with injury severity, while controlling for rider and crash specific factors, and other observed/unobserved factors. Data on 321 motorcycle injury crashes from a comprehensive US DOT FHWA's Motorcycle Crash Causation Study (MCCS) are analyzed. A unique approach is taken by analyzing an anatomical injury severity scoring system, termed as Injury Severity Score (ISS), that provided an overall score by accounting for the possibility of multiple injuries to different body parts of a rider. ISS varies from 1 to 75, averaging at 10.12 for this sample (above 9 is considered serious injury), with a spike at 1 (very minor injury). As two alternative measures of injury severity, a strong correlation is found between AIS and ISS classification (Kendall's tau of 0.911), but significant contrasts are observed in that, when compared to ISS, AIS tends to underestimate the injury severity sustained by a rider. For modeling, fixed and random parameter Tobit modeling frameworks were used in a corner-solution setting to account for the left-tail spike in the distribution of ISS and to account for unobserved heterogeneity. To additionally account for the interactive effects of key risk factors, the developed random parameters Tobit framework allows for possible correlations among the random parameters. A correlated random parameter Tobit model was found to significantly out-perform uncorrelated random parameter Tobit and fixed parameter Tobit models. Several findings related to rider experience, helmet coverage, and alcohol/multiple drugs intake are quantified.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1416
Session Title	Motorcycle Crash Causation Study: Early Results and Future Directions
Paper Number	19-05819
Paper Title	**Contrasting Crash- and Non-Crash Involved Riders: An Analysis of Data from the Motorcycle Crash Causation Study**
Abstract	Motorcycle crashes and fatalities remains a significant public health problem despite recent decrease in rates for other vehicle types in the United States. Analysis of causal factors for motorcycle crashes is often challenging given lack of reliable traffic volume and the fact that such crashes comprise a relatively small portion of all traffic crashes. Given these limitations, on-scene crash investigations represent an ideal setting through which to investigate the precipitating factors for motorcycle-involved crashes. This study examines motorcycle crash risk factors by employing data recently made available from the Federal Highway Administration Motorcycle Crash Causation Study (MCCS). The MCCS represents a comprehensive investigative effort to determine the causes of motorcycle crashes in the United States, which involved the collection of in-depth data from 351 crashes, as well as the collection of comparison data from 702 paired control observations. All investigations and interviews were conducted in Orange County, California. This dataset provides a unique opportunity to understand how the risk of crash involvement varies across different segments of the riding population. In analyzing the MCCS data, logistic regression models are estimated to identify the rider and vehicle attributes associated with motorcycle crashes. The results of the study suggest that motorcycle crash risks are related to rider age, physical status, and educational attainment. In addition, several modifiable risk factors, which arguably affect the riders' proclivity to take risks, were also associated with motorcycle crash risk, including motorcycle type, helmet coverage, motorcycle ownership and speed, trip destination and traffic violation history.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Lectern Session 1416
Session Title	Motorcycle Crash Causation Study: Early Results and Future Directions
Paper Number	19-05186
Paper Title	**Motorcycles in Connected and Unconnected Traffic**
Abstract	With the coming deployment of autonomous vehicles and advanced driver assistance systems (ADAS) in cars, the characteristics and causes of motorcycle accidents are likely to undergo profound changes in the next generation. Motorcycles may be the most complex -- and most neglected – element in the mix of connected vehicles. Up to this time, riding a motorcycle in traffic of driver-operated cars has been complicated but is likely to become far more difficult if autonomous and ADAS equipped vehicles sometimes fail to "see" the motorcycle. Riders must predict what a driver-controlled car will do but learning to predict what an autonomous car will do may prove even more difficult. The current research methods available to monitor motorcycle crash causation are either statistical analysis of large databases of police reports, on-scene-in-depth studies or naturalistic studies. Of the three, on-scene, in-depth investigations are likely to offer the best compromise of cost and high quality information about failures that lead to crashes. However, the many years that elapse between research funding and completion of a final report of occasional short-term studies like the 1981 Hurt Report or the current Motorcycle Crash Causation Study suggest motorcycle safety will lag far behind the changes in motorcycle crash causation. Instead, what is needed is a continuing, long term effort to collect on-scene, in-depth motorcycle accident data and identify not only human failures but failures of a connected intelligent traffic system. Suggestions for maintaining the high quality of motorcycle crash research in such an environment are presented.

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Sponsoring Committee Standing Committee on Highway Safety Performance (ANB25)
Session Number Poster Session 1306
Session Title Case Studies in Performance-Based Analysis of Geometric Design
Paper Number P19-21495
Paper Title **Evaluation of an Alternative Calibration Process for the Highway Safety Manual by Data from Illinois, Maryland, and Washington States**

Abstract Background – The predictive method of the Highway Safety Manual (HSM) estimates crash frequency by applying uncalibrated safety performance function (SPF) and a set of uncalibrated crash modification factors (CMFs) to each location individually; then the predicted crashes must be adjusted by a local calibration factor (LCF) at the aggregate level (i.e., at least 30-50 sampled sites per SPF). Although this calibration procedure assures total predicted crashes will be localized, still the prediction of crashes for individual locations suffers from the aggregate localization process. While the HSM calibration method has been used in many states and countries, the HSM calibration procedure has some shortcomings and some alternative methods such as calibration function were suggested in past studies.

Method – An alternative approach of locally calibrating the HSM predictive method is proposed to improve prediction quality at individual locations while maintaining equality of total observed and total predicted crashes. The parameters of SPF variables and each individual CMF are estimated by five different methods (Min. SSD, Min. RMSE, Min. MAD, Max. Log Likelihood for Poisson Regression, and Max. Log Likelihood for Negative Binomial Regression).
Data – The proposed approach is validated using the rural two-lane, two-way roads (R2U) roadway inventory, traffic volumes, and crash data from the states of Illinois (six years; 2005-10), Maryland (three years; 2008-10), and Washington (six years, 2010-15). A tool named “Road Safety Data Integrator (RSDI)” was developed for combining, segmentation, and selection of homogeneous HSIS R2U roadway segments for the years of study.

Results – Comparing different GOF measures along with CURE plots of the proposed methods with the HSM calibration method, calibration function, and calibrated Washington State models (for the case of Washington data) and some alternative calibration methods suggested by past studies showed that the proposed method of “Proposed-11: Weights & powers for SPF parameters and CMFs ≠ 1” could perform significantly better while keeping the total number of predicted crashes equal to the total number of observed crashes. Moreover, the results indicated that the additional parameters for CMFs could improve the performance significantly; this result was not observed in the study on calibration function because of data limitation.

Conclusions – Application of the proposed approach can lead to more accurate identification of hot-spots and site-specific strategies in terms of funding allocation. The developed RSDI tool can be used for combining, segmentation, and selection of homogeneous roadway segments of the HSIS data and any datasets that follow linear referencing. Considering the limitations of this study, some avenues for further research are discussed.

Key Words: Highway Safety Manual, Prediction Quality, Local Calibration Factor/Function, HSIS

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Lectern Session 1413
Session Title	Highway Safety Performance Data-Driven Analyses: When It Counts
Paper Number	19-03826
Paper Title	**Effects of signalization at rural intersections considering the elderly driving population**
Abstract	The main objective of this study is to quantify the safety impacts of signalization at Florida's rural three-leg and four-leg stop-controlled intersections by estimating crash modification factors. The intersections are those in which stop signs are provided for the minor approaches or all-way stop-controlled intersections. The CMFs are estimated using the cross-sectional method. Generalized linear models (GLM) and multivariate adaptive regression spline models (MARS) are employed with four-years of Florida crash data. The K-nearest neighbor and K-means clustering algorithms are implemented to identify the comparison sites which are sites having similar characteristics as those of the converted intersections. Furthermore, the quasi-induced exposure method is used to evaluate the safety effects of signalization for elderly and non-elderly drivers, separately. According to the results, signalization contributes to an increase in PDO and rear-end crashes. In addition, elderly drivers are more at risk of being involved in such crashes than non-elderly drivers. In particular, at rural four-leg two-way stop-controlled intersections, signalization decreases crash severity, and greater percentage of the decrease is observed for the elderly drivers than non-elderly especially when the intersection has a high level of major road AADT and elderly driver proportion. This study also demonstrates that the MARS model shows a better model fit than the GLM model due to its strength in capturing nonlinear relationships and interaction effects among variables. This study's findings have implications for both practitioners and researchers.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Lectern Session 1413
Session Title	Highway Safety Performance Data-Driven Analyses: When It Counts
Paper Number	19-04607
Paper Title	**Evaluation of Protected Left-Turn Phasing and Leading Pedestrian Intervals Effects on Pedestrian Safety**
Abstract	Pedestrian safety is an important public health issue for the United States, with pedestrian fatalities representing approximately 16 percent of all traffic related fatalities in 2016. Nationwide, transportation agencies are increasing their efforts to implement engineering-based improvements that increase pedestrian safety. These agencies need statistically rigorous crash modification factors (CMFs) to demonstrate the safety effectiveness of such countermeasures, and to apply in benefit–cost analyses to justify their implementation. This study focused on developing CMFs for two countermeasures that show promise for improving pedestrian safety: protected or protected/permissive left-turn phasing, and leading pedestrian intervals (LPIs). Data were acquired from four North American cities that had installed one or both of the countermeasures of interest: Chicago, IL; New York City, NY; Charlotte, NC; and Toronto, ON. The empirical Bayes (EB) before-after study design was applied to estimate the change in expected crash frequency for crashes following treatment. The protected left-turn phasing evaluation showed a benefit in reducing vehicle–vehicle injury crashes, but did not produce statistically significant results for vehicle–pedestrian crashes, although a disaggregate analysis revealed that this treatment could be especially beneficial where pedestrian volumes exceed 5,000 per day. The LPI evaluation showed a statistically significant reduction in vehicle–pedestrian crashes with an estimated CMF of 0.87.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Lectern Session 1413
Session Title	Highway Safety Performance Data-Driven Analyses: When It Counts
Paper Number	19-03519
Paper Title	**A Comparative Analysis of Empirical Bayes and Bayesian Hierarchical Models in Hotspot Identification**
Abstract	Hotspot identification is an important step in the highway safety management process. Errors in hotspot identification (HSID) may result in an inefficient use of limited resources for safety improvements. The empirical Bayesian (EB)-based HSID has been widely applied as an effective approach in identifying hotspots. However, there are some limitations with the EB approach. It assumes that the parameter estimates of the safety performance function (SPF) are correct without any uncertainty, and does not consider temporarily instability in crashes, which has been reported in recent studies. Bayesian hierarchical model is an emerging technique that addresses the limitations on the EB method. Thus, the objective of this study is to compare the performance of the standard EB method and the Bayesian hierarchical model in identifying hotspots. Three methods (i.e. Crash rate, EB, and the Bayesian hierarchical model-based methods) were applied to identify risky intersections with different significant levels. Four evaluation tests (i.e., Site Consistency; Method Consistency; Total Rank Differences; and Poisson Mean Differences tests) were conducted to assess the performance of these three methods. The testing results suggest that: (1) the Bayesian hierarchical model outperforms the crash rate and the EB-based methods in most cases. Bayesian hierarchical model improves the accuracy of HSID significantly; (2) hotspots identified with crash rates are generally unreliable. It is significant for roadway agencies and practitioners to accurately rank sites in the roadway network in order to effectively manage safety investments. Roadway agencies and practitioners are encouraged to consider the Bayesian hierarchical models in identifying hotspots.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-05379
Paper Title	**Safety Evaluation of Pedestrian Countdown Signals - Definitive Results from Two Cities in the United States**
Abstract	The pedestrian countdown signals (PCS) treatment involves the display of a numerical countdown that shows how many seconds are left in the flashing DON'T WALK interval. Although many studies have attempted to evaluate the safety of PCS, the results have been inconsistent due to many reasons including inadequate samples, and the inability to control for possible bias due to regression to the mean, and exposure. This study performed a before-after empirical Bayes (EB) analysis using data from 115 treated intersections in Charlotte, North Carolina and 218 treated intersections in Philadelphia, Pennsylvania to evaluate the safety effects of PCS. The evaluation also included 136 reference intersections in Charlotte, and 597 reference intersections from Philadelphia. Following the implementation of PCS, total crashes decreased by approximately 8 percent and rear-end crashes decreased approximately 12 percent, and these reductions were statistically significant at the 95-percent confidence level. Pedestrian crashes decreased by about 9 percent and this reduction was statistically significant at the 90-percent confidence level. The economic analysis revealed a benefit-cost ratio of 23 with a low of 13 and a high of 32.

Authors	Samer Katicha, Virginia Polytechnic Institute and State University John Khoury, Lebanese American University Gerardo Flintsch, Virginia Polytechnic Institute and State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-03895
Paper Title	**Estimating Safety with the Multiresolution HAAR Wavelet Method: Comparison with the Safety Performance Function Approach**
Abstract	This paper presents the multiresolution Haar wavelet (MHW) approach to estimate the expected number of crashes at roadway sections. The MHW is similar to kernel density estimation or sliding window (moving average) estimation with the additional benefit of being spatially adaptive. This means that the window size (or bandwidth) can be different at different locations allowing different averaging length (or amount of smoothing). Furthermore, the optimal window size (at each location) is determined solely based on the data. The MHW approach is compared to the current state of the practice Safety Performance Function (SPF) approach on the entire State of Virginia interstate network. The results of the comparison showed that the MHW better predicts future crashes. The MHW approach, unlike the SPF approach, does not require any data other than the crash counts to estimate the expected number of crashes. This makes it easy to implement and simple to use. We have implemented the approach in an Excel spreadsheet that is freely available for use.

Authors	Kui Yang, Tongji University Xuesong Wang, Tongji University Mohammed Quddus, Loughborough University Rongjie Yu, Tongji University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-03921
Paper Title	**Predicting real-time crash risk on urban expressways using Recurrent Neural Network**
Abstract	Real-time crash risk prediction is an important area of research that focuses on identifying hazardous traffic conditions as part of proactive traffic safety management. Although there is a plethora of classification algorithms applied to predict an unsafe traffic condition, they cannot capture spatio-temporal variability in traffic dynamics and are not transferable. In this paper, a state-of-the-art approach based on supervised machine learning - recurrent neural network (RNN) is developed and implemented to address the challenges of predictability of crash risk models. In relation to existing techniques, one of the unique features of RNN is to employ feedback loops where the output from each of the steps is feedback to the RNN to affect the outcome of the current step. It also has a self-updating ability of model parameter via a time sequence, which is helpful for the model adaptability by overcoming the spatial-temporal variability of traffic dynamics. Historical crash data and real-time traffic data from Shanghai Urban Expressway System were matched and split into a training dataset and a test dataset: the training dataset was designed in the matched case-control study and used to develop the crash risk prediction models; the test dataset was a full set including all cases and employed to evaluate the performance of the models via the area under ROC curve (AUC) and sensitivity. In addition, the prediction results were compared with those given by other frequently used classification algorithms, including logistic regression and support vector machine (SVM). The results proved that RNN had a better prediction performance. It could increase the crash prediction accuracy by an average of 13.3% and 7.9% compared to the SVM and logistic regression model, respectively. Furthermore, the optimal ratio of crashes to non-crashes has found to be 1:4 for the model development.

Authors	Xuesong Wang, Tongji University Dongjie Tang, Tongji University Saijun Pei, Tongji University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-04352
Paper Title	**Comparison of Calibration Methods for Improving the Transferability of Safety Performance Functions**
Abstract	Safety performance functions (SPFs) are critical for traffic safety management. They have been applied for identifying significant risk factors, estimating crash frequencies, and screening potentially hazardous locations. Since SPFs proposed by Highway Safety Manual (HSM) are developed based on certain states in the United States, regions without jurisdiction-specific SPFs need model calibrations for the localization of SPFs. The main objective of this study is to compare the typical calibration methods that used in the literature and identify the appropriate ones. Random effects Negative Binomial (NB) models were established for urban arterials in Shanghai and Guangzhou during peak hours and off-peak hours separately. Four calibration methods, including the calibration factor, empirical Bayes (EB) method, K Nearest Neighbor (KNN) regression method, and pooled data, were applied. The performance in improving model transferability was measured by transfer index and the adaptability to insufficient data was assessed by necessary data collected for each method. Based on the modeling results, pooled data approach that composed of the entire Shanghai dataset and 50% proportion of the Guangzhou dataset provides the best performance. And EB method and KNN regression method are preferable to the calibration factor. Furthermore, modeling and calibrating for different time periods should be considered when average speed is incorporated in the model.

Authors	Mingjie Feng, Tongji University Xuesong Wang, Tongji University Jaeyoung Lee, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-04898
Paper Title	**Transferability of Safety Performance Functions and Hotspot Identification for Freeways of the United States and China**
Abstract	Safety performance functions have been a vital tool in traffic safety evaluation including finding contributing factors to crashes, identifying hotspots, and assessing safety effects of countermeasures. In the United States, the Highway Safety Manual has provided a series of SPFs for a variety of road facilities. Due to the limited availability of traffic data in many regions, the transferability of SPFs has been an important topic in the traffic safety field and several studies have been conducted to evaluate the transferability of SPFs. Nevertheless, no study has investigated the international transferability of freeway SPFs and the consistency in hotspot identification has been rarely investigated. Using data from Shanghai and three U.S. states: Florida, Texas and New York, we examine the transferability of freeway SPFs between China and the United States. SPFs were developed separately for total crashes, single-vehicle and multi-vehicle crashes. According to the estimated transfer indices (TIs), all Shanghai SPFs are reasonably transferable to U.S. data, but no U.S. SPFs can be transferred to Shanghai data. The modeling results suggest that this discrepancy might be due to the greater sensitivity of U.S. crashes to annual average daily traffic (AADT), and the likelihood that Shanghai crashes are influenced by factors other than segment length and AADT. The method consistency test (MCT) shows that both Shanghai and U.S. SPFs can identify quite consistent hotspots in the other country. The findings from study are expected to be a good reference for researchers and practitioners in developing countries who want to understand the transferability and applicability of SPFs in the international context.

Authors	Deo Chimba, Tennessee State University Chacha Wambura, Tennessee State University Asad Khattak, University of Tennessee, Knoxville Jim Waters, Tennessee Department of Transportation Behram Wali
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-00228
Paper Title	**Comparing HSM Calibrated and Local Developed SPFs for Rural Two Way Intersections**
Abstract	

Authors	Nancy Dutta, University of Virginia Michael Fontaine, Virginia Transportation Research Council
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-03693
Paper Title	**Developing Rural Four Lane Freeway Crash Prediction Models Using Hourly Flow Parameters**
Abstract	Most past crash prediction research has examined the relationship between crashes, traffic volumes, and other factors at the annual level, due to the rare and random nature of crash occurrence and data availability. For example, the current functional form of safety performance functions in the Highway Safety Manual is based on annual average daily traffic (AADT). Less attention has been given to explicitly modeling the safety effects of vehicle density, volume-to-capacity ratio, and speed distribution at a sub-daily level. This research used continuous count station data from 4 lane rural freeway segments in Virginia and developed crash prediction models using traffic and geometric information provided at hourly aggregation intervals. The results showed that using average hourly volume along with average speed and selected geometric variables improved predictions compared to models that used AADT. When comparing an AADT-based model to an average hourly volume model, the mean absolute prediction error improved by 15% for total crashes. This value improved by 20% after including geometric variables, and by 30% after adding speed to the volume and geometry model. Similar improvements were observed for injury crashes. These results provide a strong indication that crash predictions could be improved using more disaggregate data and justifies further exploration of these relationships using larger datasets and other statistical methodologies. The findings from this research also indicate that inclusion of quality of flow variables, like speed, could create improvements in the quality of crash prediction models.

Authors	Jaeyoung Lee, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Maria Rosaria De Blasiis, Roma Tre University Xuesong Wang, Tongji University Ilaria Mattei, Ferrovie dello Stato Italiano
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-02530
Paper Title	**International Transferability of Macro-Level Safety Performance Functions: A Case Study of the United States and Italy**
Abstract	Safety performance functions (SPFs) or crash prediction models have played an important role in identifying the contributing factors of crashes, predicting crash counts, identifying hotspots, etc. Because it needs a lot of time and efforts to estimate a SPF, previous studies have evaluated if a SPF could be applied to data from other regions, i.e., transferability. Although many efforts have been made for micro-level SPF transferability, not many have been done for macro-level SPF transferability. Transferability analysis of macro-level SPFs in the international context, especially between western countries, has not been conducted. Therefore, we evaluate the transferability of SPFs of several states in the United States (i.e., Illinois, Florida, and Colorado) and Italy in this study. The SPFs were developed using data from counties in the United States and provincias in Italy, and the results show that there are multiple common significant variables across the countries. Subsequently, transfer indexes are calculated between the developed SPFs, and the indexes show that the Italian SPFs for total and bicyclists crashes are transferable to U.S. data after calibration factors are applied while the U.S. total and bicycle SPFs, except for the Colorado SPF, cannot be transferred to the Italian data. On the other hand, none of the developed pedestrian SPFs are transferable to other countries. This paper provides insights into the applicability of macro-level SPFs between the U.S. and Italy, and shows a good potential of international SPFs' transferability. Nevertheless, further investigation is needed for the SPF transferability between more countries.

Authors	Boris Claros, University of Wisconsin, Madison Madhav Chitturi, University of Wisconsin, Madison Glenn Vorhes, University of Wisconsin, Madison Andrea Bill, University of Wisconsin, Madison David Noyce, University of Wisconsin, Madison
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-02139
Paper Title	**Seasonal Crash Prediction Model for Urban Signalized Intersections: Wisconsin Southeast Region**
Abstract	The Highway Safety Manual (HSM) provides methods to quantitatively evaluate safety for a vast range of roadway transportation facilities. The Negative Binomial has been traditionally used for modeling crashes (i.e. crashes per year). Highly aggregated cross-sectional data omits natural time dependent variations leading to important loss of information and introducing error in model predictions. Furthermore, traffic conditions and weather vary over time and space. An alternative approach with seasonal crash estimates is proposed in this paper. Local crashes, traffic, geometry, signal type, and weather data of urban signalized intersections in the Southeast region of Wisconsin were used. Four seasons were considered: Winter, Spring, Summer, and Fall. The Negative Multinomial was used for modeling to account for seasonal variations. The functional form for each predictor variable was optimized. Measures of log-likelihood, inverse overdispersion, cumulative residual (CURE) plots, and Akaike information criterion (AIC) showed adequate model prediction accuracy. Seasonal estimates for fatal and injury (FI) crashes showed that during the Spring season, crash estimates were the lowest and during the Summer were the highest. In contrast, model crash estimates for Property Damage Only (PDO) crashes peaked during the Winter season and remain below annual estimates for the rest of the seasons. Magnitude of fluctuations and accuracy of crash estimates contribute to managerial decisions and allocation of resources for the implementation of treatments, safety programs, minimize safety impacts, and reduce risk of crashes—contributing to reduction in costs associated with crashes, property damage, maintenance, and emergency services.

Authors	Karla Cristina Rodrigues Silva, Centro Federal de Educação Tecnológica de Minas Gerais Antonio Clovis Pinto Ferraz, USP
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-02949
Paper Title	**Transferability and Calibration of Highway Safety Manual Safety Performance Function for Two Lane Highways in Brazil**
Abstract	The present study focused on evaluating HSM crash prediction model for two lane highways on Brazilian conditions. Also, the transferability of the model was considered, specifically by means of a comparison between Brazil and HSM conditions. The analysis of two lane highways crash prediction models was promising when the road characteristics were well known and there was not much difference from base conditions. This conclusion was attained regarding the comparison of results for all segments, non-curved segments and curved segments, confirming that a transferred model can be used with caution. Finally, there are many factors that could not be measured by these models and reflects road safety various condition. Even so, the study of crash predict models in Brazilian context could provide a better start point in safety road analysis.

Authors	Brionne Henderson, Tennessee State University Deo Chimba, Tennessee State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-00124
Paper Title	**Clustering the effects of traffic control type, functional class and spatial distributions to intersections traffic safety**
Abstract	This paper contributes to the literature by examining the effects of traffic control type, spatial distribution and functional class to the traffic safety at intersections. The goal is to correlate crash occurrences to intersection types based on the amount of traffic volume entering the intersection, functional classes of intersecting streets, traffic control type, and the location with respect to CBD areas. Using data from Davidson County in Nashville Tennessee, the study evaluated the intersections considering crashes occurring within 50 feet and 250 feet from the intersection. The study found that signal controlled intersection crash rates are high within the CBD areas but lower in non-CBD areas. However, all-way stop controlled intersections have high crash rates than signalized intersections in non-CBD areas. The overall finding is that the signal controlled intersections are more hazardous within CBD areas relative to non CBD areas compared to stop controlled intersections. Considering the functional class of intersecting streets, the study found that signal controlled intersections crash rates are lowest when the municipal roads are intersecting state roads. Stop controlled intersections have high crash rates when two municipal roads are crossing compared to other combination of functional classes. The intersection of municipal and state roads showed the lowest crash rates for non CBD areas. The statistical modeling validated the findings by quantifying the effect of these variables and their direction of impact (increasing or decreasing probability of crashes).

Authors	Imalka Matarage, Kansas State University Sunanda Dissanayake, Kansas State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-02869
Paper Title	**Calibration of Highway Safety Manual Predictive Models for Kansas Freeway Segments**
Abstract	Prediction models in the Highway Safety Manual (HSM) are used to quantify the potential safety experience of existing and new roadways. Safety Performance Functions (SPFs) in the HSM predictive method are statistical formulas developed based on limited data gathered from selected few states. Therefore, HSM recommends to modify SPFs for a certain jurisdiction by following a calibration methodology or develop local SPFs to enhance the accuracy of predicted crash frequencies. This paper demonstrates the calibration procedure and quality assessment of the calibration process for freeway segments in Kansas utilizing crash data from 2013-2015. Most of the required data were collected from two main databases maintained by Kansas Department of Transportation and the remaining were gathered using Google Earth and ArcGIS tools. A sampling technique was applied and a minimum sample size of 446 freeway segments was calculated corresponding to 95% confidence level and 5% error. Consequently, data for 521 freeway segments were collected and utilized in this freeway calibration. Estimated calibration factors were 0.952, 0.936, 1.982 and 1.843 for multiple vehicle fatal and injury, single vehicle fatal and injury, multiple vehicle property damage only and single vehicle property damage only models respectively. Results indicated that HSM methodology overpredicts crashes for fatal and injury freeway segment models and underpredicts crashes for property damage only freeway segment models in Kansas. Results of quality assessment of the calibration process showed that estimated calibration factors were satisfactory for all freeway facilities considered in this study.

Authors	Yao Chen, Tongji University Yingying Xing, Tongji University Jian Lu, Tongji University Tao Xu, Tongji University Yujie Liu, Tongji University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-04098
Paper Title	**Comparison and analysis of crash frequency and rate in cross-river tunnels using random-effect models**
Abstract	Underground road systems are becoming popular in cites as it can overcome urban space constraints and increase capacity and accessibility for urban transport systems. For cities with rivers and seas, the construction of cross-river tunnel can preserve land resources and reduce traffic congestion without affecting navigation. However, tunnel traffic safety has become an increasing concern due to frequent and serious tunnel traffic crashes. The severity of crashes and the difficulty of rescue in tunnels are higher than those of other road sections. In order to improve the safety of tunnel operation, this paper analyzes the crash data of 14 river-crossing tunnels in Shanghai from 2015 to 2016. A negative binomial (NB) model and a random-effect negative binomial (RENB) model were developed to investigate the relationship between crash frequency and potential influence factors, including tunnel geometry characteristics, traffic volume and crash location. The results show that AADT, speed limit, grade, grade differences and RGR) are likely to increase the crash frequency in cross-river tunnels while horizontal curve radius, vertical curve radius and long tunnel are associated with less crashes. This study also explored the use of crash rate instead of crash frequency as dependent variable by using random-effect Tobit model. The results indicate that the significance of most independent variables is consistent with the results found upon the RENB model based on crash frequency.

Authors	Gary Davis, University of Minnesota, Twin Cities Jingru Gao, University of Minnesota, Twin Cities
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-03007
Paper Title	**Transferability of Crash Modification Factors via Graphical Causal Models: An Introduction**
Abstract	This paper describes an exploratory analysis of how to transfer a crash modification factor, estimated for one set of conditions, to a different set of conditions. Such situations are likely to become important as automated vehicles improve their capabilities and increase their market share. Our starting point is a graphical model describing the dependencies among the variables in a crash mechanism, and we focus on (1) identifying sufficient conditions for taking causal information determined in one situation and applying to another, and (2) deriving expressions for computing the transferred quantities. Three simplified but plausible scenarios are proposed. For each scenario transportability analyses developed by Pearl and his associates are used to develop a re-calibration formula with which an existing CMF can be adjusted to reflect new conditions. Computation examples are used to illustrate these results.

Authors	Rijesh Karmacharya, Kansas State University Sunanda Dissanayake, Kansas State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-02897
Paper Title	**Calibration of the Highway Safety Manual Predictive Methods for Unsignalized Intersections at Urban and Suburban Areas in Kansas.**
Abstract	The Highway Safety Manual (HSM) provides predictive methodologies which help predict crashes on various facility types based on traffic and geometric characteristics, incorporated through Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs). Since the SPFs were developed using data from the states of Minnesota and North Carolina for three-leg unsignalized intersections (3ST) and four-leg unsignalized intersections (4ST), the calibration of the predictive methodologies would increase the accuracy of the prediction for Kansas. In this study, a total of 234 3ST intersections (128 having minor AADT data and 106 intersections using estimated minor AADT data) were used for the calibration, to satisfy the HSM criteria of at least 100 crashes per year for the selected set of sites. Multiple linear regression, with log10 transformation of the continuous variables was carried out to develop a minor AADT estimation model, for which the R-squared value was 0.3281. A calibration factor of 0.51 was calculated when considering all crashes, and 0.40 for fatal and injury (FI) crashes. For 4ST, 167 intersections were used as the sample sites resulting in the calibration factor of 0.61 when considering all crashes and 0.72 for FI crashes. For both facility types, the calibration factors were less than 1.00, implying that the HSM predictive methodology overpredicted the number of crashes for the state of Kansas. The effectiveness of the developed calibration factors were checked with the help of CURE plots and Coefficient of Variation, which showed that the obtained calibration factors are acceptable for application.

Authors	Kenneth Velez, Virginia Polytechnic Institute and State University Samer W. Katicha, Virginia Polytechnic Institute and State University Gerardo Flintsch, Virginia Polytechnic Institute and State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-04991
Paper Title	**An Enhanced Methodology for the Identification of Locations with High Risk of Wet Crashes**
Abstract	About 18% of crashes on Virginia's interstates from 2014 to 2016 were reported to be wet crashes. Although extensive research on crashes has been conducted, limited attention has been devoted to the prediction of wet crashes. The ratio of wet over dry crashes (wet over dry ratio, WDR) has traditionally been the parameter of interest. In this paper, negative binomial regression is used to quantify the relationship between WDR and traffic and road parameters. One issue with the WDR is the handling of sites with zero dry crash counts. This was addressed by numerically replacing the zeros with 0.5 or by using an empirical Bayes estimate of the expected number of dry crashes instead of the dry crash counts. The empirical Bayes approach resulted in a better model fit as measured using Akaike's Information Criterion (AIC). The negative binomial model developed for wet crashes was used to identify parameters that affect the pavement water film thickness and the expected number of wet crashes. The approach identified the longitudinal grade difference as an important parameter.

Authors	Alan Hachey, AICP, CDM Smith Michael Lawrence, Jack Faucett Associates, Inc. Frank Gross, VHB Geni Bahar, NAVIGATS Inc. Karen Scurry , Federal Highway Administration (FHWA)
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-04233
Paper Title	**Evaluating Performance of Safety Countermeasures: Applied Benefit Cost Analysis**
Abstract	A Benefit Cost Analysis (BCA) is a key component of a comprehensive project or program development process that considers quantitative and qualitative impacts of highway investments. This research developed methods and procedures that transportation agencies can use to identify, quantify, and assign value to the economic benefits and costs of highway projects and programs over multiyear timeframes. This paper introduces fundamental concepts of BCA and the safety management process, defines economic measures for BCA, provides an overview of BCA in the safety management process and project development process, and identifies several related resources. The paper describes a BCA tool developed by the FHWA, Safety BCA, that supports transportation professionals in applying BCA to safety countermeasure project performance evaluation. Finally, the paper applies the process to a safety countermeasure project example: converting a rural arterial four-way stop intersection into a signalized intersection or a roundabout.

3 Network Screening

Raghavan Srinivasan, University of North Carolina, Chapel Hill

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

The subcommittee identified nine papers related to newtwork screening. Some papers in this category provide a case study of an application in a specific context. Other studies discuss methods with suggestions on the possibility of using these methdos for network screening. Both groups of studies are included in this review.

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

- Transferability of SPFs for hot spot identification, use of method consistency test (MCT) (Feng et al.; 19-04898);
- Integrated approach that incorporates a weighted ranking to rank the sites with higher potential for improvement (Dadashova et al.; 19-02198);
- Short segment approach versus sliding window approach (Famili et al.; 19-01589);
- Empirical Bayes and Bayesian Hierarchical Models (Guo et al.; 19-03519);
- Crash frequency, empirical Bayesian (EB), potential for safety improvement (PSI), and full Bayesian (FB) methods applied at the meso level (combination of intersections and adjacent segments) (Li and Wang; 19-01591);
- Multivariate full-Bayesian spatial mixed crash model (CM) (Amer and Sayed; 19-05425);
- Binary logit versus machine learning methods for identifying hot spots for different age groups (Mafi and Abdelrazig; 19-05497);
- Hot spot versus systemic approaches (Gross and Harmon; 19-01977).

From an **application perspective**, the following applications/settings are covered:

- Freeways (Feng et al.; 19-04898);
- Urban intersections (Dadashova et al.; 19-02198);
- Midblock crashes (Famili et al.; 19-01589);
- Wet crashes (Velez et al.; 19-04991);
- Urban Arterials (Li and Wang; 19-01591).

Below, for each of the nine papers involving network screening, the following information is provided: authors, sponsporing committee, session numer, session title, paper number, paper title, and abstract. Papers are ordered according their ID number.

Authors	Afshin Famili, Clemson University Wayne Sarasua, Clemson University Adika Iqbal, Clemson University Devesh Kumar, Clemson University Jennifer Ogle, Clemson University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-01589
Paper Title:	Short Segment Statewide Screening of Mid-Block Crashes in South Carolina
Abstract:	The AASHTO Highway Safety Manual (HSM) presents a variety of methods for quantitatively estimating crash frequency or severity at a variety of locations. The HSMpredictive methods require the roadway network to be divided into homogeneous segments and intersections, or sites populated with a series of attributes. It recommends a minimum segment length of 0.1 miles. This research focuses on segment lengths of less than 0.1 miles for statewide screening of midblock crash locations to identify site specific locations with high crash incidence. The paper makes an argument that many midblock crashes can be concentrated along a very short segment due to an undesirable characteristic of a specific site. The use of longer segments may “hide” the severity of a single location if the rest of the segment has few or no additional crashes. In actuality, this research does not divide sections of roads into short segments. Instead, a short window approach is used. The underlying road network is used to create a layer of segment polygons using GIS buffering. Crash data are then overlaid and aggregated to the segment polygons for further analysis. The paper makes a case for the use of short fixed segments to do statewide screening and how accurately geocoded crash data is key to its use. A comparison is made with a sliding window approach (Network Kernel Density). The benefits of using fixed segments is that they are much less complex then using the sliding window approach.

Authors	Jia Li, Beijing University of Technology Xuesong Wang, Tongji University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-01591
Paper Title	Hot Spot Identification of Urban Arterials at the Meso Level
Abstract	Urban arterials form the main structure of street networks. They typically have high traffic volume and high crash frequency. Hotspot identification (HSID) is the first step for traffic safety management process and often utilizes crash prediction models. The classical crash prediction models investigate the relationship between arterial characteristics and traffic safety at micro level, since they treat road segments and intersections as isolated units. This micro-level analysis has limitations when examining urban arterial crashes because: 1) signal spacing is typically short for urban arterials in dense street network, and there are interactions between intersections and road segments that classical models do not accommodate; 2) in practical engineering, a hotspot consists of several adjacent intersections and road segments instead of a single intersection or road segment. Taking these into account, a meso-level unit that combined signalized intersections and their adjacent road segments as a whole was adopted. To investigate the suitable research unit and method for urban arterial HSID, this study identified hazardous micro-level (intersections or road segments) and meso-level units at the same time using crash frequency, empirical Bayesian (EB), potential for safety improvement (PSI), and full Bayesian (FB) methods. Consistency was tested to evaluate the performance of the HSID methods. The results showed that 1) meso-level units performed better than micro-level units regardless of which HSID method was adopted; 2) EB and PSI performed better than the other methods no matter for which research unit; 3) there was a big difference between the identified hazardous micro- and meso-level units.

Authors	Frank Gross, VHB Timothy Harmon, VHB
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Lectern Session 1126
Session Title	Safety Management Policies and Decision-Support Frameworks—Hybrid Session
Paper Number	19-01977
Paper Title	Allocating Spending Between Hot Spot and Systemic Approaches to Safety Management
Abstract	There are more opportunities to improve safety across a highway network than funds available to implement projects. As such, safety program managers are challenged with selecting projects and allocating resources to maximize the program's return on investment. The hotspot and systemic approaches are two complementary approaches to safety management. A common question is how to allocate funding between these two approaches to achieve the maximum return on investment, considering the objectives and relative risks of each. This paper presents a framework to consider tradeoffs of allocating funding between hotspot and systemic projects as well as when to apply each approach. The framework is based on average project costs, average project effectiveness, and average crash costs. To demonstrate the framework, this paper presents average values based on six countermeasures that represent the hotspot approach and six countermeasures that represent the systemic approach. In general, this paper uses higher-cost and higher-effectiveness projects to represent the hotspot approach and lower-cost and lower-effectiveness projects to represent the systemic approach. Based on the sample of countermeasures and data included in this paper, the average cost-effectiveness of systemic countermeasures is greater than the average cost-effectiveness of hotspot countermeasures. While systemic countermeasures tend to be more cost-effective than hotspot countermeasures on average, there is a need to balance these two approaches. The framework could also apply to other situations, such as allocating funding between other safety programs (e.g., roadway departure and intersection safety programs) or prioritizing among project alternatives within a program (e.g., roundabouts, signals, or signing).

Authors	Bahar Dadashova, Texas A&M Transportation Institute Karen Dixon, Texas A&M Transportation Institute Ioannis Tsapakis, Texas A&M Transportation Institute Jing Li, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-02198
Paper Title:	Integrated Approach to the Network Screening of Urban Intersections
Abstract:	As the first and one of the most important steps of Highway Safety Improvement Program (HSIP), network screening aims to identify sites with the highest potential for improvement. Network screening is not a trivial process and depends on several factors such as crash frequency and severity, traffic volume and roadway characteristics, and crash history of similar sites. The reliability of network screening is based on the safety performance measure selected for conducting the analysis. In this paper, the authors propose an integrated approach that incorporates a weighted ranking to rank the sites with higher potential for improvement. The results of the pilot study show that the proposed methodology is more reliable than using individual performance measures and could be implemented by transportation agencies that identify highway safety improvement projects.

Authors	Xiaoyu Guo, Texas A&M Transportation Institute Lingtao Wu, Texas A&M Transportation Institute Yajie Zou, Tongji University Lee Fawcett, Newcastle University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Lectern Session 1413
Session Title	Highway Safety Performance Data-Driven Analysis: When It Counts
Paper Number	19-03519
Paper Title	A Comparative Analysis of Empirical Bayes and Bayesian Hierarchical Models in Hot Spot Identification
Abstract	Hotspot identification is an important step in the highway safety management process. Errors in hotspot identification (HSID) may result in an inefficient use of limited resources for safety improvements. The empirical Bayesian (EB)-based HSID has been widely applied as an effective approach in identifying hotspots. However, there are some limitations with the EB approach. It assumes that the parameter estimates of the safety performance function (SPF) are correct without any uncertainty, and does not consider temporarily instability in crashes, which has been reported in recent studies. Bayesian hierarchical model is an emerging technique that addresses the limitations on the EB method. Thus, the objective of this study is to compare the performance of the standard EB method and the Bayesian hierarchical model in identifying hotspots. Three methods (i.e. Crash rate, EB, and the Bayesian hierarchical model-based methods) were applied to identify risky intersections with different significant levels. Four evaluation tests (i.e., Site Consistency; Method Consistency; Total Rank Differences; and Poisson Mean Differences tests) were conducted to assess the performance of these three methods. The testing results suggest that: (1) the Bayesian hierarchical model outperforms the crash rate and the EB-based methods in most cases. Bayesian hierarchical model improves the accuracy of HSID significantly; (2) hotspots identified with crash rates are generally unreliable. It is significant for roadway agencies and practitioners to accurately rank sites in the roadway network in order to effectively manage safety investments. Roadway agencies and practitioners are encouraged to consider the Bayesian hierarchical models in identifying hotspots.

Authors	Kenneth Velez, Virginia Polytechnic Institute and State University Samer W. Katicha, Virginia Polytechnic Institute and State University Gerardo Flintsch, Virginia Polytechnic Institute and State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-04991
Paper Title	An Enhanced Methodology for the Identification of Locations with a High Risk of Wet Crashes
Abstract	About 18% of crashes on Virginia's interstates from 2014 to 2016 were reported to be wet crashes. Although extensive research on crashes has been conducted, limited attention has been devoted to the prediction of wet crashes. The ratio of wet over dry crashes (wet over dry ratio, WDR) has traditionally been the parameter of interest. In this paper, negative binomial regression is used to quantify the relationship between WDR and traffic and road parameters. One issue with the WDR is the handling of sites with zero dry crash counts. This was addressed by numerically replacing the zeros with 0.5 or by using an empirical Bayes estimate of the expected number of dry crashes instead of the dry crash counts. The empirical Bayes approach resulted in a better model fit as measured using Akaike's Information Criterion (AIC). The negative binomial model developed for wet crashes was used to identify parameters that affect the pavement water film thickness and the expected number of wet crashes. The approach identified the longitudinal grade difference as an important parameter.

Authors	Mingjie Feng, Tongji University Xuesong Wang, Tongji University Jaeyoung Lee, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 1706
Session Title	Highway Safety Performance
Paper Number	19-04898
Paper Title:	Transferability of Safety Performance Functions and Hot Spot Identification for Freeways of the United States and China
Abstract:	Safety performance functions have been a vital tool in traffic safety evaluation including finding contributing factors to crashes, identifying hotspots, and assessing safety effects of countermeasures. In the United States, the Highway Safety Manual has provided a series of SPFs for a variety of road facilities. Due to the limited availability of traffic data in many regions, the transferability of SPFs has been an important topic in the traffic safety field and several studies have been conducted to evaluate the transferability of SPFs. Nevertheless, no study has investigated the international transferability of freeway SPFs and the consistency in hotspot identification has been rarely investigated. Using data from Shanghai and three U.S. states: Florida, Texas and New York, we examine the transferability of freeway SPFs between China and the United States. SPFs were developed separately for total crashes, single-vehicle and multi-vehicle crashes. According to the estimated transfer indices (TIs), all Shanghai SPFs are reasonably transferable to U.S. data, but no U.S. SPFs can be transferred to Shanghai data. The modeling results suggest that this discrepancy might be due to the greater sensitivity of U.S. crashes to annual average daily traffic (AADT), and the likelihood that Shanghai crashes are influenced by factors other than segment length and AADT. The method consistency test (MCT) shows that both Shanghai and U.S. SPFs can identify quite consistent hotspots in the other country. The findings from study are expected to be a good reference for researchers and practitioners in developing countries who want to understand the transferability and applicability of SPFs in the international context.

Authors	Ahmed Osama Amer, Ain Shams University Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-05425
Paper Title	A Novel Approach for Identifying, Diagnosing, and Treating Active Transportation Safety Issues
Abstract	There has been an increasing interest in active transportation due to its many health, environmental, and economical benefits. However, active commuters are subjected to an elevated level of severe crashes' risk, which can be a deterrent to many road users to shift to active transportation. Therefore, there is a need for developing systematic approaches to improve the safety of active commuters. This paper presents a new approach for identifying, diagnosing and remedying active transportation safety issues. The approach is demonstrated through a case study of City of Vancouver's 134 traffic analysis zones (TAZs). A comprehensive GIS data related to traffic exposure, socio-economics, land use, built environment, street network, and cyclist and pedestrian networks was used in the analysis. A multivariate full-Bayesian spatial mixed crash model (CM) was developed incorporating cyclist and pedestrian crashes as well as motorized and non-motorized traffic exposure measures. The CM was used to identify the top 10% active transportation crash-prone zones (CPZs) and safe zones (SZs) using the novel Mahalanobis Distance method. CPZs were found clustered in the downtown. Sixteen trigger variables were statistically investigated for each CPZ and SZ. Lastly, remedies, related to land use, traffic demand, and traffic supply management, were proposed using the trigger variable analysis and literature consultation.

Authors	Somayeh Mafi, Florida A&M University Yassir Abdelrazig, Florida A&M University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-05497
Paper Title	Identification and Prediction of Severity-Based Crash Hot Spots for Occupants of Different Age Groups in Various Time Intervals of a Day
Abstract	The identification and prediction of crash hotspots is an essential task in the highway safety management, particularly when highway officials have a limited budget for roadway mitigations. Implementing suitable methods for crash hotspot identification and prediction can result in the efficient employment of federal, state and local government resources for enhancing transportation safety. This paper aims to conduct GIS-based hotspot analysis to identify the crash-prone locations for various occupant age groups during different time intervals of a day and predict the location of these hotspots using statistical and machine learning models. For this purpose, first, the crash-prone locations for different occupant age groups and various time intervals of a day (twelve combinations) were identified by using severity-weighted crash hotspots analyses on a case study in Tampa Bay region (Florida, District 7). Since the number of crash hotspots in each dataset was so limited compared to non-hotspots, undersampling was used in order to adjust the class distribution of each dataset before implementing the classifiers. Then, binary logit models (BLM) were implemented to predict crash hotspots and investigate the influence of a range of parameters on the probability of creating a crash hotspot. In the end, the prediction performance of BLMs was compared with the C4.5 machine learning models. Results showed that C4.5 machine learning models outperformed BLMs in accurately predicting crash hotspots. Moreover, the models displayed substantial differences in crash hotspot determinants and their coefficients across the occupants' age groups and time intervals of a day.

4 Safety Performance Functions

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Studies involving safety performance functions (SPFs) aim to model crash counts, or frequencies, as a function of various contributing factors and to explain the effects of the identified factors on the counts. The subcommittee identified fifty-two papers, which are classified as those pertaining to the use of SPFs. The papers are classified by type of roadway facilities, type of crashes (e.g., non-motorized road users involved), scope, methodology, and so on.

Many papers analyzed the safety effects of **alternative intersections or interchanges** (19-00233, 19-00396, 19-01950, 19-03377, 19-03728, 19-04086, and 19-04385), including continuous green-T intersections (19-00233 and 19-04086), median U-turn intersections (19-03377), restricted crossing U-turn intersections (19-03728), displaced left-turn intersections (19-04385), and diverging diamond interchanges (19-00396 and 19-01950). In addition, multiple papers investigated the safety performance for **non-motorized user involved crashes** (19-00054, 19-00055, 19-00614, 19-02530, 19-03034, and 19-03108). This topic is important, as non-motorized users are much more vulnerable to traffic crashes compared to vehicle occupants.

Overall eleven papers studied the safety performance at the **macroscopic level** (19-00055, 19-00573, 19-00614, 19-02530, 19-02686, 19-02874, 19-03258, 19-03389, 19-03576, 19-03653, 19-04346, and 19-05507). Two of the macro-level papers focused on home-based features (19-02874 and 19-03576). In addition, four macro-level papers considered spatial effects and/or temporal effects in their studies (19-02686, 19-03258, 19-03389, and 19-04346). Other papers analyzed the safety performance at the **mesoscopic level** or **corridor level** (19-01591, 19-02198, and 19-03034).

SPF transferability and **local calibration** are among the popular topics this year. This phenomenon may imply that many jurisdictions and researchers started applying SPFs to evaluate the safety performance in their regions. Five papers explored the transferability of the SPFs to other regions (19-02530, 19-02949, 19-04352, 19-04401, and 19-04898). The international transferability of the developed SPFs/HSM SPFs are explored in 19-02530 (U.S. and Italy), 19-02949 (U.S. and Brazil), and 19-04898 (U.S. and China). Four papers studied the local calibration of the SPFs (19-00228, 19-02144, 19-02653, 19-02869, and 19-02897).

Also, there are several common topics among the SPF papers. Some papers collected and applied **weather or climate** variables in the SPFs (19-00614, 19-03285, and 19-03858), and found the weather plays an important role in safety performance. Further, the safety performance on **rural highways** (19-01242, 19-02361, 19-03113, 19-03596, and 19-03693), **rural intersections** (19-00228, 19-03696, 19-03826, and 19-04086), and the safety effects of **pavement** (19-00735, 19-01242, and 19-01673) were investigated by multiple papers.

Lastly, it is noteworthy to mention that there are many papers applying **innovative methodologies** in their analyses. The papers 19-00055, 19-04486, and 19-05124 applied data mining techniques. The paper 19-0005 developed decision tree regression models for pedestrian and bicycle crashes and found that the decision tree regression model considering spatial predictors, outperforms its counterpart without spatial predictors. The paper 19-04486 adopted random forest approach for exploring the effects of intersection skew angle in safety performance. Likewise, the paper 19-05124 also employed random forest to analyze the data and identify the contributing factors to the focus crash types and facility types. The paper 19-03034 investigated pedestrian and bicycle crashes at the corridor level using a structural equation model (SEM), and the paper 19-03519 used both empirical Bayes and Bayesian hierarchical models for identifying hotspots. The paper 19-03744 used a social network analysis approach to investigate factors contributing to fatal crashes, and the paper 19-03826 used generalized linear modeling and MARS (multivariate adaptive regression splines) approaches to compare the safety performance at signalized and unsignalized intersections in rural areas. The paper 19-04346 used smartphone-based connected vehicle data for analyzing zone-based time-depedent safety performance. The paper 19-05507 compares simulation-based multivariate modeling with copula-based multivariate modeling approaches and found that the copula-based approach is superior.

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

Authors	Omar Abou Kasm, New York University Ziyi Ma, New York University Joseph Chow, New York University Ali Diabat, New York University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-00054
Paper Title	Quantifying the Effect of Cyclist Behavior on Bicycle Crashes and Fatalities
Abstract	This paper is dedicated to quantifying the effect of cyclist riding behavior in bicycle crashes, injuries and fatalities. The motivation of the paper comes from the New York City (NYC) Vision Zero program and moreover aims to fill the literature gap that misses the consideration of cyclist behavior in existing crash models. The quantification is done by the introduction of three regression models for Manhattan in NYC. The first two relate cyclist behavior to crash counts and crash rates; the third relates behavior to fatality equivalent counts. Results show that riding counter flow in a bicycle lane is the largest cause of crashes while riding in a lane other than the bike lane or the one adjacent to it is the largest cause for fatality equivalent counts. Other measures are also quantified, namely the use of helmets and area specific effects. The latter shows that crashes are more likely to happen in the area around the Central Park (Upper West and Upper East Manhattan), whereas the built environment in Midtown is very safe for bikes. Moreover, a helmet-use sensitivity analysis is presented showing that helmets can aid in decreasing fatality equivalent counts by up to 60% from current use. Finally, the use of the quantifications for severity-based fine pricing is introduced.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-00055
Paper Title	Applying Data Mining Techniques to Analyze the Pedestrian and Bicycle Crashes at the Macroscopic Level
Abstract	This paper presents different data mining techniques to analyze the vulnerable road user (i.e., pedestrian and bicycle) crashes by developing crash prediction models at macro-level. In this study, we developed data mining approach (i.e., decision tree regression (DTR) models) for both pedestrian and bicycle crash counts. To author knowledge, this is the first application of DTR models in the growing traffic safety literature at macro-level. The empirical analysis is based on the Statewide Traffic Analysis Zones (STAZ) level crash count data for both pedestrian and bicycle from the state of Florida for the year of 2010 to 2012. The model results highlight the most significant predictor variables for pedestrian and bicycle crash count in terms of three broad categories: traffic, roadway, and socio demographic characteristics. Furthermore, spatial predictor variables of neighboring STAZ were utilized along with the targeted STAZ variables in order to improve the prediction accuracy of both DTR models. The DTR model considering spatial predictor variables (spatial DTR model) were compared without considering spatial predictor variables (aspatial DTR model) and the models comparison results clearly found that spatial DTR model is superior model compared to aspatial DTR model in terms of prediction accuracy. Finally, this study contributed to the safety literature by applying three ensemble techniques (Bagging, Random Forest, and Boosting) in order to improve the prediction accuracy of weak learner (DTR models) for macro-level crash count. The model's estimation result revealed that all the ensemble technique performed better than the DTR model and the gradient boosting technique outperformed other competing ensemble technique in macro-level crash prediction model.

Authors	Deo Chimba, Tennessee State University Chacha Wambura, Tennessee State University Asad Khattak, University of Tennessee, Knoxville Jim Waters, Tennessee Department of Transportation Behram Wali
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-00228
Paper Title	Comparing HSM Calibrated and Local Developed SPFs for Rural Two Way Intersections
Abstract	This study developed HSM calibration factors for Rural Two-Lane, Two-Way Intersections in Tennessee for three leg stop controlled intersections (3ST), four leg stop controlled intersections (4ST), and four leg signalized intersections (4SG). Utilizing crash data from 2011 to 2015, and by applying crash modification factors (CMFs), corresponding statewide and regional calibrations factors for 2010 HSM Safety Performance Functions (SPFs) were developed as 0.633 for 3ST intersections, 0.980 for 4ST intersections and 0.730 for 4SG intersections. The calibration factors changed slightly without applying CMFs (using HSM default values) as 0.514 for 3ST, 0.747 for 3ST and 0.461 for 4SG. Overall, the developed statewide calibration factors for 3ST, 4ST and 4SG intersections were less than 1.0 indicating that Tennessee has fewer crashes than those predicted using 2010 HSM SPFs. Comparing to findings from other states, the Tennessee-developed Rural Two-Lane, Two-Way intersections calibration factors are comparable to, but slightly higher than, those developed in most states. Using Tennessee crash and traffic data, the study developed local safety performance functions (SPFs) reflecting those developed in 2010 HSM. The sign and magnitude of the model constants and variable coefficients of the locally developed Tennessee SPFs were very close to those in 2010 HSM. For three leg stop controlled intersection (3ST), the Tennessee-developed SPF has a constant term of -9.25 (-9.86 in HSM), the major road AADT coefficient of 0.71 (0.76 in HSM) and the minor road AADT coefficient is 0.41 (0.49 in HSM).

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-00233
Paper Title	The Safety Implications of the Conversion of Continuous Green T-Intersections Back to Conventional T-Intersections
Abstract	A continuous green T-intersection (CGT) is an innovative intersection that could improve the through traffic capacity by allowing major-leg vehicles on the top side of T-intersection to pass through without stopping. Recently, traffic engineers decided to stop CGT operations at several T-intersections in Florida because of traffic safety concerns, conversion to four-legged intersection, pedestrians' demand, and non-compliance with the latest Manual on Uniform Traffic Control Devices. In this study, safety effects of recent conversions of CGTs back to conventional T-intersections in Florida are explored. A before-and-after study with the comparison group method are adopted. The results indicate significant reductions in total, fatal-and-injury, rear-end, and CGT-related crashes by 40% to 60% after the conversion. In order to validate the results, a cross-sectional analysis was conducted with new data from four states. The results are consistent for total, fatal-and-injury, and CGT-related crashes with those from the before-and-after study. The results also show that crashes at CGTs could be minimized by providing a physical separation between the acceleration lane for the merging vehicles and the CGT through lane, along with other factors. Because Florida's T-intersections that were converted back to the conventional design from CGT had no physical separation, and the results showed a significant safety improvement after the conversion. Therefore, the decision to stop CGT operations at the Florida's study sites was supported from the safety aspect. The study concluded that safety at CGTs could be a concern compared to non-CGTs; however, it could be significantly improved by providing appropriate countermeasures.

Authors	Amirarsalan Mehrara Molan, University of Wyoming Joseph Hummer, North Carolina Department of Transportation Khaled Ksaibati, University of Wyoming
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-00396
Paper Title	Modeling Safety Performance of the New Super DDI Design in terms of Vehicular Traffic and Pedestrian
Abstract	Most existing interchanges in the United States were built more than 50 years ago based on old design policies. Many of these designs are not consistent with current traffic and pedestrian demands anymore. This paper models the safety performance of a new design called a super diverging diamond interchange (super DDI) using VISSIM simulation and the Surrogate Safety Assessment Model (SSAM). Six other interchange designs were also considered for comparing to the new super DDI design. Also, the same number of tests were conducted to evaluate pedestrian performance of the designs considered in this study. Based on the results, the super DDI showed a high potential either in terms of traffic safety and pedestrian safety. In comparison to other designs, the super DDI had the minimum number of simulated conflicts as well as the lowest mean speed and time to collision (TTC) of simulated conflicts. Reviewing the geometry of the super DDI, lower traffic volumes involved in each conflict point should be one of the main reasons for the promising traffic safety performance of the design. Regarding pedestrian performance, there is no free-flowing conflict between vehicles and pedestrians in a super DDI. Therefore, pedestrian paths of the super DDI are predicted to be safer than the paths in a typical DDI design.

Authors	Ali Farhan, University of Calgary Lina Kattan, University of Calgary Richard Tay, RMIT University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-00573
Paper Title	Collision Models of Local Roads: Impacts of Zonal Attributes and Transit Fare Sensitivity
Abstract	The problem of collisions on local roads has received little specific attention despite the considerable number of such collisions that occur each year. This study examines collision frequency on local roads at the traffic analysis zone (TAZ) level. The City of Calgary is used as a case study, where we focus on the impacts of land use, demographic characteristics, and travel characteristics. We also investigate the effects of some key transportation planning parameters for which there have been very limited studies, including the number of personal and commercial trips and the employment numbers in various categories. This study examines the impact of the number of trips made by automobile versus more sustainable transport modes like transit, walking, and biking for personal travel. It also examines the impact of commercial truck movement on the number of collisions on local roads in a TAZ. The impact of transit-oriented development zone initiatives is explored, as is the relationship between the predominant land use type (e.g., residential, commercial, industrial) and the number of collisions on local roads. Using a Regional Transportation Model (RTM) and calibrated Crash Prediction Models (CPMs), this study uses sensitivity analysis to explore how changes in transit fares impact the collision count on local roads. Results provided some important insights for policy level implications.

Authors	Jaeyoung Lee, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Helai Huang, Central South University Qing Cai, University of Central Florida
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1126
Session Title	Safety Management Policies and Decision-Support Frameworks—Hybrid Session
Paper Number	19-00614
Paper Title	Transportation Safety Planning Approach for Pedestrians: An Integrated Framework of Modeling Walking Duration and Pedestrian Fatalities
Abstract	Multiple approaches have been proposed to take traffic safety into consideration in the long-term transportation plans, which is called transportation safety planning. Some early studies used trip generation data as the explanatory variables for their macro-level crash safety performance functions, or crash prediction models. Nevertheless, no study has attempted to integrate walking exposure and pedestrian safety at the modeling stage. Thus, a novel methodological framework for integrating the analyses of walking exposure and the pedestrian crashes is proposed toward the better transportation safety planning for pedestrians. In comparison with walking trips and walking miles, the walking hours was identified as the best walking exposure variable by a preliminary analysis. Thus, the integrated modeling structure with walking hours as an exposure were developed. The modeling results indicate that climate conditions, population, and car usage pattern affect walking hours, and predicted walking hours, climate condition, percentage of mid-elderly (64-75 years), proportions of minority race/ethnicity, and percent of tertiary industry occupations have significant effects on pedestrian fatalities. In addition, the integrated modeling framework is compared with the non-integrated ones, and the result indicates that the integrated framework outperforms its counterparts, in terms of deviance information criterion. The proposed approach and the findings from this study are expected to provide useful insights not only to researchers but also to policy-makers and practitioners in the fields of transportation planning and traffic safety.

Authors	Jaeyoung Lee, University of Central Florida Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-00735
Paper Title	Safety Effects of Pavement Roughness for Freeways: A Comparative Analysis of Interstate Highways in Five States
Abstract	Traffic crashes occur usually because of the contribution of a combination of human, roadway/ environment, and vehicle factors. Pavement condition is closely related to the three factors as it is one of the most important roadway/environment factors and it affects driving behavior and vehicle performance at the same time. Previous studies have shown that pavement conditions have played an important role in safety. In this study, we develop four different safety performance functions to evaluate the effect of pavement roughness, which is measured by the International Roughness Index (IRI), on the number of crashes using the interstate highway data from five states representing different geographical and weather regions in the US: Arizona, Colorado, Florida, Maryland, and Michigan. The modeling results identify many significant variables including traffic volume and proportion of trucks, through lane count, shoulder type, median width, high-occupancy vehicle lane operation and HOV lane count, speed limit, area type along with IRI-related factors. The results indicate that the increased IRI (deterioration of pavement quality) contribute to larger numbers of total crashes. On interstate highways with speed limit of 70 mph and higher, the effects of IRI are relatively smaller. On the other hand, the effects of IRI increase with a larger traffic volume. Based on the modeling results, seven crash modification functions of IRI values by crash type and speed limit were estimated. The findings from this study are expected to be useful for both pavement and safety engineers to understand the relationship between IRI and safety on freeways.

Authors	Haitao Gong, Jackson State University Shontria Dent, Jackson State University Feng Wang, Jackson State University Bin Zhou, Central Connecticut State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-00817
Paper Title	Application of Random Effects Negative Binomial Models with Clustered Dataset for Vehicle Crash Frequency Analysis
Abstract	For the past few years, vehicle crash frequency analysis has been one of the study areas of great interests in highway safety research. One of the major challenges is how to deal with the unobserved heterogeneity of crash data. While statistical models of crash frequency analysis based upon single probability distributions are constantly improving, several researchers discovered that multiple distribution models might better describe crash frequency data and capture more unobserved heterogeneity. Based upon the hypothesis that total crash counts occurring at an intersection may be affected by different unique sets of contributing factors, this research proposes a two-step approach to study the crash contributing factors at intersections in Mississippi Coast which is one of the most frequent crash areas in the State of Mississippi. In this study, the crash data are first clustered into subpopulations with the application of a hierarchical clustering method, and then a Random Effects Negative Binomial model is applied to each component at the intersection level. A model with no data clustering is also estimated to serve as the comparison benchmark. The analysis results show that this two-step approach can reveal more information about crash contributing factors and have increased predictive power and goodness of fit.

Authors	Iliya Nemtsov, Ryerson University Alireza Jafari Anarkooli, Ryerson University Bhagwant Persaud, Ryerson University Ian Lindley, Ryerson University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-01242
Paper Title	Safety Effects of Pavement Maintenance Treatments for Two-Lane Rural Roads – Insights for Pavement Management
Abstract	The research used data from two-lane rural roads in Ontario, Canada and the empirical Bayes (EB) before-after methodology to evaluate the change in safety following maintenance treatments over a 12 year period to improve pavement condition as measured by International Roughness Index (IRI). The results indicate statistically significant reductions (P<0.10) in severe (fatal plus injury) crashes of about 7% (a crash modification factor (CMF) of 0.93) for arterial roads and 10% for collector roads. For property damage only (PDO) crashes there was a significant reduction of about 7% for arterial roads and a tiny, insignificant increase for collector roads. As part of the EB methodology, safety performance functions (SPFs), which, importantly, included IRI as a variable, were developed to control for effects caused by factors such as regression-to-the-mean and traffic volume changes. The inference from the IRI coefficients in the SPFs corroborated the implication from the EB study that a reduction in IRI could result in an improvement in safety. A key aspect of the research was an investigation of how the safety effect is impacted by the levels of safety and IRI before treatment and the change in IRI accomplished. The results provide interesting, and sometimes counterintuitive insights for those planning maintenance treatments to improve IRI.

Authors	Jia Li, Beijing University of Technology Xuesong Wang, Tongji University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-01591
Paper Title	Hotspot Identification of Urban Arterials at the Meso Level
Abstract	Urban arterials form the main structure of street networks. They typically have high traffic volume and high crash frequency. Hotspot identification (HSID) is the first step for traffic safety management process and often utilizes crash prediction models. The classical crash prediction models investigate the relationship between arterial characteristics and traffic safety at micro level, since they treat road segments and intersections as isolated units. This micro-level analysis has limitations when examining urban arterial crashes because: 1) signal spacing is typically short for urban arterials in dense street network, and there are interactions between intersections and road segments that classical models do not accommodate; 2) in practical engineering, a hotspot consists of several adjacent intersections and road segments instead of a single intersection or road segment. Taking these into account, a meso-level unit that combined signalized intersections and their adjacent road segments as a whole was adopted. To investigate the suitable research unit and method for urban arterial HSID, this study identified hazardous micro-level (intersections or road segments) and meso-level units at the same time using crash frequency, empirical Bayesian (EB), potential for safety improvement (PSI), and full Bayesian (FB) methods. Consistency was tested to evaluate the performance of the HSID methods. The results showed that 1) meso-level units performed better than micro-level units regardless of which HSID method was adopted; 2) EB and PSI performed better than the other methods no matter for which research unit; 3) there was a big difference between the identified hazardous micro- and meso-level units.

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Sponsoring Committee	Standing Committee on Geometric Design (AFB10)
Session Number	1554
Session Title	Confirming Existing, Enhancing Current, and Developing New Geometric Design Practices
Paper Number	19-01673
Paper Title	Safety Performance Functions Incorporating Geometric Design and Pavement Condition Variables I
Abstract	Urban arterials form the main structure of street networks. They typically have high traffic volume and high crash frequency. Hotspot identification (HSID) is the first step for traffic safety management process and often utilizes crash prediction models. The classical crash prediction models investigate the relationship between arterial characteristics and traffic safety at micro level, since they treat road segments and intersections as isolated units. This micro-level analysis has limitations when examining urban arterial crashes because: 1) signal spacing is typically short for urban arterials in dense street network, and there are interactions between intersections and road segments that classical models do not accommodate; 2) in practical engineering, a hotspot consists of several adjacent intersections and road segments instead of a single intersection or road segment. Taking these into account, a meso-level unit that combined signalized intersections and their adjacent road segments as a whole was adopted. To investigate the suitable research unit and method for urban arterial HSID, this study identified hazardous micro-level (intersections or road segments) and meso-level units at the same time using crash frequency, empirical Bayesian (EB), potential for safety improvement (PSI), and full Bayesian (FB) methods. Consistency was tested to evaluate the performance of the HSID methods. The results showed that 1) meso-level units performed better than micro-level units regardless of which HSID method was adopted; 2) EB and PSI performed better than the other methods no matter for which research unit; 3) there was a big difference between the identified hazardous micro- and meso-level units.

Authors	Timothy Scott Nye, North Carolina Department of Transportation Christopher Cunningham, North Carolina State University Elizabeth Byrom, North Carolina State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-01950
Paper Title	A National-Level Safety Evaluation of Diverging Diamond Interchanges
Abstract	A national-level safety evaluation of Diverging Diamond Interchanges (DDIs) in the United States was completed. This study aimed to update previous evaluations and to expand the treatment group size of previous studies to provide a more robust and reliable safety assessment of DDI deployments. For this particular treatment, it was determined that, of the observational before-and-after evaluation methodologies, the comparison group approach yields the best evaluation results. The naïve method can be influenced by outside factors that cannot be accounted for (weather, crash reporting tendencies, etc.). The empirical Bayes methods is unnecessary as DDIs are installed for operational benefits, meaning that risk of selection bias and regression-to-the-mean is minimal. This study recommends a total crashes CMF of 0.633 based on the comparison group analysis of 26 DDIs in 11 states. The comparison group method was also applied to a variety of crash variables for this study. Angle, rear-end, and sideswipe crashes were found to have CMFs of 0.441, 0.549, and 1.139, respectively. Fatal-and-injury crashes provided a CMF of 0.461. Daytime and nighttime crashes provided CMFs of 0.648 and 0.638, respectively.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-02139
Paper Title	Seasonal Crash Prediction Model for Urban Signalized Intersections: Wisconsin Southeast Region
Abstract	The Highway Safety Manual (HSM) provides methods to quantitatively evaluate safety for a vast range of roadway transportation facilities. The Negative Binomial has been traditionally used for modeling crashes (i.e. crashes per year). Highly aggregated cross-sectional data omits natural time dependent variations leading to important loss of information and introducing error in model predictions. Furthermore, traffic conditions and weather vary over time and space. An alternative approach with seasonal crash estimates is proposed in this paper. Local crashes, traffic, geometry, signal type, and weather data of urban signalized intersections in the Southeast region of Wisconsin were used. Four seasons were considered: Winter, Spring, Summer, and Fall. The Negative Multinomial was used for modeling to account for seasonal variations. The functional form for each predictor variable was optimized. Measures of log-likelihood, inverse overdispersion, cumulative residual (CURE) plots, and Akaike information criterion (AIC) showed adequate model prediction accuracy. Seasonal estimates for fatal and injury (FI) crashes showed that during the Spring season, crash estimates were the lowest and during the Summer were the highest. In contrast, model crash estimates for Property Damage Only (PDO) crashes peaked during the Winter season and remain below annual estimates for the rest of the seasons. Magnitude of fluctuations and accuracy of crash estimates contribute to managerial decisions and allocation of resources for the implementation of treatments, safety programs, minimize safety impacts, and reduce risk of crashes—contributing to reduction in costs associated with crashes, property damage, maintenance, and emergency services.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-02144
Paper Title	Jurisdiction-specific versus SafetyAnalyst-default Safety Performance Functions: A Case Study on Two-lane and Multi-lane Arterials
Abstract	Network screening is the most important step in the highway safety management process. Screening criteria based on the Empirical Bayes (EB) approach are considered to be most reliable as it accounts for the regression-to-the-mean (RTM) bias. However, the EB approach requires Safety Performance Functions (SPFs), preferably calibrated to local conditions, which are often unavailable. The SafetyAnalyst software, developed by the Federal Highway Administration (FHWA), automates the EB approach using the default SPFs which were developed using multiple states' data. Local agencies are encouraged to develop jurisdiction-specific SPFs to better reflect the local conditions. However, the benefits of developing local SPFs for rural and urban two-lane and multi-lane highway facilities are unclear and may vary from state to state. This research compares the performance of Florida-specific SPFs with SafetyAnalyst-default SPFs calibrated to Florida data using mean absolute deviation, mean squared predicted error, and Freeman-Tukey R-square goodness-of-fit measures. The results showed that Florida-specific SPFs generally produced better-fitted models than the calibrated SafetyAnalyst-default SPFs. In contrast, when the crash prediction capabilities of the already-available local SPFs calibrated to the latest time period for which they will be applied are compared to the calibrated SafetyAnalyst-default SPFs, the calibrated SafetyAnalyst-default SPFs in general were found to better predict crash frequencies compared to the existing Florida-specific SPFs calibrated to the latest data. Therefore, the local SPFs are recommended when developed using present data; however, the calibrated SafetyAnalyst-default SPFs could be used if local SPFs developed from present data are not available.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-02198
Paper Title	Integrated Approach to the Network Screening of Urban Intersections
Abstract	As the first and one of the most important steps of Highway Safety Improvement Program (HSIP), network screening aims to identify sites with the highest potential for improvement. Network screening is not a trivial process and depends on several factors such as crash frequency and severity, traffic volume and roadway characteristics, and crash history of similar sites. The reliability of network screening is based on the safety performance measure selected for conducting the analysis. In this paper, the authors propose an integrated approach that incorporates a weighted ranking to rank the sites with higher potential for improvement. The results of the pilot study show that the proposed methodology is more reliable than using individual performance measures and could be implemented by transportation agencies that identify highway safety improvement projects.

Authors	Steven Stapleton, Michigan State University Anthony Ingle, Michigan State University Timothy Gates, Michigan State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1412
Session Title	Safety Data, Analysis, and Evaluation: Research in Four Acts
Paper Number	19-02361
Paper Title	Speed-Related Characteristics Contributing to Vehicle-Deer Crashes on Rural Two-Lane Roadways
Abstract	Deer-vehicle crashes (DVCs) continue to be a problem in the United States, with 1.2 million such crashes occurring annually. DVCs are particularly an issue on two-lane rural highways in Michigan, accounting for more than 60 percent of all crashes. Such a high proportion of DVCs limits the transferability of existing safety models, including those found in the HSM, that are often based on data from states with considerably lower proportions of deer crashes. To counter this, a cross-sectional analysis of deer crashes was performed using data from the state of Michigan. Four categories of rural, two-lane two-way highway segments were analyzed separately, including: state-maintained, county federal aid paved, county non-federal aid paved, and county unpaved (i.e., gravel) surfaces. Negative binomial regression models with spatial and temporal random effects were generated. The results showed that speed-related factors, including lane width and horizontal curvature, had a significant effect on vehicle deer crashes occurring on rural two-lane two-way roadway segments in Michigan. Wider lanes were associated with a greater occurrence of deer crashes, perhaps due to higher prevailing travel speeds. Conversely, the presence of curves with design speeds lower than the statutory speed limit was associated with fewer deer crashes, perhaps due to lower travel speeds on curved segments. Wider shoulders, which afford greater separation between the travel lanes and the roadside, were found to significantly reduce deer crash occurrence. Unfortunately, the concentration of hunting licenses, a potentially useful predictor for deer crashes, did not appear to have a consistent influence on DVCs.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-02530
Paper Title	International Transferability of Macro-Level Safety Performance Functions: A Case Study of the United States and Italy
Abstract	Safety performance functions (SPFs) or crash prediction models have played an important role in identifying the contributing factors of crashes, predicting crash counts, identifying hotspots, etc. Because it needs a lot of time and efforts to estimate a SPF, previous studies have evaluated if a SPF could be applied to data from other regions, i.e., transferability. Although many efforts have been made for micro-level SPF transferability, not many have been done for macro-level SPF transferability. Transferability analysis of macro-level SPFs in the international context, especially between western countries, has not been conducted. Therefore, we evaluate the transferability of SPFs of several states in the United States (i.e., Illinois, Florida, and Colorado) and Italy in this study. The SPFs were developed using data from counties in the United States and provincias in Italy, and the results show that there are multiple common significant variables across the countries. Subsequently, transfer indexes are calculated between the developed SPFs, and the indexes show that the Italian SPFs for total and bicyclists crashes are transferable to U.S. data after calibration factors are applied while the U.S. total and bicycle SPFs, except for the Colorado SPF, cannot be transferred to the Italian data. On the other hand, none of the developed pedestrian SPFs are transferable to other countries. This paper provides insights into the applicability of macro-level SPFs between the U.S. and Italy, and shows a good potential of international SPFs' transferability. Nevertheless, further investigation is needed for the SPF transferability between more countries.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-02653
Paper Title	Comparison of the Highway Safety Manual Predictive Method with Jurisdiction-Specific Safety Performance Functions and Effects of Geometric Design Consistency
Abstract	Road safety is a major public health concern in our society. Effective road design and accurate safety analyses must be a component of programs focused on reducing and eliminating roadway injuries and deaths. Various methodologies exist to determine the expected number of crashes on rural two-lane, two-way roadway segments with a goal of improving road safety. This research compares different procedures which allow for the estimation of the number of crashes on entire homogeneous road segments. In this effort, a total of 27 two-lane rural road sections located in North Carolina were considered, resulting in 59 homogeneous road segments composed of 350 horizontal curves and 375 tangents along 150 km (90 miles) of road. Four methods were applied to the selected roadways: the HSM predictive method, two jurisdiction-specific Safety Performance Functions (SPFs), and a SPF which includes a consistency parameter. This research found that the use of SPFs which incorporate a consistency parameter allows practitioners and highway engineers to consider human factor impacts on road safety assessment. The use of a consistency parameter can also simplify the crash estimation process. Analysis methods which only included local geometric variables provided unreliable results due to the calibration of only the specific road elements instead of their relationship with other road elements along homogeneous road segments.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-02686
Paper Title	Sensitivity Analysis of Bayesian Semiparametric Spatial Crash Frequency Models
Abstract	This study focused on the sensitivity analysis of Bayesian semiparametric spatial models which combine the strengths of spatially structured random effects and the Dirichlet mixture to account for the unobserved heterogeneity of crash counts. The three-year bicycle crash data from the city of Irvine in California aggregated at the transportation planning level of Traffic Analysis Zones (TAZ) were utilized for model development. Various evaluation criteria were employed to compare the performance of models with varying spatial weight matrices and precision parameters (alpha). The results demonstrate that there exists strong correlation among the posterior number of clusters (K), alpha, the fraction of variation explained by the spatial random effect, and different evaluation criteria. Even though the increased upper bound value of alpha does not necessarily lead to the enhanced model performance, the models with the full flexibility to choose the desirable amount of clustering tend to perform better than those with limited flexibility due to smaller allowable mass components. Compared with the precision parameter, no obvious trend is illustrated for the different evaluation criteria along the varying spatial weight matrices. However, the existence of significant performance variation among the models suggests the need to explore various spatial neighboring structures for the potential better modeling results.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-02869
Paper Title	Calibration of Highway Safety Manual Predictive Models for Kansas Freeway Segments
Abstract	Prediction models in the Highway Safety Manual (HSM) are used to quantify the potential safety experience of existing and new roadways. Safety Performance Functions (SPFs) in the HSM predictive method are statistical formulas developed based on limited data gathered from selected few states. Therefore, HSM recommends to modify SPFs for a certain jurisdiction by following a calibration methodology or develop local SPFs to enhance the accuracy of predicted crash frequencies. This paper demonstrates the calibration procedure and quality assessment of the calibration process for freeway segments in Kansas utilizing crash data from 2013-2015. Most of the required data were collected from two main databases maintained by Kansas Department of Transportation and the remaining were gathered using Google Earth and ArcGIS tools. A sampling technique was applied and a minimum sample size of 446 freeway segments was calculated corresponding to 95% confidence level and 5% error. Consequently, data for 521 freeway segments were collected and utilized in this freeway calibration. Estimated calibration factors were 0.952, 0.936, 1.982 and 1.843 for multiple vehicle fatal and injury, single vehicle fatal and injury, multiple vehicle property damage only and single vehicle property damage only models respectively. Results indicated that HSM methodology overpredicts crashes for fatal and injury freeway segment models and underpredicts crashes for property damage only freeway segment models in Kansas. Results of quality assessment of the calibration process showed that estimated calibration factors were satisfactory for all freeway facilities considered in this study.

Authors	Amin Mohamadi Hezaveh, University of Tennessee, Knoxville Christopher Cherry, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-02874
Paper Title	Likelihood of Involvement in Traffic Crashes: Introducing Home-Based Approach
Abstract	It is well-known that the crash rate varies across countries, one may question that how does crash rate of individuals who lives in a certain geographic area vary within a country in a fine geographic level; to the best of authors' knowledge, no study has explored this issue. The predominant approach of road safety analysis attributes focuses on the location of traffic crashes, which makes measuring individuals' likelihood of involvement in traffic crashes (e.g., crash rate) challenging. In this study, we established Home-Based Approach (HBA) definition to complement the traditional definition of the road safety that focuses on the residential location, i.e., the expected number of crashes that road users who live in a certain geographic area have during a specified period. We use the addresses of the individual who had a direct role in traffic crashes to evaluate road safety at the zonal level. Census tract and police report crashes were used to extract the location of the traffic crashes and home-address of road users in Tennessee, and accompanying socioeconomics. Findings indicate that a mixed-effect negative binomial model was more suitable than a fixed-effect model for HBA crash frequency. Findings indicate that education, age cohorts between 16-42, and 43-60 years, share of motorized transport mode to work, portion of individuals with college-degree, and vehicles per capita have positive associations with HBA crash frequency. Instead, median household income and percent of White race have a negative association with HBA crash frequency. Findings are discussed in line with road safety countermeasures.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-02897
Paper Title	Calibration of the Highway Safety Manual Predictive Methods for Unsignalized Intersections at Urban and Suburban Areas in Kansas
Abstract	The Highway Safety Manual (HSM) provides predictive methodologies which help predict crashes on various facility types based on traffic and geometric characteristics, incorporated through Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs). Since the SPFs were developed using data from the states of Minnesota and North Carolina for three-leg unsignalized intersections (3ST) and four-leg unsignalized intersections (4ST), the calibration of the predictive methodologies would increase the accuracy of the prediction for Kansas. In this study, a total of 234 3ST intersections (128 having minor AADT data and 106 intersections using estimated minor AADT data) were used for the calibration, to satisfy the HSM criteria of at least 100 crashes per year for the selected set of sites. Multiple linear regression, with log10 transformation of the continuous variables was carried out to develop a minor AADT estimation model, for which the R-squared value was 0.3281. A calibration factor of 0.51 was calculated when considering all crashes, and 0.40 for fatal and injury (FI) crashes. For 4ST, 167 intersections were used as the sample sites resulting in the calibration factor of 0.61 when considering all crashes and 0.72 for FI crashes. For both facility types, the calibration factors were less than 1.00, implying that the HSM predictive methodology overpredicted the number of crashes for the state of Kansas. The effectiveness of the developed calibration factors were checked with the help of CURE plots and Coefficient of Variation, which showed that the obtained calibration factors are acceptable for application.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-02949
Paper Title	Transferability and Calibration of Highway Safety Manual Safety Performance Function for Two Lane Highways in Brazil
Abstract	The present study focused on evaluating HSM crash prediction model for two lane highways on Brazilian conditions. Also, the transferability of the model was considered, specifically by means of a comparison between Brazil and HSM conditions. The analysis of two lane highways crash prediction models was promising when the road characteristics were well known and there was not much difference from base conditions. This conclusion was attained regarding the comparison of results for all segments, non-curved segments and curved segments, confirming that a transferred model can be used with caution. Finally, there are many factors that could not be measured by these models and reflects road safety various condition. Even so, the study of crash predict models in Brazilian context could provide a better start point in safety road analysis.

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Sponsoring Committee	Safety Data, Analysis, and Evaluation: Research in Four Acts
Session Number	1412
Session Title	Safety Data, Analysis, and Evaluation: Research in Four Acts
Paper Number	19-03034
Paper Title	Analyzing Pedestrian and Bicyclist Crashes At The Corridor Level: A Structural Equation Modeling Approach
Abstract	Pedestrian and bicycle crashes have been increasing at an alarming pace in recent years. Between 2009 and 2016, annual US pedestrian fatalities increased 46 percent, and bicyclist fatalities increased 34 percent. Crashes involving pedestrians and bicyclists, or vulnerable roadway users (VRUs), are negatively correlated with roadway factors, and positively correlated with environmental and socioeconomic factors. However, specific variables representing these factors are often correlated, making it difficult to accurately characterize relationships between individual variables and pedestrian and bicyclist safety. Our study used the structural equation model (SEM) technique to overcome this problem. We collected pedestrian and bicyclist crash frequency and more than 60 explanatory variables for 200 highway corridors in Wisconsin. We tested the interrelationships between observed “manifest” variables and unobserved “latent” variables. Our results suggest that the most important latent variables influencing the crash frequency of VRUs are bicycle/pedestrian-oriented roadway design (e.g., paved shoulders, sidewalks, and bike lanes), exposure (e.g., walking and biking activity, and employment density), and low social status (e.g., educational level, and wage percentage). The benefits of this study may help community planners, transportation researchers and policymakers with a better understanding of the intricate interrelationship of the influential factors contributing to VRUs road crashes.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1439
Session Title	School Transportation Safety
Paper Number	19-03108
Paper Title	Evaluating the Effectiveness of Safe Routes to School Interventions in Indiana
Abstract	The Safe Routes to School (SRTS) program apportions funding for safety interventions aimed at encouraging walking and bicycling to school. Initially, the SRTS program (2006-2012) allocated over $20 million to schools throughout Indiana for infrastructure- and non-infrastructure-related safety interventions. Under the continuation of the SRTS program, many states (including Indiana) do not provide special consideration for SRTS using federally allocated funds. Nevertheless, there are provisions for non-infrastructure projects to be funded through the program. This paper examines the initial implementation of SRTS to gauge the effectiveness of infrastructure and non-infrastructure safety interventions using econometric modeling techniques. The impact of SRTS interventions on child (6-17 years) pedestrian and bicyclist crashes nearby schools was evaluated over time using a panel data structure that included SRTS and control group (no interventions) schools in Indiana. In the period before implementing the SRTS interventions, the schools selected for the program experienced higher crash frequencies than the control group, thus supporting their inclusion in the program. After the program's implementation, infrastructure interventions were found to be effective in reducing child pedestrian and bicyclist crashes, while non-infrastructure interventions showed a nonsignificant impact. Covariates such as vehicle miles travelled (VMT), school enrollment, median age of residents, median income of household head, and average annual precipitation also influenced safety in the region surrounding the studied schools. Based on the results of this study, SRTS programs including infrastructure-related safety interventions appeared to be most promising in improving safety for child pedestrians and bicyclists.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-03113
Paper Title	An Analysis of Rural Interstate Fatality Rates in Consideration of Recent Increases in Maximum Statutory Speed Limits
Abstract	The relationship between traffic safety and speed limits has been an area of significant research. Since the repeal of the National Maximum Speed Law in 1995, states have full autonomy in establishing maximum statutory speed limits. Since 2001, at least 25 states have increased their maximum limits to speeds as high as 85 mph. This study examines changes in rural interstate fatalities from 2001 to 2016 in consideration of such increases. Speed limit policy data include the maximum speed limit for each state-year combination, as well as the proportion of rural interstate mileage posted at each speed limit in each state. Random parameter negative binomial models are estimated to control for unobserved heterogeneity, as well as time-invariant effects unique to each state. The results show that increasing the mileage of rural interstates posted at 70, 75, or 80 mph by one percent is associated with fatality increases of 0.2%, 0.5%, and 0.6%, respectively. These increases are more pronounced than when considering only the maximum statutory limits in each state. The study also examines the influence between these higher limits and the frequency of fatal crashes involving speeding and driver distraction. At the highest limits of 75 and 80 mph, the increases among these subsets of crashes are greater than the increases in total fatalities. Ultimately, this study provides important empirical evidence in support of continuing speed limit policy discussions, in addition to identifying salient analytical concerns that should be considered as a part of longitudinal analyses of state-level fatality data.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03130
Paper Title	An Investigation of Relationship Between the United States Road Assessment Program Star Rating and Crash Experience
Abstract	Over the recent decades, the International Road Assessment Program (iRAP) has been widely used as a systemic safety management tool. iRAP uses the risk-based non-crash measure of Road Protection Score (RPS) for assessing the level of safety of the roads on a 1 to 5 Star Rating scale. Given that few published studies exist in this area, one of the most significant current research needs is the validation of the relationship between the crashes and Star Ratings. Moreover, the previous validation studies have been mostly limited only to the descriptive comparison of crash rate and Star Rating averages and have failed to establish a comprehensive statistical relationship. In order to investigate such a relationship, this study develops a crash prediction model using a sample of two lane rural roads in North Carolina. The crash frequency was estimated as a function of Road Protection Score and Annual Average Daily Traffic using a negative binomial model. The results of this study showed that the crash frequency consistently increases with Road Protection Score. The developed safety performance function showed that moving from a 3-star road to a 2-star road would result in 47% more crashes. These findings confirm that Star Rating is a valid risk measure for crash frequency on two lane rural roads.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03258
Paper Title	Comprehensive Cost of Traffic Crashes at Zonal Level
Abstract	Global road safety records demonstrated the spatial variation of comprehensive cost of traffic crashes; to the best of our knowledge, no study has explored the variation of this matter at a fine geographical level. This study proposes a method to estimate the comprehensive crash cost at zonal level by using person injury cost unit. The current metric of road safety attributes safety to the location of the crash, which makes it challenging to assign the crash cost to the origin of the individuals who were involved in traffic crashes. To overcome this limitation, we introduced Home-Based Approach as the expected number of crashes by severity that road users who live in a certain geographic area have during a specified period. Home addresses of individuals who were involved in traffic crashes in Tennessee were assigned to their corresponding census tract. The average comprehensive crash cost per capita (CCCPC) at the census tract level was $11932. Poisson and Geographically Weighted Poisson Regression (GWPR) models were used to analyzing the data. The GWPR model was more appropriate compared to the global model to capture the spatial heterogeneity. Findings indicate population under 16-year-old and over 60-year-old, the proportion of residents that use non-motorized transportation, household income, population density, household size and metropolitan indicator have a negative association with CCCPC. Alternatively, VMT, vehicle per capita, percent educated over 25-year-old, the proportion of minority races and individuals who use a motorcycle have a positive association with CCCPC. Findings are discussed in line with road safety literature.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03285
Paper Title	Modeling the Effects of Lake-Effect Snow Related Weather Conditions on Daily Traffic Crashes: A Time Series Count Data Approach
Abstract	Winter weather in many parts of North America is characterized by heavy snowfall that affects traffic safety. Lake Effect Snow (LES) in the Great Lakes region exacerbates the problem by increasing snowfall totals and severity of winter weather locally. Past studies investigating the effects of winter weather on traffic crashes have mainly focused on site-specific weather conditions and overlooked mesoscale meteorological phenomena. Therefore, the primary objective of this paper is to develop a crash count model establishing the relationship between LES and winter traffic crashes. Daily crash data, traffic exposure data and meteorological data from State of Michigan are modelled to examine the impact of meteorological characteristics behind LES formation on the observed counts. Additionally, this paper introduces a relatively new class of time series models known as Negative Binomial Integer-valued Generalized Autoregressive Conditional Heteroscedastic (NB-INGARCH) model. NB-INGARCH offers an alternative to the integer-valued time series models and accounts for the overdispersion, non-negativity, and time interdependencies. The performance of the NB-INGARCH model is compared with Poisson INGARCH model using the Probability Integral Transformation (PIT) histogram, marginal calibration plot and scoring rules. The resultant models were quite similar in terms of coefficient estimates and goodness of fit. The results suggest that several predictor variables for LES formation are significantly related to crash data. However, NBINGARCH model exhibits better predictive performance than Poisson INGARCH by addressing overdispersion and unobserved heterogeneity issues.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-03377
Paper Title	Safety Performance of Median U-Turn Conversions in Michigan
Abstract	Alternative intersection designs can offer safety and operational benefits with potentially lower costs than conventional intersections when used in the proper setting. One such alternative intersection design that has been used extensively across Michigan for decades is the median U-turn (MUT), which accommodates left turns via a U-turn crossover within the median. This evaluation examined 28 stop-controlled MUT intersections as well as 100 signalized MUT intersections in order to help quantify the safety benefits of implementing MUTs. The percentage of angle collisions at stop-controlled intersections was substantially lower in the post-conversion period (5.7 percent) compared to the pre-conversion period (50.3 percent). The decrease in the proportion of angle collisions was offset by a notable increase in rear-end collisions (25.8 percent in the pre-conversion sites and 75.7 percent in the post-conversion sites). There was also a decrease in the proportion of head-on left-turn collisions in the post-conversion period (0.6 percent) compared to the pre-conversion period (2.8 percent) for signalized MUTs. Stop-controlled MUT intersections exhibited superior safety performance in terms of fatal and injury (FI) crashes over traditional intersections but experienced more property damage only (PDO) crashes as major approach volumes exceed 15,000 entering vehicles per day. Signalized MUT and traditional intersections performed similarly up to approximately 20,000 entering vehicles per day along the major approach, at which point MUTs experienced more FI crashes but fewer PDO crashes. Ultimately, fully-specified negative binomial regression models were developed to estimate the FI and PDO crash frequencies for both stop-controlled and signalized MUT intersections.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03389
Paper Title	Incorporating Spatial Effects into Temporal Dynamic of Traffic Fatality Risks: A Case Study on Lower States of the USA, 1975-2015
Abstract	Road traffic fatality rate has long served as a regular indicator to evaluate and compare road safety performances for different administrative divisions. This article introduced a novel method known as spatial Markov chains model to incorporate the spatial effects into the temporal dynamic of the fatality rates. Comparing with the traditional Markov chains model, the proposed spatial Markov chains model can quantify the influence of neighboring sites explicitly in the transition process. A case study using a long time span dataset from 1975 to 2015 in the 48 lower states of the United Sates was conducted to illustrate the proposed model. The fatality rates were measured as the number of traffic fatalities per 100 million vehicle miles or per 10,000 residents. Our results show that the probability of transition for one state between different levels of traffic fatality risks depends largely on the context of its surrounding neighbors. Another important finding is that relative to the estimates of traditional Markov chains model, states surrounded by neighborhoods with relatively low fatality rates takes a longer time to transform to a higher level of fatality risk in the spatial Markov chains model, whereas those with high risk neighborhoods takes less time to deteriorate. These findings confirm that it is imperative to incorporate spatial effects when modeling the temporal dynamic of safety indicators to assess and monitor the safety trends of the areas of interests.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1413
Session Title	Highway Safety Performance Data-Driven Analyses: When It Counts
Paper Number	19-03519
Paper Title	A Comparative Analysis of Empirical Bayes and Bayesian Hierarchical Models in Hotspot Identification
Abstract	Hotspot identification is an important step in the highway safety management process. Errors in hotspot identification (HSID) may result in an inefficient use of limited resources for safety improvements. The empirical Bayesian (EB)-based HSID has been widely applied as an effective approach in identifying hotspots. However, there are some limitations with the EB approach. It assumes that the parameter estimates of the safety performance function (SPF) are correct without any uncertainty, and does not consider temporarily instability in crashes, which has been reported in recent studies. Bayesian hierarchical model is an emerging technique that addresses the limitations on the EB method. Thus, the objective of this study is to compare the performance of the standard EB method and the Bayesian hierarchical model in identifying hotspots. Three methods (i.e. Crash rate, EB, and the Bayesian hierarchical model-based methods) were applied to identify risky intersections with different significant levels. Four evaluation tests (i.e., Site Consistency; Method Consistency; Total Rank Differences; and Poisson Mean Differences tests) were conducted to assess the performance of these three methods. The testing results suggest that: (1) the Bayesian hierarchical model outperforms the crash rate and the EB-based methods in most cases. Bayesian hierarchical model improves the accuracy of HSID significantly; (2) hotspots identified with crash rates are generally unreliable. It is significant for roadway agencies and practitioners to accurately rank sites in the roadway network in order to effectively manage safety investments. Roadway agencies and practitioners are encouraged to consider the Bayesian hierarchical models in identifying hotspots.

Authors	Jillian Strauss, Ecole Polytechnique de Montreal Felix Lamothe, Universite de Montreal Patrick Morency, Montréal Public Health Department Catherine Morency, Ecole Polytechnique de Montreal
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03576
Paper Title	Risk of Road Injury According To Home Location: The Influence of Population Density, Car Use and Distance Travelled (Montreal, Canada)
Abstract	Population density is known to be associated with road safety but, within metropolitan areas, there is some confusion in previous studies which use population at the crash location instead of at the home location of the injured people. This study aims to estimate the road injury risk associated with home location in Montreal (Canada), using a representative survey of a typical weekday of travel. The likelihood of car occupant, bus occupant and pedestrian injury was estimated for each intersection, road segment and highway. Injury risk was then calculated for each trip, as a function of the specific route taken (e.g. intersections crossed) and summed for each individual to obtain an individual risk of injury over the day. The 107 municipalities of Montreal were classified into quintiles according to net population density. Regression models were developed to further explore the independent effect of density at home location and of individual travel behaviour. Considering all modes, the injury rate per capita is 2.5 times greater for people living in the least dense sector than for people living in the densest sector. The regression models show that higher household density near the home location is associated with a reduced risk of injury. However, including car use, distance travelled and number of intersections crossed greatly reduces the estimated effect of population density. The results clearly show an inverse relationship between population density at home location and the risk of road injury. Furthermore, the underlying mechanisms, car use and distance travelled, have been made explicit.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-03596
Paper Title	Developing Safety Performance Functions for North Carolina Low-Volume Roadways
Abstract	The Moving Ahead for Progress in the 21st Century Act (MAP-21) mandates for a Highway Safety Improvement Program (HSIP) for all states that “emphasizes a data-driven, strategic approach to improving highway safety on all public roads that focuses on performance”. To determine the predicted crashes on a specific roadway facility, the most convenient and widely used tool is the first edition of Highway Safety Manual (HSM), which provides predictive models (known as safety performance functions, SPFs) of crash frequencies for different roadways. Low-volume roads are defined as roads located in rural areas with daily traffic volumes of less than or equal to 400 vehicles per day (vpd). Low-volume roadways cover a significant portion of the roadways in the U.S. While much work has been done to develop SPFs for high-volume roads, less effort has been devoted to low-volume road safety issues. This study used 2013-2017 traffic count, roadway network, and crash data to develop six SPFs for three low-volume roadways, which can be used to predict total crashes, fatal, and injury crashes. These SPFs will provide state and local agencies with the means to quantify safety impacts on low-volume roadway networks.

Authors	Nadia Naqvi, Loughborough University Mohammed Quddus, Loughborough University Marcus Enoch, Loughborough University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03653
Paper Title	Do Higher Fuel Prices Help Reduce Road Traffic Accidents?
Abstract	Road traffic accidents have decreased in most developed nations over the last decade. This has been attributed to improvement in vehicle and road design, medical technology as well as driver education and training. Recent evidence however indicates that fuel price changes have a significant impact on road traffic accidents through other mediating factors such as more fuel-efficient driving behaviours, less car travel through changing modes and speed reduction on high-speed roads. However, there is a lack of evidence to support the effects of changes in fuel prices on road traffic accidents in the UK which is the focus of this paper. For this purpose, weekly time series of fuel prices (between 2005-2015) have been used to study the effects on road traffic accidents using Prais-Winsten model of first order autoregressive (AR1) and the Box and Jenkins seasonal autoregressive integrated moving average models (SARIMA). This study is designed to quantify the effects of fuel price on road traffic accidents frequency through changes and adjustments in travel behaviour. The findings provide the evidence that the relationship between fuel prices and fatal road accident is negative, with every 1% increase in fuel price there is a 0.4% reduction in the fatal road traffic accidents frequency. However, with recent government plans to ban petrol and diesel vehicles by 2040, wiping away benefits from high fuel prices through reducing fatal accidents, to gain environmental benefits, transport policy makers need reviewing their policy to reduce road accident externality in the absence of road fuel prices.

Authors	Nancy Dutta, University of Virginia Michael Fontaine, Virginia Transportation Research Council
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-03693
Paper Title	Developing Rural Four Lane Freeway Crash Prediction Models Using Hourly Flow Parameters
Abstract	Most past crash prediction research has examined the relationship between crashes, traffic volumes, and other factors at the annual level, due to the rare and random nature of crash occurrence and data availability. For example, the current functional form of safety performance functions in the Highway Safety Manual is based on annual average daily traffic (AADT). Less attention has been given to explicitly modeling the safety effects of vehicle density, volume-to-capacity ratio, and speed distribution at a sub-daily level. This research used continuous count station data from 4 lane rural freeway segments in Virginia and developed crash prediction models using traffic and geometric information provided at hourly aggregation intervals. The results showed that using average hourly volume along with average speed and selected geometric variables improved predictions compared to models that used AADT. When comparing an AADT-based model to an average hourly volume model, the mean absolute prediction error improved by 15% for total crashes. This value improved by 20% after including geometric variables, and by 30% after adding speed to the volume and geometry model. Similar improvements were observed for injury crashes. These results provide a strong indication that crash predictions could be improved using more disaggregate data and justifies further exploration of these relationships using larger datasets and other statistical methodologies. The findings from this research also indicate that inclusion of quality of flow variables, like speed, could create improvements in the quality of crash prediction models.

Authors	Kai Wang, University of Connecticut Shanshan Zhao, Connecticut Transportation Safety Research Center Eric Jackson, Connecticut Transportation Safety Research Center
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-03696
Paper Title	Functional Forms of the Negative Binomial Models in Safety Performance Functions for Rural Two-Lane Intersections
Abstract	Safety Performance Functions (SPFs) play a prominent role in estimating intersection crashes, and identifying the sites with the highest potential for safety improvement. To maximize the crash prediction accuracy, this paper describes the application of different functional forms of the negative binomial models (i.e. NB-1, NB-2 and NB-P) in estimating safety performance functions by crash type for rural two-lane intersections. Crash types were aggregated into same-direction, opposite-direction, intersecting-direction and single-vehicle crashes. Major and minor road AADT were used as predictors in the SPF estimation. The over-dispersion parameter of the NB models was estimated by the AADT to account for the crash data heterogeneity. The models were compared based on both the model estimation goodness-of-fit and the prediction performance. The model goodness-of-fit indicates that the NB-P model outperforms the NB-1 and NB-2 for most crash types and intersection types, by providing a flexible variance structure to the NB approaches. The parameterization of the over-dispersion factor verifies that the over-dispersion parameter of the NB models highly depends on how the variance structure is defined in the model, and the over-dispersion parameter is shown to vary among different crashes and can be estimated using both the major and minor road AADT at rural two-lane intersections. The prediction performance comparison illustrates that the NB-P model slightly improves the crash prediction accuracy compared with the other two models. Therefore, the NB-P model with parameterized over-dispersion factor is recommended to provide more unbiased parameter estimates when estimating SPFs by crash type for rural two-lane intersections.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03728
Paper Title	Improving Intersection Safety with RCUT: Louisiana Experience
Abstract	The safety of intersections on major corridors is always a concern because of the high-risk vehicle maneuvers intertwined with a high operating speed. It is especially a problem for intersections with a two-way stop-sign control where vehicles on a low-speed minor roadway must cross multiple lanes and the median before merging into the path of high-speed traffic. To improve the intersection safety, Restricted Crossing U-turns (RCUT) has been constructed in Louisiana since 2011. Because of the short history of the RCUT implementation, there are limited studies available that address the RCUT safety effectiveness. This paper evaluates the safety benefit of six RCUTs in Louisiana including five intersections in urban and suburban areas. Unlike the previous studies, this investigation covers both the RCUT intersection only and RCUT system (consisting of the intersection, two U-turns and segments in between). The crash analysis shows a 100% reduction in fatalities, 41.5% in injuries and 22.3% in property damage only crash for the RCUT intersection only, and less impressive reductions for the RCUT system. The review of the original crash reports greatly benefits the investigation on why the crashes increased at few locations, thus, provides the valuable information on how to correct these crash problems through the detailed design and traffic control. The safety improvement plus the high ratio of benefit to cost strongly demonstrate that the RCUT is an effective and economically justified countermeasure on high-speed roadways in both rural and urban areas.

Authors	Seifeldeen Eteifa, University of Tennessee, Knoxville Asad Khattak, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1126
Session Title	Safety Management Policies and Decision-Support Frameworks—Hybrid Session
Paper Number	19-03744
Paper Title	Understanding Factors Contributing to Rising Fatal Crashes: A Social Network Analysis Approach
Abstract	Fatal crashes are on the rise, costing many lives in the US and worldwide and inhibiting economic growth on a yearly basis. Every crash is a complex interaction between many contributing factors which need to be better understood in order to be effectively addressed. Researchers have developed theoretical models and implemented a variety of statistical techniques to better understand how crashes occur. This study proposes an analytical framework based on social network analysis to achieve a more holistic understanding of fatal crashes. The study adopts a three-step methodology which is to prepare the data, map social network terminology and metrics to transportation safety and analyze the network of contributing factors to fatal crashes. The methodology is applied to 97,034 fatal crashes occurring from 2014 to 2016. The framework successfully identifies the key contributing factors to fatal crashes as well as the relationships between them. It successfully visualizes the different contributing factors and how they combine with one another to contribute to different scenarios for fatal crashes. It also provides objective quantitative metrics which can help prioritize and assess the contribution of each factor to crash occurrence. The study shows that driver errors and violations of traffic laws are the most substantial contributing factors to fatal crashes and that elements like seatbelts and airbags continue to play a crucial role in minimizing the impact fatal crashes. This study can transform the current understanding of crash dynamics by providing an approach that focuses heavily on relations between different factors contributing to crashes.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1413
Session Title	Highway Safety Performance Data-Driven Analyses: When It Counts
Paper Number	19-03826
Paper Title	Effects of Signalization at Rural Intersections Considering the Elderly Driving Population
Abstract	The main objective of this study is to quantify the safety impacts of signalization at Florida's rural three-leg and four-leg stop-controlled intersections by estimating crash modification factors. The intersections are those in which stop signs are provided for the minor approaches or all-way stop-controlled intersections. The CMFs are estimated using the cross-sectional method. Generalized linear models (GLM) and multivariate adaptive regression spline models (MARS) are employed with four-years of Florida crash data. The K-nearest neighbor and K-means clustering algorithms are implemented to identify the comparison sites which are sites having similar characteristics as those of the converted intersections. Furthermore, the quasi-induced exposure method is used to evaluate the safety effects of signalization for elderly and non-elderly drivers, separately. According to the results, signalization contributes to an increase in PDO and rear-end crashes. In addition, elderly drivers are more at risk of being involved in such crashes than non-elderly drivers. In particular, at rural four-leg two-way stop-controlled intersections, signalization decreases crash severity, and greater percentage of the decrease is observed for the elderly drivers than non-elderly especially when the intersection has a high level of major road AADT and elderly driver proportion. This study also demonstrates that the MARS model shows a better model fit than the GLM model due to its strength in capturing nonlinear relationships and interaction effects among variables. This study's findings have implications for both practitioners and researchers.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03858
Paper Title	Analysis of Factors Affecting the Frequency of Crashes on Interstate Freeways by Vehicle Type and Severity Incorporating Weather Prediction Models
Abstract	Since the introduction of the interstate system in 1956, motorists have relied heavily on these roadways for both personal and commercial travel. However, the interstate system experiences a large number of traffic crashes which cause property damage, injuries, fatalities, and non-recurring delay. Understanding what causes these crashes at a system wide level is of vital importance for all users. This study utilized seven years of crash data from the State of Arizona, examining factors affecting the frequency of crashes with a focus on different vehicle types and simulated precipitation data. Vehicle type categories included passenger vehicles, freight vehicles, motorcycles, and buses/recreational vehicles/trailers. The study utilized statewide crash data along Arizona interstates including I-8, I-10, I-17, I-19 and I- 40, along with roadway geometric data and traffic data. Additionally the Weather Research and Forecasting (WRF) model was used to simulate precipitation data to analyze precipitation effects on crash frequency and provide an example of how this validated data can be used in traffic safety and operational management. Random parameters negative binomial models were developed for different vehicle types and crash severities, and the results show that several roadway and traffic variables, as well as precipitation, are associated with crash frequency and the results vary among different vehicle types and crash severities. Ultimately, the findings provide important insights into factors affecting interstate freeway crash frequency for different vehicle types, and may be useful in planning countermeasures in efforts to improve safety on these freeways.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-04086
Paper Title	Rural Intersection SPFS – Slip Lanes and Seagulls
Abstract	In New Zealand the majority of rural intersection fatal and serious crashes occur at rural priority T-intersections. While most intersections have a standard layout higher volume intersections often have alternative layouts that include auxiliary lanes and/or channelization. Two alternative intersection layouts are reviewed in this research: 'priority controlled seagull (channelized) intersections' and ‘intersections with slip lanes’. Seagull intersections are used on roads to reduce traffic delays. However, some do experience high crash rates. Slip lanes (left turn for left-hand drive and right turn for right-hand drive) allow turning traffic to move clear of the through traffic before decelerating. Although there is debate about the safety problems that occur at Seagull intersections and slip lanes there has been very little research to quantify the safety impact of different layouts. In this study, safety performance functions have been developed for standard rural T-intersections and the two alternative intersection layouts for the key crash types. A point of difference in the modelling is that a design index has been developed for road layout variables, rather than including each layout variable separately in the models, along with exposure and speed variables.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-04098
Paper Title	Comparison and analysis of crash frequency and rate in cross-river tunnels using random-effect models
Abstract	Underground road systems are becoming popular in cites as it can overcome urban space constraints and increase capacity and accessibility for urban transport systems. For cities with rivers and seas, the construction of cross-river tunnel can preserve land resources and reduce traffic congestion without affecting navigation. However, tunnel traffic safety has become an increasing concern due to frequent and serious tunnel traffic crashes. The severity of crashes and the difficulty of rescue in tunnels are higher than those of other road sections. In order to improve the safety of tunnel operation, this paper analyzes the crash data of 14 river-crossing tunnels in Shanghai from 2015 to 2016. A negative binomial (NB) model and a random-effect negative binomial (RENB) model were developed to investigate the relationship between crash frequency and potential influence factors, including tunnel geometry characteristics, traffic volume and crash location. The results show that AADT, speed limit, grade, grade differences and RGR) are likely to increase the crash frequency in cross-river tunnels while horizontal curve radius, vertical curve radius and long tunnel are associated with less crashes. This study also explored the use of crash rate instead of crash frequency as dependent variable by using random-effect Tobit model. The results indicate that the significance of most independent variables is consistent with the results found upon the RENB model based on crash frequency.

Authors	
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-04346
Paper Title	Zone-based Modeling of Time-dependent Safety Performance Using Smartphone-based Connected Vehicle Data
Abstract	Safety performance functions (SPFs) are generally used to correlate risk factors with crash counts aggregated over a long time (e.g. a year), and to identify hotspots that have excessive crashes regardless of different time periods. However, it is highly likely that the relationship between risk factors and crash occurrence can vary across different times of day. This study aims to characterize time-dependent safety performance in urban areas by modeling crash counts for different times of day. Anonymized and aggregated driving data collected by the Zendrive's smartphone-based technology is used to capture time-dependent dangerous driving events. Multivariate conditional autoregressive (MVCAR) models are developed to jointly account for spatial and temporal dependence of crash observations. Results of two-sample Kolmogorov-Smirnov tests affirm the heterogeneity of the safety effects of dangerous driving events in different time periods. Time-dependent hotspots are identified using potential for safety improvement (PSI) metric. According to the results of Wilcoxon signed-rank tests, hotspots identified by times of day are found to be mostly different from each other. The findings of this study provide insights into temporal effects of risk factors and can support the development of police patrolling plan and other road safety interventions in different times of day. Besides, this study also shows the potential of leveraging anonymized and aggregated driving data to assess traffic safety issues.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-04352
Paper Title	Comparison of Calibration Methods for Improving the Transferability of Safety Performance Functions
Abstract	Safety performance functions (SPFs) are critical for traffic safety management. They have been applied for identifying significant risk factors, estimating crash frequencies, and screening potentially hazardous locations. Since SPFs proposed by Highway Safety Manual (HSM) are developed based on certain states in the United States, regions without jurisdiction-specific SPFs need model calibrations for the localization of SPFs. The main objective of this study is to compare the typical calibration methods that used in the literature and identify the appropriate ones. Random effects Negative Binomial (NB) models were established for urban arterials in Shanghai and Guangzhou during peak hours and off-peak hours separately. Four calibration methods, including the calibration factor, empirical Bayes (EB) method, K Nearest Neighbor (KNN) regression method, and pooled data, were applied. The performance in improving model transferability was measured by transfer index and the adaptability to insufficient data was assessed by necessary data collected for each method. Based on the modeling results, pooled data approach that composed of the entire Shanghai dataset and 50% proportion of the Guangzhou dataset provides the best performance. And EB method and KNN regression method are preferable to the calibration factor. Furthermore, modeling and calibrating for different time periods should be considered when average speed is incorporated in the model.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-04385
Paper Title	Safety Performance of Displaced Left Turn Intersections Case Studies in San Marcos, Texas
Abstract	Intersections with the displaced left turn (DLT) design are innovative intersections that are designed to increase the mobility of vehicles by relocating the left turn lane (lanes) to the far-left side of the road upstream of the main signalized intersection. Since DLT is a relative new design and very limited crash data are available, previous studies have focused mainly on analysis of the design's operational performance rather than its safety performance. To fill this gap, in this study we investigated the safety performance of two DLT intersections located in San Marcos, Texas. Crash data from 2011 to April 2018 were extracted from the TxDOT Crash Record Information System (CRIS). These crash data were analyzed using two different approaches, i.e., 1) statistical analysis and 2) collision diagram based analysis. The results of this study indicated that the DLT design has reduced conflicts related to left turns significantly. Also, some safety problems associated with traffic signage, geometric design, and access management of the DLT design also were identified. As a result of these analyses, recommendations were provided for safe implementation of the DLT design in the future.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-04401
Paper Title	A Meta-Analysis of Collision Expectations at Signalized and Stop-Controlled Intersections in North America
Abstract	Safety performance functions (SPFs) have been developed for specific jurisdictions and road authorities across North America, but there are practical applications for national average SPFs. Some examples include use by jurisdictions lacking resources to develop their own SPFs and for developing national guidelines such as traffic signal warrants. The only work on average collision expectation models to date are those presented in the Highway Safety Manual (HSM), but there are questions as to how representative the HSM equations are of a national average due to the scope of the studies that developed those models. This study developed models for average intersection collision expectation across Canada and the United States based on a diverse set of published jurisdiction-specific SPFs and HSM calibrations. The models focused on the effects of traffic volume, region fixed-effects, and local jurisdiction random-effects on intersection collision expectation. In general, it was found that the models that included a jurisdiction random-effect provided the best fit. These results were compared to the HSM models and there was substantial variation between the two in terms of predicting collision expectation and collision modification factors (CMFs) for signalization, suggesting that the HSM models do not adequately represent a national average. CMFs based on this research suggest that collision rates tend to increase due to signalization, whereas most published CMFs suggest a decrease. This finding suggests that jurisdiction-specific CMFs for signalization may not be transferable for use outside of the jurisdictions where they are developed.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1413
Session Title	Highway Safety Performance Data-Driven Analyses: When It Counts
Paper Number	19-04486
Paper Title	Identification of Critical Intersection Angle through Crash Modification Functions
Abstract	A significant portion of both fatal and total crashes occur at intersections in the United States. Skew angle may be a significant contributor to these crashes. This paper examines the effects of intersection angle on intersection safety performance. With seven years of crash data from Minnesota and five years of crash data from Ohio, random forest regression data mining and negative binomial regression models were developed to estimate crash modification functions at three-leg and four-leg, stop-controlled intersections with two-lane and multilane major legs. Where possible, the results were compared between the two states and used to develop average crash modification function curves. This study shows that over half of the intersection types experience the highest number of predicted crashes when the intersection angle between roadway legs is between 50 degrees and 65 degrees. These results have practical implications for engineers and safety professionals. First, the crash modification function curves supplement and revise the guidance for intersection angle in the Highway Safety Manual and Policy on Geometric Design of Highways and Streets. Second, the functions offer new guidance to agencies planning intersection improvements. Third, the crash modification functions can be used to determine the safety effect of changes in intersection angle.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-04898
Paper Title	Transferability of Safety Performance Functions and Hotspot Identification for Freeways of the United States and China
Abstract	Safety performance functions have been a vital tool in traffic safety evaluation including finding contributing factors to crashes, identifying hotspots, and assessing safety effects of countermeasures. In the United States, the Highway Safety Manual has provided a series of SPFs for a variety of road facilities. Due to the limited availability of traffic data in many regions, the transferability of SPFs has been an important topic in the traffic safety field and several studies have been conducted to evaluate the transferability of SPFs. Nevertheless, no study has investigated the international transferability of freeway SPFs and the consistency in hotspot identification has been rarely investigated. Using data from Shanghai and three U.S. states: Florida, Texas and New York, we examine the transferability of freeway SPFs between China and the United States. SPFs were developed separately for total crashes, single-vehicle and multi-vehicle crashes. According to the estimated transfer indices (TIs), all Shanghai SPFs are reasonably transferable to U.S. data, but no U.S. SPFs can be transferred to Shanghai data. The modeling results suggest that this discrepancy might be due to the greater sensitivity of U.S. crashes to annual average daily traffic (AADT), and the likelihood that Shanghai crashes are influenced by factors other than segment length and AADT. The method consistency test (MCT) shows that both Shanghai and U.S. SPFs can identify quite consistent hotspots in the other country. The findings from study are expected to be a good reference for researchers and practitioners in developing countries who want to understand the transferability and applicability of SPFs in the international context.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-05124
Paper Title	Contributing Factors for Focus Crash Types and Facility Types
Abstract	This paper describes efforts to identify focus crash types, focus facility types, and associated crash contributing factors to inform applications of systemic safety improvements. Systemic safety improvements—when selected and targeted appropriately—provide a tremendous opportunity to proactively reduce crashes and their resulting harm. The main objectives of this study are to (1) select reliable and applicable data resources, statistical methodologies, analysis procedures, and tools, (2) conduct data analysis to identify and validate focus crash types and facility types and their associated contributing factors, and (3) identify potential low-cost safety strategies that may effectively be used as systemic safety improvements. The study used intersection data from Washington and Ohio and non-intersection data from California and Ohio. The data were enhanced with information from the National Oceanic and Atmospheric Administration and US Census Bureau. Random forest algorithm was adopted to analyze the data and identify the contributing factors to the focus crash types and facility types. The roadway factors uncovered by the analysis as influencing the frequencies of the different crash types were generally consistent with what was expected based on previous research and existing practice. Findings related to the socioeconomic and weather-related factors showed promise, but there is not yet a significant amount of theory to support or refute the socioeconomic- and weather-related results of this effort. A six-step countermeasure selection process is also identified to use the contributing factor findings to assist safety practitioners in making informed choices regarding countermeasures to address the focus crash types.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-05507
Paper Title	Alternative Model Structures for Multivariate Crash Frequency Analysis: Comparing Simulation-based Multivariate Model with Copula-based Multivariate Model
Abstract	In safety literature, there are two ways to incorporate the potential correlation between multiple crash frequency variables: (1) simulation-based approach and (2) analytical closed form approach. The current research effort proposed a comparison between simulation-based multivariate model and copula-based closed form approach to analyze zonal level crash counts for different crash types. The empirical analysis is based on traffic analysis zone (TAZ) level crash count data for both motorized and non-motorized crashes from Central Florida for the year 2016. A comprehensive set of exogenous variables including roadway, built environment, land-use, traffic, socio-demographic and spatial spillover characteristics are considered for the analysis. The resulting data fit and prediction performance offered by the copula-based approach clearly highlights the copula-based approach's superiority over the simulation-based multivariate model. The applicability of the model for hot zone identification is illustrated by generating plots identifying hot and cold zones by crash type in the Central Florida region.

5 Crash Severity Prediction

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

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

The subcommittee identified fifty-two papers dealing with crash severity prediction. The number of papers dealing with crash severity prediction is increasing over time (19 in 2012, 25 in 2013, 16 in 2014, 29 in 2015, 24 in 2016, 41 in 2017, 40 in 2018, and 52 in 2019), highliting how this issue is becoming important for the scientific community. Great emphasis is given to serious injuries crashes also at political level. The EU set the target of halving the number of serious injuries in the EU by 2030 from the 2020 baseline using a common definition based on the MAIS 3+ trauma scale.

The papers are scattered across various sessions, with most papers presented at the poster sessions: 1160 From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety (Monday 8:00 AM – 9:45 AM), 1366 Gaining Insight into Highway Safety and Risk Through Improved Methods and Models (Monday 3:45 PM – 5:30 PM), 1367 Truck and Bus Safety Research (Monday 3:45 PM – 5:30 PM), and 1708 Advances in Pedestrian Safety Research (Wednesday 8:00 AM – 9:45 AM).

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:

- Multinomial logit model (19-01493, 19-02204, 19-02387, 19-04596, 19-04885);
- Random parameters (mixed) logit model (19-02356, 19-02726, 19-02901, 19-03455, 19-05135, 19-05887);
- Bayesian multinomial logit model with a Dirichlet random effect parameter (19-03082);
- Bayesian logistic regression (BLR) (19-05476); and
- Latent segmentation-based logit (LSOL) model (19-03367).

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

- Ordered logit model (19-01493);
- Random parameters (mixed) ordered logit model (19-02142);
- Proportional odds (PO) logit model (19-05757);
- Partial proportional odds (PPO) logit model (19-02385);

- Geographically weighted ordered logit (GWOLR) model (19-01147);
- Geographically and temporally weighted ordered logit (GTWOLR) model (19-01140);
- Cross-classified multilevel ordered logit model (CCMM) (19-01102);
- Random parameters ordered logit model (RPOL) (19-02748);
- Generalized ordered logit model (19-04801, 19-06001);
- Ordered probit model (19-00165, 19-04637, 19-05103, 19-05810);
- Hierarchical ordered probit model (19-00944);
- Copula-based multivariate ordered probit model (19-05069); and
- Zero-inflated hierarchical ordered probit model with correlated disturbances (19-00886).

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

- AdaBoost (19-01646);
- Association Rules (19-05097);
- Bayesian Approach (19-03778);
- Extreme Gradient Boosting (XGBoost) (19-03241);
- Fault Tree Analysis (FTA) (19-05097);
- Generalized Structure Equation Models (GSEM) (19-02963);
- Gradient Boost (19-01646);
- Latent Cluster Analysis (19-02901);
- Path Analysis (19-00598);
- Random Forests (RF) (19-01646, 19-02387, 19-04885); and
- Weighted-Least-Squares-Based Structure Equation Models (SEM) (19-01706).

One paper used a non-parametric **machine learning approach** that use the Support Vector Machine (SVM) and improves the model performance by applying three metaheuristic algorithms: Particle Swarm Optimization (PSO), Harmony Search (HS), and the Whale Optimization Algorithm (WOA) (19-05887). One paper **combined data mining techniques and discrete choice models** (19-02901) by a two-step method integrating latent cluster analysis and mixed logit model. Some of these papers **compared** prediction performamces of **data mining methods and discrete outcome models** and found better performances of the data mining algorithms (19-02387, 19-04885, 19-05887).

Some papers used **SHRP2 naturalistic driving study data** to investigate the **role of speed**, and speed related mesures, on crash severity (19-00471, 19-01981).

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

- Environmental factors (19-00944, 19-01140, 19-01706, 19-02142, 19-02204, 19-02356, 19-02385, 19-2726, 19-02748, 19-02963, 19-03082, 19-03367, 19-03455, 19-04885, 19-04596, 19-04905, 19-05069, 19-05097, 19-05103, 19-05476, 19-05757, 19-06001);
- Highway characteristics (19-00598, 19-01493, 19-01646, 19-02142, 19-02204, 19-02356, 19-02385, 19-2726, 19-02748, 19-02901, 19-03082, 19-03367, 19-03455, 19-04801, 19-04905, 19-05069, 19-05097, 19-05103, 19-05135, 19-05476, 19-06001);
- Road users' characteristics and behaviour (19-00598, 19-00944, 19-01140, 19-01147, 19-01646, 19-01706, 19-02142, 19-02204, 19-02356, 19-02385, 19-02387, 19-2726, 19-02748, 19-02963, 19-03082, 19-03367, 19-03455, 19-04801, 19-04885, 19-04596, 19-04905, 19-05069, 19-05097, 19-05103, 19-05135, 19-05476, 19-06001);
- Roadside features (19-03241);
- Traffic control devices (19-02356, 19-02748, 19-02901, 19-04637, 19-05069, 19-05097, 19-05135, 19-06001);
- Traffic characteristics (19-00165, 19-00944, 19-01147, 19-02963, 19-03082, 19-03455, 19-05135);
- Vehicle characteristics (19-00165, 19-00944, 19-01140, 19-01147, 19-01646, 19-01706, 19-02142, 19-02356, 19-2726, 19-02963, 19-03367, 19-04885, 19-04596, 19-04905, 19-05069, 19-05476, 19-06001); and
- Workzone characteristics (19-04801, 19-05887).

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

- Cyclists (19-00598, 19-01147, 19-04905);
- Motorcyclits (19-01493, 19-02901, 19-03082); and
- Pedestrians (19-01102, 19-01140, 19-02356, 19-02385, 19-2726).

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

Authors	Conor J Seat, Avenue Consultants B Wyatt Clegg, Los Alamos National Laboratory Mitsuru Saito, Saito Research and Consulting Grant Schultz, Brigham Young University
Sponsoring Committee	Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-00093
Paper Title	Crash Severity Distributions for Life-Cycle Benefit-Cost Analysis of Safety-Related Improvements on Utah Roadways
Abstract	The Utah Department of Transportation (UDOT) developed life-cycle benefit-cost analysis spreadsheets that allow engineers and analysts to evaluate multiple countermeasures. The spreadsheets have included the functionality to evaluate a roadway based on the 11 facility types from the Highway Safety Manual (HSM) with the use of crash severity distributions. The HSM recommends that local agencies should develop crash severity distributions based on their local crash data. UDOT had only one severity distribution for all the facility types. The primary objective of this research was to utilize available roadway characteristic and crash data to develop crash severity distributions for the 11 facility types in the HSM. This objective was accomplished by segmenting the roadway data based on homogeneity and developing statistical models to determine the distributions. Due to insufficient data, the facility types 10 and 11 (freeway speed change lanes and freeway ramps, respectively) were excluded from the scope of this research. In order to accommodate more roadway segments for the analysis the facility type definitions were expanded. The statistical models that were developed for this research include multivariate regression, frequentist binomial regression, frequentist multinomial, and Bayesian multinomial regression models. A cross-validation study was conducted to determine the models that described the data the best. Bayesian Information Criterion, Deviance Information Criterion, and Root-Mean-Square Error values were used to compare model reliabilities. The Bayesian multinomial regression model was found to be the most effective model to describe the crash severity distributions for the nine facility types evaluated.

Authors	Seolyoung Lee, Hanyang University Eunbi Jeong, Korea Railroad Research Institute Cheol Oh, Hanyang University Gunwoo Lee, Chung-Ang University
Sponsoring Committee	Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-00165
Paper Title	Identification of the Factors Affecting Injury Severity using the Korean In-Depth Accident Study (KIDAS) Database and its Application
Abstract	Derivation of the contributing factors and understanding of the interactions among them are of keen interest in deriving effective countermeasures to enhance traffic safety. In-vehicle safety measures are expected to reduce the injury severity of occupants when a crash occurs. However, few efforts have been made in conducting an effectiveness analysis of such in-vehicle safety measures using an in-depth crash database that includes not only crash severity data but also on-the-scene crash information obtained from the accident reconstruction. This study analyzed crash severity using an ordered probit model to identify the contributing factors based on the Korean In-Death Accident Study (KIDAS) Database. In addition, the statistical relationship between the collision speeds and the crush extents were further analyzed. A method to evaluate the safety benefits that would be potentially obtained from the analyses conducted in this study was proposed, and an application was presented. This study should be useful in promoting the rapid propagation of in-vehicle safety measures and developing relevant policies.

Authors	Mohamadreza Banihashemi, GENEX Systems Michael Dimaiuta, GENEX Systems Abdul Zineddin, Federal Highway Administration (FHWA) Bruce D. Spear, Caliper Corporation Omar Smadi, Iowa State University Zachary Hans, Iowa State University
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-00471
Paper Title	Using Linked SHRP2 RID and NPMRDS Data to Study Speed-Safety Relationships on Urban Interstates and Major Arterials
Abstract	Although speed is widely recognized as having serious safety impacts, these effects are complex and only partially understood. This research investigates relationships between posted and operating speed and severity of crashes on urban interstates and major arterials. Travel speeds derived from the National Performance Management Research Dataset (NPMRDS) (1) were conflated with roadway and crash data from the SHRP2 Roadway Information Database (RID) (2) for portions of Washington State. Non-congested speed was estimated from NPMRDS travel times, and relationships of crash occurrence and severity with speed differentials were investigated. Regression models were developed to estimate 85th-percentile and average speeds during non-congested periods, as a function of Posted Speed and "Weighted Average Degree of Curvature." Crash severity was represented by the ratio of fatal and injury (FI) crashes to total crashes, and the relationships of this crash severity measure with different speeds and speed differentials were examined. The results suggest that as the operating vs. posted speed differential increases, the ratio of FI crashes to total crashes decreases. While this finding appears to be counterintuitive, it can be explained as follows. The operating vs. posted speed differentials are greater on sections with lower posted speeds. Higher speeds generally result in more severe crashes; therefore, an expectation is that crashes are relatively less severe at lower speeds. Since greater speed differentials correspond to lower posted speeds, then the FI to total crash ratio could be lower on those sections compared to sections with smaller speed differentials (i.e., sections with higher posted speeds).

Authors	Jun Liu, University of Alabama Steven Jones, University of Alabama
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-00598
Paper Title	Behavioral pathways in bicycle-motor vehicle crashes: From contributing factors, pre-crash actions, to injury severities
Abstract	Bicyclists are more vulnerable than motorists in bicycle-motor vehicle crashes. There is a behavioral pathway, from contributing factors, pre-crash actions to injury severities, in crashes, which has been underexplored. This study performed a path analysis to uncover the behavioral pathways in bicycle-motor vehicle crashes. We build models to investigate more than 7,000 bicycle-motor vehicle crashes in North Carolina between 2007 and 2014. Pre-crash actions investigated in the study include "bicyclist failed to yield", "motorist failed to yield", "bicyclist overtaking motorist" and "motorist overtaking bicyclist". Model results show significant correlates of pre-crash actions and bicyclist injury severity. For example, young bicyclists (18 years old or younger) are more likely to fail to yield to motor traffic prior to the event of a crash than elder bicyclists. The "bicyclist failed to yield" action is associated with increased bicyclist injury severity than other actions. The path analysis highlights contributing factors related to risky pre-crash actions that lead to severe injuries. For example, intoxicated bicyclists are found to be more likely to involve the "bicyclist failed to yield" action which often results in severe injuries. The path analysis can also identify factors (e.g., intersection) that are not directly but indirectly correlated to injury severity through pre-crash actions. This study offers a methodological framework to quantify the behavioral pathways in bicycle-motor vehicle crashes. The findings are expected to be useful for bicycling safety recommendations from the perspective of bicyclist and motorist behavior, such as the educational program for students in school.

Authors	Grigorios Fountas, Edinburgh Napier University Panagiotis Anastasopoulos, University at Buffalo, The State University of New York
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-00886
Paper Title	Analysis of Accident Injury-Severity Outcomes: The Zero-Inflated Hierarchical Ordered Probit Model with Correlated Disturbances
Abstract	In accident injury-severity analysis, an inherent limitation of the traditional ordered probit approach arises from the a priori consideration of a homogeneous source for the accidents that result in a no-injury (or zero-injury) outcome. Conceptually, no-injury accidents may be subject to the effect of two underlying injury-severity states, which are more likely to be observed in accident datasets with excessive amounts of no-injury accident observations. To account for this possibility along with the possibility of heterogeneity stemming from the fixed nature of the ordered probability thresholds, a zero-inflated hierarchical ordered probit approach with correlated disturbances is employed, for the first time – to the authors' knowledge – in accident research. The latter consists of a binary probit and an ordered probit component that are simultaneously modeled in order to identify the influential factors for each underlying injury-severity state. At the same time, the model formulation accounts for possible correlation between the disturbance terms of the two model components, and allows for the ordered thresholds to vary as a function of threshold-specific explanatory variables. Using injury-severity data from single-vehicle accidents that occurred in the State of Washington, from 2011 to 2013, the implementation potential of the proposed approach is demonstrated. The comparative assessment between the zero-inflated hierarchical ordered probit approach with correlated disturbances and its lower-order counterparts highlights the potential of the proposed approach to account for the effect of underlying states on injury-severity outcome probabilities and to explain more with the same amount of information.

Authors	Hongtai Yang, Southwest Jiaotong University Guocong Zhai, Southwest Jiaotong University Jun Liu, University of Alabama
Sponsoring Committee	Occupant Protection (ANB45)
Session Number	1603
Session Title	Data Linkages and Statistical Approaches to Examine Crash, Vehicle, and Occupant Protection Issues
Paper Number	19-00944
Paper Title	Is the front passenger seat always the "death seat"? An application of hierarchical ordered probit model for occupant injury severity
Abstract	It is often believed that the front passenger seat in a vehicle associates with a higher risk of severe injuries than rear seats if involved in a crash. However, is this always true? With this question, this study conducted hierarchical ordered probit model to examine the correlation between sitting positions and occupant injury severities. The hierarchical model is able to account for the potential influence of occupant injury severities within the same crash. We investigated crashes provided by the Department of Planning, Transport and Infrastructure website (data years: 2012-2016). The data includes injury information, driver information, vehicle information, environment information. The results indicated that both the front passenger seat and rear seats are associated with increased injury severity compared with the driver seat (passengers vs. the driver). If the front row has two passenger seats and the driver seat, the occupant sitting in the middle of the front row is found to be related to the highest injury severity. There is no significant difference between the rear seat passengers. Other correlates of occupant injury severity are also discussed in this paper, related to occupant age, vehicle speed, blood alcohol level, vehicle type, crash type, seat belt and traffic volume. The information generated by this study could help reduce the extent of harms occupants may suffer when involved in a traffic crashes and also offer insights for policy regulations regarding where an occupant might sit in a vehicle.

Authors	Ho-Chul Park, Seoul National University Yang-Jun Joo, Colorado State University, Fort Collins Seung-Young Kho, Seoul National University Dong-Kyu Kim, Seoul National University
Sponsoring Committee	Task Force on Transit Safety and Security (AP018T)
Session Number	1440
Session Title	Selected Topics in Transit Safety, Security, and Emergency Management
Paper Number	19-01102
Paper Title	Effects of Regional and Company Characteristics on the Injury Severity in Bus-Pedestrian Crashes
Abstract	Bus-pedestrian crashes typically result in more severe injuries and deaths than any other type of bus crashes. It is necessary to screen and improve the risk factors that affect bus-pedestrian crashes. Using bus-pedestrian crash data in South Korea from 2011 to 2015, this study investigates the factors related to the injury severity in the crashes, including crash level factors and regional and company group factors. Bus-pedestrian crashes that are affected by company and regional characteristics have a cross-classified hierarchical structure, which is difficult to address properly using a single-level model or even a two level multi-level model. Therefore, in this study, we use a cross-classified, multi-level model (CCMM) to consider simultaneously the unobserved heterogeneities in two distinct levels, i.e., the company and regional levels. The results indicate that the company and regional effects are 16.8% and 5.1%, respectively, which justify the use of multi-level model. We also confirm that type I errors may arise when the effects of upper-level groups are ignored. This shows the advantage of using the CCMM compared to using either a single-level model or a two-level model. The stasitscally significant factors include three regional-level factors, i.e., the elderly ratio, the ratio of the transportation infrastructure budget, and the number of doctors, and 13 crash-level factors. The results provide useful insights concerning bus-pedestrian crashes.

Authors	Jun Liu, University of Alabama Alexander Hainen, University of Alabama Shashi Nambisan, University of Alabama
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-01140
Paper Title	Pedestrian injury severity in motor vehicle crashes: An integrated spatio-temporal modeling approach
Abstract	Traffic crashes are outcomes of human activities interacting with the diverse cultural, socio-economic and geographic contexts, presenting a spatial and temporal nature. This study employs an integrated spatio-temporal modeling approach to untangle the crashed injury correlates that may vary across the space and time domain. Specifically, this study employs Geographically and Temporally Weighted Ordinal Logistic Regression (GTWOLR) to tackle the correlates of pedestrian injury severity in motor vehicle crashes. The method leverages the space- and time-referenced crash data and powerful computational tools. This study performed non-stationarity tests to verify whether the local correlates of pedestrian injury severity from GTWOLR have a significant spatio-temporal variation. Results showed that some variables passed the tests, indicating they have significantly varying relationships with pedestrian injury severity. These factors include pedestrian age, pedestrian position, crash location, motorist age and gender, DUI, motor vehicle type and the crash time in a day. The spatially and temporally varying correlates of pedestrian injury severity are valuable for researchers and practitioners who develop pedestrian safety improvement solutions. For example, results showed that DUI crashes in the city of Charlotte and Asheville are more likely to cause severe pedestrian injuries than same crashes in other areas; and DUI crashes are associated with an increasing likelihood of causing severe pedestrian injuries. Therefore, DUI may be a near-future focus for pedestrian safety improvements in North Carolina and especially for the city of Charlotte and Asheville. More implications can be drawn from the modeling results.

Authors	Jun Liu, University of Alabama Asad Khattak, University of Tennessee, Knoxville Jiaqi Ma, University of Cincinnati Ziwen Ling, University of Tennessee, Knoxville
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-01147
Paper Title	Examining non-stationary correlates of bicyclist injury severity in traffic crashes: A spatial approach for geo-referenced crash data
Abstract	This study employed a spatial modeling approach to uncover non-stationary correlates of bicyclist injury severity in traffic crashes. The approach is Geographically Weighted Ordinal Logistic Regression (GWOLR), extended from the regular ordered logistic regression (OLR) by incorporating the spatial perspective of traffic crashes. The GWOLR modeling approach allows the relationships between injury severity and its contributing factors vary across the spatial domain, to account for the spatial heterogeneity. This approach makes use of geo-reference data. This study explored more than 7,000 geo-referenced bicycle-motor vehicle crashes in North Carolina. Results from GWOLR show local (rather than global) relationships between contributing factors and bicyclist injury severity. This study performed a series of non-stationarity tests to identify local relationships that vary substantially across the spatial domain. Contributing factors that were identified to have a significant non-stationary relationship with bicyclist injury severity include bicyclist age, bicyclist intoxication status, bicycle direction (as relative to the traffic), bicycle position, driver age, driver intoxication status, vehicle speed, vehicle type, pre-crash action and traffic volume. Researchers and practitioners may use GWOLR to prioritize cycling safety countermeasures for specific regions. For example, GWOLR modeling estimates in the study highlighted the west part (from Charlotte to Asheville) in North Carolina for extra increased bicyclist injury severity due to the intoxication of road users including both bicyclists and drivers. Therefore, if a countermeasure is concerned with the road user intoxication, there may be a priority for the region from Charlotte to Asheville (relative to other areas in North Carolina).

Authors	Xiaoqi Zhai, Central South University Helai Huang, Central South University Nang Ngai Sze, Hong Kong Polytechnic University Kai Kwong HON, Aviation Weather Services Branch, Hong Kong Observatory, Tsim Sha Tsui, Hong Kong
Sponsoring Committee	Pedestrians (ANF10)
Session Number	1708
Session Title	Advances in Pedestrian Safety Research
Paper Number	19-01451
Paper Title	Diagnostic Analysis of the Effects Of Weather Condition On Pedestrian Crash Severity
Abstract	Pedestrians are vulnerable to severe injury and mortality in the road crashes. Numerous studies have attempted to identify factors contributing to the crashes and injury risks of pedestrians. As an active transport mode, walking behavior is sensitive to the changes in weather condition. However, it is not common that comprehensive real-time weather data be available for road safety analysis. In this study, high resolution weather data in the terms of temporal and spatial distribution were integrated with the crash data, using the Geographical Information System (GIS) approach. Then, a mixed logit model was established to measure the association between pedestrian crash severity and possible risk factors. Also, the interaction effects by weather condition on the association were considered to examine the pedestrians' and drivers' risk behavior under adverse weather condition. Results indicated that high temperature and presence of rain were associated with higher likelihood of Killed and Severe Injury (KSI) crashes. Also, high temperature and presence of rain could moderate the effects of convicted driver and pedestrian behaviors on crash severity. Results were indicative to real-time traffic control and management measures that could enhance the pedestrian safety, and therefore promote the walkability in the long run.

Authors	Tânia Torres, Universidade Federal do Rio Grande do Sul Rafaela César Machado, Universidade Federal do Rio Grande do Sul Ana Margarita Uriarte Larrañaga, Universidade Federal do Rio Grande do Sul Christine Tessele Nodari, Universidade Federal do Rio Grande do Sul
Sponsoring Committee	Motorcycles and Mopeds (ANF30)
Session Number	1500
Session Title	Advances in Pedestrian Safety Research
Paper Number	19-01493
Paper Title	Recent Research on Motorcycles and Mopeds
Abstract	This paper uses traffic crashes and detailed built environment (BE) data from Porto Alegre (Brazil) to evaluate the effects of BE's contributing factors on motorcycles' crash-injury severities. Differences among contributing factors on crash severity of traffic crashes involving motorcycles from those involving automobiles were compared. Several data sources were analyzed with GIS software tools to capture BE characteristics. Ordered and unordered discrete-choice models were estimated to analyze crash-injury severities. Two model structures were tested: (i) ordinal logit (OL) and (ii) multinomial logit (MNL). Marginal effects were computed to analyze severity level changes when a given one occurs in the contributing factors. Comparison between OL and MNL showed that standard ordered logit models overestimate the marginal effects of most variables, and forces the effect of other variables to be statistically insignificant, especially those related to built environment, which present the highest impact. Also, MNL models present better overall fit. The results underscore the importance of population density, number of shops and services and bus-stop density on motorcycles' crash-injury severities in both approaches. Street lighting and intersections density revealed to be key factors in motorcycles' injury-severity level in the MNL model. Results showed that BE characteristics are more related to automobiles' crash-injury severities than to the severity of crashes involving motorcycles. The identification of these elements contributes to promoting improvements in the built environment to better address the specific safety needs for motorcycles and automobiles, as also to qualify trade-offs of conflicting elements to improve safety in urban roads.

Authors	Liming Jiang, University of Massachusetts, Lowell Yuanchang Xie, University of Massachusetts, Lowell Tianzhu Ren, University of Massachusetts, Lowell
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-01646
Paper Title	Modeling highly unbalanced crash injury severity data by ensemble methods and global sensitivity analysis
Abstract	Due to its significance, Crash Injury Severity (CIS) has been extensively studied and numerous methods have been developed for investigating the relationship between crash outcome and explanatory variables. CIS data is often characterized by highly unbalanced injury distributions, with most crashes in the Property-Damage-Only (PDO) category and the severe injury category making up only a fraction of the total observations. Existing methods tend to favor crash outcome categories with the most observations. This often leads to a high modeling accuracy for PDO crashes but poor prediction accuracies for other injury categories. This research introduces three ensemble methods to model unbalanced CIS data: random forest, AdaBoost, and Gradient Boost. A more reasonable performance metric, F1 score, is used for model selection. It is found that AdaBoost and Gradient Boost clearly outperform the remaining methods and generate more balanced prediction accuracies. Additionally, a global sensitivity analysis method is adopted to determine the individual and joint impacts of various CIS impact factors on crash injury outcome. Grade percentage, driver restraint, accident type, road characteristics, and truck percentage are found to be the most influential factors. Finally, a simulation-based approach is adapted to further study how the impact of a particular factor (e.g., horizontal curve) may vary with respect to different value ranges.

Authors	Yalong Yuan, Southeast University Min Yang, Southeast University Zuoxian Gan, Southeast University Jingxian Wu, Southeast University Chengcheng Xu, Southeast University
Sponsoring Committee	Truck and Bus Safety (ANB70)
Session Number	1367
Session Title	Truck and Bus Safety Research
Paper Number	19-01706
Paper Title	An Analysis of Risk Factors Affecting Accident Size in Truck Involved Fatal Accident Based on the Structural Equation Model
Abstract	Due to the large numbers of casualties and property losses caused by truck involved fatal accidents, efforts to improve our understanding of the risk factors and their impacts on the fatal accidents are urgently needed. First, for scaling fatal accident size, two latent endogenous variables which includes truck occupant injury factors and accident size were selected from occupant and crash level respectively. Then, a general structural model was built to explore the relationships between environmental, roadway, vehicle, driver factors and fatal accident damaged size. Afterwards, by analyzing 2010 data from the Trucks Involved in Fatal Accident (TIFA), a weighted-least-squares-based structure equation model(SEM) was adopted to estimate the parameters of the general structural model. Significant difference between various risk factors determining truck occupant injury factors and accident size were identified. And the results indicate that environmental, roadway, vehicle and driver factors all have statistically significant effects on accident size and occupant injury factors. But the impacting sizes of risk factors on these two endogenous variables are different distinctly. Furthermore, measurement models including different latent risk factors and corresponding observed variables are analyzed. The results show environment factors of weather and light condition, roadway factors of intersection area, and speed limit, vehicle factors of truck weight, and body type, driver factors of age, driving experience, and history of convictions are the main indicators that significantly affect accident size. Finally, several countermeasures are suggested for truck manufactures and safety planners with the goal of reducing the number and severity of truck involved fatal accidents.

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Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-01791
Paper Title	Hit and Run Crashes: An Application of Correlated Random Parameter Probit Model Using Real-Time Crash Data
Abstract	The issue of unobserved heterogeneity in crash data has been highlighted by many recent traffic safety studies. The safety literature has demonstrated the capability of the full random parameters approach to address the issue of unobserved heterogeneity. However, such approach has been mostly restricted to the investigation of general crash frequency models. The current study provides the application of this approach to a concerning crash behavior of Hit and run (HR) by extending the conventional random parameter model to allow the correlation between parameters. This study also focuses on utilizing the real-time traffic data to predict the HR crash risk. Additionally, three other models are developed, representing the current safety literature, to compare the performance of the proposed correlated random parameter model. The results from the posterior model estimates demonstrated the evidence of parameters varying with observations. The model fit results illustrated the worst performance for the traditional probit model while the random parameters model was relatively superior. However, the model with correlated random parameters exhibited the best performance, potentially due to its advantage to replicate the realistic scenario where the explanatory variables may act as confounding factors due to their interactions. The results for model performance based on predictive accuracy were monitored by using ROC (receiver operating characteristic) curves. The results corroborated the model fitness trends and revealed that the accommodation of correlations for random parameters improved the model prediction performance, especially at threshold levels generally adopted by safety practitioners. Keywords: correlated random parameters, hit and run, real-time, probit.

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Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-01883
Paper Title	Wrong-Way Driving Crashes: A Random-Parameters Ordered Probit Analysis of Injury Severity
Abstract	In the context of traffic safety, whenever a motorized road user moves against the proper flow of vehicle movement on physically divided highways or access ramps, this is referred to as wrong-way driving (WWD). WWD is notorious for its severity rather than frequency. Based on data from the NHTSA, an average of 355 deaths occur in the U.S. each year due to WWD. This total translates to 1.34 fatalities per fatal WWD crashes, whereas the same rate for other crash types is 1.10. Therefore, WWD crashes, and specifically their severity, must be meticulously analyzed using the appropriate tools to develop sound and effective countermeasures. The objectives of this study were to use a random-parameters ordered probit model to determine the features that best describe WWD crashes and to evaluate the severity of injuries in WWD crashes. This approach takes into account unobserved effects that may be associated with roadway, environmental, vehicle, crash, and driver characteristics. To that end and given the rareness of WWD events, 15 years of crash data from the states of Alabama and Illinois were obtained and compiled. Based on this data, a series of contributing factors including responsible driver characteristics, temporal variables, vehicle characteristics, and crash variables are determined, and their impacts on the severity of injuries are explored. An elasticity analysis was also performed to accurately quantify the effect of significant variables on injury severity outcomes. According to the obtained results, factors such as driver age, driver condition, roadway surface conditions, and lighting conditions significantly contribute to the injury severity of WWD crashes.

Authors	Ramin Arvin, University of Tennessee, Knoxville Mohsen Kamrani, University of Tennessee, Knoxville Asad Khattak, University of Tennessee, Knoxville
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-01981
Paper Title	Examining the Role of Speed and Driving Stability on Crash Severity Using SHRP2 Naturalistic Driving Study Data
Abstract	While the cost of crashes nears $1 Trillion a year in the U.S., the availability of high-resolution naturalistic driving data provides an opportunity for researchers to conduct in-depth analysis of crash contributing factors, and design appropriate interventions. The SHRP2 Naturalistic Driving Study (NDS) is a unique dataset that allows new insights due to detailed information on driver behavior in normal pre-crash and near crash situations, in addition to trip characteristics, and vehicle performance characteristics. NDS data are used to investigate not only the vehicle movements in space but also the speed and stability of vehicles prior to crash and their contribution to severity using path analysis. A subset of the data containing 617 crash events with around 180,000 temporal trajectory data are analyzed. To quantify driving stability, microscopic variations or volatility in vehicular movements before a crash is analyzed. Specifically, nine measures of pre-crash driving volatility are calculated and used to explain crash severity. While most of the measures are significantly correlated with severity, substantial positive correlations are observed for two measures representing speed and deceleration volatilities. Additionally, the average speed prior to a crash is highly correlated with severity outcomes, as expected. Interestingly, distracted and aggressive driving are highly correlated with driving volatility, and have substantial indirect effects on crash severity. With volatile driving serving as a leading indicator of crash severity, given the crashes analyzed in this study, early warnings and alerts for the subject vehicle driver and proximate vehicles can be helpful when volatile behavior is observed.

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Sponsoring Committee	Pedestrians (ANF10)
Session Number	1708
Session Title	Advances in Pedestrian Safety Research
Paper Number	19-01987
Paper Title	Louisiana Pedestrian Crash Analysis with Multinomial Logit Model and Bayesian Network
Abstract	Pedestrians are the most vulnerable users of highway transportation system. While encouraging "Green Transportation", a concerning fact emerges in the United States: pedestrian deaths are climbing faster than motorist fatalities, reaching nearly 6,000 in 2016 - the highest in more than two decades. In Louisiana, pedestrian fatalities reached 110 in 2015, nearly 15% of total traffic fatalities. In the same year, Louisiana pedestrian fatality rate (pedestrian fatalities per 100,000 population) is 2.18, higher than the U.S. average of 1.67. This paper presents an analysis of Louisiana pedestrian crashes from 2006 to 2015 with the multinomial logit and Bayesian networks models to explore the potential relationship between pedestrian injury severity and a host of factors including pedestrian behavior, demographics, and built environment. The MNL model is utilized to identify the significant factors, and the BN model is structured to reveal probabilistic dependence between pedestrian crash severity and explanatory variables. The results indicate that fatal and severe crashes are closely linked to pedestrians' alcohol or drugs involvement and older age. The probability of having a fatal or severe injury crash is much higher for pedestrian traveling on roadways away from intersection area (i.e., crossing street or walking along or against roadway). The likelihood of pedestrian crashes resulting in fatality or severe injury increases 49% by walking on unlighted roadways with a speed limit higher than 60 mph at night. The findings of this study show some unique characteristics of pedestrian crashes in Louisiana, which can be useful in selecting the targeted countermeasures.

Authors	Emmanuel James, Northern Arizona University Brendan Russo, Northern Arizona University
Sponsoring Committee	Native American Transportation Issues (ABE80)
Session Number	1778
Session Title	Native American Transportation Practices
Paper Number	19-02142
Paper Title	Analysis of Factors Affecting Injury Severity in Traffic Crashes on Arizona Tribal Lands
Abstract	Reducing fatal and serious injuries sustained in traffic crashes on tribal lands is a priority of federal, state, and local agencies. In the state of Arizona, the proportion of fatal crashes on several areas of tribal land is 4.0 percent higher compared to statewide statistics. There is a need to investigate why higher proportions of fatal and severe injuries are occurring on tribal lands in order to plan effective countermeasures aimed at improving traffic safety in these areas. This study presents an analysis of factors affecting injury severity in crashes occurring on several large areas of tribal land in the state of Arizona including Navajo, Hopi, Tohono O'odham, San Carlos Apache, and White Mountain Apache Nations. Crash data were obtained from the Arizona Department of Transportation, and the analysis included data for 9,597 persons involved in traffic crashes on these tribal lands from 2010-2016. An ordered logit model with random parameters was estimated using this data to identify factors significantly associated with severe injury outcomes in the event of a crash on tribal lands. Several person-, vehicle-, roadway-, and environmental-related variables were found to impact injury severity. For instance, alcohol and safety device usage were significantly associated with injury severity level sustained in a crash. The results of this study have the potential to aid transportation agencies effectively plan strategies to reduce traffic crash injuries and fatalities on tribal lands, and potential countermeasures considering the 4E's of traffic safety (engineering, education, enforcement, and emergency medical services) are discussed.

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Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-02204
Paper Title	Identifying Contributing Factors to Crash Severity: Analysis of Gender Differences
Abstract	In the context of traffic safety, whenever a motorized road user moves against the proper flow of vehicle movement on physically divided highways or access ramps, this is referred to as wrong-way driving (WWD). WWD is notorious for its severity rather than frequency. Based on data from the NHTSA, an average of 355 deaths occur in the U.S. each year due to WWD. This total translates to 1.34 fatalities per fatal WWD crashes, whereas the same rate for other crash types is 1.10. Therefore, WWD crashes, and specifically their severity, must be meticulously analyzed using the appropriate tools to develop sound and effective countermeasures. The objectives of this study were to use a random-parameters ordered probit model to determine the features that best describe WWD crashes and to evaluate the severity of injuries in WWD crashes. This approach takes into account unobserved effects that may be associated with roadway, environmental, vehicle, crash, and driver characteristics. To that end and given the rareness of WWD events, 15 years of crash data from the states of Alabama and Illinois were obtained and compiled. Based on this data, a series of contributing factors including responsible driver characteristics, temporal variables, vehicle characteristics, and crash variables are determined, and their impacts on the severity of injuries are explored. An elasticity analysis was also performed to accurately quantify the effect of significant variables on injury severity outcomes. According to the obtained results, factors such as driver age, driver condition, roadway surface conditions, and lighting conditions significantly contribute to the injury severity of WWD crashes.

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Sponsoring Committee	Alcohol, Other Drugs, and Transportation (ANB50)
Session Number	1632
Session Title	Alcohol, Other Drugs, and Transportation
Paper Number	19-02215
Paper Title	Factors associated with alcohol-related motor vehicle crash injury and alcohol-related enforcement in the Upstate and Long Island Regions of New York State
Abstract	Background. Rural areas of New York State (NYS) have higher alcohol-related motor vehicle (MV) crash injury than metropolitan areas. Alcohol-related injury has declined across the three geographic regions of NYS, but rural areas continue to have higher rates and to experience smaller declines. Methods. To examine factors associated with crashes in Upstate and Long Island, we used multi-sourced county level data and the Crash Outcome Data Evaluation System (CODES) with emergency department visits and hospitalizations, crash reports, traffic citations, demographic, economic, transportation, alcohol outlets, and Rural-Urban Continuum Codes (RUCCS). A cross-sectional study design employed zero-truncated negative binominal regression models to assess relative risks (RR) with 95% CI. Findings. Counties were categorized by mean annual alcohol-related MV injuries per 100,000 population: low (24.7+3.9), medium (33.9+1.7) and high (46.1+ 8.0)($p<0.0001$). In multivariable analyses, alcohol-related MV injury was elevated for non-adjacent, nonmetropolitan counties (RR 2.5, 95% CI: 1.6-3.9) with higher citations for impaired driving showing a small, but significant protective effect. Despite less metropolitan areas having significantly higher alcohol-related MV injury, the proportion of alcohol-related citations among all moving violations was not significantly different and the percentage of interlock citations among alcohol-related citations was significantly lower. Conclusions. Higher alcohol-related MV injury rates in nonmetropolitan counties demonstrated a dose-response relationship with proximity to a metropolitan area. In addition to previously reported inter-regional disparities, these findings also highlight significant intra-regional differences and provide clues to areas where focused intervention efforts might be effective in lowering NYS alcohol-related MV injury in less metropolitan areas.

Authors	
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-02356
Paper Title	Modeling Pedestrian Injury Severity in Pedestrian-Vehicle Crashes in Rural and Urban Areas: Mixed Logit Model Approach
Abstract	Pedestrian-vehicle crashes are more likely to result in severe pedestrian incapacitating injuries and fatalities. In this study, mixed logit models are developed to investigate and identify significant contributing factors to the pedestrian injury severity in pedestrian-vehicle crashes in both rural and urban areas in North Carolina, U.S.A. Pedestrian-vehicle crash data from Highway Safety Information System (HSIS) database from 2005 to 2012 are collected and used in this study. Crash injury severities are classified into five categories: no injury (property damage only), injury class 3 (possible injury), injury class 2 (evident injury), injury class 1 (disabling injury), and fatality. The estimation results show that factors such as bad driver's physical condition, heavy trucks, dark light condition, speed limit between 35-50 mph and speed limit above 50 mph will significantly increase pedestrian injury severities in both rural and urban areas. The developed model and analysis results provide insights on developing effective countermeasures to reduce pedestrian injury severities in pedestrian-vehicle crashes and improve traffic system safety performance.

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Sponsoring Committee	Pedestrians (ANF10)
Session Number	1708
Session Title	Advances in Pedestrian Safety Research
Paper Number	19-02376
Paper Title	Proactive Approach for Pedestrian Safety Evaluation Using Choice Model for Unprotected Mid-Block Crossings Under Mixed Traffic Conditions
Abstract	Mid-block crosswalks act as imaginary bridge between adjoining activities based on a particular land-use type on both side of the road. At unprotected mid-block pedestrian crossing, the chance of conflict is high particularly under heterogeneous traffic conditions during crossing. This paper investigates pedestrians' safety at mid-block street crossing in Western and Northern part of India at nine different urban locations. The pedestrian safety can be evaluated by proactive methods. Proactive method is a cost-effective and less time consuming technique as compared to the historic crash data analysis. A binary logistic regression model was developed to examine the effect of various factors on the PSM values as well as predicting the probability to avoid conflict with an approaching vehicle and parameters of pedestrians' decisions. From the study, it is observed that pedestrian behavioural characteristics such as rolling behaviour and roadway characteristics significantly reduce the PSM values. From the elastic analysis, it was found that the vehicle gap, vehicle speed, pedestrian speed, concentration on vehicle gap, platoon size has positive effect whereas, rolling behaviour, pedestrian age, land use has negative effect. Further, from the sensitivity analysis, it was found that the pedestrian safety decreases with increase in vehicle speed, number of lanes and rolling behaviour. The probability of avoiding collision with approaching vehicle was decreases with respect to the type of vehicle although, it increases with increase in vehicular gap. The results of the present paper may be useful to design pedestrian facility and suggest appropriate remedial measures to improve pedestrian safety.

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Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-02385
Paper Title	Pedestrian-Injury Severities in Pedestrian-Vehicle Crashes and the Partial Proportional Odds Logit Model: Accounting for Age Difference
Abstract	This study investigates factors that significantly contribute to the severity of pedestrian injuries resulting from pedestrian-vehicle crashes. Multinomial logit (MNL) models, mixed logit (ML) models, and ordered logit/probit models have been widely used in modelling crash injury severities, including pedestrian injury severities in pedestrian-vehicle crashes. However, both MNL and ML models treat injury severity levels as non-ordered, ignoring the inherent hierarchical nature of crash injury severities, and the data used in ordered logit models need to be strictly subjected to the proportional odds (PO) assumption. In this study, a partial proportional odds (PPO) logit model approach is employed to explore the issues of pedestrian safety associated with each age group: young (ages under 24), middle-aged (ages 25-55), and older pedestrians (ages over 55). Data used in this study are police reported pedestrian crash data collected from 2007-2014 in North Carolina. A variety of motorist, pedestrian, environmental, and roadway characteristics are inspected. Results from Likelihood Ratio tests statistically show the better performance of developing separate injury severity models for each age group compared to estimating a single model utilizing all data. Relevant parameter estimates and associated marginal effects are used to interpret the results, followed by recommendations made in the conclusion section.

Authors	M. Ashifur Rahman, University of Louisiana, Lafayette Xiaoduan Sun, University of Louisiana, Lafayette
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-02387
Paper Title	Prediction of Distracted Driving Crash Severity With Multinomial Logistic Regression and Data Mining Algorithm
Abstract	While the ongoing developments of autonomous vehicles show a great promise to reduce fatalities and injuries, the full implementation will take years to become a reality. Due to the escalating usage of cell phone and social networking, distracted driving is and will remain as one of the most serious problems faced by the Departments of Transportation (DOTs) and law enforcement agencies. Although crash data is underreported and there have been many advanced and expensive technologies to identify and measure distracted driving behaviors, crash data is still an important resource for identification of factors related to distracted driving. Louisiana is one of the worst states in road safety performance in the United States while distracted driving remains a key source of road crashes. In terms of severity, three types of distracted driving related crashes are discussed — Fatal (K) and Severe (A) Injury; Moderate (B) and Complaint (C) Injury; Property-damage only (PDO). One statistical method was used for prediction — ‘multinomial logistic regression’; one data mining algorithms were used — ‘random forest’. Sensitivity and specificity were used to compare the predicted results. Higher speed limit, curved road, head-on crashes were identified among the key factors. Data mining algorithms performs better in prediction compared to the multinomial logistic regression. The prediction of severity models is expected to help transportation authorities and enforcement agencies to identify underlying factors behind distracted driving crashes

Authors	
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1160
Session Title	From Fundamental Relationships to Data Mining Techniques: Understanding Vulnerable User Safety
Paper Number	19-02726
Paper Title	Mixed Logit Analysis of Pedestrian Red-Light Violations and Injury Severity in Pedestrian Crashes at Signalized Crossings
Abstract	Pedestrian red-light violations at signalized crossings are an important traffic safety concern. We aimed to quantitatively investigate factors associated with pedestrian red-light violations and injury severity resulting from pedestrian–motor vehicle crashes at signalized crossings. Mixed logit models are used to account for individual-specific heterogeneity that arises from a set of unmeasured factors related to traffic conditions and the pedestrians' physical and mental status. Data for the analysis are based on the historical crash record maintained by the Hong Kong Transport Department. Children younger than 11 years are not only associated with a higher likelihood of pedestrian red-light violations but also tend to have a higher probability of fatal or serious injuries. Factors including summer, dual carriageways with a central traffic island, and pedestrian age of 12 to 25 years are solely related to a higher likelihood of pedestrian red-light violations; meanwhile, variables solely associated with a higher probability of fatal or serious injuries include crashes that occur between 22:00 and 06:59, crashes occurring in rainy weather, crashes involving pedestrians older than 46 years, and bus crashes. Based on identified statistically significant factors, appropriate countermeasures are recommended to curb pedestrian red-light violations and to reduce the severity of pedestrian crashes.

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Sponsoring Committee	Truck and Bus Safety (ANB70)
Session Number	1367
Session Title	Truck and Bus Safety Research
Paper Number	19-02748
Paper Title	Investigation of Heterogeneity in Severity Analysis for Large Truck Crashes
Abstract	This paper presents a study in investigating the impacts of contributing factors to large track crash severity outcomes, with particular interest in examining the role of heterogeneity and potential sources of heterogeneity. The study focused on large truck vehicle-in-motion crashes on state highways occurred between 2007 and 2016 throughout the state of Florida. Random-parameter ordered logit (RPOL) models were developed to identify random parameters and explore interaction effects. Results showed that physical roadway characteristics such as roadway alignment and shoulder type showed significant random impacts on crash severity. In order to detect potential heterogeneity sources, various driver attributes were incorporated into the model structure as interaction variables, including demographic characteristics, drive condition, driver action, distraction, and vision obstruction, etc. Only few of them showed statistical significance. Accordingly, vision obstruction due to fixed objects or fog were significant environmental conditions on straight roadway alignments. In view of driver actions, running red light and following too closely were among the most hazardous driver actions on straight alignment and unpaved shoulders. Interestingly, the presence of parked-stopped vehicle that obstructed driver's vision tended to decrease crash severity in presence of unpaved shoulders. Model results show that incorporating heterogeneity and interaction effects significantly improved the goodness-of-fit of the model. results of this study provide better understanding of the contributing factors to large truck crash severity, and lead to the development of more effective countermeasures to enhance freight safety and mobility.

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Sponsoring Committee	Motorcycles and Mopeds (ANF30)
Session Number	1500
Session Title	Recent Research on Motorcycles and Mopeds
Paper Number	19-02901
Paper Title	Investigating the Injury Severities of Motorcyclist-Involved in Traffic Crashes: Integrated Approach Integrating Latent Cluster Analysis and Random Parameters Logit Model
Abstract	Despite the enormous safety burden suffered by motorcyclists, a limited number of studies have specifically investigated the motorcycle related safety issues in China. Instead of applying one single model to the whole dataset or focusing on pre-defined crash types as in previous motorcycle injury severities, the present study first proposed a two-step method integrating latent cluster analysis and mixed logit model. A latent class cluster approach was first used to segment the motorcycle crashes into relatively homogeneous clusters. A mixed logit model was then elaborately developed for each cluster to identify its unique influential factors. The analysis was based on the police-reported crash dataset (2015-2017) of Hunan province, China. The goodness-of-fit indicators and the Receiver Operating Characteristic (ROC) curves showed that the proposed method is more accurate when modeling the riders' injury severities. More importantly, the results demonstrated that segmenting traffic crashes into 6 clusters as a preliminary step helps to reveal some underlying relationships in the injury severity analysis. The identified risk factors that influence motorcycle crash severities under specific conditions is beneficial to providing more reliable information for engineers, policy makers and planners to improve geometry, traffic control measures, traffic facilities, education, enforcement actions, and then motorcycle traffic safety.

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Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-02963
Paper Title	Determinants of crash type and severity using Generalized Structure Equation Modeling
Abstract	rash type is an informative indicator to infer driving behaviors and conditions that cause a crash. In particular, rear-end and sideswipe crashes are typically caused by improper vehicle interaction such as sudden lane-changing or speed control while hit-object crashes are likely the result of single driver's mistake. This study developed vehicle grouping measures to represent the vehicle interaction considering that the vehicles could affect each other when travelling as a group. Then, the effects of vehicle interaction on crash type and severity were investigated using Generalized Structure Equation Modeling (GSEM). The proposed GSEM captures the complex relationships among the various crash factors such as traffic condition, driver characteristics, environmental conditions, and vehicle interaction to the crash attributes including type and severity. Vehicle interaction and resulting driving behaviors are observed from microscopic traffic data. This study collected over 3 million individual vehicle data and matched to 1,360 crash reports. Results showed that the vehicle grouping measures have significant impacts on crash types. The proportions of vehicles forming a homogenous or heterogeneous group positively affect rear-end and sideswipe while speed difference in the heterogeneous group had a positive effect on hit-object crashes. In addition, truck involvement is identified as a significant influential factor for sideswipe crashes while human factors such as age and gender play important roles in all type of crashes. Crash severity was negatively affected by total flow, and rear-end were more likely to result severe crashes than hit-object crashes. Keywords: vehicle group, interaction, crash type, severity, GSEM

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Sponsoring Committee	Motorcycles and Mopeds (ANF30)
Session Number	1500
Session Title	Recent Research on Motorcycles and Mopeds
Paper Number	19-03082
Paper Title	Using a Dirichlet Multinomial Logit Model to Investigate Factors Influencing the Severity of Motorcycle Crashes in Tanzania
Abstract	Motorcycles are becoming increasingly popular, especially in developing countries. This increasing exposure, combined with their adverse impact on the proportion of road traffic crashes, necessitates new strategies to alleviate serious injury crashes. In the current study, an analysis of factors affecting the injury severity outcome of motorcycle causal crashes in Dar es Salaam, Tanzania is presented. The analysis used a Bayesian Multinomial Logit Model with a Dirichlet random effect parameter to examine 4 years (2013-2016) of crash data. The main benefit of this model is that it accounts for the unobserved heterogeneity that exists in the data. The response variable is injury severity with three categories: fatal/severe injury, minor injury, and possible/no injury. The potential variables affecting motorcycle crashes were grouped by common characteristics into four categories: human, environmental, roadway, and crash. Relative risk ratios and average pseudoelasticity were obtained to interpret the factors influencing motorcyclist-caused crashes severity. The estimation results suggest that factors such as speeding, violations, head-on collisions, weekend, and off-peak hour crashes increase the probability of fatal/severe injury crashes. Meanwhile, factors such as speed, driving under the influence, and collector roads were observed to reduce the likelihood of minor injuries. From the findings, several countermeasures are recommended. The proposed countermeasures take the holistic safety improvement strategies encompassing the three E's of highway safety, namely Engineering, Education, and Enforcement.

Authors	Subasish Das, Texas A&M Transportation Institute Anandi Dutta, Texas A&M University Songjukta Datta, Texas A&M Transportation Institute
Sponsoring Committee	Artificial Intelligence and Advanced Computing Applications (ABJ70)
Session Number	1756
Session Title	Machine Learning Methods for Prediction, Forecasting, and Analysis of Transportation Applications
Paper Number	19-03241
Paper Title	Injury Severity Analysis from Crash Narratives: A Case Study of Interpretable Machine Learning using Tree and Utility Pole related Traffic Crashes
Abstract	Despite tremendous enhancements in vehicle safety, roadway design and operations, the toll of traffic crashes regarding injury and productivity loss are still excessively high. Although there are countless research studies have been conducted to understand better the factors that influence the crash frequency and injury severity, there is still much work to be done. Tree and utility pole/other pole related (TUOP) crashes represent around 12 percent to 15 percent of all roadway departure (RwD) fatal crashes in the U.S. This toll is excessively higher for Louisiana, where TUOP crashes represent around 22 percent of all fatal crashes. During 2010-2016, there were 55,857 reported TUOP crashes in Louisiana. Examining all these crash reports is not a feasible solution. This study applied text mining and interpretable machine learning techniques on all TUOP crashes (with available crash narratives) occurred in Louisiana from 2010 to 2017. This study has two major objectives: 1) to develop a framework for applying machine learning models to classify injury levels from unstructured textual content, and 2) to apply an interpretable machine learning framework which can identify the probability of the keywords in determining the classification mechanism. This study applied three machine learning algorithms to classify the injury levels from the crash narrative data. The XGBoost model was found as the best classifier. The accuracy ranges from 0.70 percent to 24 percent for the training data. This range is from 0.30 percent to 16 percent for the test dataset.

Authors	Mahmudur Fatmi, University of British Columbia, Okanagan Muhammad Habib, Dalhousie University
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-03367
Paper Title	Modeling Vehicle Collision Injury Severity Involving Distracted Driving: Assessing the Effects of Land Use and Built Environment
Abstract	This paper presents the findings of vehicle occupant injury severity model, particularly focusing on the collisions involving distracted driving. The study develops latent segmentation-based logit (LSOL) model for analyzing crash injury severity utilizing police reported collision data from 2007-2011 in Nova Scotia, Canada. A segment allocation model is estimated to capture latent heterogeneity based on individual victims and drivers' profile, and collision attributes including vehicle type, vehicle trajectory, collision object, and collision type. The segment allocation model results suggest the existence of a high-risk and a low-risk injury severity segments. This study extensively tests the effects of built environment characteristics. The model results suggest that rain, curved road, freeway, and mid-block collisions aggravate vehicle occupant injury severity; whereas, higher land use mix, longer length of sidewalk, and higher population density mitigate injury severity. Significant heterogeneity is found across the high and low-risk segments. For instance, straight road alignment is found to yield higher injury severity in the high-risk segment and lower severity in the low-risk segment. Moreover, the model unveils the interplay between built environment and distraction type. Driver distracted by communication device increases injury severity at a curved road intersection. Additionally, distraction due to inattentiveness increases injury severity. The findings of this study assist road safety engineers and planners to identify effective countermeasures and awareness programs on reducing the crash injury severity/consequence of vehicle occupants.

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Sponsoring Committee	Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03455
Paper Title	Analysis of Driver Injury Severity in Single-Vehicle Roadway Departure Crashes on Curved Rural Segments With a Mixed Logit Approach
Abstract	Roadway departure crashes are considered as a core emphasis area in Strategic Highway Safety Plan (SHSP) at state and national level because they account for considerable fatalities and serious injuries on the roadway system. The injury severity issue for these crashes is even more pronounced on the rural roadways. The focus of this study to identify and quantify the factors leading to single-vehicle roadway departure crashes on rural curved segments in Minnesota. The crash data is extracted from the Highway Safety Information System (HSIS) from 2010 to 2014. This study applies a mixed logit approach to model driver injury severity to account for possible unobserved heterogeneity in the data resulting from driver, roadway, traffic, and/or environment conditions. This analysis adds value to the existing literature since this approach is potentially applicable as part of a safety programming process implemented by agencies. The model results indicate that there is a complex interaction of driver characteristics and actions (gender, age, and unsafe speed), roadway and traffic characteristics (2-lane undivided road and traffic volume), environmental conditions (adverse weather, cloudy weather, lighting and surface condition), crash event (rollover), and vehicle characteristics (vehicle type – sport utility vehicle). A brief discussion on how this approach and results may help stakeholders encompassing the policymakers, safety professionals, and engineers in the safety planning process is provided.

Authors	Gary Davis, University of Minnesota, Twin Cities Christopher Cheong, University of Minnesota, Twin Cities
Sponsoring Committee	Pedestrians (ANF10)
Session Number	1708
Session Title	Advances in Pedestrian Safety Research
Paper Number	19-03641
Paper Title	Pedestrian Injury Severity vs Vehicle Impact Speed: Uncertainty Quantification and Calibration to Local Conditions
Abstract	This paper describes a method for fitting predictive models relating vehicle impact speeds to pedestrian injuries, where results from a national sample are calibrated to reflect local injury statistics. Three methodological issues identified in the literature: outcome-based sampling, uncertainty regarding estimated impact speeds, and uncertainty quantification, are addressed by (i) implementing Bayesian inference using Markov Chain Monte Carlo sampling and (ii) applying multiple imputation to conditional maximum likelihood estimation. The methods are illustrated using crash data from the Pedestrian Crash Data Study coupled with an exogenous sample of pedestrian crashes from Minnesota's Twin Cities. The two approaches produced similar results and, given a reliable characterization of impact speed uncertainty, either approach can be applied in any jurisdiction having an exogenous sample of pedestrian crash severities.

Authors	Subasish Das, Texas A&M Transportation Institute Anandi Dutta, Texas A&M University Srinivas Geedipally, Texas A&M Transportation Institute Chaolun Ma, Texas A&M University Zachary Elgart, Texas A&M Transportation Institute
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03778
Paper Title	Effect of Vehicular Defects on Crash Severity: A Bayesian Data Mining Approach
Abstract	Vehicle defects have an adverse effect upon overall roadway safety. Although vehicles with safety and emission related issues are more prone to crash occurrences, the sensitivity of crashes to vehicle defects is minimal. The National Motor Vehicle Crash Causation Survey (NMVCCS), conducted from 2005 to 2007, showed that an estimated 44,000 crashes occurred due to vehicular defects—about 2 percent of the NMVCCS crashes. Louisiana is one of the states that has a vehicular safety inspection in place. However, the recent traffic crash statistics showed a higher percentage of vehicle defect related crash fatalities in Louisiana (around 3 percent of all traffic fatalities). This fact called for an in-depth analysis of the vehicle defect related crashes in Louisiana. This study used seven years (2010-2016) of traffic crash data from Louisiana to investigate the association between crash severity and vehicle defect types. A Bayesian data mining approach is applied to identify the key associations. The findings showed that vehicle age is associated with severe injury crashes. Worn tires and defective brakes are the over-represented vehicle defect categories. The Empirical Bayes Geometric Mean (EBGM) scoring method, which is used to determine the relationship between vehicle defects and crash severity types, produced several top rules that require further attention. The findings of this study can be used by different stakeholders to enhance roadway safety and reduce vehicular defect associated crashes.

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Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03963
Paper Title	Enhancing Real-Time Crash Risk Prediction Performance Considering Spatial and Temporal Correlations in Support Vector Machine
Abstract	Unobserved heterogeneity in crash data could affect the predicting accuracy of crash risks. Such effects can be considered within the spatial and temporal correlation to improve the model prediction performance. This study aims at proposing an enhanced support vector machine (SVM) model that involves the spatial and temporal weight features in the model structure to address the spatial and temporal proximity in the real-time crash risk predictions. A total of 254 crash data on the Interstate 80 were obtained. Traffic flow data 5 min before the occurrence of each crash were extracted to be the case database. Non-crash traffic flow data were randomly extracted from the collision free periods to be the control database. The Receiver Operating Characteristics (ROC) curves were drawn to evaluate and compare the prediction performance of different models. The results showed that by incorporating the spatial and temporal correlations in the SVM, the model fitness was improved: the predicting accuracy was increased from 79.8% to 86.5% as compared to the basic SVM model. Two weight matrixes of spatial and temporal correlation in the SVM were tested, and the models with the 0-1 first order weight feature had the highest predicting accuracy. We also tested the modeling accuracy for different ratios of training and testing sample sizes. Findings of this study suggest that the proposed SVM model with the spatial and temporal correlation can effectively improve the predicting accuracy of real-time crash risks based on the traffic variables from loop detector stations.

Authors	Fangrong Chang, Central South University Hanchu Zhou, Central South University Pengpeng Xu, University of Hong Kong Jaeyoung Lee, University of Central Florida Helai Huang, Central South University
Sponsoring Committee	Motorcycles and Mopeds (ANF30)
Session Number	1500
Session Title	Recent Research on Motorcycles and Mopeds
Paper Number	19-03967
Paper Title	Identifying High-Risk Motorcycle-Riding Behaviors: A Multilevel Mixed-Effects Ordered Logit Model
Abstract	Although crash occurrence has been largely attributed to motorcycle riders' risk-taking behaviors, relatively limited research effort has been devoted to investigating the associations between motorcyclist riding behaviors and crash severity. This study aims to comprehensively quantify the role of improper riding behaviors as the causations of crashes based on 2,284 police-reported motorcycle-vehicle crashes in 2014 in Hunan Province, China. A multilevel mixed-effects ordered logit model was first developed to explore the relationships between motorcyclist post-crash injuries and their pre-crash riding behaviors. Three types of behaviors, i.e., right-of-way violation, riding in the opposite direction and violation of traffic controls, were found to significantly increase motorcyclist injury levels. A multinomial logit model was then used to identify the traffic scenes in which these three types of high-risk riding behaviors were more prone to occur. Our results indicated that motorcyclists were more likely to violate right-of-way and traffic control devices at four-legged intersections; to involve in crashes caused by riding in the opposite direction or disobeying traffic control devices on urban streets and under streetlights; and to ride in the opposite direction on curved roads. These findings are beneficial in the formulation of targeted interventions to reduce motorcyclist risk-taking behaviors and their associated injury severities.

Authors	Chongyi Li, Tongji University Jinzhao zhou, South China University of Technology Yichuan Peng, Tongji University Jian Lu, Tongji University
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-04002
Paper Title	Examining Multilayer Perceptron Based Machine Learning Method to Predict Imbalanced Sample of Traffic Crash
Abstract	This paper combined a data processing method with imbalanced sample distribution and a machine learning method based on multi-layer function approximator was employed to deal with the prediction of crash severity, especially when the sample size of the crashes is small. Severe injury and caused to death crashes are needed to be dedicated to avoid. However, few study focused on improving the prediction accuracy of the few but more devastating severe injury crashes. The purpose of this research is to improve the prediction accuracy of each level of severity of crashes. It can effectively reduce the severity of crashes and mitigate the harm caused by traffic crashes by combining the prediction results to take effective countermeasures. This research first analyzed the distribution of the severity of traffic crash injuries in California State in 2010. Seventeen important influencing factors were selected through spearman's correlation analysis. After that, the data was equalized and the multi-layer neuron network was applied to predict the severity of the crashes. Finally, the prediction results were compared with Support Vector Machine. It was shown from modeling results that the utilized sample distribution balancing processing method and multi-layer function approximators based machine learning method can be more efficient in predicting the severity of crash injuries.

Authors	Steven Stapleton, Michigan State University Timothy Gates, Michigan State University
Sponsoring Committee	Pedestrians (ANF10)
Session Number	1708
Session Title	Advances in Pedestrian Safety Research
Paper Number	19-04228
Paper Title	Empirical Analysis of the Impact of Vehicle Type on Injury Severity in Vehicle-Pedestrian Crashes
Abstract	Pedestrian fatalities continue to be a large problem in the United States, with pedestrian fatalities increasing every year, and increasing at a more rapid pace than motor vehicle crashes. While some attribute these increases with distracted driving, alcohol, or lighting conditions, these factors have not changed in recent years. On the other hand, media reports have begun attributing this increase to the increasing proportion of SUVs on the road. This study sought to evaluate that hypothesis by evaluating crash severity probability based on the proportion of vehicle registrations per county per year by vehicle type, as well as with the proportion of observed vehicles collected from annual safety belt surveys. Ordered logit regression was performed, finding that as SUVs increase as a proportion of both registered and observed vehicles increase, pedestrian crashes are likely to be more severe.

Authors	Mouyid Islam, USF Center for Urban Transportation Research Seckin Ozkul, University of South Florida
Sponsoring Committee	Truck and Bus Safety (ANB70)
Session Number	1367
Session Title	Truck and Bus Safety Research
Paper Number	19-04596
Paper Title	Identifying Fatality Risk Factors for the Commercial Vehicle Driver Population
Abstract	Commercial/large-truck fatal crash involvement by drivers of different age groups is a critical issue for the trucking industry. Escalating safety concerns of these heavy vehicles serving the freight economy in the U.S. impact national freight reliability and economic growth. This study identifies major contributing factors leading to large-truck fatal crashes by four age groups: <30, 30–49, 50–65, and 65+. The analysis in this study is based on five years (2012–2016) of Fatality Analysis Reporting System (FARS) data and provides an overall picture of risk factors in large-truck fatal crashes. In total, 30 variables were found to be significant in the logit models, indicating varying risks associated with large-truck drivers of these four age groups. Model results indicate different risk factors associated with driver characteristics, spatial and temporal characteristics, vehicle and vehicle maneuvering characteristics, and environmental conditions at the time of the crashes. Identifying the risk factors for different age groups of drivers is important so proper countermeasures can be implemented from the perspective of human factors (e.g., safe speed choice, fatigue), roadway engineering (e.g., designs of roadside barriers and radius of ramps), enforcement (e.g., presence of law enforcement personnel at critical locations), and emergency medical attention in remote areas. Considering the aging of the truck driver population in the U.S. and around the world, the findings of this study are vital to better understand the importance of safety related to large-truck fatal crashes.

Authors	Zulqarnain H. Khattak, University of Virginia Michael Fontaine, Virginia Transportation Research Council Jiaqi Ma, University of Cincinnati Brian L. Smith, University of Virginia
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-04637
Paper Title	Crash Severity Effects of Adaptive Signal Control Technology: Insights from Pennsylvania and Virginia
Abstract	Adaptive signal control technology (ASCT) is an intelligent transportation systems (ITS) technology that optimizes signal timings in real time to improve corridor flow. While several past studies have examined the impact of ASCT on crash frequency, little is known about its effect on injury severity outcomes. This paper used ordered probit models to estimate the injury severity outcomes resulting from ASCT deployment using 8 years of crash data from 42 intersections in Pennsylvania and 11 years of crash data from 49 intersections in Virginia. A unique aspect of this data was the availability of before and after deployment characteristics for two different ASCT technologies. The estimation results revealed that both ASCT systems were associated with a reduced propensity for injury crashes. The best fit model also revealed a similar trend towards reductions in severe crashes. This model performed well on validation data with low forecast error of 0.301 and was also observed to be spatially transferable. These results encourage the consideration of ASCT deployments at intersections with high crash severities and have practical implications for aiding agencies in making future deployment decisions about ASCT.

Authors	Zhenhua Chen, Ohio State University Youngbin Lym, Ohio State University
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-04801
Paper Title	Impact of Built Environment on the Severity of Vehicle Crashes Caused by Distracted Driving
Abstract	This study evaluates the influences of built environment on the severity of vehicle crashes with focuses on a comparative analysis between the crashes caused by distracted driving and non-distracted driving. Using a comprehensive dataset with 1.4 million crash records in Ohio for the period 2013-2017 as an example, the relationships between built environments and the severity of vehicle crashes caused by distracted driving were examined using the generalized order logit regression method. The outcomes of severity analysis confirm that distracted driving related crashes tend to be more severe than non-distracted driving related crashes. In particular, the crashes by distracted driving were found to be much more severe if the accident occurs at work zones or on interstate highways. On the other hand, roundabout was confirmed effective in reducing crash severities in general with a more significant effect on mitigating severity for DD distracted driving related crashes.

Authors	Xinyi Wang, Georgia Institute of Technology (Georgia Tech) Sung Hoo Kim, Georgia Institute of Technology (Georgia Tech)
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-04845
Paper Title	Prediction and Factor Identification for Crash Severity: Comparison of Discrete Choice and Tree-based Models
Abstract	In the traffic safety area, crash severity is a widely studied topic, using various types of models. The aims of this study are twofold: (1) to identify factors contributing to crash severity, including road-environment factors, human factors, and vehicle factors, and (2) to compare the prediction performance and the interpretation ability of discrete choice and tree-based models. Specifically, we compare the multinomial logit (MNL) model and the random forest (RF) model. This study employs 2017 Maryland crash data, which are publicly available from the Department of Maryland State Police. The estimated models identify contributing variables such as collision type, occupant age, and speed limit. For the given dataset, RF outperforms MNL based on multiple measures (precision, recall, and F1-score). Two models indicate some variables that significantly affect crash severity such as collision type and vehicle body type. Based on sensitivity analyses, in general, MNL is more sensitive to the change of variables than RF. In addition, RF can automatically capture the nonlinear effects of continuous variables, reduce the influence of collinearity relationships existing among explanatory variables, and automatically consider variable interactions.

Authors	Dibakar Saha, Florida Atlantic University Priyanka Alluri, Florida International University Albert Gan, Florida International University
Sponsoring Committee	Bicycle Transportation (ANF20)
Session Number	1499
Session Title	Bicycle Transportation Research
Paper Number	19-04905
Paper Title	An Investigation into the Varying Effects of Factors Contributing to Injury Severity of Different Bicyclist Age Groups in Bicycle-Vehicle Crashes
Abstract	This study aims to understand the varying effect of factors contributing to the injury severity of bicyclists of different age groups in bicycle-vehicle crashes. An examination of bicyclist crash-related injury by age groups could provide insights on programming more effective educational and safety campaigns focusing on bicyclists of specific age. Using four years of bicycle-vehicle crash data from Florida, injury severity models were developed for four age groups of bicyclists: very young (6-19 years), young (20-44 years), middle-aged (45-64 years), and old (65 years or above). Several crash, geometric, environmental, temporal, vehicle, bicyclist, and driver characteristics were examined. The number of significant variables and their effects on the bicyclist injury severity were different by age groups. The variables, including crash type, lighting condition, vehicle type, driver's inappropriate action, alcohol and drug influence, and use of safety gear are found to have varying effects on the injury severity levels of different bicyclist age groups. Specific suggestions to implement age-specific safety programs are provided.

Authors	Kai Wang, University of Connecticut Tanmoy Bhowmik, University of Central Florida Shamsunnahar Yasmin, University of Central Florida Shanshan Zhao, Connecticut Transportation Safety Research Center Naveen Eluru, University of Central Florida Eric Jackson, Connecticut Transportation Safety Research Center
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-05069
Paper Title	Multivariate Copula Modeling of Intersection Crash Consequence Metrics: A Joint Estimation of Injury Severity, Crash Type, Vehicle Damage and Driver Error
Abstract	This study employs a copula-based multivariate ordered probit model to simultaneously estimate the four common intersection crash consequence metrics – driver error, crash type, vehicle damage and injury severity – by accounting for potential correlations due to common observed and unobserved factors. To this end, a comprehensive literature review of relevant studies was conducted; four different cupula model specifications including Frank, Clayton, Joe and Gumbel were estimated to identify the dominant factors contributing to each crash consequence indicator; and specific countermeasures were recommended for each of the contributing factors to improve the intersection safety. The model goodness-of-fit illustrates that the Joe copula model with the parameterized copula parameters outperforms the other models, which verifies that the injury severity, crash type, vehicle damage and driver error are significantly correlated due to common observed and unobserved factors and, accounting for their correlations, can lead to more accurate model estimation results. The parameterization of the copula function indicates that their correlation varies among different crashes, including crashes that occurred at stop-controlled intersections and four-leg intersections and crashes which involved drivers younger than 25. The model coefficient estimates indicate that the driver's age and gender, driving under the influence of drugs and alcohol, intersection geometry and control types, adverse weather and light conditions and the vehicle type are the most critical factors contributing to severe crash outcomes. It is anticipated that this study can shed light on identifying intersection safety issues, and help develop effective countermeasures to improve intersection safety.

Authors	Peijie Wu, Harbin Institute of Technology Xianghai Meng, Professor, School of Transportation Science and Engineering, Harbin Institute of Technology Li Song, Harbin Institute of Technology Wenze Zuo, Harbin Institute of Technology
Sponsoring Committee	Transportation in the Developing Countries (ABE90)
Session Number	1490
Session Title	Traffic Safety in Developing Countries
Paper Number	19-05097
Paper Title	Crash Risk Evaluation and Crash Severity Pattern Analysis for Different Types of Urban Junctions: Fault Tree Analysis and Association Rules Approaches
Abstract	Urban junctions usually present a significant safety concern, and a majority of total crashes in urban areas happened in or near the junctions. Efforts have been made in exploring the contributory factors of crash severity at junctions, however, the crash risk levels and crash severity patterns of different junction types were rarely investigated in previous literatures. In order to fill this gap, the safety performance of six junction types and the contributory factors of crash severity were analyzed in this study, which is helpful for city transportation authorities to conduct effective countermeasures. Fault tree analysis (FTA) was applied for the risk evaluation of urban junctions and association rules (AR) algorithm was employed for the crash severity pattern analysis based on the data of STATS19 database from 2012 to 2016. Overall, four types of urban junctions with high crash risk level and over 4,000 association rules contributed to crash severity were identified in the present paper. Results show that 1) roundabouts and mini-roundabouts have the lowest fatality and casualty while T or staggered junction and crossroads have highest crash risk level; 2) FTA may produce inaccurate outcomes because of incorrect logic gates, but RA can generate real potential relationships between crash severity and risk factors; 3) the crash severity pattern is quite complex and the interdependence between risk factors of each junction type is different; 4) risk factors such as male, no physical crossing facilities within 50 meters, and give way or uncontrolled are common in high-risk junctions at night.

Authors	Xiaodong Lang, Washington State University Eric L. Jessup, Washington State University Salvador Hernandez, Oregon State University
Sponsoring Committee	Truck and Bus Safety (ANB70)
Session Number	1367
Session Title	Truck and Bus Safety Research
Paper Number	19-05103
Paper Title	An Analysis of Driver's Injury Severity Related to Commercial Truck Parking Availability
Abstract	The rapid growth of freight tonnage has made the availability of adequate commercial parking a national safety issue in the United States. This paper applies an ordered probit model to examine how the availability of commercial truck parking potentially affects the injury severity of commercial vehicle drivers normalized for other driving-related and environmental factors. The results suggest that an increase in the total number of parking spots within a thirty-minute driving distance reduces the probability of a higher degree of injury and increases the probability of less severe injury. Other factors that increase the probability of severe injuries include adverse surface conditions, night driving, older drivers, male drivers, and drug- or alcohol-related offenses.

Authors	Samantha Islam, University of South Alabama Akhter B Hossain, Alabama Department of Transportation
Sponsoring Committee	Safe Mobility of Older Persons (ANB60)
Session Number	1633
Session Title	Methodologies to Explore Older Adult Safety
Paper Number	19-05135
Paper Title	Injury Severity Analysis of Older Driver At-Fault Crashes: Alabama Case Study
Abstract	The research described in this paper explored the factors contributing to the injury severity resulting from the male and female older driver (65 years and older) at-fault accidents at unsignalized intersections in Alabama. Given the occurrence of an older driver at-fault crash at an unsignalized intersection, random parameter logit models of injury severity were estimated. The estimated models identified a variety of statistically significant factors influencing the injury severities resulting from older driver at-fault crashes. According to these models, some variables were found to be significant only in one model (male or female) but not in the other one. For example, variables such as driver under the influence of alcohol/drugs, horizontal curve, and stop sign were found significant only in the male model. On the other hand, variables such as intersection approaches on tangents with flat grade, and driver older than 75 years were found significant only in the female model. In addition, variables such as making turning maneuver, freeway-ramp junction, high speed approach, etc. were found significant in both models. Estimation findings showed that two parameters in the male model and another two parameters in the female model could be modeled as random parameters indicating their varying influences on the injury severity due to unobserved effects. Based on the results obtained, this study identified several problem areas that are amenable to engineering or education countermeasures.

Authors	Sherif Gaweesh, University of Wyoming Mohamed Ahmed, University of Wyoming
Sponsoring Committee	Truck and Bus Safety (ANB70)
Session Number	1367
Session Title	Truck and Bus Safety Research
Paper Number	19-05476
Paper Title	Exploring Factors Affecting Crash Severity for Large Trucks on Rural Mountainous Freeways using a Bayesian Logistic Regression: A Case Study on Wyoming Interstate 80
Abstract	Interstate 80 in Wyoming is an important corridor to trucking economy in the US. The high percentage of truck traffic poses serious safety issues where nearly 40% of total crashes on this corridor are large truck-related crashes. Interstate 80 in Wyoming was selected for the Connected Vehicle (CV) Pilot Deployment Program by the Federal Highway Administration with a main focus to promote safety and mobility for commercial trucks. This study aims to investigate the factors influencing large truck crashes for this unique rural mountainous freeway section. Eight years of truck crash data, 2009 to 2016, were considered for this analysis. The explanatory factors included roadway characteristics, weather factors, road surface conditions, driver and vehicle characteristics, and temporal factors. This study used Bayesian Logistic Regression (BLR) to conduct the crash severity analysis utilizing Markov Chain Monte Carlo (MCMC) stochastic simulation. The Bayesian model has the advantage of incorporating prior information about the data in the model development. Additionally, it accounts for unobserved heterogeneity and the uncertainty associated with crash data by utilizing the MCMC simulation. Three separate BLR models were developed to investigate the factors affecting single vehicle truck crashes, multi-vehicle truck crashes, and total truck crashes. Results showed that the adverse weather conditions and challenging roadway geometry were the common factors affecting the three investigated truck crash types.

Authors	Amrita Goswamy, Iowa State University Shauna Hallmark, Iowa State University Theresa Litteral, Iowa State University
Sponsoring Committee	Visibility (AND40)
Session Number	1536
Session Title	Roadway Lighting, Visibility, and Safety
Paper Number	19-05757
Paper Title	Impact of Destination Lighting and Other Factors on Driver's Injury Severity of Nighttime Crashes at Rural Stop-Controlled Cross-Intersections using Proportional Odds Model
Abstract	Unlit or inadequately lit intersections may reduce the ability of drivers to detect an upcoming intersection at night. Lack of adequate lighting increases the likelihood of not detecting conflicting vehicles or pedestrians. In rural areas, vehicles headlights generally serve as the only source of light. Drivers recognizing presence and visibility of signs and markings are difficult if proper reflective material on signs. Destination lighting can be a solution for nighttime crashes at rural intersections. It is typically placed at one approach. Even if it does not provide a full lighting, intersections with lesser traffic volumes receives some illumination. Effects of destination lighting on driver's injury severity levels are closely investigated in this study. Locations with destination lighting were gathered with the assistance of several state agencies. After manual selection of a similar number of control intersections, propensity score matching using caliper width technique was used to match 245 treatments with 245 control sites. A proportional odds model was used to evaluate crash severity. It was seen that presence of destination lighting at stop-controlled cross intersections tend to decrease the severity of nighttime crashes. Destination lighting reduces the probability of fatality by 0.2%, decrease the probability of incapacitating injury crashes by 0.8%, non-incapacitating injury crashes by 2.7% and possible injury crashes by 2.9% when compared with absence of destination lighting. The probability of no-injury crash or PDO crash at intersections with destination lighting is 6.5% higher than at intersections without destination lighting.

Authors	Parag Pareekh Sudeshna Mitra, Indian Institute of Technology, Kharagpur Dipanjan Mukherjee, IIT Kharagpur Shirin Wadhwaniya, Johns Hopkins Bloomberg School of Public Health Shivam Gupta, Johns Hopkins Bloomberg School of Public Health Adnan A. Hyder, Johns Hopkins International Injury Research Unit
Sponsoring Committee	Transportation in the Developing Countries (ABE90)
Session Number	1490
Session Title	Traffic Safety in Developing Countries
Paper Number	19-05810
Paper Title	A Study of Road Traffic Injuries using Data from Trauma Care Facilities: Additional Perspectives from India
Abstract	Road traffic injuries (RTIs) are globally recognized as a public health issue with the problem being particularly acute in Low and Middle-Income Countries (LMICs) such as India. This increase in crash frequency and injury severity is linked to construction of high speed corridors amidst poor access control and the concomitant phenomena of rapid urbanization and motorization. While behavior of road users, lack of enforcement, and poor road design have all contributed to the poor road safety scenario, quality of post-crash response also significantly impacts injury severity and deaths. Hence, analysis of RTI data from hospital Emergency Room can yield important insights about critical determinants of post-crash response. This paper presents key findings from a hospital surveillance study with RTI data collected at the Emergency Room (ER) of hospital at the time of admission. Further, the study also compares and contrasts information about injury data collected by police at crash scene. Key findings from the analyses of the emergency room data indicate significantly high representation of pedestrians and motorcyclists amongst all crash victims. Significant associations are revealed between hospital transfer time, mode of transfer, and injury severity. Adverse impacts of not using safety equipment while travelling are also reflected in the analyses.

Authors	Seyedmirsajad Mokhtarimousavi, Florida International University Jason Anderson, Portland State University Atorod Azizinamini, Florida International University Mohammed Hadi, Florida International University
Sponsoring Committee	Artificial Intelligence and Advanced Computing Applications (ABJ70)
Session Number	1298
Session Title	Artificial Intelligence and Machine Learning Methods for Transportation Applications, Part 1
Paper Number	19-05887
Paper Title	Improved Support Vector Machine Models for Work Zone Crash Injury Severity Prediction and Analysis
Abstract	Work zones have been a high-priority issue due to their impacts on traffic safety. A better understanding of work zone crashes can help to identify the contributing factors and countermeasures in order to enhance roadway safety. This study investigates the prediction of work zone crash severity and the contributing factors to this prediction by employing a parametric approach using the Mixed Logit (MXL) modeling framework and a non-parametric machine learning approach that use the Support Vector Machine (SVM). The MXL model belongs to the class of random parameters models, in which flexible variable impacts across different observations are identified, i.e. data-heterogeneity is taken into account. The SVM model performance is enhanced by applying three metaheuristic algorithms: Particle Swarm Optimization (PSO), Harmony Search (HS), and the recently introduced Whale Optimization Algorithm (WOA). Empirical findings indicate that SVM provides higher prediction accuracy and outperforms the MXL model. Estimation results reveal key factors that increase the likelihood of severe work zone crashes. Furthermore, the analysis illustrates the ability of the three metaheuristics to enhance the SVM and the superiority of the HS algorithm in improving the SVM performance.

Authors	Ihsan Khan, North Dakota State University Kimberly Vachal, North Dakota State University
Sponsoring Committee	Occupant Protection (ANB45)
Session Title	Occupant Protection Committee
Paper Number	19-06001
Paper Title	Investigating the factors affecting the injury severity of single-vehicle rollover crashes in the United States
Abstract	Rollover crashes are among the most violent types of motor vehicle (MV) crashes. It is critical to explore the factors associated with severity outcomes of rollover crashes. This study develops a generalized ordered logit model to investigate the effects of various factors on injury severity of single-vehicle rollover crash occupants based on five-year crash data in the United States. The effects of explanatory variables considered in model development include roadway attributes, crash and environmental information, driver characteristics and vehicle features. Results show that likelihood of serious and fatal injuries increases in rollover crashes with occupant's ejection (partial and complete), over-speeding, higher posted speed limits, roadside and median rollovers, undulating terrain, rural roads (as opposed to urban), daytime, driver age, no occupant protection, previous driver crash recorded, careless or inattentive driving, driver-passenger engagement, aggressive driving, and passenger car vehicle type(as opposed to light vehicles such as sport utility vehicle and pickup truck). The study findings can help safety stakeholders in developing effective countermeasures through a better understanding of factors in rollover crash injury severity outcomes.

6 Crash Modification Factors

Filomena Mauriello, University of Naples Federico II

The subcommittee identified fifteen papers dealing with crash modification factors (CMFs).

The papers are scattered across various sessions, with most papers presented at the poster session 1706 Highway Safety Performance (Wednesday 8:00 AM – 9:45 AM).

From a **methodological perspective**, almost all the papers employed the empirical Bayes approach (19-01242, 19-03134, 19-03454, 19-04234, 19-04607, 19-04784, 19-04815, 19-05167, 19-05379). Almost all the studies employed before-after techniques (19-01242, 19-03134, 19-03454, 19-04234, 19-04607, 19-04784, 19-04815, 19-05167, 19-05379). One study compared the CMFs calculated by a before-after study to the CMFs calculated by a cross-sectional study (19-03826), while Wu et al. (19-03454) propose a novel approach for estimating CMFs.

From a **countermeasures point of view**, the papers addressed:

- Intersections
  - Continuous green T (19-00233), finding CMFs for total, fatal-and-injury, rear-end, and CGT-related crashes between 0.40 and 0.60;
  - Flashing Red Arrow Protected Permissive Left Turn Signal Control (19-04784), finding CMFs equal to 0.53 for left-turn crashes and equal to 0.75 for total crashes;
  - Low-Cost Countermeasures for Preventing Wrong-Way Driving crashes (19-04815), finding controversial results;
  - Protected or protected/permissive left-turn phasing, and leading pedestrian intervals (19-04607);
  - Restricted Crossing U-turns (19-03728);
  - Right Turn Lanes (19-05167), finding a CMF of 0.41 for total crashes;
  - Signalization of rural three-leg and four-leg stop-controlled intersections (19-03826);
  - Skew Angle (19-04486, 19-04401);
- Pavement condition as measured by the International Roughness Index (19-01242), finding CMFs for severe crashes equal to 0.93 for arterial roads and equal to 0.90 for collector roads;
- Pedestrian countdown signals (19-05379), finding CMFs equal to 0.92 for total crashes and equal to 0.88 for rear-end crashes;
- Variable speed limits (19-03134), finding a CMF for total crashes equal to 0.68; and
- Wider edge lines (19-04234), finding a CMF for equal to 0.90 for fatal and serious ROR crashes.

Authors	Jaeyoung Lee, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Alan El-Urfali, Florida Department of Transportation
Sponsoring Committee	Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-00233
Paper Title	The Safety Implications of the Conversion of Continuous Green T-Intersections Back to Conventional T-Intersections
Abstract	A continuous green T-intersection (CGT) is an innovative intersection that could improve the through traffic capacity by allowing major-leg vehicles on the top side of T-intersection to pass through without stopping. Recently, traffic engineers decided to stop CGT operations at several T-intersections in Florida because of traffic safety concerns, conversion to four-legged intersection, pedestrians' demand, and non-compliance with the latest Manual on Uniform Traffic Control Devices. In this study, safety effects of recent conversions of CGTs back to conventional T-intersections in Florida are explored. A before-and-after study with the comparison group method are adopted. The results indicate significant reductions in total, fatal-and-injury, rear-end, and CGT-related crashes by 40% to 60% after the conversion. In order to validate the results, a cross-sectional analysis was conducted with new data from four states. The results are consistent for total, fatal-and-injury, and CGT-related crashes with those from the before-and-after study. The results also show that crashes at CGTs could be minimized by providing a physical separation between the acceleration lane for the merging vehicles and the CGT through lane, along with other factors. Because Florida's T-intersections that were converted back to the conventional design from CGT had no physical separation, and the results showed a significant safety improvement after the conversion. Therefore, the decision to stop CGT operations at the Florida's study sites was supported from the safety aspect. The study concluded that safety at CGTs could be a concern compared to non-CGTs; however, it could be significantly improved by providing appropriate countermeasures.

Authors	Iliya Nemtsov, Ryerson University Alireza Jafari Anarkooli, Ryerson University Bhagwant Persaud, Ryerson University Ian Lindley, Ryerson University
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-01242
Paper Title	Safety Effects of Pavement Maintenance Treatments for Two-Lane Rural Roads: Insights for Pavement Management
Abstract	The research used data from two-lane rural roads in Ontario, Canada and the empirical Bayes (EB) before-after methodology to evaluate the change in safety following maintenance treatments over a 12 year period to improve pavement condition as measured by International Roughness Index (IRI). The results indicate statistically significant reductions ($P<0.10$) in severe (fatal plus injury) crashes of about 7% (a crash modification factor (CMF) of 0.93) for arterial roads and 10% for collector roads. For property damage only (PDO) crashes there was a significant reduction of about 7% for arterial roads and a tiny, insignificant increase for collector roads. As part of the EB methodology, safety performance functions (SPFs), which, importantly, included IRI as a variable, were developed to control for effects caused by factors such as regression-to-the-mean and traffic volume changes. The inference from the IRI coefficients in the SPFs corroborated the implication from the EB study that a reduction in IRI could result in an improvement in safety. A key aspect of the research was an investigation of how the safety effect is impacted by the levels of safety and IRI before treatment and the change in IRI accomplished. The results provide interesting, and sometimes counterintuitive insights for those planning maintenance treatments to improve IRI.

Authors	Gary Davis, University of Minnesota, Twin Cities Jingru Gao, University of Minnesota, Twin Cities
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-03007
Paper Title	Transferability of Crash Modification Factors via Graphical Causal Models: An Introduction
Abstract	This paper describes an exploratory analysis of how to transfer a crash modification factor, estimated for one set of conditions, to a different set of conditions. Such situations are likely to become important as automated vehicles improve their capabilities and increase their market share. Our starting point is a graphical model describing the dependencies among the variables in a crash mechanism, and we focus on (1) identifying sufficient conditions for taking causal information determined in one situation and applying to another, and (2) deriving expressions for computing the transferred quantities. Three simplified but plausible scenarios are proposed. For each scenario transportability analyses developed by Pearl and his associates are used to develop a re-calibration formula with which an existing CMF can be adjusted to reflect new conditions. Computation examples are used to illustrate these results.

Authors	Ziyuan Pu, University of Washington Xiaoyu Guo, Texas A&M Transportation Institute Zhibin Li, Southeast University Ying Jiang, University of Washington Yinhai Wang, University of Washington Chao Zhang, Tsinghua University
Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1706
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03134
Paper Title	Before-After Analysis of Safety Effects of Variable Speed Limit System Using Full Bayesian Models
Abstract	Variable speed limits (VSL) have been increasingly used to improve traffic safety on freeway mainlines. The primary objective of this study was to evaluate the safety impacts of the VSL system implemented on Interstate 5 in Seattle, United States since 2010. A Full Bayesian (FB) before-after analysis was conducted based on 9,787 crashes that occurred in a 72-month study period. The analysis was conducted for all crashes, crash severity levels, crash types and crash causes. The FB before-after results implied that the total crash count was reduced by 32.3% with a standard deviation of 3.58% after the implementation of VSL system on the target freeway. The decrease in number of no injury crashes is greater than the decrease in crashes with severe injury and possible injury. The effect with respect to reducing head-on, face and leading-end crashes was with the most beneficial among all crash types, while the effect on rear-end crash was the least. The study also compared the traffic speed features in the before and after periods in order to fully evaluate the impacts of the VSL system on traffic operations. The result indicated that, the difference in speed was apparently reduced with the VSL system deployed The results of this study are particularly valuable for policy making and cost-benefit evaluation associated with VSL system implementations.

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Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-03454
Paper Title	A Novel Approach for Estimating Crash Modification Factors: Jointly Modeling Crash Counts and Time Intervals between Crashes
Abstract	Crash modification factors (CMFs) play important roles in roadway safety management. Safety analysts have proposed various methods for developing CMFs, and nearly all of them are crash count-based. Intervals between crashes are not considered, while survival theory has been widely used in other fields. The objective of this study is to incorporate survival models into the estimation of CMFs and to examine if it increases estimation accuracy. To accomplish the objective, this study proposed a joint modeling approach, simultaneously analyzing crash counts and time intervals between crashes, for estimating CMFs. In order to assess the performance, this study developed CMFs for a dummy treatment at 90 sites on rural two-lane highways in Texas, with the standard empirical Bayes (EB) method and the joint model, separately. The findings are very interesting: (1) The standard EB method tends to over-estimate the CMFs for the treatment, and under-estimate the standard error of the CMFs. Most of the cases, the results are biased; (2) The CMFs developed with the joint model have greater standard errors, but their values are closer to the true effects, which is more realistic; (3) Temporary instability in traffic crashes are also observed in this study. Increasing the duration of study period does not always increase the accuracy of CMF estimates. Roadway agencies are encouraged to deploy the joint model for dynamical monitoring safety effects of treatments by flexible feedback.

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Sponsoring Committee	Safety Data, Analysis and Evaluation (ANB20)
Session Number	1706
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-03728
Paper Title	Improving Intersection Safety with RCUT: Louisiana Experience
Abstract	The safety of intersections on major corridors is always a concern because of the high-risk vehicle maneuvers intertwined with a high operating speed. It is especially a problem for intersections with a two-way stop-sign control where vehicles on a low-speed minor roadway must cross multiple lanes and the median before merging into the path of high-speed traffic. To improve the intersection safety, Restricted Crossing U-turns (RCUT) has been constructed in Louisiana since 2011. Because of the short history of the RCUT implementation, there are limited studies available that address the RCUT safety effectiveness. This paper evaluates the safety benefit of six RCUTs in Louisiana including five intersections in urban and suburban areas. Unlike the previous studies, this investigation covers both the RCUT intersection only and RCUT system (consisting of the intersection, two U-turns and segments in between). The crash analysis shows a 100% reduction in fatalities, 41.5% in injuries and 22.3% in property damage only crash for the RCUT intersection only, and less impressive reductions for the RCUT system. The review of the original crash reports greatly benefits the investigation on why the crashes increased at few locations, thus, provides the valuable information on how to correct these crash problems through the detailed design and traffic control. The safety improvement plus the high ratio of benefit to cost strongly demonstrate that the RCUT is an effective and economically justified countermeasure on high-speed roadways in both rural and urban areas.

Authors	Lishengsa Yue, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida Ahmed Farid, University of Central Florida
Sponsoring Committee	Highway Safety Performance (ANB25)
Session Number	1413
Session Title	Highway Safety Performance Data-Driven Analyses: When It Counts
Paper Number	19-03826
Paper Title	Effects of Signalization at Rural Intersections Considering the Elderly Driving Population
Abstract	The main objective of this study is to quantify the safety impacts of signalization at Florida's rural three-leg and four-leg stop-controlled intersections by estimating crash modification factors. The intersections are those in which stop signs are provided for the minor approaches or all-way stop-controlled intersections. The CMFs are estimated using the cross-sectional method. Generalized linear models (GLM) and multivariate adaptive regression spline models (MARS) are employed with four-years of Florida crash data. The K-nearest neighbor and K-means clustering algorithms are implemented to identify the comparison sites which are sites having similar characteristics as those of the converted intersections. Furthermore, the quasi-induced exposure method is used to evaluate the safety effects of signalization for elderly and non-elderly drivers, separately. According to the results, signalization contributes to an increase in PDO and rear-end crashes. In addition, elderly drivers are more at risk of being involved in such crashes than non-elderly drivers. In particular, at rural four-leg two-way stop-controlled intersections, signalization decreases crash severity, and greater percentage of the decrease is observed for the elderly drivers than non-elderly especially when the intersection has a high level of major road AADT and elderly driver proportion. This study also demonstrates that the MARS model shows a better model fit than the GLM model due to its strength in capturing nonlinear relationships and interaction effects among variables. This study's findings have implications for both practitioners and researchers.

Authors	Mohamed Mohamed, University of Idaho Maged Mohamed, University of Idaho Ahmed Abdel-Rahim, University of Idaho Kevin Chang, University of Idaho
Sponsoring Committee	Traffic Control Devices (AHB50)
Session Number	1628
Session Title	Traffic Control Devices 2019
Paper Number	19-04234
Paper Title	Safety Impact of Edge Lines Wider Pavement Marking
Abstract	The primary role of pavement markings is to provide a visual cue to drivers to assist them with vehicle position along a roadway and help them make a proper lane change decision. For this study, the objective was to determine the safety effectiveness of wider pavement markings with regard to traffic safety. Before and after studies using comparison group and Empirical Bayes methods were applied using crash data from thirty-eight independent two-lane rural highway locations in the state of Idaho to determine that if there was a relationship between the implementation of wider pavement markings and vehicle crashes. Safety performance functions (SPF) for run-of-the-road crashes (ROR) in Idaho for two-lane rural highways were also developed. This study concluded that there is a strong relationship between wider pavement marking width and a reduced number of ROR crashes particularly those involving fatal and serious injuries crashes. The research results showed that wider pavement marking implementation has the potential to reduce fatal and serious ROR crashes by 10.1 percent with an expected cost to benefit ratio of approximately 1:25. For this reason, the implementation of wider pavement marking widths by agencies along two-lane rural highways is encouraged to provide a long-term safety benefit for the motoring public.

Authors	Andrew Northmore, University of New Brunswick Eric Hildebrand, University of New Brunswick
Sponsoring Committee	Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-04401
Paper Title	Identification of Critical Intersection Angle through Crash Modification Functions
Abstract	Safety performance functions (SPFs) have been developed for specific jurisdictions and road authorities across North America, but there are practical applications for national average SPFs. Some examples include use by jurisdictions lacking resources to develop their own SPFs and for developing national guidelines such as traffic signal warrants. The only work on average collision expectation models to date are those presented in the Highway Safety Manual (HSM), but there are questions as to how representative the HSM equations are of a national average due to the scope of the studies that developed those models. This study developed models for average intersection collision expectation across Canada and the United States based on a diverse set of published jurisdiction-specific SPFs and HSM calibrations. The models focused on the effects of traffic volume, region fixed-effects, and local jurisdiction random-effects on intersection collision expectation. In general, it was found that the models that included a jurisdiction random-effect provided the best fit. These results were compared to the HSM models and there was substantial variation between the two in terms of predicting collision expectation and collision modification factors (CMFs) for signalization, suggesting that the HSM models do not adequately represent a national average. CMFs based on this research suggest that collision rates tend to increase due to signalization, whereas most published CMFs suggest a decrease. This finding suggests that jurisdiction-specific CMFs for signalization may not be transferable for use outside of the jurisdictions where they are developed.

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Sponsoring Committee	Highway Safety Performance (ANB25)
Session Number	1413
Session Title	Highway Safety Performance Data-Driven Analyses: When It Counts
Paper Number	19-04486
Paper Title	Identification of Critical Intersection Angle through Crash Modification Functions
Abstract	A significant portion of both fatal and total crashes occur at intersections in the United States. Skew angle may be a significant contributor to these crashes. This paper examines the effects of intersection angle on intersection safety performance. With seven years of crash data from Minnesota and five years of crash data from Ohio, random forest regression data mining and negative binomial regression models were developed to estimate crash modification functions at three-leg and four-leg, stop-controlled intersections with two-lane and multilane major legs. Where possible, the results were compared between the two states and used to develop average crash modification function curves. This study shows that over half of the intersection types experience the highest number of predicted crashes when the intersection angle between roadway legs is between 50 degrees and 65 degrees. These results have practical implications for engineers and safety professionals. First, the crash modification function curves supplement and revise the guidance for intersection angle in the Highway Safety Manual and Policy on Geometric Design of Highways and Streets. Second, the functions offer new guidance to agencies planning intersection improvements. Third, the crash modification functions can be used to determine the safety effect of changes in intersection angle.

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Sponsoring Committee	Highway Safety Performance (ANB25)
Session Number	1413
Session Title	Highway Safety Performance Data-Driven Analyses: When It Counts
Paper Number	19-04607
Paper Title	Evaluation of Protected Left Turn Phasing and Leading Pedestrian Intervals Effects on Pedestrian Safety
Abstract	Pedestrian safety is an important public health issue for the United States, with pedestrian fatalities representing approximately 16 percent of all traffic related fatalities in 2016. Nationwide, transportation agencies are increasing their efforts to implement engineering-based improvements that increase pedestrian safety. These agencies need statistically rigorous crash modification factors (CMFs) to demonstrate the safety effectiveness of such countermeasures, and to apply in benefit–cost analyses to justify their implementation. This study focused on developing CMFs for two countermeasures that show promise for improving pedestrian safety: protected or protected/permissive left-turn phasing, and leading pedestrian intervals (LPIs). Data were acquired from four North American cities that had installed one or both of the countermeasures of interest: Chicago, IL; New York City, NY; Charlotte, NC; and Toronto, ON. The empirical Bayes (EB) before-after study design was applied to estimate the change in expected crash frequency for crashes following treatment. The protected left-turn phasing evaluation showed a benefit in reducing vehicle–vehicle injury crashes, but did not produce statistically significant results for vehicle–pedestrian crashes, although a disaggregate analysis revealed that this treatment could be especially beneficial where pedestrian volumes exceed 5,000 per day. The LPI evaluation showed a statistically significant reduction in vehicle–pedestrian crashes with an estimated CMF of 0.87.

Authors	Ranteg Singh Rao, University of Maryland Piotr Rachtan, Maryland State Highway Administration Gang-Len Chang, University of Maryland, College Park
Sponsoring Committee	Traffic Control Devices (AHB50)
Session Number	1628
Session Title	Traffic Control Devices 2019
Paper Number	19-04784
Paper Title	Evaluating the Safety Impact of Flashing Red Arrow Protected Permissive Left Turn Signal Control in Maryland
Abstract	Maryland has used flashing red arrow (FRA) since the 1980's at intersections operated with protected-permissive left-turn (PPLT) control, but impacts of this display on traffic safety have yet to be rigorously assessed. To evaluate the safety impacts of FRA and develop reliable guidelines this study has used data from 23 intersections in Maryland where the PPLT display was converted from a five-section (doghouse) cluster signal head with circular green to a three-section signal head with FRA and a supplemental sign. Safety Performance Functions (SPFs) calibrated for Maryland are developed on a sample of 20 intersections using PPLT display with circular green. Using the Empirical Bayes (EB) method, the results from the safety evaluation of FRA show that the respective crash modification factors (CMF) for left-turn crashes and total crashes were 0.53 and 0.75, thereby showing that FRA signals for PPLT control increase the safety at signalized intersections. Similarly, the CMFs for left-turn and total crashes resulting in injuries were found to be 0.63 and 0.71 respectively. Overall, among the 23 intersections, the left-turn crashes decrease by as much as 87%, and similar patterns were also observed for left-turn crashes resulting in injuries.

Authors	Qing Chang, Auburn University Md Atiquzzaman, Auburn University Huaguo Zhou, Auburn University
Sponsoring Committee	Traffic Control Devices (AHB50)
Session Number	1628
Session Title	Traffic Control Devices 2019
Paper Number	19-04815
Paper Title	An Evaluation of Low-Cost Countermeasures for Preventing Wrong-Way Driving Incidents Based on Two Before-and-After Case Studies
Abstract	In this study, before-and-after analyses were conducted at two exit-ramp terminals of partial cloverleaf interchanges (I-65 Exit 284 and I-65 Exit 208) in Alabama. Based on a previous research project, these two locations were identified as high-risk locations for Wrong-Way Driving (WWD) having more than 10 WWD incidents at each during a typical weekend. Alabama Department of Transportation (ALDOT) regional engineers have implemented some low-cost countermeasures to mitigate the WWD activities at these two locations. At I-65 Exit 284, the pavement marking was improved, including (1) new double yellow line and left-turn skip strips on the crossroad, and (2) yield line for right turn lane and stop bar for left turn lane at end of the exit ramp. At I-65 Exit 208, raised-curb channelized island was implemented to reduce the width of exit ramp. There has little document on the effectiveness of these types of low-cost countermeasures in reducing WWD incidents. In this study, the WWD incident data were collected at these two locations before and after the countermeasures were implemented. At I-65 Exit 284, the implemented countermeasures reduced 65% of the total and approximately 89% of nighttime WWD incidents. The study found that drivers follow more closely to left-turn skip strips during nighttime than the daytime. However, at I-65 Exit 208, implemented channelized island resulted in approximately 80% increase in WWD incidents. Additional signage and pavement markings need to be improved along with the channelized island to achieve better effectiveness in preventing WWD incidents at this location.

Authors	Kerrie Schattler, Bradley University Trevor Hanson, Illinois Department of Transportation
Sponsoring Committee	Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-05167
Paper Title	Empirical Bayes Safety Evaluation of a Modified Right Turn Lane Design at Intersections
Abstract	From 2006 to 2014, ten right-turn approaches in Peoria, Illinois, were reconstructed with a modified right-turn lane design. The major purpose of the modified design was to improve the line of sight for passenger vehicles turning right, while also accommodating semi-tractor trailer trucks. While the actual changes varied among intersections, the final result at each was an improvement to the approach angle for right-turning vehicles stopped to view cross traffic. The authors of this paper were involved in a two-part research study in which they (1) performed site-specific effectiveness evaluations of the modified sites, and (2) conducted a crash causation analysis of right-turn crashes at 116 sites in Illinois to identify geometric design variables that correlate with right-turn crashes. In the site-specific evaluation, traffic crash–based safety analyses were performed to assess the safety performance of the modified right-turn lane design using the empirical Bayes method. Statistically significant reductions in crashes were observed at the subject approaches (59.0%) after the modifications were made. The results of the crash causation analyses revealed significantly higher right-turn crashes for approaches with head-turn angles greater than 140□, right-turn angles less than 45□, and acute intersection angle less than 75□. Recommendations on the characteristics of good candidate sites for the installation of the modified right-turn lane design in Illinois are presented in this paper. This research received a 2017 AASHTO Research Advisory Committee High-Value Research Maintenance and Safety Project designation.

Authors	Raghavan Srinivasan, University of North Carolina, Chapel Hill Bo Lan, UNC Highway Safety Research Center Daniel Carter, UNC Highway Safety Research Center Sarah Smith, University of North Carolina Bhagwant Persaud, Ryerson University Kari Signor, UNC Highway Safety Research Center Taha Saleem, UNC Highway Safety Research Center
Sponsoring Committee	Highway Safety Performance (ANB25)
Session Number	1706
Session Title	Highway Safety Performance
Paper Number	19-05379
Paper Title	Safety Evaluation of Pedestrian Countdown Signals - Definitive Results from Two Cities in the United States
Abstract	The pedestrian countdown signals (PCS) treatment involves the display of a numerical countdown that shows how many seconds are left in the flashing DON'T WALK interval. Although many studies have attempted to evaluate the safety of PCS, the results have been inconsistent due to many reasons including inadequate samples, and the inability to control for possible bias due to regression to the mean, and exposure. This study performed a before-after empirical Bayes (EB) analysis using data from 115 treated intersections in Charlotte, North Carolina and 218 treated intersections in Philadelphia, Pennsylvania to evaluate the safety effects of PCS. The evaluation also included 136 reference intersections in Charlotte, and 597 reference intersections from Philadelphia. Following the implementation of PCS, total crashes decreased by approximately 8 percent and rear-end crashes decreased approximately 12 percent, and these reductions were statistically significant at the 95-percent confidence level. Pedestrian crashes decreased by about 9 percent and this reduction was statistically significant at the 90-percent confidence level. The economic analysis revealed a benefit-cost ratio of 23 with a low of 13 and a high of 32.

7 Surrogate Measures of Safety

Cristhian Lizarazo, Raul Pineda-Mendez, and Thomas Hall, Purdue University

Thirty-five papers involving surrogate measures of safety were identified. In these studies, the surrogate measures were used either as the primary approach to safety analysis or to complement the more traditional crash-based approach.

Four topics stood out from the review: **Intersections and interchanges**, **pedestrians and non-motorized users**, **connected and autonomous vehicle technologies,** and **real-time safety analysis**. Eighteen papers addressed safety at **intersections and interchanges** (Arhin et al., 19-00100; Gu et al., 19-00286; Zheng and Sayed, 19-00425; Zheng and Sayed, 19-00438; Appiah et al., 19-00595; Wei et al., 19-00990; Pietrucha et al., 19-01314; Ma et al., 19-01569; Alagbe and Jin, 19-01767; St-Aubin et al., 19-01827; Dinakar and Muttart, 19-03061; Paul and Ghogh, 19-03075; Niaki et al., 19-03202; Zaki et al., 19-04031; Wu et al., 19-04251; Pan et al., 19-04471; Fu et al., 19-05276; Yoshioka et al., 19-05311). Furthermore, **pedestrians and non-motorized users** were investigated in eight papers (Wei et al., 19-00990; Alagbe and Jin, 19-01767; St-Aubin et al., 19-01827; Niaki et al., 19-03202; Wu et al., 19-04251; Hussain et al., 19-04399; Ulak et al., 19-04583; Fu et al., 19-05276). **Connected and autonomous vehicle technologies** were discussed in five papers (Gu et al., 19-00286; Li et al., 19-00736; Osman et al., 19-01344; Jing et al., 19-01824; Khattak et al., 19-04570), while **real-time safety analysis** was highlighted in five papers (Wei et al., 19-00990; Tarko, 19-03682; Formosa et al., 19-04003; Xue et al., 19-04355; Tang et al., 19-05279).

Concerning the surrogate measures of safety, **traffic conflicts** were used in eighteen articles (Alsalhi et al., 19-00183; Gu et al., 19-00286; Zheng and Sayed, 19-00425; Zheng and Sayed, 19-00438; Appiah et al., 19-00595; Wei et al., 19-00990; Ma et al., 19-01569; Jing et al., 19-01824; St-Aubin et al., 19-01827; Arvin et al., 19-01981; Paul and Ghogh, 19-03075; Niaki et al., 19-03202; Tarko, 19-03682; Formosa et al., 19-04003; Wu et al., 19-04251; Xue et al., 19-04355; Shah and Lee, 19-04843; Fu et al., 19-05276). The main traffic conflict indicators included **time-to-collision (TTC)** and **post-encroachment time (PET)**. **TTC** was used in nine papers (Gu et al., 19-00286; Zheng and Sayed, 19-00425; Zheng and Sayed, 19-00438; Ma et al., 19-01569; Jing et al., 19-01824; St-Aubin et al., 19-01827; Niaki et al., 19-03202; Wu et al., 19-04251; Xue et al., 19-04355), while **PET** was applied in four papers (Zheng and Sayed, 19-00425; St-Aubin et al., 19-01827; Paul and Ghogh, 19-03075; Wu et al., 19-04251). Additionally, the **deceleration to avoid crash (DRAC)** was used in four papers (Zheng and Sayed, 19-00425; Wei et al., 19-00990; Arvin et al., 19-01981; Shah and Lee, 19-04843). **Speed characteristics** were used in fourteen papers (Gu et al., 19-00286; Li et al., 19-00736; Wei et al., 19-00990; Osman et al., 19-01344; Kamrani et al., 19-01980; Arvin et al., 19-01981; Ghasemzadeh and Ahmed, 19-03306; Zaki et al., 19-04031; Hussain et al., 19-04399; Khattak et al., 19-04570; Shah and Lee, 19-04843; Fu et al., 19-05276; Tang et al., 19-05279; Wu et al., 19-05427).

Some authors target specific maneuvers and driving behavior using surrogate measures of safety such as **lane keeping**, **stop compliance**, and **red-light violations**. **Lane keeping** was analyzed in four articles (Gu et al., 19-00286; Li et al., 19-00736; Tarko, 19-03682; Das et al., 19-04999). **Stop compliance** was investigated in two papers (Arhin et al., 19-00100; Pietrucha et al., 19-01314), while **red-light violations** was studied by Zaki et al., 19-04031 and Pan et al., 19-04471.

In terms of input data, **field observations** were the primary data source in twelve papers (Arhin et al., 19-00100; Alsalhi et al., 19-00183; Gu et al., 19-00286; Zheng and Sayed, 19-00425; Zheng and Sayed, 19-00438; Appiah et al., 19-00595; Pietrucha et al., 19-01314; Alagbe and Jin, 19-01767; Paul and Ghogh, 19-03075; Niaki et al., 19-03202; Ulak et al., 19-04583; Yoshioka et al., 19-05311). **Naturalistic driving data** was utilized in nine papers (Osman et al., 19-01344; Kamrani et al., 19-01980; Arvin et al., 19-01981; Dinakar and Muttart, 19-03061; Ghasemzadeh and Ahmed, 19-03306; Xue et al., 19-04355; Das et al., 19-04999; Tang et al., 19-05279; Wu et al., 19-05427). Data from user **trajectories** were used in nine papers (Li et al., 19-00736; Wei et al., 19-00990; Jing et al., 19-01824; St-Aubin et al., 19-01827; Ghasemzadeh and Ahmed, 19-03306; Xue et al., 19-04355; Pan et al., 19-04471; Shah and Lee, 19-04843; Das et al., 19-04999). **Simulated data** was used in five papers (Alsalhi et al., 19-00183; Appiah et al., 19-00595; Ma et al., 19-01569; Jing et al., 19-01824; Wu et al., 19-04251), while data extracted from **video records** was the input in six papers (Gu et al., 19-00286; Alagbe and Jin, 19-01767; St-Aubin et al., 19-01827; Formosa et al., 19-04003; Zaki et al., 19-04031; Fu et al., 19-05276). Three studies were found to use **driving simulator** data (Tarko, 19-03682; Wu et al., 19-04251; Shah and Lee, 19-04843). Pan et al., 19-04471 utilized **GPS and smartphone data**, and a **meta-analysis** on speed and pedestrian safety was conducted by Hussain et al., 19-04399.

Regarding data analysis, **statistical regression models** were used in nine papers (Arhin et al., 19-00100; Gu et al., 19-00286; Li et al., 19-00736; Ma et al., 19-01569; St-Aubin et al., 19-01827; Kamrani et al., 19-01980; Ghasemzadeh and Ahmed, 19-03306; Tarko, 19-03682; Khattak et al., 19-04570). **Machine learning and deep learning** algorithms were implemented in four papers (Wei et al., 19-00990; Osman et al., 19-01344; Formosa et al., 19-04003; Xue et al., 19-04355).

To conclude, it is relevant to highlight that the **crash risk** was predicted in twelve papers (Gu et al., 19-00286; Appiah et al., 19-00595; Li et al., 19-00736; Wei et al., 19-00990; Ma et al., 19-01569; Kamrani et al., 19-01980; Wu et al., 19-04251; Xue et al., 19-04355; Hussain et al., 19-04399; Shah and Lee, 19-04843; Yoshioka et al., 19-05311; Wu et al., 19-05427).

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

Authors	Stephen Arhin, Howard University Adam Gatiba, Howard University Melissa Anderson, Howard University Melkamsew Ribbiso, Howard University
Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	1628
Session Title	Traffic Control Devices 2019
Paper Number	19-00100
Paper Title	Predicting STOP-sign Compliance at All-Way Stop Intersections in Close Proximity to Signalized Intersections
Abstract	STOP signs (at unsignalized intersections) that are in close proximity to signalized intersections are often violated by drivers while "speeding up" to go through the upstream or downstream signalized intersection that have the green interval upon approach. It is thought that if the distance between the upstream or downstream signalized and the AWSC intersection is long, drivers usually comply with STOP signs at AWSC intersections. This research determined driver compliance rates (CRs) at All-Way STOP Control (AWSC) intersections that are in close proximity to upstream or downstream signalized intersections and, explored the existence of a relationship between CR and the distance between a pair of signalized and AWSC intersections. Thirty (30) isolated segments with combinations of signalized and AWSC intersections in the District of Columbia were selected for the study. Field data were obtained at each intersection in addition to observation of driver compliance with STOP signs at AWSC intersections via video playback. In all, 13,956 observations were made at 57 AWSC intersections in 2017. The study showed that lower CRs were observed at AWSC intersections that are in closer proximity to the signalized intersections. Thus, the shorter the distance from the existing AWSC to signalized intersections, the lower the CR (or higher violation rate). Based on the data obtained, a non-linear relationship between CR and distance between pairs of intersections was developed. From the model, to achieve a minimum STOP sign compliance rate of 95% at an AWSC, an optimal distance of approximately 1,300 feet between intersections is required.

Authors	Raed Alsalhi, University of New South Wales Vinayak Dixit, University of New South Wales Vikash Gayah, Pennsylvania State University
Sponsoring Committee	Standing Committee on Traffic Flow Theory and Characteristics (AHB45)
Session Number	1656
Session Title	Traffic Flow Theory and Characteristics, Part 1
Paper Number	19-00183
Paper Title	On the existence of network macroscopic safety diagrams to describe traffic conflicts
Abstract	Recent studies have proposed using well-defined relationships between network productivity and accumulation—otherwise known as Network or Macroscopic Fundamental Diagrams (network MFDs)—to model the dynamics of large-scale urban traffic networks. Network MFDs have been used to develop a variety of network-wide traffic control policies to improve a network's operational efficiency. However, the relationship between a network's MFD and its safety performance has not been well explored. This study proposes the existence of a Macroscopic Safety Diagram (MSD), which relates safety performance (e.g., likelihood of a crash occurring or number of vehicle conflicts observed) with the current network state (i.e., average density) in an urban traffic network that is dynamically evolving. We theoretically posit a relationship between a network's MSD and its MFD based on the average maneuver envelop of vehicle's traveling within the network. Based on this model, we show that the density associated with maximum crash propensity is always expected to be larger than the density associated with maximum network productivity. This finding suggests that congested states are not only inefficient in urban networks, but they might also be more unsafe. These theoretical results are validated using surrogate safety assessment metrics in microsimulation and limited field empirical data from a small arterial network in Riyadh, the capital and largest city of the Kingdom of Saudi Arabia. The existence of such MSDs can be used to develop more comprehensive network-wide control policies that can ensure both safe and efficient network operations.

Authors	Xin Gu, Southeast University Mohamed Abdel-Aty, University of Central Florida Qiaojun Xiang, Southeast University Qing Cai, University of Central Florida Jinghui Yuan, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-00286
Paper Title	Analyzing Crash Risk at Interchange Merging Areas using Aerial Data
Abstract	The interchange merging area suffers from a high crash risk in the freeway system, which is greatly related to the intense mandatory merging maneuvers. Recently, the availability of unmanned aerial vehicles (UAV) provide an opportunity to collect individual vehicle's data to conduct traffic analysis at the microscopic level. Hence, this paper contributes to the literature by proposing a new framework to analyze crash risk at freeway interchange merging areas considering drivers' merging behavior. The analysis framework is conducted based on individual vehicle data from UAV videos. A multilevel random parameters logistic regression model is proposed to investigate each driver's merging behavior in the acceleration (auxiliary) lane. The model could identify the impact of different factors related to traffic and drivers on the merging behavior. Then, the crash risk between the merging vehicle and surrounding vehicles is calculated by incorporating the time-to-collision (TTC) and the output of the estimated merging behavior's model. The results suggest that the proposed method provides more valuable insights about the crash risk at interchange merging areas by simultaneously considering the merging behavior and the safety measure. It is concluded that the merging speed, driving ability (e.g., lane change confidence, lane-keeping instability), and the merging location can affect the crash risk. These results can help traffic engineers propose efficient countermeasures to enhance the safety of the interchange merging area. The results also have implications to the design of merging areas and the advent of connected vehicles' technology.

Authors	Lai Zheng, Harbin Institute of Technology Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-00425
Paper Title	A Comparison of Traffic Conflict Indicators for Crash Estimation Using Peak over Threshold Approach
Abstract	Traffic conflict techniques have drawn considerable research interest and a number of conflict indicators have been developed. Previous studies have qualitatively analyzed indicator differences from their definitions and empirically investigated their similarities based on identified traffic conflicts. This study compares conflict indicators from a validity perspective by comparing crashes estimated from conflict indicators to observed crashes. The peak over threshold (POT) approach is employed for crash estimation. Four commonly used indicators were compared: time to collision (TTC), modified time to collision (MTTC), post encroachment time (PET), and deceleration to avoid a crash (DRAC). Based on the conflict and crash data collected from three signalized intersections, POT models were developed for different thresholds in the appropriate ranges, and crash estimation methods were proposed for individual conflict indicators. The identified conflicts and estimated crashes associated with different indicators were then compared. The results show that traffic conflicts identified by the four indicators vary. For these indicators, MTTC outperforms other indicators and generates most accurate estimated crashes; the estimated crashes from TTC and PET are also reasonable but there is a tendency of overestimation for TTC and underestimation for PET. The estimated crashes of DRAC are all outside the confidence intervals of observed crashes, and its poor performance stems from the uncertainty of vehicle braking capacity.

Authors	Lai Zheng, Harbin Institute of Technology Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1366
Session Title	Gaining Insight into Highway Safety and Risk Through Improved Methods and Models
Paper Number	19-00438
Paper Title	Application of Extreme Value Theory for Before–After Road Safety Analysis
Abstract	Because of well-recognized quality and quantity problems associated with the historical crash data, traffic conflict techniques have been increasingly used in the before-after safety analysis in recent years. This study proposes to use extreme value theory (EVT) approach to conduct the traffic conflict-based before-after analysis. The capability of providing confident estimation of extreme events by the EVT approach drives the before-after analysis to shift from normal traffic conflicts to more serious conflicts, which are relatively rare but have more in common with actual crashes. The approach is applied to evaluate the safety effects of converting channelized right-turn lanes to smart channels, based on traffic conflicts defined by time to collision (TTC) collected from three treatment intersections and one control intersection in the city of Penticton, British Columbia. Odds ratios and treatment effects are calculated from extreme-serious conflicts, the frequencies of which are estimated from the Generalized Pareto distributions of traffic conflicts with TTC≤0.5s. The results show approximately 34% reduction in total extreme-serious conflicts (i.e., combining merging conflicts and rear-end conflicts), indicating overall a remarkable safety improvement following the smart channel treatment. This finding is consistent with the analysis result based on traffic conflicts with TTC≤3.0s. It is also found that the reduction in extreme-serious merging conflicts is small and insignificant. This is caused by the fact the TTC values of merging conflicts become smaller after the treatment, and it is possibly because drivers get more aggressive with the better view of approaching cross-street traffic provided by the smart channel.

Authors	Justice Appiah, Virginia Transportation Research Council F. Adam King, Virginia Department of Transportation Michael Fontaine, Virginia Transportation Research Council Benjamin H Cottrell, Jr., Virginia Transportation Research Council
Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	1628
Session Title	Traffic Control Devices 2019
Paper Number	19-00595
Paper Title	Left Turn Crash Risk Analysis: Development to a Microsimulation Modeling Approach
Abstract	The recent widespread application of the flashing yellow arrow (FYA) provides the opportunity to vary left-turn phasing mode by time of day. There is therefore a need for tools that predict how the risk for left-turn crashes might vary at a more disaggregated level (e.g. hourly) than that provided by existing crash prediction models, which typically predict annual totals of left-turn crashes, often based on average daily traffic volumes. The use of traffic simulation to analyze complex transportation issues has become common practice in transportation engineering. The further application of microsimulation to the analysis of traffic safety in a systematic, rigorous, and controlled fashion is becoming increasingly viable as simulation models improve and tools for quantifying surrogate safety measures become readily accessible. Using a calibrated VISSIM traffic microsimulation model and surrogate safety assessment model (SSAM) analysis, this paper examined how the risk for left-turn crashes varied as traffic conditions changed at a signalized intersection. Safety impacts for 750 unique combinations of intersection geometry, traffic, and signal timing parameters were simulated and the number of left-turn conflicts per hour noted. Results of the simulation analyses were used to develop statistical models that expressed the risk of occurrence of a left-turn crash during a given hour as a function of the left-turn phasing mode and prevailing conditions during that hour. Potential application of the model to the implementation of a time-variable safety-based left-turn phasing selection scheme using FYA was successfully demonstrated.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-00736
Paper Title	Evaluating the Rear-end Collision Risks of Mandatory Lane-Changing Behaviors Using Trajectory Data
Abstract	Mandatory lane-changing behaviors increase crash risks significantly. Particularly in a weaving section of highways, vehicles driving into and out the main lane have to search for acceptable gaps and perform lane-changing maneuvers, resulting in high risks of crash occurring. This study aimed to evaluate the rear-end collision risks of two type of mandatory lane-changing behaviors using trajectory data. The two type of lane-changing behaviors were first introduced. Then, a dataset from NGSIM project was used to extract trajectory data. A risk evaluation algorithm was developed based on a novel crash risk index (CRI) to collect lane-changing vehicles' trajectory and quantify rear-end collision risks. Statistics of the key variables were compared and two logistic regression models were developed and specified to investigate impacts of various factors. The Results indicate that for both driving into and out highway situations, the following vehicle on the target lane has significant impacts on collision risks. However, the front vehicle has more influence on crash risks when the subject vehicle drives into the main lane. The leading vehicle has remarkable effects when the subject vehicle exit off the highway. The speed differences between the subject lane-changing vehicle and surrounding vehicles are the dominating factor affecting the rear-end collision risks. Results of logistic regression models demonstrate the validation of the proposed risk evaluation algorithm. Findings of this study provide useful information for lateral control strategy designs of CAVs in the future.

Authors	Yanning Wei, Tongji University Keping Li, Tongji University Keshuang Tang, Tongji University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-00990
Paper Title	Trajectory-based Identification of Critical Instantaneous Decision Events at Mixed-Flow Signalized Intersections
Abstract	Mixed-flow intersections are prevailing in many developing countries such as China and India. At mixed-flow intersections, there is no clear lane discipline or regular trajectories within the intersection, especially for the non-motorized traffic. This leads to more interactions and encounters between the motorized traffic and the non-motorized traffic. Hence, critical instantaneous decision events, such as abrupt accelerating, decelerating, jerking, swerving, and swinging, may occur more frequently, resulting in traffic conflicts and crashes. This study presents a methodology based on the entropy theory and vehicle trajectory data to identify critical instantaneous decision events at the mixed-flow signalized intersections. A three-dimensional cube searching algorithm is firstly proposed to extract general events by examining the proximity between trajectories. A novel model incorporating Vehicle Kinematics and Permutation Entropy is then developed to identify critical events by quantifying driving volatility based on the time-serial trajectory data. Next, 1,205 vehicle trajectories and 384 bicycle trajectories with a resolution of 0.12 s are collected at a signalized intersection in Shanghai and used to demonstrate the proposed method. Results show that the proposed method is capable of identifying all the critical instantaneous decision events and tends to produce a higher identification ratio compared with the conventional method solely using kinematic thresholds. A sensitivity analysis is also conducted to investigate the effects of model parameters on the performance of the proposed model. This work could be applied for traffic safety assessment, real-time driving alert systems, and early diagnosis of risk-prone road users at mixed-flow intersections.

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Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	1628
Session Title	Traffic Control Devices 2019
Paper Number	19-01314
Paper Title	Evaluating Drivers' Stop-Line Violation Behavior at Signalized Intersections
Abstract	Stop lines are common at intersections; however, few studies have focused on the position of stopped vehicles with respect to the stop line. Often drivers will stop their vehicles over the line creating potential operational or safety problems. In this paper, data collected from local intersections in State College, Pennsylvania, indicated that only 61 percent of the vehicles observed were in compliance and 13 percent of the vehicles observed were committing severe violations. The data were analyzed to characterize driver behavior related to stop location during red phases. Driver stop line violations were influenced by many factors in this study. Lane usage (right turn only) was associated with high violation rates. Minor roads, when compared to major roads, were more likely to have more severe violations, while morning periods had more minor violations than other time periods. Through only lanes or increased distance from the stop line to the crosswalk or curb extension line promoted higher rates of compliance. Improving sight lines and maintaining sufficient sight distance and vehicle stopping distance could cut down on the problem. Increasing the distance from a stop line to a crosswalk or curb extension line an additional 10 feet might provide enough space for the majority of the vehicles stopping at an intersection from entering the crosswalk or intersection area.

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Sponsoring Committee	Section - Data and Information Systems (ABJ00) Standing Committee on Artificial Intelligence and Advanced Computing Applications (ABJ70)
Session Number	1143
Session Title	Advances in Machine Learning for Traffic and Crashes
Paper Number	19-01344
Paper Title	Prediction of Near-Crashes from Observed Vehicle Kinematics Using Machine Learning
Abstract	This study introduces a machine learning model for near-crash prediction from observed vehicle kinematics data. The main hypothesis is that vehicles tend to experience discernible turbulence in their kinematics shortly before involvement in near-crashes. To test this hypothesis, the SHRP2 NDS vehicle kinematics data (speed, longitudinal acceleration, lateral acceleration, yaw rate, and pedal position) are utilized. Several machine learning algorithms are trained and comparatively analyzed including K Nearest Neighbor (KNN), Random Forest, Support Vector Machine (SVM), Decision Trees, Gaussian Naïve Bayes (Gaussian NB), and Adaptive Boost (AdaBoost). Sensitivity analysis is performed to determine the optimal prediction horizon length (the time period before the occurrence of a near-crash) and the turbulence horizon length (the time period during which near-crash related changes in vehicle kinematics take place). The results indicate that optimal prediction performance can be achieved at one-second prediction horizons and three-second turbulence horizon. At these values, the AdaBoost model outperforms all other models in terms of its recall (100%), precision (98%), and F1-score (99%). These values imply that the near-crash prediction model is highly efficient in predicting most instances of near-crashes with minimal false near-crash predictions. This promising prediction performance offers a viable tool for supporting crash avoidance systems in the emerging connected/autonomous vehicle technology.

Authors	Yongfeng Ma, Southeast University Hongcheng Meng, Southeast University Shuyan Chen, Southeast University Jiguang Zhao, HNTB Corporation Shen Li, Yan'an Transportation Bureau
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-01569
Paper Title	Crash Risk Prediction Model for Expressway Diverging Areas Based on Traffic Conflict Technique and Microscopic Simulation
Abstract	This paper investigated the influential factors for traffic crashes in the expressway diverging areas based on traffic conflict technique and microscopic simulation. The hourly conflict risk index (HCRI) was defined to establish a crash rish prediction model for the expressway diverging area. The unmanned aerial vehicle (UAV) was used to collect interchange data, and observers were trained to identify conflict severity, and Tracker 5.0 was used to calculate the time to collision (TTC) for rear-end and lane-change collision, respectively. Based on the value of direct economic losses, the traffic risk index for traffic conflict of different types and severities is established, and the severity of traffic conflict was characterized by HCRI. The number of traffic conflicts under different conditions was derived from VISSIM simulation data and imported into surrogate safety assessment model (SSAM). The multivariate linear regression model was adopted to analyze the relationship between HCRI and various influential factors. A comparison between hourly conflict ratio (HCR) model and HCRI model showed that the HCRI model is better. Finally, it was found that the mainline traffic volume, the ramp traffic volume and the proportion of heavy vehicles are positively associated with HCRI, while the acceleration lane length is negatively associated with HCRI. The study results can be used to improve the safety performance of expressway diverging areas.

Authors	Jérémie Alagbe, Zhejiang University Sheng Jin, Zhejiang University
Sponsoring Committee	Standing Committee on Pedestrians (ANF10)
Session Number	1276
Session Title	Pedestrian Crossing Behavior and Safety
Paper Number	19-01767
Paper Title	Safety of Pedestrian Road-Crossing Behaviors With the Implication of Mobile Phone in a Mixed Bicycle-Pedestrian Platoon Situation at Signalized Crosswalks: Case Study of Hangzhou
Abstract	Research among drivers suggests that pedestrians using mobile phones may behave riskily while crossing the road, and casual observation suggests concerning levels of pedestrian mobile-use. In China, the risk may be greater with the frequent presence of cyclists on the crosswalks disputing the way with pedestrians. An observational video based survey of about 800 pedestrians was conducted to establish rates of mobile phone use, measure pedestrian crossing behavior, and compare the safety of crossing behaviors for pedestrians using, versus not using, a mobile phone. Among females and males, pedestrians who crossed while talking/listening or texting, on a mobile phone were less likely to display caution when initiating the crossing, to look at traffic while crossing, to avoid opposite pedestrians and bicycles, or to have eyes communication with right/left-turning vehicles and on-crosswalk bicycles, compared to those not using a mobile phone. Furthermore, female pedestrians who were texting reacted more slowly to the pedestrian green (PG) display. These effects suggest that talking or listening on a mobile phone is associated with cognitive or auditory distraction, and texting is associated with decreased situation awareness, and these might undermine pedestrian safety. Messages explicitly suggesting techniques for avoiding mobile-use while road crossing may benefit pedestrian safety: problem caused by technology can be solved by technology. Keywords: Pedestrians, mobile phones, bicycles, traffic safety

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Sponsoring Committee	Standing Committee on Vehicle-Highway Automation (AHB30)
Session Number	1384
Session Title	Algorithms and Models for Connected and Automated Vehicle Systems
Paper Number	19-01824
Paper Title	Centralized Cooperative Vehicle Optimal Trajectory Planning for Collision Avoidance and Merging in Weaving Sections under Connected Vehicle Environment
Abstract	Weaving sections is one of the most crucial highway facilities and traffic bottlenecks that may cause massive congestion and accidents. The traffic safety and efficiency is usually handled by a connected vehicle, which improves the traffic by effective communication and control. This study proposes a centralized cooperative vehicle longitudinal optimal trajectory planning method, which avoids collision, improves the traffic efficiency and reduces the fuel consumption and passenger discomfort. In addition, the proposed method harmonizes the vehicle speed and eliminates the stop-and-go phenomenon in weaving sections. Such a methodology operates based on the finite-horizon optimal control. The trajectory planning is formed by two parts, i.e. sideswipe collision avoidance and the merging. The planning of the on-ramp vehicle is comprised of two steps, that is, avoiding the collision and merging onto the main road. The cost function is represented by the acceleration and its first derivatives, corresponding to the fuel consumption and jerk. A sideswipe collision prediction algorithm considering the vehicle geometric features is proposed to predict the terminal time of collision avoidance and the Intelligent Driver Model is used to predict the terminal state of merging relying on the downstream traffic flow. The analytical solution is derived based on the Pontryagin Minimum Principle. We validate the effectiveness of the proposed model through the simulation, where the proposed method is compared with a baseline to demonstrate its potential in reducing the fuel consumption and travel time.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-01827
Paper Title	Safety Study at Partially Stop-Controlled Intersections using Surrogate Measures
Abstract	This paper reports the analysis of a large-scale video dataset aimed at better understanding the safety of stop signs and of the configuration of partially to fully stop-controlled intersections. Video data collected at 66~intersections is automatically processed to extract road user trajectories and two surrogate measures of safety (SMoS), time-to-collision (TTC) and post-encroachment time (PET), for every road user pair, for interactions between motorized vehicles and between a pedestrian and a motorized vehicle. Using a random effects model with random intercept and random slopes, each SMoS is studied against intersection configuration factors, land use factors, and microscopic exposure to vulnerable road users. The results show that stop control configuration has a significant correlation with TTC and PET, but that it depends on the type of road users and SMoS. The clearest relationship is for pairs of motorize vehicles where more stop signs and full stop control are associated with higher TTCs and, hypothetically, improved safety. As in past research, general practical recommendations are difficult to make. In particular, results are inconclusive for pedestrian safety, while this is the most frequently stated reason for installing stop signs. Research into more appropriate statistical models is warranted to improve the model fits, especially for the PET and pedestrian models.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-01980
Paper Title	The Role of Aggressive Driving and Speeding in Road Safety: Insights from SHRP2 Naturalistic Driving Study Data
Abstract	By harnessing the rich information available from naturalistic driving study data, this paper studies the impact of detailed driving behavior and recently developed measures of driving volatility on crash and near-crash risks. Building on previous efforts in developing of driving volatility measures, highly correlated measures with crash risk are identified and then driving behaviors contributing to driving volatilities and crash risk are explored. The paper incorporates driver, vehicle and infrastructure data collected in a naturalistic setting into the analysis along with studying the near-crash risks. In particular, both direct and indirect effects (through driving volatility) of aggressive driving and speeding on crash and near-crash risks are investigated through structural equation modeling (SEM). According to the results, aggressive driving is associated with increased risk of near-crash and crashes by 35% and 6% respectively. Speeding also was found to be correlated to increased chance of near-crash and crash events by 16% and 9% respectively. The findings are beneficial in two ways. First, they are helpful in identifying dangerous driving behaviors in order to reduce crash risk directly by avoiding them. Second, avoiding such behaviors will lead to reduced driving volatility which in turn, is effective in crash risk reduction.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-01981
Paper Title	Examining the Role of Speed and Driving Stability on Crash Severity Using SHRP2 Naturalistic Driving Study Data
Abstract	While the cost of crashes nears $1 Trillion a year in the U.S., the availability of high-resolution naturalistic driving data provides an opportunity for researchers to conduct in-depth analysis of crash contributing factors, and design appropriate interventions. The SHRP2 Naturalistic Driving Study (NDS) is a unique dataset that allows new insights due to detailed information on driver behavior in normal pre-crash and near crash situations, in addition to trip characteristics, and vehicle performance characteristics. NDS data are used to investigate not only the vehicle movements in space but also the speed and stability of vehicles prior to crash and their contribution to severity using path analysis. A subset of the data containing 617 crash events with around 180,000 temporal trajectory data are analyzed. To quantify driving stability, microscopic variations or volatility in vehicular movements before a crash is analyzed. Specifically, nine measures of pre-crash driving volatility are calculated and used to explain crash severity. While most of the measures are significantly correlated with severity, substantial positive correlations are observed for two measures representing speed and deceleration volatilities. Additionally, the average speed prior to a crash is highly correlated with severity outcomes, as expected. Interestingly, distracted and aggressive driving are highly correlated with driving volatility, and have substantial indirect effects on crash severity. With volatile driving serving as a leading indicator of crash severity, given the crashes analyzed in this study, early warnings and alerts for the subject vehicle driver and proximate vehicles can be helpful when volatile behavior is observed.

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Sponsoring Committee	Standing Committee on Vehicle User Characteristics (AND10)
Session Number	1311
Session Title	Human Factors Potpourri: Driver Health, Behavior, Technology, and the Environment
Paper Number	19-03061
Paper Title	Behaviors during Left Turn Across Path from the Opposite Direction Crashes and Near Crashes in Naturalistic Driving
Abstract	The turn-across-path from opposite-direction [LTAP-OD] crash type contributes to one of the major fatal crash types in young drivers. The study evaluates the crashes and near crash LTAP-OD crash scenarios from the Second Strategic Highway Research Program [SHRP-2] and driver responses for the through were evaluated. 111 such events were analyzed to extract driver braking behavior, secondary tasks, age, perception-response times. All measures of through driver variables were compared with respect to turning driver behavior. The study aimed to identify the trigger event for drivers to respond to the left turning vehicle. Perceived time to contact was a significant factor which affected driver response times. Drivers also responded significantly faster when subjected to shorter time to contact events compared to longer ones. Other short time to contact events where the turning vehicle did not stop before entering the intersection or when turning vehicle was visible for a short duration. Driver factors such as age, gender or secondary task engagement did not significantly influence response times.

Authors	Madhumita Paul, Indian Institute of Technology, Roorkee Indrajit Ghogh, Indian Institute of Technology, Roorkee
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-03075
Paper Title	Identification of Post Encroachment Time Threshold for Safety Assessment at Unsignalized Intersections Under Heterogeneous Traffic Conditions
Abstract	Traffic conflict based safety evaluation, utilizing Post Encroachment Time (PET) as a proximal indicator, has gained widespread attention for the last few decades. However, the development of an appropriate methodology for identifying a PET threshold to classify critical conflicts is still a grey area. The process of defining a safe PET threshold, below which conditions can be regarded as “near-crash”, becomes more complicated under heterogeneous traffic scenario where vehicles with diverse static and dynamic characteristics use the same traffic facility. Consequently, this study proposes a novel approach of PET threshold identification with a proof of application for carrying out the reliable and faster safety evaluation at unsignalized intersections under heterogeneous traffic conditions. Consequently, crossing conflicts and right turn related crashes (for the left-hand drive) are collected from six unsignalized intersections in the National Capital Region (NCR), India. Initially, relationships between crashes and conflicts are thoroughly studied for each PET threshold using the quantitative technique for all as well as individual conflicting vehicle categories. Later, a qualitative method is adopted by ranking the sites based on cumulative PET and subject crashes. A PET threshold of 1 sec is obtained from both techniques which can be used to identify critical conflicts for unsignalized intersections located on four-lane highways. The proposed methodology can be utilized as an alternative, faster and effective tool to identify the most hazardous unsignalized intersections and other traffic facilities in order to treat them on a priority basis and improve safety at such locations.

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Sponsoring Committee	Standing Committee on Bicycle Transportation (ANF20)
Session Number	1499
Session Title	Bicycle Transportation Research
Paper Number	19-03202
Paper Title	Is That Move Safe?: A Case Study of Cyclist Movements at Intersections with Cycling Discontinuities
Abstract	Cyclist safety deals with methods to analyse safety and case studies to better understand the factors that lead to cyclist crashes. Surrogate measures of safety (SMoS) are being used as a proactive approach to identify severe interactions that do not result in an accident and interpreting them for a safety diagnosis. While most cyclist studies adopting SMoS have evaluated interactions by counting the total number of severe events per location, only a few have focused on the interactions between general directions of movement e.g. through cyclists and right turning vehicles. However, road users perform maneuvers that are more varied at a high spatiotemporal resolution such as a range of sharp to wide turning movements. These maneuvers (motion patterns) have not been considered in past studies as a basis for analysis to identify, among a range of possible motion patterns in each direction of travel, which ones are safer and which are more likely to result in a crash. In this study, cyclist motion patterns are obtained from two cycling network discontinuity and two control sites in Montréal. A probabilistic SMoS method is adopted to obtain cyclist-vehicle interactions and compute their time-to-collision. The Kruskal-Wallis and Kolmogorov–Smirnov tests are used to compare the TTC distribution between motion patterns in each site and between sites with and without a discontinuity. Results show that interactions are more severe and less safe, at both locations with a cycling network discontinuity and that cyclists following different movements have statistically different levels of safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1161
Session Title	Applying New Data to Old Questions and Seeing Old Data in a New Light
Paper Number	19-03306
Paper Title	A Multi-Level Modeling Approach to Analyze Driver Speeding Behavior Considering Regional Heterogeneity Using Trajectory-Level SHRP2 Naturalistic Driving Data
Abstract	Driver-behavioral factors, specifically speeding behavior, which is a critical aspect of traffic safety, have received less attention in case of analyzing the impact of local characteristics on driver-behavioral choices that might increase the risk of crashes. In recent years, evolving data from the connected and automated vehicles as well as similar second-by-second trajectory level data from naturalistic driving studies worldwide, considering the impact of local characteristics on various driver behaviors is even more important. In fact, neglecting mentioned impact might lead to erroneous inferences due to the disparities in socioeconomic characteristics in different regions. Therefore, this paper, for the first time, utilized multilevel logistic regression modeling approach to evaluate the effect of driver's locality-related factors on driver speeding behavior using naturalistic driving data collected from the SHRP2 project in six US states. The methodology and the results from this study can pave the road for future human factor studies utilizing trajectory-level data from different geographical locations to reduce the heterogeneity and increase the transferability of the results without introducing a bias in inferences.

Authors	Andrew Tarko, Purdue University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1412
Session Title	Safety Data, Analysis, and Evaluation: Research in Four Acts
Paper Number	19-03682
Paper Title	Estimating Safety with Failure-Related Traffic Conflicts: An Example of Road Near Departures
Abstract	Surrogate measures of safety attract revived interest thanks to the advancements in traffic observations techniques and the growing need for rapid safety evaluation. This paper briefly introduces the latest method of analyzing traffic conflicts caused by some sort of failures to estimate the expected frequency of crashes. The Lomax distribution of drivers' response delays to failures is derived from the causality mechanism. The Lomax distribution belongs to the family of extreme value (exceedance version) distributions. The proposed method delivers a consistent and logical framework, intuitive interpretation of the results and conceptually sound and practical way of setting a proper threshold separation between conflicting road users to address the primary concern among traffic conflict experts and users. From this perspective, the proposed method is less restrictive and more appealing than the early proposed extreme value distributions. The fundamentals of the method are briefly explained and an example application to analyzing road departures in a driving simulator presented. The results confirm the expectations derived from the concept of the method. More implementations and further evaluation is needed to faithfully introduce the method to the safety engineering practice.

Authors	Nicolette Formosa, Loughborough University Mohammed Quddus, Loughborough University Stephen Ison, Loughborough University
Sponsoring Committee	Standing Committee on Artificial Intelligence and Advanced Computing Applications (ABJ70)
Session Number	1298
Session Title	Artificial Intelligence and Machine Learning Methods for Transportation Applications, Part 1
Paper Number	19-04003
Paper Title	Predicting Real-Time Traffic Conflicts Using Deep Learning
Abstract	Recently, technologies for real-time prediction of traffic conflicts have been gaining momentum due to their proactive nature of application and the growing implementation of ADAS systems and in-vehicle sensors. These traffic conflicts can be estimated by adopting machine learning classifiers which can make use of sensor data. However, the complexity in developing classifiers lies in the lack of calibration and integration of the sensor data to extract meaningful and accurate information in a timely manner. Additionally, a significant portion of the models used in previous work, are subject to unrealistic data requirements and cannot cater for a big imbalanced dataset with complex characteristics. To overcome these limitations, this paper presents a centralised architecture system for the data collected for a section of the UK M1 motorway and employs a Deep Learning methodology to predict traffic conflicts. The traffic conflicts on the road are identified by a Regional–Convolution Neural Network (R-CNN) model which detects lane markings and track vehicles from images captured by a single front-facing camera. This data is then integrated with other factors including traffic variables and estimated safety surrogate measures (SSMs) via a centralised architecture system to develop a Deep Neural Network (DNN) model to predict traffic conflicts. The results indicate that the DNN network can predict 68-77% and 78-83% of the traffic conflicts at the cost of 5% and 10% false alarm rate respectively.

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Sponsoring Committee	Standing Committee on Information Systems and Technology (ABJ50)
Session Number	1297
Session Title	Information Systems and Technology
Paper Number	19-04031
Paper Title	Automating Traffic Video Analysis for Intersection Safety Device Programs (ISD): Two Case Studies from Canadian Cities
Abstract	This paper demonstrates the application of automated video analysis for Intersection Safety Device (ISD) programs. Computer vision (CV) is a versatile tool for traffic analysis. With the ability of accurate speed measurements and tracking vehicle coordinates, red-light violations and speed enforcements are practically possible using CV. Video analysis is a non-invasive tool that can also be used to identify and analyze traffic components like phases of traffic lights, road geometry, and lane positions. Two studies using CV are presented in the paper. The first study considers automated video analysis as an evaluation tool for three deployed ISDs in the City of Edmonton, Alberta. The evaluation is performed by comparing the speed, and enforcement data from the ISD log files and the corresponding CV tracking output. The second study considers the automated video analysis as guidance for selecting potential locations for the deployment of ISDs. Red-light and Speed violation automated detection is applied to video data collected from two intersections in the City of Fredericton, New Brunswick. Validations against manual observations are also provided to demonstrate the accuracy of the CV technology based on three factors: 1) Capability for accurate measurement of crossing speed 2) Ability to detect all red-light violations 3) Ability to detect all speeding violations.

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Sponsoring Committee	Standing Committee on Pedestrians (ANF10)
Session Number	1276
Session Title	Pedestrian Crossing Behavior and Safety
Paper Number	19-04251
Paper Title	Pedestrian-Vehicle Conflict Analysis at Signalized Intersection With a Concurrent Pedestrian Phasing
Abstract	Pedestrian fatalities are of major concern to transportation engineers, planners, and the public. Worldwide, more than 270,000 pedestrians lose their lives on roads each year, accounting for 22% of the total 1.24 million road traffic deaths. Half of these fatalities are at intersections. The main objective of this study is to evaluate the severity of pedestrian-vehicle conflicts with different potential risk factors at signalized intersections with a concurrent pedestrian phase using a driving simulator. A full factorial experiment was designed to study these conflicts. The potential risk factors included time of day (night vs. day), vehicle movement (right turn vs. left turn), pedestrian movement (far side vs. near side), pedestrian visibility (dark color clothes vs. bright color clothes). Fifty-nine subjects were selected to participate in this driving simulator experiment. Based on the results, night time driving impacts the minimum distance, post-encroachment time, and the minimum time-to-collision. In comparison, vehicle movement and pedestrian movement only have effects on the minimum distance and the minimum time-to-collision. Moreover, it is also found that pedestrian visibility is a significant factor that affect the minimum distance and post-encroachment time.

Authors	Qingwen Xue, Tongji University Jian Lu, Tongji University Ke Wang, Tongji University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-04355
Paper Title	Rapid Driving Pattern Recognition Based on Rear-End Collision Risk
Abstract	Rear-end collision crashes is one of the most common accidents in road transportation. Rapid and accurate pattern recognition for rear-end collision risk is crucial to design useful driver assistance systems and vehicle control systems. The purpose of this study is to develop a rapid recognition method of driving patterns based on vehicle trajectory data from the Next Generation Simulation (NGSIM). First, three features, Inversed Time to Collision (ITTC), Time-Headway (THW) and Modified Margin to Collision (MMTC), are selected to evaluate the rear-end collision risk of individual vehicles. The histogram results of three features are used to find the threshold values of driving risk level. Then the vehicle trajectory segments separated by threshold values are clustered by K-means algorithm into three types: safe, moderate and risky driving pattern. Finally, Multi-Class Supporting Vector Machine (MCSVM) classifier is applied to recognize the driving patterns based on the labeled drivers. The vehicle trajectory features and collision risk features are respectively adopted to facilitate the driving pattern recognition. The “leave-one-out” method is used to validate the performance and effectiveness of the proposed method. The results show that the combination of ITTC, THW, and MMTC achieves 89.1% accuracy, the highest of all collision risk features, while the combination of vehicle trajectory features achieves 83.2% accuracy.

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Sponsoring Committee	Standing Committee on Pedestrians (ANF10)
Session Number	1708
Session Title	Advances in Pedestrian Safety Research
Paper Number	19-04399
Paper Title	Impact Speed and Probability of Pedestrian Fatality: A Systematic Review and Meta-Analysis
Abstract	Background: Pedestrians struck in motorised vehicle crashes constitute the largest group of traffic fatalities worldwide. Excessive speed is the primary contributory factor in such crashes. The relationship between impact speed and the risk of a pedestrian fatality has generated much debate concerning what should be a safe maximum speed limit for vehicles in high pedestrian active areas. Methods: Four electronic databases (MEDLINE, EMBASE, COMPENDEX, SCOPUS) were searched to identify relevant studies. Records were assessed, and data retrieved independently by two authors in adherence with the PRISMA statement. The included studies reported data on pedestrian fatalities from motorised vehicle crashes with known impact speed. Summary odds ratios (OR) were obtained using meta-regression models. Time trends and publication bias were assessed. Results: Fifty-five studies were identified for a full-text assessment, 27 met inclusion criteria, and 20 were included in a meta-analysis. The analyses found that when the impact speed increases by 1km/h, the odds of a pedestrian fatality increases on average by 11% (OR=1.11, 95%CI: 1.10-1.12). The risk of a fatality reaches 5% at an impact speed of 28km/h, 10% at 36km/h, 50% at 57km/h, 75% at 67km/h and 90% at 78km/h. Evidence of Publication bias and time trend bias among included studies were found. Conclusions: The results of the meta-analysis support setting speed limits of 30 to 40 km/h for high pedestrian active areas. These speed limits are commonly used by best practice countries that have the lowest road fataility rates and that practice a Safe System Approach to road safety.

Authors	Melrose Pan, University of Arizona Xiaofeng Li, University of Arizona Robert Kluger, University of Louisville Yao-Jan Wu, University of Arizona
Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	1628
Session Title	Traffic Control Devices 2019
Paper Number	19-04471
Paper Title	Red-Light Violation Identification Using GPS Trajectories
Abstract	Red-light violations often result in serious crashes. However, few monitoring systems are in place for system operators to monitor their occurrence. This paper successfully uses crowd-sourced GPS-based vehicle trajectories, combined with high-resolution traffic signal event-based data, to identify instances of red-light violations. Red light violations are defined based on the nature of the violation in relation to the signal phase. A detailed framework is proposed to combine temporal and spatial, GPS data and signal timing data and classify different movement behaviors through intersections as they relate to the red phase. The GPS data cleaning and processing procedures are presented in the context of the framework developed. With the proposed method, different patterns of RLVs are identified in a case study in Tucson, Arizona during the morning peak hours over December, 2017. The results were consistent with the body of knowledge and expectations associated with RLVs.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-04570
Paper Title	An Exploratory Investigation of Disengagements and Crashes in Autonomous Vehicles
Abstract	Autonomous Vehicles (AVs) have a large potential to improve traffic safety but also pose some critical challenges. While AVs may help reduce crashes caused by human error, they still may experience failures of technologies and sensing, as well as decision-making errors in a mixed traffic environment. The California Department of Motor Vehicles (DMV) mandated that manufacturers testing AVs make both disengagements and crash reports publicly available. An AV transitioning control from autonomous systems to the trained test driver is termed a disengagement. This study provides a first attempt to combine both crashes and disengagements and analyze them using a rigorous modeling approach. A nested logit model was calibrated using three different outcomes: (1) disengagement with a crash, (2) disengagement with no crash, and (3) no disengagement with a crash, to analyze the safety effects of AVs. The results show that factors related to other roadway participants are more likely to lead to a disengagement without a crash. Furthermore, AVs were observed to disengage less often as the technology matured over time. For this reason, crash proportions between more recent and older tests were compared, but no statistically significant change in crash proportions over the two periods was observed. The results thus suggest that disengagements are a part of AVs' safe performance and disengagement alerts may need to be triggered in order to avoid certain failures with current technology. Since this analysis examined early generation testing, the crash data needs to be revisited as the technology matures and more data becomes available.

Authors	Mehmet Baran Ulak, Florida State University Ayberk Kocatepe, Connetics Transportation Group Eren Ozguven, Florida A&M University Ashutosh Kumar, Connetics Transportation Group
Sponsoring Committee	Task Force on Transit Safety and Security (AP018T)
Session Number	1538
Session Title	Selected Topics in Bus Transit Safety
Paper Number	19-04583
Paper Title	Are There More Pedestrian-Involved Crashes Around Bus Stops? Development of a Safety Index
Abstract	The U.S. has been experiencing a significant increase in the car ownership per household over the last 10 years. With an increasing number of vehicles, safety becomes an even more critical issue due to existence of more cars on the roadways, particularly for pedestrians. Moreover, in Florida, people who use buses for transportation mostly walk to go to bus stops, which imposes more risks on people who use public transportation. Then, the question becomes: Is there a relationship between pedestrian crashes and bus stop locations? And what are the the reasons for this diminished safety for pedestrians around the bus stops? As such the purpose of this study is twofold: 1) to determine whether there is a significant spatial correlation between the bus stop locations and pedestrian crashes, and 2) to develop a quantitative safety index, namely bus stop severity index (SSI) that can help evaluating bus stops from safety perpective and to develop plans and policies accordingly. Analyses findings showed that that bus stop configuration along the network affects the spatial distribution of pedestrian crashes, which evidences the potential connection between bus stops and pedestrian crashes. Furthermore, SSI values of bus stops show that bus stops with high SSIs are clustered in some regions rather than being spatially dispersed. This clustered pattern indicates that the bus stop safety problem is not a ubiquitous issue, on the contrary, it is more of a localized problem that can be addressed by safety agencies and officials.

Authors	Dhwani Shah, University of Windsor Chris Lee, University of Windsor
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-04843
Paper Title	Assessing Rear-End Collision Risk During Driver's Evasive Action Using Vehicle Dynamics and Trajectories
Abstract	Surrogate safety measures (SSM) have been estimated to assess collision risk using individual vehicle trajectories. However, it is hard to determine whether the driver actually took evasive action or not, and when the driver took evasive action from the trajectories only. In this regard, vehicle dynamics data (e.g., accelerator/brake pedal use) can capture the presence and time of the driver's evasive action. Thus, the objectives of this study are to estimate SSM during driver's evasive action using both vehicle dynamics and trajectories, and to assess the effect of the type of lead vehicle (car or truck) on the car driver's behavior and rear-end collision risk based on SSM. In this study, 50 car drivers' behavior was observed using a driving simulator. The time periods of driver's evasive action (deceleration) were determined based on vehicle dynamics. Each driver tested two virtual traffic scenarios - Cars and Trucks scenario where surrounding vehicles were cars and trucks, respectively. It was found that the Deceleration Rate to Avoid Crash (DRAC) was generally higher for the Trucks scenario than the Cars scenario; however, the effects of trucks on DRAC varied across road sections with different driving conditions. The results also show that longer evasive action time reduced DRAC and DRAC was closely related to drivers' gender, age and driving experience at the road sections with complex driving conditions. These findings help better understand drivers' behavior to avoid collision in various driving conditions, driver characteristics associated with such behavior, and its effect on rear-end collision risk.

Authors	Anik Das, University of Wyoming Mohamed Ahmed, University of Wyoming Ali Ghasemzadeh, University of Wyoming
Sponsoring Committee	Standing Committee on Visibility (AND40)
Session Number	1634
Session Title	Visibility Issues 2019
Paper Number	19-04999
Paper Title	Association Rules Mining Approach for Investigating Driver Lane-keeping Ability in Fog Utilizing Trajectory-level SHRP2 Naturalistic Driving Data
Abstract	Foggy weather has been proven to adversely impact driver performance and behavior. Fog causes limited visibility that may obscure the driving environment and affects safety. One of the lateral driver behavior is lane-keeping ability that can be very crucial in run-off-road crashes under reduced visibility conditions. In order to examine driver behavior including lane-keeping ability, several data mining techniques have been adopted in previous studies. A promising data mining technique is association rules mining that has been adopted in this study to investigate driver lane-keeping ability in foggy weather conditions using trajectory-level SHRP2 Naturalistic Driving Study datasets. In total 124 trips in fog and 248 matching trips in clear weather conditions were considered to achieve the study objectives. The results revealed that affected visibility was a key component for having poor lane-keeping performance in several rules. It was also found that male drivers, a higher number of lanes, and the presence of curves have significant effects on a higher proportion of poor lane-keeping performance. Furthermore, drivers with more miles driven last year were found to better in maintaining lanes in general. The results from this study might provide guidance on selecting appropriate countermeasures in order to mitigate run-off-road crashes under foggy weather conditions.

Authors	Ting Fu, McGill University Weichao Hu, McGill University Nicolas Saunier, Ecole Polytechnique de Montreal Luis Fernando Miranda-Moreno, McGill University
Sponsoring Committee	Standing Committee on Pedestrians (ANF10)
Session Number	1708
Session Title	Advances in Pedestrian Safety Research
Paper Number	19-05276
Paper Title	Investigating Secondary Interactions: Are Drivers Paying Attention to Pedestrians When Exiting Non-Signalized Intersections?
Abstract	Most studies investigating pedestrian-vehicle interactions at non-signalized intersections have focused on interactions at the crosswalk on the same approach the vehicle is coming from, which are called primary interactions in this study. However, secondary interactions, defined as interactions between vehicles exiting the intersection and crossing pedestrians, have not been studied by themselves; these interactions can be dangerous due to driver's unclear knowledge of right-of-way, acceleration attempts to recover the speed, and the complex situation the driver faces in the intersection. This paper's goal is to highlight the safety issue of secondary pedestrian-vehicle interactions at non-signalized intersections. For that purpose, a case study involving ten all-way stop intersections from Montreal, Canada, was conducted by collecting video data. Different measures are used in the study: from the interaction analysis (behavior measures based on a Distance-Velocity model), average crossing speed analysis and vehicle approaching behaviour analysis (approaching speed and acceleration). Primary and secondary interactions are analyzed and compared. Results show that secondary interactions are more dangerous compared to primary interactions. Among the three secondary interaction types, secondary through interactions are the most dangerous.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	1162
Session Title	Surrogates, Conflicts, and Other Indirect Measures to Quantify Safety and Risk
Paper Number	19-05279
Paper Title	Online Aggressive Driving Identification Based on In-Vehicle Kinematic Parameters Under Naturalistic Driving Conditions
Abstract	Aggressive driving, amongst all driving behaviors, is largely responsible for leading to traffic accidents. With the objective to improve road safety, this paper develops an on-line approach for vehicle running state monitoring and aggressive driving identification, using kinematic parameters captured by the in-vehicle recorder under naturalistic driving conditions. To characterize the roads in reality, a novel road conceptual model is proposed. It accounts for not only the curve on the horizontal plane but also the slope on the vertical plane, as well as the cross slope. For each position where the vehicle is driving, the vehicle motion is decomposed into two circular motions on the horizontal and vertical planes. On each plane, the vehicle maneuver is first identified. Then, aggressive driving is identified according to the limit equilibrium of driving safety or comfortability. Based on the proposed method called “three-elements”, the vehicle maneuver, radius and slope angle on the vertical plane can be solved in an on-line manner. The novel approach is an elaborate analytical model with clear physical meaning but small computation load, and therefore is potential to be implemented in the mobile devices for real-time aggressive driving identification and labeling. The developed approach is applied to a real case on the curved and sloped route in Nanjing, China. Empirical results of extensive experiments, based on the kinematic parameters collected from the in-vehicle data recorder under naturalistic driving conditions, demonstrate that aggressive driving behaviors are mostly found on the pavements with curve and slope, and can be identified by the developed approach.

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Sponsoring Committee	Standing Committee on Roundabouts (ANB75)
Session Number	1604
Session Title	Advancing Aspects of Roundabout Design Through Research
Paper Number	19-05311
Paper Title	Evaluating Safety Performance of Roundabout Geometry Through Crash Risk Index
Abstract	In the geometric design of a roundabout, a safety performance-oriented design scheme is required, rather than a specification design that simply determines the dimensions of the geometric structural elements. In this study, a “risk index” is proposed as a safety performance evaluation measure of roundabout geometry. The risk index is estimated from the product of the “invisible probability” for the probability of an accident and the “crash impact” for the severity of an accident. From the evaluation of geometric design of roundabouts by using the risk index, it was clarified that a circulatory roadway width exceeding 6m and an entry corner radius exceeding 20m are inappropriate. Furthermore, from the evaluation of the existing roundabouts in Japan by using the risk index, problems in the geometric design, such as the absence of an apron step, were quantitatively extracted and the applicability of the risk index as a performance measure was demonstrated.

Authors	Kun-Feng Wu, National Chiao Tung University Muhammad Nashir Ardiansyah, National Chiao Tung University Hsin-Li Chang, National Chiao Tung University Paul P. Jovanis, Pennsylvania State University
Sponsoring Committee	Standing Committee on Simulation and Measurement of Vehicle and Operator Performance (AND30)
Session Number	1199
Session Title	Driver State and Crash Detection and Prediction
Paper Number	19-05427
Paper Title	Utilizing In-vehicle Data Recorder (IVDR) Data to Model Driver Crash Risk over Time While Driving
Abstract	The increasing availability and implementation of in-vehicle data recorder (IVDR) technologies have resulted in more and more safety applications based on the behavior of drivers during actual driving. However, to utilize IVDR data for these applications, it remains challenging to incorporate both aggregate and disaggregate data collected to model driver crash risk over time while driving, as well as how these effects would change over time, i.e. time-varying effects. The challenge is mainly due to the fact that crash risk is associated with the coevolution of many crash contributing factors. In response to these challenges, this study seeks to develop a flexible analysis structure model that can be applied to model the crash risks over time while driving. This research proposes a method which first formulates a homogeneous trip segment (HTS) and then applies a survival model to model how long it would take for a safety-related event to occur from the onset of a trip and whether the safety-related event would occur. This study utilized the data collected in the Road Departure Crash Warning System Field Operational Test conducted by University of Michigan Transportation Research Institute (UMTRI) to test the method proposed. The safety-related events employed in this study are traveling too fast on horizontal curves, which are measured by the triggers of a pre-specified curve-speeding warning (CSW). By applying the approach proposed, the results show speed, driving experience, roadway characteristics, and driving time are associated with increasing crash risk in terms of traveling too fast on horizontal curves.

8 Transportation Safety Management

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

Twenty-seven describing different aspects of transportation safety management will be presented at the 2019 TRB Annual Meeting, which are briefly discussed below.

Seven papers discuss safety management policies and frameworks, and will be presented in Session 1126 titled, *Safety Management Policies and Decision-Support Frameworks—Hybrid Session*. Lee et al. (19-00614) develop an integrated framework of modeling pedestrian exposure and fatalities at the planning level. Gross and Harmon (19-01977) develop an approach to objectively allocate funding between hotspot and systemic safety program, which represent high-cost and low-cost safety improvements respectively. Salem et al. (19-02366) describe the application of process modelling tools to document processes within a state transportation agency, including work responsibilities, quality assurance procedures, and workforce training requirements. Eteifa and Khattak (19-03744) employ a social network analysis approach to identify crash contributing factors based on 97,034 fatal crashes occurring from 2014 to 2016. Ralph et al. (19-03892) apply concepts from the field of media studies to offer opportunities to use more subjective language in media reporting of crashes to help raise awareness of the public health issue: road-related fatalities. Krishnappa et al. (19-05535) present the results of a study of more than 6 million safety inspection records to offer insights on tire tread inspection standards. Ecola et al. (19-06014) discuss a different perspective on the Road to Zero, combining elements of the Three-Horizon Foresight and Assumption-Based Planning methods to develop a participatory foresight-based scenario development process.

Two papers discuss the enhancement of **safety plans and partnerships**. Ecola et al. (19-06014), discussed above. Smith-Colin and Liu (19-02802) investigate one state's effort to develop a regional approach to safety plan development using regional safety coalitions, focusing on opportunities to improve the collaborative processes used to engage coalition members.

Five papers discuss **system planning and network screening**. Li and Wang (19-01591) test the performance of meso-level unit analysis (i.e., combined intersections and adjacent segments) and compared the results to traditional micro-level analysis (i.e., analyzing intersections and segments separately). Parvinashtiani and Smadi (19-03130) investigate the relationship between the United States Road Assessment Program (usRAP) star rating and crash experience, validating the star rating as a risk measure on rural, two-lane roads. Proulx and Sanders (19-03851) present an overview of the High Injury Network (HIN) concept and discuss various considerations and decisions that must be made in the development of a HIN, demonstrating how these decisions can impact the structure of the network. Rouhana et al. (19-05591) present an approach for identifying high-risk segments, considering existing crashes in the context of developing countries where poor crash-related data can be a major impediment to establishing an effective road safety program. Amer and Sayed (19-05425) present a new approach for identifying, diagnosing, and treating active transportation safety issues based on a spatial analysis of traffic analysis zones (TAZs), using data related to traffic exposure, socio-economics, land use, built environment, street network, and cyclist and pedestrian networks.

Eight papers explored the **safety effects of factors such as operations, environment, economics, vehicles, driver behavior, and demographics**. Lee et al. (19-00165) analyze the Korean In-Depth Accident Study (KIDAS) database to better understand the factors and interactions contributing to crash severity, focusing on opportunities related to in-vehicle safety measures and relevant policies. Choi et al. (19-00360) employ a novel approach to evaluate regional safety performance based on in-vehicle driving event data collected from an on-board device, supporting more effective decision making at the local level. Salmon et al. (19-01477) employ causal loop diagrams to identify and represent crash contributing factors, including impaired driving, distracted driving, fatigued driving, speeding, and seatbelt use. Hezaveh and Cherry (19-02874) apply a "home-based approach" to identify crash contributing factors based on police crash reports, census tract data, and socioeconomics. Islam and Pande (19-03455) analyze factors contributing to driver injury severity in single-vehicle roadway departure crashes on rural, horizontal curves. Strauss et al. (19-03576) estimate the road injury risk associated with home location based on the likelihood of car occupant, bus occupant, and pedestrian injury for individual intersections, road segments, and highways. Naqvi et al. (19-03653) quantify the effects of fuel price on crash frequency through changes and adjustments in travel behavior. Hagen (19-03775) employs a policy transfer framework to determine if street design contributed to the insignificant traffic safety impacts of area-wide traffic calming in New York City based on a comparison to London.

Three papers address **data collection, data integration, and data management**. Bigham and Oum (19-03601) evaluated changes in the reported injury severity for severe injury and fatal collisions in the California collision data over time, identifying the need to perform regular checks to ensure that fatal and severe injury collisions are properly reported. Kraus and Pollack (19-03622) summarize the results of two pilot projects by Washington State DOT and Missouri DOT that implemented the Roadway Data Extraction (RDE) Tool to extract and integrate roadway data from existing DOT and local transportation sources. Doggett et al. (19-05465) examine past studies that used data linkage to explore potential underreporting of pedestrian and/or bicyclist injury in police collision reports.

Two papers discuss **crash costs.** Hezaveh and Cherry (19-03258) propose a method to estimate the comprehensive crash cost at zonal level by using person injury cost unit. Harmon et al. (19-06067) examine crash cost practices across state DOTs, present national average crash costs, and provide methods to help agencies adjust and transform crash costs for analysis.

A single paper by Lou et al. (19-01234) discusses **project prioritization** related to maintenance activities. They develop an objective and comprehensive model to help prioritize road maintenance activities, incorporating road safety factors in the prioritization.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1126
Session Title	Safety Management Policies and Decision-Support Frameworks—Hybrid Session
Paper Number	19-00614
Paper Title	Transportation Safety Planning Approach for Pedestrians: An Integrated Framework of Modeling Walking Duration and Pedestrian Fatalities
Abstract	Multiple approaches have been proposed to take traffic safety into consideration in the long-term transportation plans, which is called transportation safety planning. Some early studies used trip generation data as the explanatory variables for their macro-level crash safety performance functions, or crash prediction models. Nevertheless, no study has attempted to integrate walking exposure and pedestrian safety at the modeling stage. Thus, a novel methodological framework for integrating the analyses of walking exposure and the pedestrian crashes is proposed toward the better transportation safety planning for pedestrians. In comparison with walking trips and walking miles, the walking hours was identified as the best walking exposure variable by a preliminary analysis. Thus, the integrated modeling structure with walking hours as an exposure were developed. The modeling results indicate that climate conditions, population, and car usage pattern affect walking hours, and predicted walking hours, climate condition, percentage of mid-elderly (64-75 years), proportions of minority race/ethnicity, and percent of tertiary industry occupations have significant effects on pedestrian fatalities. In addition, the integrated modeling framework is compared with the non-integrated ones, and the result indicates that the integrated framework outperforms its counterparts, in terms of deviance information criterion. The proposed approach and the findings from this study are expected to provide useful insights not only to researchers but also to policy-makers and practitioners in the fields of transportation planning and traffic safety.

Authors	Frank Gross, VHB Timothy Harmon, VHB
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1126
Session Title	Safety Management Policies and Decision-Support Frameworks—Hybrid Session
Paper Number	19-01977
Paper Title	Allocating Spending between Hotspot and Systemic Approaches to Safety Management
Abstract	There are more opportunities to improve safety across a highway network than funds available to implement projects. As such, safety program managers are challenged with selecting projects and allocating resources to maximize the program's return on investment. The hotspot and systemic approaches are two complementary approaches to safety management. A common question is how to allocate funding between these two approaches to achieve the maximum return on investment, considering the objectives and relative risks of each. This paper presents a framework to consider tradeoffs of allocating funding between hotspot and systemic projects as well as when to apply each approach. The framework is based on average project costs, average project effectiveness, and average crash costs. To demonstrate the framework, this paper presents average values based on six countermeasures that represent the hotspot approach and six countermeasures that represent the systemic approach. In general, this paper uses higher-cost and higher-effectiveness projects to represent the hotspot approach and lower-cost and lower-effectiveness projects to represent the systemic approach. Based on the sample of countermeasures and data included in this paper, the average cost-effectiveness of systemic countermeasures is greater than the average cost-effectiveness of hotspot countermeasures. While systemic countermeasures tend to be more cost-effective than hotspot countermeasures on average, there is a need to balance these two approaches. The framework could also apply to other situations, such as allocating funding between other safety programs (e.g., roadway departure and intersection safety programs) or prioritizing among project alternatives within a program (e.g., roundabouts, signals, or signing).

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1126
Session Title	Safety Management Policies and Decision-Support Frameworks—Hybrid Session
Paper Number	19-02366
Paper Title	Process Mapping of Safety Applications in Transportation Organizations
Abstract	The operational reality that dominates organizations can inhibit their ability to systematically and appropriately document recurring work processes. This is especially true for situations where the workflow transcends across multiple entities. Documenting these processes is instrumental in defining work responsibilities, incorporating quality assurance procedures, evaluating lead time, eliminating inefficiencies, and developing workforce training requirements. Over time, due to natural employment turnover, this problem becomes aggravated and efforts to reverse-engineer and document legacy processes becomes more challenging. This paper describes the application of applying process modelling tools to address such concerns within a state transportation agency. It is accomplished here through a set of maps—relationship, cross-functional, and flowchart maps—in the form of process mapping, as used in some industries. This specific case study was conducted to map a process used by Caltrans to identify high collision concentration locations (HCCLs) across the California. Mapping these processes was accomplished through several steps including questionnaire surveys, stakeholder interviews, and data assembly across multiple iteration. The outcome includes a documentation of the overall process to identify HCCLs as demonstrated in three different maps. Each map shows a level of detail of the process ranging from interactions between the various entities involved, to the actual workflow within each entity. In addition to the ability to determine the relationship between entities, the findings include facilitation for better communication about the roles and responsibilities, as well as opportunities to enhance, modify, and improve a priority safety programs to better meet the needs of an agency.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1126
Session Title	Safety Management Policies and Decision-Support Frameworks—Hybrid Session
Paper Number	19-03744
Paper Title	Understanding Factors Contributing to Rising Fatal Crashes: A Social Network Analysis Approach
Abstract	Fatal crashes are on the rise, costing many lives in the US and worldwide and inhibiting economic growth on a yearly basis. Every crash is a complex interaction between many contributing factors which need to be better understood in order to be effectively addressed. Researchers have developed theoretical models and implemented a variety of statistical techniques to better understand how crashes occur. This study proposes an analytical framework based on social network analysis to achieve a more holistic understanding of fatal crashes. The study adopts a three-step methodology which is to prepare the data, map social network terminology and metrics to transportation safety and analyze the network of contributing factors to fatal crashes. The methodology is applied to 97,034 fatal crashes occurring from 2014 to 2016. The framework successfully identifies the key contributing factors to fatal crashes as well as the relationships between them. It successfully visualizes the different contributing factors and how they combine with one another to contribute to different scenarios for fatal crashes. It also provides objective quantitative metrics which can help prioritize and assess the contribution of each factor to crash occurrence. The study shows that driver errors and violations of traffic laws are the most substantial contributing factors to fatal crashes and that elements like seatbelts and airbags continue to play a crucial role in minimizing the impact fatal crashes. This study can transform the current understanding of crash dynamics by providing an approach that focuses heavily on relations between different factors contributing to crashes.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1126
Session Title	Safety Management Policies and Decision-Support Frameworks—Hybrid Session
Paper Number	19-03892
Paper Title	Editorial Patterns in Bicyclist and Pedestrian Crash Reporting
Abstract	The World Health Organization characterizes traffic deaths as a "preventable health epidemic". Despite the scale of the problem, this issue has not led to a concerted call to action. Why not? The field of media studies offers potential insight. Not only does media coverage help determine which issues merit attention; coverage also shapes how issues get framed. The aim of this paper is to examine local news coverage of vehicle crashes involving someone walking or biking. To that end, this paper used content analysis of 200 local news articles to answer the research questions: 1) How do articles apportion blame between Vulnerable Road Users (VRUs) and drivers?; 2) To what extent do articles frame crashes as a public health issue? The results reveal that local news coverage tends to shift blame towards VRUs and away from drivers. Coverage almost always treats crashes as isolated incidents, obscuring the public health nature of the problem. This pattern of coverage likely contributes to the limited public outcry about pedestrian and bicyclist fatalities. Journalists can counteract these patterns by subtly altering their coverage. Planners can assist their efforts by making their expertise readily available to journalists. These simple changes would help the public identify links between seemingly isolated events and increase public pressure to reduce road deaths.

Authors	Vinod Krishnappa, Carnegie Mellon University H. Scott Matthews, Carnegie Mellon University Yi Liu, Carnegie Mellon University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1126
Session Title	Safety Management Policies and Decision-Support Frameworks—Hybrid Session
Paper Number	19-05535
Paper Title	Data-Driven Analysis to Support Revised Tire Tread Inspection Standards
Abstract	Despite a long-term focus on passenger vehicle safety, there are still 38,000 vehicle-related fatalities annually. Some are the result of failure to maintain safety components of vehicles, such as brakes, tires, or headlights. Following NHTSA guidelines, 18 states have implemented periodic safety inspection programs where certified inspectors assess components, and owners are required to repair or replace deficient components. For tires, when a tire's tread depth falls to 2/32 of an inch, its stopping distance on a road becomes very high. Thus, this tread depth level was built into the safety inspection thresholds for tires. A social challenge is that in an annual vehicle inspection, if a tire passes at a level of 3/32", it may fall below the safe (2/32") threshold soon after the inspection. In an era of higher vehicle miles traveled (VMT) and reduced attention to maintenance, perhaps the thresholds set for the safety inspections should be higher than the 'safe level' to provide a buffer. Using 6 million safety inspection records from Pennsylvania from 2006-16 we calculate tread depth deterioration and annual VMT at the vehicle level. We estimate the 'percent of vehicles at risk of having unsafe tires before the next inspection' (using the 2/32" threshold) to be about 30%. We also estimate how that percent of 'at risk vehicles' decreases as the inspection thresholds are raised, and find an attractive threshold at about 5/32" where the percent of at-risk vehicles would be very low. Such changes could further reduce fatal and non-fatal accidents.

Authors	Liisa Ecola, RAND Corporation Steven Popper, RAND Corporation Richard Silberglitt, RAND Corporation Laura Fraade-Blanar, University of Washington
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1126
Session Title	Safety Management Policies and Decision-Support Frameworks—Hybrid Session
Paper Number	19-06014
Paper Title	Road to Zero: Developing A Vision for a Future With Zero Roadway Fatalities
Abstract	Imagine that in 2050, not a single person in the United States dies in a traffic crash. To develop a rigorous framework about how this might be achieved, the authors developed a participatory foresight-based scenario development process, combining elements of the Three-Horizon Foresight and Assumption-Based Planning methods. This exercise brought together stakeholders from a variety of backgrounds to develop a shared vision of how roadway deaths could be reduced to zero. This vision was based on three approaches. The first is doubling down on programs and policies that have already been shown to be effective. The second is accelerating advanced technology, beginning with advanced driver assistance systems and progressing up to fully automated vehicles. The third is prioritizing safety, which includes both (1) embracing a new safety culture and (2) widespread adoption of the "Safe System" approach, a paradigm shift in addressing the causes and prevention of roadway deaths and injuries. Key stakeholders—including professional engineering and planning organizations, public-sector organizations, safety advocates, vehicle manufacturers, technology developers, public health, emergency medical and trauma care organizations, and law enforcement and judicial system representatives—can bring about the changes needed to achieve zero roadway deaths by 2050.

Authors	Seolyoung Lee, Hanyang University Eunbi Jeong, Korea Railroad Research Institute Cheol Oh, Hanyang University Gunwoo Lee, Chung-Ang University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-00165
Paper Title	Identification of the Factors Affecting Injury Severity using the Korean In-Depth Accident Study (KIDAS) Database and its Application
Abstract	Derivation of the contributing factors and understanding of the interactions among them are of keen interest in deriving effective countermeasures to enhance traffic safety. In-vehicle safety measures are expected to reduce the injury severity of occupants when a crash occurs. However, few efforts have been made in conducting an effectiveness analysis of such in-vehicle safety measures using an in-depth crash database that includes not only crash severity data but also on-the-scene crash information obtained from the accident reconstruction. This study analyzed crash severity using an ordered probit model to identify the contributing factors based on the Korean In-Death Accident Study (KIDAS) Database. In addition, the statistical relationship between the collision speeds and the crush extents were further analyzed. A method to evaluate the safety benefits that would be potentially obtained from the analyses conducted in this study was proposed, and an application was presented. This study should be useful in promoting the rapid propagation of in-vehicle safety measures and developing relevant policies.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-00360
Paper Title	Identification of Regional Safety Performance using In-Vehicle Hazardous Driving Event Data in Public Transportation Systems
Abstract	Assessing the safety performance of local jurisdictional areas is essential for the central government to support policy-making activities and efficient budget allocation. This study proposes a novel method to evaluate the regional safety performance in Korea based on in-vehicle hazardous driving event data collected from an on-board device, which is called a digital tachograph (DTG). Hazardous driving events in public transportation vehicles such as buses and taxies collected at the national-level were systematically analyzed and further applied to input features of a support vector machine (SVM) to identify the levels of safety performance by local jurisdictional areas. Then, the SVM model performance was evaluated using a cross validation method. The promising result of a classification accuracy of approximately 80% demonstrates that the proposed methodology is useful to facilitate effective decision-making by the central government to support the improvement of traffic safety for local jurisdictional governments in Korea.

Authors	Yuexin Lou, Tongji University Shengdi Chen, Shanghai Maritime University Hong Lang Jian Lu, Tongji University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-01234
Paper Title	A Study of Safety-oriented Evaluation Model for Road Maintenance in China
Abstract	In China, existing road maintenance standards and codes mainly focus on evaluating the conditions of the road usage to prolong the service life of the road, taking no account of road safety. Moreover, the safety evaluation system is imperfect, while the evaluation criterion and results are not intuitive and concise. In a view of deficiencies of the present evaluation system of road safety maintenance and management, this paper aims at providing a more objective and comprehensive evaluation model for road maintenance by taking road safety factors into account. Road intersection and section are chosen as evaluation objects according to road differences, and five major impact factors are incorporated in a four-level analytic hierarchy method, in order to derive a more objective and comprehensive evaluation system. Evaluation criteria are established for each indicator and their rationality is verified by Kendall's W method. An evaluation model is thus developed based on synthetical index method, and parameters are calibrated by principal component analysis and weight factor judgment table. Field data are collected from Wenchuan road, Hutai road, and S20 road in Shanghai. This model is further validated through field evaluations and expert scores, the correlation coefficient of 0.9353, 0.8609 and 0.8832 are obtained. In comparison with other models, the R2 indicates that the model yields better results with higher coefficient of determination. Then, four levels (A to D) were used to evaluate road maintenance safety performance, with A indicating the highest road safety and D indicating the lowest road safety, providing a scientific and accurate basis for road safety maintenance program.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-01477
Paper Title	Using Causal Loop Diagrams to Identify and Represent the Factors that Contribute to Road Trauma
Abstract	Research is beginning to show the merits of considering the broader road transport system when attempting to understand and prevent road trauma. As a result, questions have been raised regarding the knowledge base around crash causation and drivers' engagement in behaviors that are known to lead to road crashes. This study involved the use of causal loop diagrams to identify and represent the network of factors underpinning drivers' engagement in the behaviors that are known to lead to crashes and trauma: drink and drug driving, driving while distracted, driving while fatigued, speeding, and failure to wear a seatbelt. CLDs were developed initially by the research team and were subsequently reviewed and refined during a road safety subject matter expert workshop. The causal loop diagrams show that there are a range of interacting factors that influence drivers' engagement in the fatal five behaviors. Importantly the analyses reveal that there are a series of wider societal and public health issues that will continue to push adverse driver behaviors regardless of road safety interventions. These include alcohol and illegal and legal drug addiction, an increasing societal pressure to remain connected, time poor lifestyles and work pressures. It is concluded an integrated public health approach, incorporating better collaboration between public health and road safety stakeholders, is required. In particular, the findings indicate that road safety interventions should move beyond enforcement, education and engineering to encompass a broader focus on societal and public health issues.

Authors	Jia Li, Beijing University of Technology Xuesong Wang, Tongji University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-01591
Paper Title	Hotspot Identification of Urban Arterials at the Meso Level
Abstract	Urban arterials form the main structure of street networks. They typically have high traffic volume and high crash frequency. Hotspot identification (HSID) is the first step for traffic safety management process and often utilizes crash prediction models. The classical crash prediction models investigate the relationship between arterial characteristics and traffic safety at micro level, since they treat road segments and intersections as isolated units. This micro-level analysis has limitations when examining urban arterial crashes because: 1) signal spacing is typically short for urban arterials in dense street network, and there are interactions between intersections and road segments that classical models do not accommodate; 2) in practical engineering, a hotspot consists of several adjacent intersections and road segments instead of a single intersection or road segment. Taking these into account, a meso-level unit that combined signalized intersections and their adjacent road segments as a whole was adopted. To investigate the suitable research unit and method for urban arterial HSID, this study identified hazardous micro-level (intersections or road segments) and meso-level units at the same time using crash frequency, empirical Bayesian (EB), potential for safety improvement (PSI), and full Bayesian (FB) methods. Consistency was tested to evaluate the performance of the HSID methods. The results showed that 1) meso-level units performed better than micro-level units regardless of which HSID method was adopted; 2) EB and PSI performed better than the other methods no matter for which research unit; 3) there was a big difference between the identified hazardous micro- and meso-level units.

Authors	Janille Smith-Colin, Southern Methodist University Lanxi Liu, Southern Methodist University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-02802
Paper Title	Assessing Collaboration Processes and Performance Outcomes: An Analysis of Regional Safety Coalitions
Abstract	Development and implementation of a local road safety plan (LRSP) has recently been adopted as a proven safety countermeasure. Yet little knowledge exists about how to effectively engage safety-related partners in a process of collaboration and coordination that results in an implementable local road safety plan. This research investigated one state's effort to develop a regional approach to safety plan development using regional safety coalitions. Evaluating ongoing efforts to develop regional safety plans is useful because of the potential to identify risks and opportunities for the development of local road safety plans. An embedded case study of nine regional safety coalitions was used to highlight opportunities for improving the collaborative processes used to engage coalition members. A survey was developed and disseminated to coalition members to assess perceptions of the collaboration process, and to identify member perceptions of each coalition's performance. The results from this research contribute to a broader understanding of safety plan development models currently in use by highlighting a regional approach. Additionally, this research outlines a process for evaluating efforts at the regional scale that may be adapted and implemented by local partners in the development of a local road safety plan.

Authors	Amin Mohamadi Hezaveh, University of Tennessee, Knoxville Christopher Cherry, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-02874
Paper Title	Likelihood of Involvement in Traffic Crashes: Introducing Home-Based Approach
Abstract	It is well-known that the crash rate varies across countries, one may question that how does crash rate of individuals who lives in a certain geographic area vary within a country in a fine geographic level; to the best of authors' knowledge, no study has explored this issue. The predominant approach of road safety analysis attributes focuses on the location of traffic crashes, which makes measuring individuals' likelihood of involvement in traffic crashes (e.g., crash rate) challenging. In this study, we established Home-Based Approach (HBA) definition to complement the traditional definition of the road safety that focuses on the residential location, i.e., the expected number of crashes that road users who live in a certain geographic area have during a specified period. We use the addresses of the individual who had a direct role in traffic crashes to evaluate road safety at the zonal level. Census tract and police report crashes were used to extract the location of the traffic crashes and home-address of road users in Tennessee, and accompanying socioeconomics. Findings indicate that a mixed-effect negative binomial model was more suitable than a fixed-effect model for HBA crash frequency. Findings indicate that education, age cohorts between 16-42, and 43-60 years, share of motorized transport mode to work, portion of individuals with college-degree, and vehicles per capita have positive associations with HBA crash frequency. Instead, median household income and percent of White race have a negative association with HBA crash frequency. Findings are discussed in line with road safety countermeasures.

Authors	Niloo Parvinashtiani, Institute of Transportation Engineers Omar Smadi, Iowa State University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03130
Paper Title	An Investigation of Relationship Between the United States Road Assessment Program Star Rating and Crash Experience
Abstract	Over the recent decades, the International Road Assessment Program (iRAP) has been widely used as a systemic safety management tool. iRAP uses the risk-based non-crash measure of Road Protection Score (RPS) for assessing the level of safety of the roads on a 1 to 5 Star Rating scale. Given that few published studies exist in this area, one of the most significant current research needs is the validation of the relationship between the crashes and Star Ratings. Moreover, the previous validation studies have been mostly limited only to the descriptive comparison of crash rate and Star Rating averages and have failed to establish a comprehensive statistical relationship. In order to investigate such a relationship, this study develops a crash prediction model using a sample of two lane rural roads in North Carolina. The crash frequency was estimated as a function of Road Protection Score and Annual Average Daily Traffic using a negative binomial model. The results of this study showed that the crash frequency consistently increases with Road Protection Score. The developed safety performance function showed that moving from a 3-star road to a 2-star road would result in 47% more crashes. These findings confirm that Star Rating is a valid risk measure for crash frequency on two lane rural roads.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03258
Paper Title	Comprehensive Cost of Traffic Crashes at Zonal Level
Abstract	Global road safety records demonstrated the spatial variation of comprehensive cost of traffic crashes; to the best of our knowledge, no study has explored the variation of this matter at a fine geographical level. This study proposes a method to estimate the comprehensive crash cost at zonal level by using person injury cost unit. The current metric of road safety attributes safety to the location of the crash, which makes it challenging to assign the crash cost to the origin of the individuals who were involved in traffic crashes. To overcome this limitation, we introduced Home-Based Approach as the expected number of crashes by severity that road users who live in a certain geographic area have during a specified period. Home addresses of individuals who were involved in traffic crashes in Tennessee were assigned to their corresponding census tract. The average comprehensive crash cost per capita (CCCPC) at the census tract level was $11932. Poisson and Geographically Weighted Poisson Regression (GWPR) models were used to analyzing the data. The GWPR model was more appropriate compared to the global model to capture the spatial heterogeneity. Findings indicate population under 16-year-old and over 60-year-old, the proportion of residents that use non-motorized transportation, household income, population density, household size and metropolitan indicator have a negative association with CCCPC. Alternatively, VMT, vehicle per capita, percent educated over 25-year-old, the proportion of minority races and individuals who use a motorcycle have a positive association with CCCPC. Findings are discussed in line with road safety literature.

Authors	Mouyid Islam, University of South Florida Anurag Pande, California Polytechnic State University, San Luis Obispo
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03455
Paper Title	Analysis of Driver Injury Severity in Single-Vehicle Roadway Departure Crashes on Curved Rural Segments With a Mixed Logit Approach
Abstract	Roadway departure crashes are considered as a core emphasis area in Strategic Highway Safety Plan (SHSP) at state and national level because they account for considerable fatalities and serious injuries on the roadway system. The injury severity issue for these crashes is even more pronounced on the rural roadways. The focus of this study to identify and quantify the factors leading to single-vehicle roadway departure crashes on rural curved segments in Minnesota. The crash data is extracted from the Highway Safety Information System (HSIS) from 2010 to 2014. This study applies a mixed logit approach to model driver injury severity to account for possible unobserved heterogeneity in the data resulting from driver, roadway, traffic, and/or environment conditions. This analysis adds value to the existing literature since this approach is potentially applicable as part of a safety programming process implemented by agencies. The model results indicate that there is a complex interaction of driver characteristics and actions (gender, age, and unsafe speed), roadway and traffic characteristics (2-lane undivided road and traffic volume), environmental conditions (adverse weather, cloudy weather, lighting and surface condition), crash event (rollover), and vehicle characteristics (vehicle type – sport utility vehicle). A brief discussion on how this approach and results may help stakeholders encompassing the policymakers, safety professionals, and engineers in the safety planning process is provided. Keywords: Single-vehicle crashes; HSIS; Roadway Departure Crashes; Curved segment; Rural Highways; Injury severity; Mixed logit model.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03576
Paper Title	Risk of Road Injury According To Home Location: The Influence of Population Density, Car Use and Distance Travelled (Montreal, Canada)
Abstract	Population density is known to be associated with road safety but, within metropolitan areas, there is some confusion in previous studies which use population at the crash location instead of at the home location of the injured people. This study aims to estimate the road injury risk associated with home location in Montreal (Canada), using a representative survey of a typical weekday of travel. The likelihood of car occupant, bus occupant and pedestrian injury was estimated for each intersection, road segment and highway. Injury risk was then calculated for each trip, as a function of the specific route taken (e.g. intersections crossed) and summed for each individual to obtain an individual risk of injury over the day. The 107 municipalities of Montreal were classified into quintiles according to net population density. Regression models were developed to further explore the independent effect of density at home location and of individual travel behaviour. Considering all modes, the injury rate per capita is 2.5 times greater for people living in the least dense sector than for people living in the densest sector. The regression models show that higher household density near the home location is associated with a reduced risk of injury. However, including car use, distance travelled and number of intersections crossed greatly reduces the estimated effect of population density. The results clearly show an inverse relationship between population density at home location and the risk of road injury. Furthermore, the underlying mechanisms, car use and distance travelled, have been made explicit.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03601
Paper Title	Evaluation of Injury Severity Updates in California Collision Data
Abstract	Fatal or injury collisions in California must be reported to the California Highway Patrol (CHP) for inclusion in the Statewide Integrated Traffic Records System (SWITRS). After records have been entered into SWITRS they are made publicly available and are accessible through the CHP's report and data retrieval site called I-SWITRS. However, records accessed in SWITRS are considered provisional and can be updated several years after initial entry. This includes the injury severity level of collisions. If the collision data was accessed prior to an injury severity update, the agency retrieving the data may unknowingly be working with an outdated version. This can have an impact on government agencies use of data driven safety analyses to apply for safety improvement funding in order to achieve key safety goals in reducing fatal and serious injury collisions. This paper evaluated the frequency and level of injury severity changes for severe injury and fatal collisions that occurred in 2016 and which were retrieved at four different times between March 2017 and June 2018. In total, 94 injury collisions were upgraded to fatal collisions (2.653%) and 2 fatal collisions were downgraded to severe injury collisions (0.056%) out of the 3,543 total fatal collisions that occurred in 2016. The authors concluded that government agencies need to perform regular checks of their data to ensure that fatal and severe injury collisions are properly accounted for to maximize their ability to achieve safety performance targets.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03622
Paper Title	MIRE Safety Data Integration Using Roadway Data Extraction Tool
Abstract	The Model Inventory of Roadway Elements (MIRE) is a guideline of roadway and traffic data elements developed and published by FHWA to help state and local transportation agencies with the development of a comprehensive roadway data inventory useful for safety data analysis. Beginning with MIRE 1.0, FHWA developed a subset of MIRE data elements called the fundamental data elements (MIRE FDEs) as required by MAP-21 and the FAST Act. States are required to have access to the MIRE FDEs on all public roads by September 30, 2026. This paper summarizes the results of two pilot implementation projects at the Washington State DOT and the Missouri DOT conducted by the FHWA Roadway Data Extraction Technical Assistance Program (RDETAP). The focus of the projects was the implementation of a Roadway Data Extraction (RDE) Tool to extract and integrate roadway data from existing DOT and local transportation sources. Both pilot implementation projects resulted in an improvement of each DOT's roadway dataset towards expansion of current roadway inventory databases and improving compliance with the federal FDE requirement. The paper documents how the RDE Tool was adapted to meet the needs of the agencies participating in the pilots, and summarizes several lessons learned that will be of interest to transportation agencies involved with improving roadway data inventories through data extraction, sharing, and integration.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03653
Paper Title	Do Higher Fuel Prices Help Reduce Road Traffic Accidents?
Abstract	Road traffic accidents have decreased in most developed nations over the last decade. This has been attributed to improvement in vehicle and road design, medical technology as well as driver education and training. Recent evidence however indicates that fuel price changes have a significant impact on road traffic accidents through other mediating factors such as more fuel-efficient driving behaviours, less car travel through changing modes and speed reduction on high-speed roads. However, there is a lack of evidence to support the effects of changes in fuel prices on road traffic accidents in the UK which is the focus of this paper. For this purpose, weekly time series of fuel prices (between 2005-2015) have been used to study the effects on road traffic accidents using Prais-Winsten model of first order autoregressive (AR1) and the Box and Jenkins seasonal autoregressive integrated moving average models (SARIMA). This study is designed to quantify the effects of fuel price on road traffic accidents frequency through changes and adjustments in travel behaviour. The findings provide the evidence that the relationship between fuel prices and fatal road accident is negative, with every 1% increase in fuel price there is a 0.4% reduction in the fatal road traffic accidents frequency. However, with recent government plans to ban petrol and diesel vehicles by 2040, wiping away benefits from high fuel prices through reducing fatal accidents, to gain environmental benefits, transport policy makers need reviewing their policy to reduce road accident externality in the absence of road fuel prices.

Authors	Jonas Hagen, Columbia University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03775
Paper Title	Humps, Circles and Chicanes: Policy Transfer of 20-MPH Zones From London to New York City
Abstract	New York City's Neighborhood Slow Zones program, the first systematic area-wide traffic calming program in a major US city, was inspired by London's Slow Zones. However, while London's zones were associated with statistically significant reductions in traffic casualties, the zones in New York were not. In this paper, I use a policy transfer framework to determine if street design contributed to the insignificant traffic safety impacts of area-wide traffic calming in New York. I use both quantitative and qualitative data on the traffic calming devices implemented in 20-mph zones in both cities. While speed humps were the only device used to slow traffic in New York City, London's 20-mph zones used a much broader range of traffic calming devices. Further, the quantity of traffic calming devices was much higher in London. The large difference in the street designs used in 20-mph zones in each city suggests that New York's more skeletal version of area-wide traffic calming contributed to the disappointing results in that city. Barriers to a more complete transfer of street designs for 20-mph zones include the cost of, and public opposition to, more robust traffic calming measures, in addition to the emergence of other traffic safety priorities in New York. Despite the NSZ program's shortcomings, I argue that the program was a partial success.

Authors	Frank Proulx, Toole Design Group, LLC Rebecca Lauren Sanders, Arizona State University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-03851
Paper Title	High Injury Networks – Why, When, and How to Use Them: A Case Study
Abstract	Cities across the United States have adopted Vision Zero policies in recent years, commiting themselves to eliminating fatal and severe traffic injuries. One of the key aspects of most Vision Zero plans is a focus on data-driven solutions, and a common tool in these dicussions is the High Injury Network (HIN). The HIN is one way to identify the highest priority locations to focus action on. The primary strength of the HIN over other techniques is its relative simplicity – it provides a compelling narrative device for drawing attention to the urgency of traffic safety issues at particular locations. In this paper, we present an overview of the state of knowledge on the HIN concept. Following that overview, we discuss the various considerations and decisions that must be made in the development of a HIN through the case study of the Vision Zero Pedestrian HIN for the City of Oakland, CA. Various iterations of the HIN are shown to demonstrate how these decisions can impact the structure of the network. The paper concludes with some general recommendations on pursuing this line of analysis and ways that the results can be used in Vision Zero planning processes.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-05425
Paper Title	A Novel Approach for Identifying, Diagnosing and Treating Active Transportation Safety Issues
Abstract	There has been an increasing interest in active transportation due to its many health, environmental, and economical benefits. However, active commuters are subjected to an elevated level of severe crashes' risk, which can be a deterrent to many road users to shift to active transportation. Therefore, there is a need for developing systematic approaches to improve the safety of active commuters. This paper presents a new approach for identifying, diagnosing and remedying active transportation safety issues. The approach is demonstrated through a case study of City of Vancouver's 134 traffic analysis zones (TAZs). A comprehensive GIS data related to traffic exposure, socio-economics, land use, built environment, street network, and cyclist and pedestrian networks was used in the analysis. A multivariate full-Bayesian spatial mixed crash model (CM) was developed incorporating cyclist and pedestrian crashes as well as motorized and non-motorized traffic exposure measures. The CM was used to identify the top 10% active transportation crash-prone zones (CPZs) and safe zones (SZs) using the novel Mahalanobis Distance method. CPZs were found clustered in the downtown. Sixteen trigger variables were statistically investigated for each CPZ and SZ. Lastly, remedies, related to land use, traffic demand, and traffic supply management, were proposed using the trigger variable analysis and literature consultation.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-05465
Paper Title	Evaluating Research on Data Linkage to Assess Underreporting of Pedestrian and Bicyclist Injury in Police Crash Data
Abstract	Traffic safety decisions are based predominantly on information from police collision reports. However, a number of studies suggest that such reports tend to underrepresent bicycle and pedestrian collisions. Underreporting could lead to inaccurate evaluation of crash rates and may under- or overestimate the effects of road safety countermeasures. This review examined ten studies that used data linkage to explore potential underreporting of pedestrian and/or bicyclist injury in police collision reports. Due to variations in definitions of reporting level, periods of study, and study locations, it was difficult to directly compare the studies. Even among the six studies using the hospital link definition, estimates of reporting levels ranged from 44 to 75 percent for pedestrian crashes, and from 7 to 46 percent for bicycle crashes, suggesting a severe underreporting problem. However, few of the studies provided estimates of the error around their reporting level estimates, and as a result, it is difficult to determine the true level of underreporting. It may be that bicycle and pedestrian crashes appear in both police and hospital datasets but are less likely to be linked. Due to linkage error, link rate can only be used to estimate reporting level. Without the variance of that estimate, the effect of underreporting on traffic safety analyses cannot be accurately determined. Future studies should include estimates of the error present in their data linkage process for greater accuracy of the underreporting in police data. Datasets should be designed for easier linkage with hospital data and other datasets.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-05591
Paper Title	Geospatial Statistical Analysis of Road Traffic Accidents and Mortality
Abstract	According to the World Health Organization, global road fatalities remain at an alarming rate of 1.25 million fatalities per year besides 50 million injuries with 90% of these fatalities happening in developing countries. Hence, road safety has moved up to the top of priorities to be tackled. Identifying high-risk road segments is one of the indispensable steps in establishing any road safety program. Operational road infrastructure interventions can be implemented to address road safety problems. These interventions aim at reducing the probability of a crash. Particular interventions can almost abolish death and serious injury while others provide more limited improvements. In this paper, an approach is put forward for identifying high-risk road segments taking into consideration the existing road crashes records in the context of developing countries where poor crash-related data can be a major impediment in developing any pressing road safety program. The proposed approach is implemented in the country of Lebanon after identifying the most critical governorate in terms of road fatalities.The available road crashes data are analyzed through detecting accident hot spots using complex spatial analysis in Geographic Information System based on statistics by Moran's I for Spatial Autocorrelation, Getis-Ord Gi* for Hot Spot, Clusters and Outliers analysis, and High/Low Clustering analysis. The main objective of hot spots and risk evaluation of road network is to distinguish high-risk road segments and aid in identifying cost-effective mitigation measures that can be implemented to enhance the safety programs in abating the index of mortality due to road accidents.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	1438
Session Title	Transportation Safety Management from Start to Finish
Paper Number	19-06067
Paper Title	Crash Costs in Practice
Abstract	Crash costs represent a monetary estimate of the impacts of highway crashes. Crash costs are used in all stages of the project development process and allow analysts to monetize changes in highway safety performance. Analysts use crash costs in estimating the return on investment for projects that affect road user safety. To assure safety analyses are accurate, crash cost values should match the units, year, and region to which they are applied. States independently select, modify, and apply their own crash costs in safety analysis. Based on a questionnaire sent to Federal Highway Administration Division Offices, states use widely varied crash costs from three major sources and apply them in different ways. For example, crash cost values applied to fatal crashes in safety analysis varied from $190,200 to $10,100,000, which reflects different cost components, estimation methods, weighting, injury scales, analysis year, and units. The questionnaire also indicated that crash costs are not always applied correctly in analysis, likely stemming from a lack of documentation on the topic. This paper examines the crash cost practices across state Departments of Transportation and formalizes calculations to adjust and transform crash costs for analysis. The methods presented in this paper can help agencies improve analysis accuracy, completeness, and consistency when applying crash costs in the safety management process. Keywords: Crash Costs, Safety Management, Economic Analysis, Safety Benefit

9 Interacting Committees

Other twenty Committees, one Section, and one Task Force sponsored several papers which are within the scopes of ANB10, ANB20, and ANB25. Names and scopes of these Committees/ Sections/Task Forces are reported below.

ABE80, Native American Transportation Issues

The Committee is concerned with research and practice pertaining to transportation issues on or near tribal lands and communities or affecting tribal historical or cultural properties wherever located. Tribal transportation issues include all modes of moving people and goods from one place to another, all relevant agencies, including tribal, state, federal, regional and local providers, and all relationships and interactive processes of various governmental units -tribal, federal, state, and local - with regard to the development, planning, administration, coordination, and implementation of transportation laws, policies, plans, programs, and projects.

ABE90, Transportation in the Developing Countries

The committee will foster research, global communications and interaction, and avenues for transfer of intellectual technology on issues related to transportation in the developing countries. Emphasis will be on integrated planning and implementation strategies which consider the appropriate role for all modes: Public transport, MVs, NMVs and Pedestrians, and include the consideration of economic, environmental and social issues as well as the framework of administrative reform and management, private-public sector roles, environmental management, needs of the poor, and the need for appropriate mix of modes for urban and regional transport.

Section ABJ00, Data and Information Systems

The Data and Information Systems Section is part of the Policy and Organization Group. It consists of 11 committees and one task force that propose research, share research findings, sponsor special activities, and provide a forum for transportation professionals to discuss today's and tomorrow's data and information systems-related transportation issues. The chairs of each of these committees are members of the Data and Information Systems Section Executive Board, who along with the section chair, provide general oversight of the activities within the Section.

ABJ50, Information Systems and Technology

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

and standards in the transportation field; technology transfer among transportation organizations, vendors, and universities; and the impact of computer technologies on transportation organizations.

ABJ70, Artificial Intelligence and Advanced Computing Applications

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

AFB10, Geometric Design

This committee focuses on expanding knowledge regarding highway and street geometric design elements that affect safe and efficient operations for all users and contexts. The committee develops research needs statements and communicates findings that advance design criteria, guidance, methods, and performance-based roadway design objectives. The committee facilitates domestic and international dialogues and idea exchanges between researchers and practitioners while supporting emerging and developing professionals.

AHB30, Vehicle-Highway Automation

This committee is concerned with the development, application, and operation of driver assistance and automated control to the vehicle and highway system. The scope includes all forms and levels of control ranging from driver assistance systems operating on existing streets and highways to full vehicle control systems operating on freeway type and/or dedicated lane facilities. It further includes systems that support specialized highway related functions including maintenance, fleet operations, and similar applications. The emphasis is on control systems that will enhance user safety, system efficiency, and operational performance while providing for increased convenience and trip quality to the highway user. The objectives of the committee are to provide a focus and forum within the TRB for vehicle-highway automation and to promote a better understanding within the transportation profession of these systems including their research, deployment, and operation.

AHB45, Traffic Flow Theory and Characteristics

This committee is concerned with the development, validation, and dissemination of theoretical, experimental, and applied research on traffic flow theory and traffic flow characteristics and the determination of the relationship of traffic flow theory and traffic flow characteristics to the planning, design, and operation of transportation systems.

AHB50, Traffic Control Devices

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

AHB65, Operational Effects of Geometrics

This committee is concerned with geometric design as related to traffic operations and safety.

ANB45, Occupant Protection

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

ANB50, Alcohol, Other Drugs, and Transportation

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

ANB60, Safe Mobility of Older Persons

Ther Committee scope is to stimulate quality research and evaluation, provide a forum for interested researchers and practitioners to disseminate research and related information to those involved and interested in improving the safety and mobility of older drivers.

ANB70, Truck and Bus Safety

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

ANB75, Roundabouts

The Committee is concerned with all factors encompassing the planning, design and safe operation of modern roundabouts. Focus is on current issues, research dissemination and future research needs. We serve as a forum for discussions about roundabout research, projects, policy, and practices for all interested stakeholders. We identify research needs and prepare problem statements. We facilitate the exchange of research knowledge by various media, meetings, webinars and conferences.

AND10, Vehicle User Characteristics

This committee is concerned with the needs, capabilities, and limitations of vehicle users as these considerations affect the design, operation, and maintenance of personal, commercial and public transportation systems embracing highway and rail operations. The objectives of this committee are to maximize performance, safety, comfort, and efficiency of such systems.

AND30, Simulation and Measurement of Vehicle and Operator Performance

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

AND40, Visibility

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

ANF10, Pedestrians

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

ANF20, Bicycle Transportation

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

ANF30, Motorcycles and Mopeds

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

Task Force AP018T, Transit Safety and Security

This committee focuses on the research, methods, practices, data and technologies important to the topic of public transportation system safety and security as they affect all modes and phases of infrastructure development and service operation. Research efforts initiated through the Task Force foster the development and professional growth of practitioners and researchers in the field of transit safety management, application, and research.