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 97th 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 http://www.trb.org/ANB10/ANB10.aspx

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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/ http://www.trb.org/ANB20/ANB20.aspx

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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 http://www.trb.org/ANB25/ANB25.aspx

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George Yannis, National Technical University of Athens

Contents

1 Introduction

This report is mainly aimed at facilitating access to Committees ANB10-ANB20-ANB25 related presentations and events at the 97th 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, forty-five events sponsored by ANB10, ANB20, and ANB25 are planned:

- Four Committee meetings (see Table 1);
- Eighteen Subcommittee meetings (see Table 2);
- Eight workshops (see Table 3);
- Eight lectern sessions (see Table 4); and
- Seven 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;
b) Network Screening;
c) Safety Performance Functions;
d) Crash Severity Prediction;
e) Crash Modification Factors;
f) Surrogate Measures of Safety; and
g) Transportation Safety Management.

[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 1 (M2)
Thursday, 8:00AM – 12:00PM	Highway Safety Performance Committee, ANB25	Marriott Marquis, Liberty K (M4)

Table 2 ANB 10, ANB20, and ANB25 Subcommittee Meetings

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

Time	Title	Location
Wednesday, 6:15PM – 7:15PM	Highway Safety Performance Policy and Legal Aspects Subcommittee, ANB25(1)	Marriott Marquis, Ballroom Salon 16 (M2)
Wednesday, 6:15PM – 7:15PM	Highway Safety Performance Conferences and Meetings Subcommittee, ANB25(4)	Marriott Marquis, Ballroom Salon 15 (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	(116) Managing Speed on Low-Speed Urban Streets	CC, 204C
Sunday, 9:00AM - 12:00PM	(119) Implementation of Pavement Friction Management Programs	CC, 209A
Sunday, 9:00AM - 12:00PM	(135) Bicycle Safety Across the Pillars of the UN's Decade of Action for Road Safety	CC, 102A
Sunday, 9:00AM - 12:00PM	(136) Roadway Design and Operation: Using Human Factors to Guide Data-Driven Decision Making	CC, 103B
Sunday, 9:00AM - 5:00PM	(144F) Safety Reporting Data Versus Accident Data and How Best to Use Them for Prevention (HF-F Ticket Required)	
Sunday, 1:30AM - 4:30PM	(152) State and Local Safety Data Integration	CC, 154
Sunday, 1:30AM - 4:30PM	(179) Emergency Response: Saving Responders and Victims Together	CC, 103B
Wednesday, 9:00AM - 12:00PM	(881) Vision Zero Evaluation Workshop	CC, 102B

Table 4 ANB 10, ANB20, and ANB25 Lectern Sessions

Time	Title	Location
Monday, 8:00AM – 9:45AM	(226) Rural Road Safety Research: Practical Applications	CC, 102B
Monday, 8:00AM – 9:45AM	(227) Addressing Road Safety Worldwide: Thoughts on Vulnerable Road Users, Human Factors, and Road Safety for Low- and Middle-Income Countries	CC, 143C
Monday, 1:30PM – 3:15PM	(359) Lessons Learned in Safety Management: A Time to Reflect—Hybrid Session	CC, Salon B
Monday, 3:45PM – 5:30PM	(426) Doctoral Student Research in Transportation Safety—Hybrid Session	CC, Salon B
Tuesday, 8:00AM – 9:45AM	(495) Counterintuitive Results in Safety Performance Analysis	CC, 103A
Tuesday, 10:15AM – 12:00PM	(551) New Research on Improving Emergency Response Time	CC, 103A
Tuesday, 10:15AM – 12:00PM	(552) SHRP 2 Safety Data: Researchers' Perspectives and Some Analysis Results	CC, 102B
Tuesday, 1:30PM – 3:15PM	(618) Zero Traffic Deaths: How Close Can We Get? What Will It Cost?	CC, 102B

Table 5 ANB 10, ANB20, and ANB25 Poster Sessions

Time	Title	Location
Monday, 1:30PM – 3:15PM	(394) Advanced Analysis to Improve Nonmotorized Transportation Safety	CC, Hall E
Monday, 3:45PM – 5:30PM	(454) Transportation Safety Management: Start to Finish	CC, Hall E
Tuesday, 8:00AM – 9:45AM	(523) The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)	CC, Hall E
Tuesday, 10:15AM – 12:00PM	(574) Highway Safety Manual 2: A Sneak Preview	CC, Hall E
Tuesday, 10:15AM – 12:00PM	(575) Highway Safety Performance	CC, Hall E
Tuesday, 3:45PM – 5:30PM	(723) Case Studies of Performance-Based Analysis of Geometric Design	CC, Hall E
Wednesday, 10:15AM – 12:00PM	(834) The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 1, Session 523)	CC, Hall E

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 2018 Annual Meeting, there were almost 100 papers that fit in this major category, with several sub-categories into which these papers could be split.

Pedestrians, Bicyclists and Multimodal Safety. There were about 30 papers related to this subject in the Annual Meeting. Wang, Y. et al. (18-00738) developed a scoring tool for pedestrian and bicycle projects. Rodriguez, M. et al. (18-00123) identified factors in urban design affecting pedestrian fatalities. Cloutier, M. et al. (18-01288) assessed the relationships between reported collisions involving pedestrians and interaction rates. Mohamadi Hezaveh, A. et al. (18-01507) introduced a data mining approach for pedestrian crashes. Ferreira, S. et al. (18-02977) studied the effect of rainfall on pedestrian crashes. Essa, M. et al. (18-03468) analyzed the users' behavior on a pedestrian-bike shared space. Ghader, S. et al. (18-04583) Analyzed the Impact of Median Treatments on Bicyclist and Pedestrian Safety. Bhat, C. et al. (18-04741) studied the pedestrian injury levels. Mansfield, T. et al. (18-05093) and E. Aguilar et al. (18-05147) studied the effects of Roadway and environment characteristics on pedestrian safety. Jamali, A. and Yiyi Wang (18-05549) studied the pedestrian crashes injury severity in rural and small urban areas. They also developed a method to identify the pedestrian crashes hotspots (18-05575). Teketi, N. et al. (18-05552) and B. Dong, et al. (18-03480) studied the pedestrian crashes in mid-block. Prasanna Srirangam. L. and S. Pulugurtha (18-05593) modeled pedestrian crashes at intersections near light rail transit stations. Kitali, A. et al. (18-05742) studied the probability of aging pedestrian severe injury. Qi Xie, S. et al. (18-06535) used Bayesian approach to model pedestrian crashes at signalized intersections. Puscar, F. et al. (18-01751) used video analysis for the assessment of the bicycle, pedestrian, and motor vehicle traffic conflicts and violations. Haus, S. and H. Gabler (18-05351) studied the characteristics of vehicle–bicycle crashes and near crashes using naturalistic driving data. Stanislaw, H. (18-05774) studied the safety of interactions between motor vehicles and an instrumented bicycle. Shirani, N. et al. (18-03065) use count regression model to investigate the nonmotorized crashes. Vilaça, M. et al. (18-00382) use integrated spatial and temporal analysis to study severity of crashes involving vulnerable road users. Wan, D. et al. conduct spatial analysis of injury severity of bicyclist-involved crashes at highway segments (18-02980) and intersections (18-02988). Fu, T. et al. (18-05083) used a distance–velocity model and speed measures derived from video data to investigate cyclist–pedestrian interactions at bus stops and nonsignalized intersections. Osama, A. et al. (18-01280) and W. Chengp et al. (18-05685) resented different approaches to identify hot zones for active transportation-related crashes. Chengp, W. et al. (18-05889) also developed and evaluated multivariate space-time models with different temporal trends and spatiotemporal interactions. And finally K. Nordback et al. (18-06245) developed SPFs to predict bicyclist crashes for roadway segments.

Human Factors Affecting Safety. There were 10 papers related to this sub-category. Dong, C. et al. (18-01455) used Multivariate Dynamic Tobit models to assess the effectiveness of highway safety laws to reduce crashes. Pour Rouholamin, M. and G H. Zhou (18-00509) studied the effect of age on single-vehicle crashes on rural two-lane highways and injury severity. Alagbe, J. et al. (18-02720) studied the safety effect of the drivers' phone at red signal. Wail, B. et al. (18-00060) and Kamrani, M. et al. [(18-00980) and (18-00089)] studied the driving volitality with respect to different factors and its effect on crashes. Bakhit, P. et al. (18-01562) and T. Mathew and A. Charly (18-06666) used naturalistic driving data to study the effect of driver performance including distracted driving on crashes and near crashes. Shi, X. et al. (18-06270) used Classification and Regression Tree (CART) to classify the driving features and eXtreme Gradient Boosting (XGBoost) to analyse the data. And M. Razaur Shaon et al. (18-03131) studied the contributing factors related to driver errors on highway segments.

Crash Data Collection and Sources Including SHRP 2 Data. There were 10 papers/presentations related to this sub-category. Parvinashtiani, N. and O. Smadi (18-05919) used United States Road Assessment Program (usRAP) star rating method in conjunction to the SHRP 2 RID to evaluate safety. Yuan, J. et al. (18-00590) used bluetooth, weather, and adaptive signal control data to evaluate safety. Wang, L. et al. (18-00800) integrated the crash frequency and real-time safety studies using real-time data. Turochy, R. et al. (18-00866) analyzed work-zone crashes. Xie, X-F and Z. Wang (18-02283) integrated FARS, Maryland State's crash data with Montgomery County's traffic violation data to study crashes. Donaldson, B. (18-02753) improved Animal-Vehicle Collisions (AVCs) data that is severly underestimated to get a better understanding of these crashes. Hallmark, S. (P18-21120), Wu, L. et al. (18-01100), J. Wang and H. Zhou (18-01012), and R. Porter (P18-20919) used SHRP 2 data and would share their experiences on using these data to the TRB Annual Meeting attendees.

Calibration and Transferability of Crash Prediction Models. There were 9 papers related to this sub-category. Yannis, G. et al. (18-05057) developed a global road safety model for the United Nations Economic Committee for Europe. Wali, B. et al. (18-00065) calibrated the HSM models for Tennessee. Farid, A. et al. [(18-00109) and (18-00658)] studied the transferrability and calibration of the safety performance functions among multiple states. Rajabi, M. et al. (18-02091) assessed alternative definitions of calibration factor. Wan, D. and C. Kamga (18-02744) calibrated the safety performance functions for four-leg signalized intersections for New York City. Wang, X. et al. (18-02939) studied the transferability of urban arterial safety performance functions between Shanghai and Guangzhou in China. Tongji, J.L. et al. (18-04325) explored the transferability of cross-country safety performance functions for urban arterials with pooled data. And B. Claros et al. (18-04969) studied the differences between calibrating existing models vs. developing new crash prediction models.

Macro-level Safety Analysys and Identifying Safety Hotspots. There were 8 papers related to this sub-category. Mohammadianamiri, A. et al. (10-01655) used different techniques to

identify crash hotspots. Jung, S. et al. (18-022930) used demographics, socio-economic features, roadway conditions, traffic violations and road user driver behavior to stratify crash fatality prediction models for different areas. Shi, Q. et al. (18-02533) identified cerash hotspots on freeways. Lee, J. et al. (18-05114) used optimization techniques to identify crash hotspots. Wang, K. et al. (18-5210) evaluated different techniques for identifying crash hotspots. Zhang, W. et al. (18-04956) proposed a macro-level crash prediction method using "Big Data." Amoh-Gyimah, R. et al. (18-02234) applied random parameter macroscopic safety models for crash hot zone identification. And Q. Cai et al. (18-00618) explored the macrolevel effects for segment and intersection crash modeling.

Spatial Data and Safety Analysis. There were 6 papers related to this sub-category. Cai, Q. et al. (18-00144) integrated macro- and microlevel safety analyses using a bayesian approach incorporating spatial interaction. Gong, H. et al. (18-02062) studied the geographic distribution of crashes in Mississippi. Bao, J. et al. (18-01687) studied the effects of trip patterns on spatially aggregated crashes with large-scale taxi gps data. Wang, C. and J. Xia (18-00189) developed a new spatial unit for macroscopic safety evaluation based on traffic flow homogeneity. Alarifi, S. et al. (18-01739) explored the effect of different neighboring structures on spatial hierarchical joint crash frequency models. And J. Liu et al. (18-03009) used a geospatial modeling method to revisit hit-and-run crashes.

Speed and Safety and Secondary Crashes. There were 6 papers related to this sub-category. Yang, H. et al. (18-03029) developed a methodological framework based on probe vehicle data for detecting secondary crashes. Himes, S. et al. (18-01486) studied the effect of changing the posted speed limit from 65 to 70 mph on rural Virginia interstate system. Durdin, P. et al. (18-01591) studied the effect of speed on crashes on horizontal curves. Xu, C. et al. (18-02662) used Bayesian Random-Parameters Accelerated Failure Time model to predict the occurrence time of secondary crashes on freeway. Choudhary, P. et al. (18-02721) studied the impacts of speed variations on freeway crashes by severity and transportation mode. And K. Kwayu et al. (18-04815) evaluated the impact of raising speed limit on urban freeways using Mixed-Effects Negative Binomial Regression.

Emergency Medical Services. There were 4 papers related to this sub-category. Amorim, M. et al. (18-00049) analyzed vehicle dispatching rules. Lee, J. et al. (18-01821) analyzed fatal traffic crash reporting and reporting arrival time intervals of emergency medical services. He, Z. et al. (18-05425) used optimization to improve rural emergency medical services. And E. Tufuor et al. (18-05729) analyzed the land stability of the EMS in California.

Connected and Automated Vehicles Safety. There were 3 papers related to this sub-category. Yue, L. et al. (18-03482) assessed the safety benefits of connected and autonomous vehicle technologies. Khattak, A. et al. (18-00058) studied the driving volatility related to intersection safety in a connected-vehicles environment. And M. Espinosa Granados et al. (18-05956) used microsimulation to evaluate the impact of automated vehicles on safety performance of signalized intersections.

Summaries of the above papers/presentations are shown below:

Authors	Yashar Zeinali Farid, University of Wisconsin, Madison Yu Song, University of Wisconsin, Madison Andrea Bill, University of Wisconsin, Madison David Noyce, University of Wisconsin, Madison
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Lecturn Session 359
Session Title	Lessons Learned in Safety Management: A Time to Reflect—Hybrid Session
Paper Number	18-01241
Paper Title	Cost–Benefit Analysis of the Highway Safety Improvement Program Projects in Wisconsin Using Empirical Bayes Method
Abstract	The Highway Safety Improvement Program (HSIP) is a core Federal-aid program which aims to reduce traffic fatalities and serious injuries on all public roads in the United States. HSIP projects implemented in Wisconsin cross a wide spectrum of highway safety improvements and enhancements. The objective of this paper is to present aggregated Benefit-Cost analysis of the HSIP projects implemented between 2007 and 2012 in Wisconsin in order to help determine the best future HSIP projects. The Benefit-Cost ratios are computed based on Before-After and Empirical Bayes methods and the cost of each project is compared with actual benefits observed in terms of reduction in the number of target crashes in the after period. Results indicate that in general, the HSIP projects implemented in Wisconsin yielded an average Benefit-Cost ratio of greater than one. Rumble strips, convert-to-signalized intersection, and guardrail-end-update projects yielded the highest Benefit-Cost ratios while convert-to-interchange and visibility improvement projects resulted in low ratios.

Authors	Chunjiao Dong, University of Tennessee, Knoxville Shashi Nambisan, University of Alabama Chunfu Shao, Beijing Jiaotong University Jin Zeng, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Lecturn Session 359
Session Title	Lessons Learned in Safety Management: A Time to Reflect—Hybrid Session
Paper Number	18-01455
Paper Title	An Assessment of the Effectiveness of Highway Safety Laws to Reduce Crashes: Use of Multivariate Dynamic Tobit Models
Abstract	Highway safety laws aim to influence driver behavior so as to reduce the frequency and severity of crashes, and their outcomes. There are 11 types of highway safety laws in the United States. For one specific highway safety law, it would have different effects on the crashes across severities. Understanding such effects can help policy makers upgrade current laws and hence improve traffic safety. To investigate the effects of highway safety laws on crashes across severities, multivariate models are needed to account for the interdependency issues in crash counts across severities. Based on the characteristics of the dependent variables, multivariate dynamic Tobit (MVDT) models are proposed to analyze crash counts that are aggregated at the state level. Lagged observed dependent variables are incorporated into the MVDT model to account for potential temporal correlation issues in crash data. The state highway safety law related factors are used as explanatory variables and socio-demographic and traffic factors are used as control variables. Three models, a MVDT model with lagged observed dependent variables, a MVDT model with unobserved random variables, and a multivariate static Tobit (MVST) model are developed and compared. The results show that among the investigated models, the MVDT models with lagged observed dependent variables have the best goodness-of-fit. The findings indicate that, compared to the MVST, the MVDT models have better explanatory power and prediction accuracy. The MVDT model with lagged observed variables can better handle the stochasticity and dependency in the temporal evolution of the crash counts and the estimated values from the model are closer to the observed values. The results show that more lives could be saved if law enforcement agencies can make a sustained effort to educate the public about the importance of motorcyclists wearing helmets. Motor vehicle crash-related deaths, injuries, and property damages could be reduced if states enact laws for stricter text messaging rules, higher speeding fines, older licensing age, and stronger graduated licensing provisions. Injury and PDO crashes would be significantly reduced with stricter laws prohibiting the use of hand-held communication devices and higher fines for drunk driving.

Authors	Qing Cai, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida Helai Huang, Central South University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00144
Paper Title	Integrating Macro- and Microlevel Safety Analyses: A Bayesian Approach Incorporating Spatial Interaction
Abstract	Crash frequency analysis is a crucial tool to investigate transportation safety problems. Traditionally, crash frequency analyses have been undertaken at the macro- and micro-levels, independently. If conducted in the same study area, the macro- and micro-level crash analyses should investigate the same crashes but by aggregating the crashes at different levels. Hence, the crash counts at the two levels should be correlated and integrating macro- and micro-level crash frequency analyses in one modeling structure might have the ability to better explain crash occurrence by realizing the effects of both macro- and micro-level factors. This study proposes a Bayesian integrated spatial crash frequency model, which links the crash counts of macro- and micro-levels based on the spatial interaction. In addition, the proposed model considers the spatial autocorrelation of different types of road entities (i.e., segments and intersections) at the micro-level with a joint structure. Two independent non-integrated models for macro- and micro-levels were also estimated separately and compared with the integrated model. The results indicated that the integrated model can provide better model performance for estimating macro- and micro-level crash counts, which validates the concept of integrating the models for the two levels. Also, the integrated model provides more valuable insights about the crash occurrence at the two levels by revealing both macro- and micro-level factors. It is expected that the proposed integrated model can help practitioners implement more reasonable transportation safety plans and more effective engineering treatments to proactively enhance safety.

Authors	Mahdi Pour Rouholamin, Grice Consulting Group, LLC Huaguo Zhou, Auburn University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00509
Paper Title	Single-Vehicle Crashes on Rural Two-Lane Highways and Injury Severity: Does the Age Matter?
Abstract	Single-vehicle crashes on rural two-lane highways impose a considerable risk to road users due to their higher severity outcome compared to other crashes on these facilities. Furthermore, considerable variation in the severity among various age groups (young, middle-aged, and older drivers) has been noticed, corroborating the need for analyzing age-classified data. Crash data from Alabama was compiled and classified based on the age group. For each age class, a generalized ordered logit model was developed to identify the effect of various variables on injury severity. This model can consider ordered nature of severity as well as provide flexibility in calculating the parameter estimates. Driver gender, seatbelt use, damage to the vehicle, driving on county roads, hitting a fixed object and animal, and speeding were found to be significant in all developed models. Intoxication is a significant factor that affects injury severity for young drivers. Time of day also significantly affects the injury severity for older drivers. Vehicle age and driving with invalid license were not found to affect injury severity for older drivers, while they affected the other age groups. It was shown that some factors have significant effect on the injury severity for all age groups while others have varying effect across different age groups. The results of this study highlight the importance of considering separate injury severity models for different age groups, specifically separating older drivers from others, as the difference among older drivers and others are substantial.

Authors	Yi Wang, Portland State University Christopher Monsere, Portland State University Chen Chen, Oregon State University Haizhong Wang, Oregon State University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00738
Paper Title	Development of a Crash Risk Scoring Tool for Pedestrian and Bicycle Projects in Oregon
Abstract	Methods for identifying and prioritizing high-crash locations for safety improvements are generally crash-based. There are fewer reported crashes involving non-motorized users and in most states, reported crashes must involve a motor vehicle. This means that minor, non-injury events are not reported and those crashes that are reported, tend to be more severe. Selecting projects based only on crash performance is sometimes limiting for these crash types and predicting where these crashes will occur next is also a challenging task. An alternative to crash-based selection is to develop risk-based criteria and methods. This paper presents the results of a research effort to develop a risk-scoring method with weights derived from data for use in project screening and selection in Oregon. To develop the risk model, data were collected from 188 segments and 184 intersections randomly selected on both state and non-state roadways. Geometric, land use, volume, and crash data were collected from Google Earth, EPA's Smart Location Database and the ODOT crash database from 2009-2013. The sample included 213 bicycle and pedestrian crashes on the segments and 238 at intersections. Logistic regression models were developed and the outputs used to create pedestrian and bicycle risk-scoring tools for segments and intersections. The risk-scoring tool was applied to safety projects identified in the 2015 All Roads Transportation Safety (ARTS) project lists from Oregon. The risk scores for the case study applications aligned reasonably well with the project's benefit-costs estimates.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-01655
Paper Title	Hotspot Identification in an Urban Network: A Comparison Among Four Different Techniques
Abstract	Knowing where clusters of accidents occur would provide us great occasion to figure out the real causes of them and the processes occurring in these areas. However, it can be really difficult to realize and evaluate the real patterns latent in the crash database and identify the locations that require further consideration. Since now, several studies have been conducted on this issue; however, all principles and techniques used in this process are still not fully realized. In this regard and within this study, different types of hotspot identification methods consisted of Point Density Estimation (PDE), Kriging, Inverse Distance Weighted (IDW), and Spline have been developed and evaluated and subsequently compared using a particular index called Prediction Accuracy Index (PAI). Also, four categories of accident risk were defined to label different locations of the map as high, medium, low and no accident risk. The accident data for this research were collected from the database of police information technology center of Mashhad, Iran that includes 40,096 accidents recorded within 3 years (from March 21, 2012 to March 21, 2015). Results indicated that, based on the amount of PAI, IDW is the most accurate method followed by Spline, PDE, and Kriging. The present paper showed that although PAI is a useful index to find the accuracy of each method for hotspot detection, more considerations are required to be taken into account for the assessment of the efficiency of a method.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02062
Paper Title	Characteristics and Factor Analysis of Vehicle Crashes in Mississippi
Abstract	Traffic crash data from 2010 to 2014 were collected by Mississippi Department of Transportation (MDOT) and extracted for the study. Three tasks were conducted in this study: (1) geographic distribution of crashes; (2) descriptive statistics of crash data; and (3) probability analysis of crash factors. Geographic Information System (GIS) was applied to show the historical crash data statewide distribution, crash distributions on primary and secondary road segments in the public road system, and crash distribution in MDOT maintenance districts. The results show a similar distribution pattern in the three crash severities in Mississippi as in other states, i.e., property damage only counts the highest, injury the second, and fatality the lowest. It also shows that large numbers of the crashes happened on specific locations and there are high crash frequencies on highway segments in Jackson metropolitan area, Hattiesburg urban area, and Gulf coastal metropolitan area. Based on the historical data and geographic distribution results, three comparison scenarios were investigated in Scenario I between US 49 and MS 25, Scenario II for statewide urban and rural areas, and Scenario III for coastal urban and hinterland urban areas. Crash data descriptive statistics for the three scenarios were initially achieved in SAS and the characteristics of differing crash frequencies and severities with the three scenarios were calculated. In order to estimate the probability of each possible causing factor to the crash severity level, the Type III analysis of variance (ANOVA) approach was adopted to assess the significance level of each crash factor, and the multinomial logit model approach with maximum likelihood estimate was applied to conduct the probability analysis and evaluate the significance of each crash factor. The strategies that may potentially decrease the crash frequencies at crash severity levels were discussed based on the probability analysis results.

Authors	Soyoung Jung, Dongyang University Xiao Qin, University of Wisconsin, Milwaukee Cheol Oh, Hanyang University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02293
Paper Title	Stratified Crash Fatality Prediction Models for Developing Targeted Safety Strategies
Abstract	In South Korea, the Korea Transportation Safety Authority (KTSA) conducts the Special Traffic Safety Culture Investigation (STSCI) every year to assist local governments in promoting road safety. To address the issue of diversity, the local agencies were grouped into four regions by administrative district unit and offered region-specific safety promotion strategies. However, it is unclear if such a classification truly reflects the underlying differences that contribute to safety. The goal of this study is to identify the most relevant attributes that affect the safety performance of local agencies so that targeted safety promotion strategies can be recommended. To accomplish the goal, latent class cluster-based negative binomial regressions were applied for a comprehensive list of factors such as demographics, socio-economic features, roadway conditions, traffic violations and road user driver behavior; resulting in seven latent class clusters of local governments. The following indexes were found to significantly and strongly affect crash fatalities in the clusters: rate of wearing helmet, rate of pedestrian's signal compliance, the number of unlicensed driving violations, total paved road length, province, ratio of male to female, and population density. Further, stratified NB regression models were developed to identify statistically significant factors for predicting fatal crashes within each cluster. These cluster-specific features allow the KTSA to design targeted strategies for effective safety promotion

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02533
Paper Title	Hotspot Identification for Freeways Considering Difference in Single- and Multiple-Vehicle Crashes
Abstract	Previous studies found that the spatial distributions of Single-vehicle (SV) and Multi-vehicle (MV) crashes are quite different, but there has not been much research on hotspots identification considering differences in SV and MV crashes. This study identified hotspots of SV, MV and total crashes separately, using road design data, traffic operational data and crash data collected from a 45-km freeway segment in Shanghai. Full Bayes Poisson Lognormal regression models were developed for SV, MV and total crashes and the potential for safety improvement (PSI) was used to rank hotspots. Model estimation results showed that the significant influencing factors vary in different crash types. Hotspots identification results demonstrated that hotspots of SV crashes are quite different from MV crashes. For example, only three of the top ten hotspots were shared by both SV and MV crashes. Additionally, hotspots of total crashes have a higher consistency with MV crashes than with SV crashes, indicating that a majority of SV crash hotspots may be ignored if total crashes are used to identify hotspots. These conclusions prove the necessity to differentiate SV and MV crashes for hotspot identification and conducting road safety management.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02720
Paper Title	Drivers' Phone Use at Red Traffic Signals: A Comparison of Two Studies to Investigate Factors Influencing the Individual Behavior
Abstract	Driver distraction is a main cause of traffic accidents, where mobile phones are a key source of distraction. In two studies, we examined drivers' phone use behavior at red traffic signalized intersection. The first was a signalized intersection video recording observation based study. Data were collected at five different sites, each, during different traffic time, that was: weekday morning (WDM) for morning peak hour traffic and weekday afternoon (WDA) for light traffic period, and different days of the week, which were: weekday and weekend (WE), in Hangzhou, China, with the aim to investigate the existence of phone use among drivers at red traffic signals at different time, and to find out its potential influencing factors. Mixed logistic models were proposed for statistical analysis of phone use. The results revealed that, the phone use did not vary in terms of time of the day or the traffic volume, but there was an overall slight variation between weekday and weekend. Red signal duration, whether the red signal has count-down or not, vehicle place in the queue, driver's waiting time, whether driver was accompanied or not, vehicle type, driver's gender and age are all influencing factors for drivers' phone use. The second study, anonymously, had 151 driver participants answer online questionnaire with 27 questions which ask them about their personal intention phone use and driving, after entering their personal information and their personality, which answers provided us the certitude to confirm the results found in the first study.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-03482
Paper Title	Assessment of the Safety Benefits of Connected and Autonomous Vehicle Technologies
Abstract	The Connected and Autonomous Vehicle (CAV) technologies are believed to have a great effect on traffic operation and safety and expected to impact the future of our cities. However, few research have determined the exact safety benefit when all vehicles are equipped with major CAV technologies. This paper seeks to fill that gap, by using a general crash avoidance effectiveness framework for major CAV technologies to make a comprehensive crash reduction estimation. Fifteen major CAV technologies that were tested in the recent twenty-year research studies are summarized and sensitivity analysis is used for estimating their crash avoidance effectiveness. Results show that crash avoidance effectiveness of a CAV technology is significantly affected by the vehicle type and the safety estimation methodology. A 70% related crash avoidance rate seems to be the highest effectiveness for one CAV technology (or integrated CAV technologies) operating in practical environment (real driving conditions). Based on the 2005-2008 U.S. GES Crash Records, the paper estimates that the CAV technologies could lead to the reduction of light vehicles' crashes by at least 28.56% per year and for heavy trucks by at least 37.06%. The Rear-End crash type for light vehicles and the Lane Change crash type for heavy trucks have the most expected crash benefits.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05057
Paper Title	Developing a Global Road Safety Model
Abstract	Road accidents constitute a major social problem in modern societies, with road traffic injuries being estimated to be the eighth leading cause of death globally. The need for action based on evidence based policy making becomes more and more pronounced. In this context, this paper presents SafeFITS, a global road safety model, developed for the United Nations Economic Committee for Europe, which is based on global historical road safety data (72 indicators for 130 countries) and may serve as a road safety decision making tool for three types of policy analysis, i.e. intervention, benchmarking and forecasting analysis. A hierarchical conceptual framework of five layers of the road safety system is suggested (namely, economy and management, transport demand and exposure, road safety measures, road safety performance indicators, and road safety outcomes), and a dedicated database was developed with various road safety indicators for each layer. A two-step approach was opted for the purposes of the research, including the calculation of composite variables and then their introduction in a regression model, and the development of a model on the basis of short-term differences, accumulated to obtain medium- and long-term forecasts. The model developed has overall satisfactory performance and acceptable prediction errors, and preliminary validation provided encouraging results. Its usage might be proved highly useful for testing road safety policies, taking however into account the model limitations, mostly related to data availability and accuracy, and the recommendations for its optimal use.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05114
Paper Title	High Collision Concentration Location Identification Method Based on Optimization Technique
Abstract	High Collision Concentration Location (HCCL) identification approach based on the highest number of excessive collisions included within the limited covered length of hotspots has been proposed in this paper. A bi-criteria optimization model is created to maximize Potential for Safety Improvement (PSI) and to minimize the covered length by detected sites after considering the bias that can be introduced in the model due to the regression-to-the-mean phenomenon. The model is solved using Dynamic Programming-based Screening (DPS) techniques. The algorithm is computationally feasible to the size of historic collision data and applied to two freeways sites in San Francisco, California. The performance of the proposed model has also been compared with Sliding Moving Window (SMW) and Continuous Risk Profile (CRP) methods are compared to the DPS. Findings indicate that DPS can outperform both SMW and CRP in selecting sites with maximum PSI per unit distance.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05210
Paper Title	Evaluation of Hot-Spot Identification Methods for Municipal Roads
Abstract	Estimating crash prediction models and applying the Empirical Bayesian approach in identifying hot spots for roads under municipal jurisdiction is often challenging due to the lack of traffic count data. This study presents five hot spot identification (HSID) methods in which AADT information is not required (*i.e.* crash frequency (CF), equivalent property damage only (EPDO), relative severity index (RSI), excess predicted average crash frequency using method of moments (MOM) and cross sectional analysis (CSA)), to identify hot spots for road segments under municipal jurisdiction in Connecticut. The segments were categorized into eleven homogenous groups based on the roadway geometric characteristics. The five HSID methods were applied to all segments in each roadway group separately and across the entire State for a systemic analysis. Four quantitative tests (*i.e*. site consistency test (SCT), method consistency test (MCT), total rank difference test (TRDT) and total score test (TST)) were used to compare the performance of the five HSID methods. The results indicate that the MOM outperforms others in identifying hot spots for urban one-way arterials, urban one-way local roads, urban two-lane two-way local roads, urban multilane two-way arterials, and urban multilane two-way collectors; the CF outperforms others for rural arterials and collectors, rural local roads, urban one-way collectors, urban two-lane two-way arterials, urban two-lane two-way collectors and urban multilane two-way local roads, and the CSA performs best in all of the five HSID methods in identifying and ranking the roadway hot spots for all roadway groups together.

Authors	Niloo Parvinashtiani, Institute of Transportation Engineers (ITE) Omar Smadi, Iowa State University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Poster Session 454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05919
Paper Title	Comparing Objective and Subjective Roadway Data Collection Methods Using the U.S. Road Assessment Program
Abstract	The United States Road Assessment Program (usRAP) is a powerful tool for conducting Systemic Safety evaluations. The level of safety of the roads can be assessed through the usRAP Star Rating method, giving one star to least safe and five stars to safest roads. As part of the Star Rating data collection process, a comprehensive list of 40 road attributes are recorded for each 100-meter segment using Google StreetView and Aerial imagery. Several challenges are associated with usRAP data collection protocols and extensive quality assurance processes are required to ensure data quality. The sources of error are human error, inaccurate measurements/estimations, and the coder's subjectivity in the data collection. To examine the effects of these errors on Star Rating results, this study has leveraged the Second Strategic Highway Research Program (SHRP 2) Roadway Information Database (RID) to complement the existing dataset. The RID includes a variety of safety-related roadway attributes collected by a mobile data collection vendor and meets high accuracy requirements by implementing a quality assurance plan. Using benefit-cost analysis, this study aims to compare the objective data collection approach of utilizing a mobile data collection vendor with high quality assurance processes versus the subjective approach of coding data manually. Star Ratings are calculated for a sample of two lane rural roads in North Carolina using the RID and the manually coded dataset. The study results showed that the dataset with more accurate input data resulted in more valid Star Rating results and more detailed safety countermeasure suggestions from the Road Assessment Program tool.

Authors	Marco Amorim Sara Ferreira, University of Porto Antonio Couto, University of Porto
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Lecturn Session 551
Session Title	New Research on Improving Emergency Response Time
Paper Number	18-00049
Paper Title	Emergency Medical Service Response: Analyzing Vehicle Dispatching Rules
Abstract	In an era of information and advanced computing power, emergency medical services (EMS), still rely on rudimentary vehicles dispatching and reallocation rules. In many countries, road conditions such as traffic or road blocks, vehicles exact position, and demand prediction are valuable information which is not considered when locating and dispatching emergency vehicles. Within this context, this paper presents an investigation of different EMS vehicle dispatching rules by comparing them using different metrics and frameworks. An intelligent dispatching algorithm is proposed and survival metrics introduced to compare the new concepts with the classical ones. This work shows that the closest idle vehicle rule (classic dispatching rule) is far from optimal and even a random dispatching of vehicles can outperform it. The proposed intelligent algorithm has the best performance in all the tested situations where resources are adequate. If resources are scarce, especially during peaks in demand, dispatching delays will occur degrading the system's performance. In this case, no conclusion could be made to which rule might be the best option. Yet, it draws attention to the need for research focused in managing dispatch delays, by prioritizing the waiting calls that inflict the higher penalty to the system performance. Finally, the authors conclude that the use of real traffic information introduces huge gain to the EMS response performance.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Lecturn Session 551
Session Title	New Research on Improving Emergency Response Time
Paper Number	18-01821
Paper Title	Analysis of Fatal Traffic Crash Reporting and Reporting Arrival Time Intervals of Emergency Medical Services
Abstract	Emergency Medical Services (EMS) play a vital role in the post-crash effort to reduce fatalities by providing first-aid and transportation to medical facilities. This study aims to analyze the time required for crash reporting and EMS arrival in fatal traffic crashes and to identify relevant crash, roadway, environmental and zonal socio-economic factors. The time required for EMS reporting and arrivals were calculated by location type (urban or rural) and roadway functional classification using Florida data. Subsequently, a variety of duration models were estimated to reveal contributing factors for the crash-reporting and reporting-arrival intervals. Although about 90% of fatal crashes are reported to EMS within ten minutes in both urban and rural settings, EMS average reporting time in rural areas (4.5 min) is greater than in urban areas (3 min). Moreover, freeways require longer time for EMS arrival (8.3 min) compared to conventional roadways (6.8 min). It was shown that the log-logistic and gamma models perform the best for the crash-reporting and reporting-arrival intervals, respectively. The modeling results reveal that both EMS reporting and arrival times are related to the crash, roadway, environmental, and socio-economic factors. The key findings indicate that EMS reporting and arrival times differ significantly according to the urban/rural designation and road functional classification, and that they have statistically significant relationship with various factors. It is expected that the findings from this study can be used to develop effective and practical strategic plans to minimize EMS reporting and arrival time and, therefore, decrease the likelihood of fatalities.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Lecturn Session 551
Session Title	New Research on Improving Emergency Response Time
Paper Number	18-05425
Paper Title	A Service Location Optimization for Improving Rural Emergency Medical Services
Abstract	Approximately 40,000 fatalities transpire on U.S. highways each year with more than half occurring in rural areas. With such a high percentage of total fatalities, efficient Emergency Medical Services (EMS) becomes even more crucial in these rural areas. After an accident occurs, the time necessary for victims to receive care from EMS is critical to their survival. EMS provides pre-hospital health care for patients from the time of the 911 call to the arrival of the ambulance where the care is then transferred to a hospital. When comparing urban EMS to rural EMS, there are obvious challenges the latter must navigate to provide efficient medical care. Consequently, it's necessary to identify approaches to improve the EMS performance in rural areas. The goal of this paper is to evaluate and optimize rural EMS stations from a spatial perspective, while evaluating the spatial pattern between EMS stations and incidents and recommending the optimal locations of EMS stations. The data that was analyzed to accomplish these goals was from South Dakota, a rural state. This data was used to perform the spatial analysis and to build the location optimization model. A location optimization model, using a genetic algorithm in R software, was developed for rural EMS to increase the coverage ratio and service equity. This method serves as a tool for rural EMS officials to develop new stations or even relocate existing stations to improve service performance, which is essential given their limited resources.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	Lecturn Session 551
Session Title	New Research on Improving Emergency Response Time
Paper Number	18-05729
Paper Title	Land Suitability Analysis for EMS Posts Along State Highways: A Case Study of California
Abstract	The response time of Emergency Medical Services (EMS) to road accidents can be the difference between life and death. The California strategic highway safety plan highlight the need to improve the response time and recognizes that: 37% and 8% of the fatal crashes are 30 or more miles away from a trauma center in rural and urban areas respectively. The paper seeks to: (1) demonstrate the viability of using spatial multi-criteria analysis in road safety management, and (2) provide a good scientific justification in selecting optimal counties for EMS posts. The goal is to propose areas that are close to probable fatality points in order to achieve a maximum response time of 10 minutes (i.e., 3 minutes below the national average). This paper adopted a multi-criteria analysis using the weighted linear combination method on raster data of various impact factors. The land selection criteria were: (1) close to probable road fatality locations, (2) far from existing trauma centers, (3) close to existing rest stop areas, and (4) not on protected lands or bodies of water. The method proved viable and the analysis resulted in 37,387 square miles of suitable land areas. About 7% moderately suitable and 69% were unsuitable. The highway corridors linking the counties between Los Angeles and San Francisco were the most suitable locations. Other identified high suitable areas were predominantly rural counties such as Amador and Calaveras. A benefit-cost analysis is recommended in future studies to determine the suitability of specific sites within the identified counties.

Authors	Michael Rodriguez, Smart Growth America Samuel Sklar, Smart Growth America Heather Zaccaro, Smart Growth America
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-00123
Paper Title	Dangerous by Design, Statistically Speaking: Pedestrian Fatalities and Urban Design
Abstract	There were 46,149 pedestrian fatalities resulting from automobile-pedestrian crashes in the U.S. from 2005 to 2014. While the transportation literature has explored various factors related to fatal crashes, this analysis fills a gap with an emphasis on pedestrian fatalities. We constructed a dataset from the Fatality Analysis Reporting System (FARS), the EPA Smart Location Database, and the Census ACS to assess the factors that explain the incidence of pedestrian fatalities at the Census Block Group level. For our analysis, we examined the metropolitan Washington, D.C. region from 2005 to 2014. We ask: to what extent do measurements of urban design influence the prevalence of pedestrian fatalities? We identify infrastructure, demographic, and geographic variables to specify our models. We then conducted Poisson, zero-inflated Poisson (ZIP), negative binomial (NB), and zero-inflated negative binomial (ZINB) regressions to test the relationship, and find the NB model to be the most appropriate. We also test for sensitivities by including and excluding pedestrian fatalities on interstate and other highways. Our findings show that the density of auto-oriented roadways was associated with more pedestrian fatalities; while the density of pedestrian-oriented roadways was associated with fewer pedestrian fatalities. Residential density was also associated with fewer pedestrian fatalities. Third, we find that wealthier areas would expect fewer pedestrian fatalities, while areas with more people of color would expect more pedestrian fatalities. These findings support the conclusion that urban design – the type of roadway infrastructure provided - matters in the prevalence of pedestrian fatalities.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-01288
Paper Title	Bound to Happen? An Empirical Example of the Relationship Between Pedestrian Collisions and Interaction Rates at Intersections
Abstract	**Background:** Research on surrogate measures of safety suggests that traffic conflict or interaction indicators, are relevant to study collisions before they actually happen. Accordingly, several studies were able to predict collisions using safety performance functions that included traffic conflict measures as a predictor. However, simple empirical evidence of the relationship between conflict or interaction measures and actual collisions are limited, especially in the pedestrian collision literature. **Objective:** This paper provides an assessment of the relationships between reported collisions involving pedestrians (within a 5 and a 10-year period) and interaction rates based on field observation of street crossing behavior, at selected urban intersections (n=60). **Methods:** Data from a naturalistic observational study of pedestrian street crossing behavior was used to compute interaction rates (n= 4286 observations) at intersections with 25 or more observations. Collisions over a 10-year period (2003-2012, n=358 pedestrian collisions) were mapped and pooled at the same intersections to evaluate the relationship between the two. Descriptive analysis and Spearman correlation were performed. **Results**: We found a positive and significant relationship between collisions (all-years) and interaction rates (Spearman's coefficient between 0.329 and 0.340). This seems to be particularly the case on larger arterial roads. **Conclusions:** Our analysis shows that interaction rates as measured by observations at street intersections are significant correlates of actual pedestrian collisions, but correlation coefficient were small. This means that further development of conflict or interaction measures could potentially provide early information on the safety performance of intersection modifications without having actual pedestrians injured.

Authors	Amin Mohamadi Hezaveh, University of Tennessee, Knoxville Mojdeh Azad, University of Tennessee, Knoxville Christopher Cherry, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-01507
Paper Title	Pedestrian Crashes in Tennessee: A Data Mining Approach
Abstract	In Tennessee, annually about 1000 people die in traffic crashes; the crash statistics sources indicate a falling pattern in traffic fatalities over time. However, pedestrian crashes are increasing, and the number of pedestrians' fatalities increased from 80 in 2011 to 118 in 2015, mimicking national trends. Data from Tennessee Integrated Traffic Analysis Network (TITAN) were used to investigate traffic crashes between 2011 to 2015. Findings indicated that odds of death and injury for the pedestrians in a traffic crash were respectively 1 in 17 and 2.6; these odds for drivers were respectively 1 in 555 and 1 in 20. CHAID analysis was used in this study to investigate the relation between crash severity of the pedestrians, pedestrian characteristic (e.g., age, gender), road characteristic (e.g., intersection type, number of lanes), and other environmental factors (e.g., weather). Results of the CHAID analysis indicated that the most key factors that predict pedestrian crash severity were the post Speed limit, Light Condition, Pedestrian Age, area designated code, pedestrian under the influence, intersection type, road curvature, and relation to the road. Results were discussed in the context of the road safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-02977
Paper Title	How Does Rainfall Affect Pedestrian–Vehicle Crashes?
Abstract	The safety of walking activity has been a primary concern for researchers and authorities, who have developed numerous studies, particularly dedicated to the interaction between pedestrians and vehicles. Nonetheless, very few studies have focused on the impact of meteorological conditions on pedestrian-vehicle crashes. The present study aims to improve knowledge on this subject, considering mixed effects representing different phenomena associated to meteorological conditions. For this purpose, the city of Porto, Portugal, was selected as case study. First, a Poisson regression model was applied to evaluate the impact of precipitation on pedestrian-vehicle crashes, considering the daily precipitation, the lagged effects associated with the past-accumulated precipitation and the type of road. In a second model, an offset term named “all crashes” was added, allowing the evaluation of the relative risk of occurrence of pedestrian-vehicle crashes in comparison with all the other types of crashes for the same meteorological conditions. The results from both models support the following conclusions: (i) the number of pedestrian-vehicle crashes increase during rainfall, however the contribution of this type of crashes to the overall crash risk decreases; (ii) wet-monthly periods increase the pedestrian-vehicle crash risk, even when compared to the risk of all other crashes; (iii) 7-day periods of accumulated rainfall decrease the risk of pedestrian-vehicle crashes compared to all crashes; (iv) the road type affects differently the pedestrian-vehicle crash risk, maintaining the same trend when compared to all crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-02996
Paper Title	Identification of Factors Contributing to Pedestrian Crashes in Rural Illinois Using Multiple Correspondence Analysis
Abstract	During the five-year period, between 2010 and 2014, there were 24,178 pedestrian crashes in Illinois. Only about 4.39% of pedestrian crashes occurred in rural areas. However, approximately 40% of those crashes resulted in a severe injury or a fatality. Apparently, there exists a pedestrian safety problem in rural locales and the factors contributing to this problem need to be investigated. The primary goal of this study is to answer the question ‘Which variable categories, when acting together, contribute more to the occurrence of pedestrian crashes in rural areas?’ Crashes are random events stemming from the convergence of a variety of factors. However, traditional statistical tools can only make pairwise comparisons of dependent and independent variables. Therefore, it is necessary to apply an analytical tool that can identify complex underlying structures in crash data and spot associations among variable categories that contribute to crash occurrence. Multiple Correspondence Analysis (MCA) method, which is used in this study, can do just that. According to the obtained results, categories of the variables such as roadway functional class, the number of lanes, lighting condition, weather condition, traffic control device, driver condition, and pedestrian condition proved to contribute to pedestrian crashes in rural Illinois.

Authors	Mohamed Essa, University of British Columbia Mohamed Hussein Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-03468
Paper Title	Behavioral and Safety Analysis of Pedestrian–Bike Shared Space of Robson Street in Vancouver
Abstract	The main objective of this paper is to conduct a road-user behavior and safety analysis of the operation of the pedestrian-bike shared space of Robson Street in Vancouver. The analysis is conducted using video-data, collected by the City of Vancouver during the summer of 2016. Automated video analysis techniques were used to detect different road users and extract their trajectories from video scenes. Afterwards, the extracted trajectories were used to estimate the speed distributions of different categories of road users, and analyze the interactions (conflicts) between them in order to assess their safety. An investigation of the effect of introducing a bike-dismount sign at both ends of the shared space on both the percentage of cyclists' compliance with the sign and the frequency of pedestrian-bike interactions is provided. Finally, the relationship between the speed of both pedestrians and bikes and the density of the shared space were investigated in order to develop speed-density relationships in such a shared space environment. The results show that the percentage of bike dismounts increased from 17% to 36% after placing the sign. The traffic conflict analysis shows a reduction of 34% in the pedestrian-bike conflict rate after placing the sign, which indicates an improvement in safety. The average and standard deviations of the pedestrian and bike speeds were found to be (1.12 ± 0.05 m/s) and (2.95 ± 1.80 m/s), respectively. In addition, two models were developed to investigate the speed-density relationships of pedestrians and bikes. Both models showed good fit to the data, with R-squared values of 0.73 and 0.80, respectively. The results obtained in this paper can be useful in providing insights into understanding the operational and safety performance of pedestrian-bike shared space environments.

Authors	Sepehr Ghader, University of Maryland, College Park Arash Asadabadi, University of Maryland, College Park Mark Franz, University of Maryland, College Park Lei Zhang, University of Maryland, College Park
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-04583
Paper Title	Analyzing the Impact of Median Treatments on Bicyclist and Pedestrian Safety
Abstract	In response to a disproportionately high number of pedestrian and bicyclist crashes related to illegal mid-block crossings, Maryland Department of Transportation's State Highway Administration (SHA) implemented various median treatments and safety enhancement countermeasures at identified high-frequency bicyclist/pedestrian crash locations. While median treatments are generally perceived as effective and beneficial, this study seeks to quantify their impact. The research team collected required data and applied trend analysis and statistical analysis (Empirical Bayes methods) to assess the effectiveness of installed safety countermeasures. The trend analysis focused on the general crash trend for different types of crashes. Statistical modeling methods were employed to link bicycle and pedestrian crashes to median treatments and other influencing variables. The Empirical Bayes methods separated the effect of median treatments from the effects of other factors. To investigate public opinion of median treatments and pedestrian/bicycle safety, on-site pedestrian and bicyclist surveys were conducted at study locations. The surveys were supplemented with business and community interest group interviews. The results shed light on the socio-demographic factors that may influence attitudes toward the installed median treatments. Results of the trend analysis showed that treatment sites experienced lower or similar crash rates for all crash types after the treatment, while control sites experience higher crash rates during the same period. The statistical analysis showed a significant reduction in total crash rates and fatalities because of the treatments. Survey results showed that more than 50% of pedestrians and bicyclists are likely to cross roads mid-block, but median treatments are effective in discouraging it.

Authors	Chandra Bhat, University of Texas, Austin Sebastian Astroza, University of Texas, Austin Patricia Lavieri, University of Texas, Austin
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-04741
Paper Title	A Model for the Analysis of Pedestrian Injury Counts by Severity Level
Abstract	We propose in this paper a spatial random coefficients flexible multivariate count model to examine, at the spatial level of a census tract, the number of pedestrian injuries by injury severity level. Our model, unlike many other macro-level pedestrian injury studies in the literature, explicitly acknowledges that risk factors for different types of pedestrian injuries can be very different, as well as accounts for unobserved heterogeneity in the risk factor effects. We also recognize the multivariate nature of the injury counts by injury severity level within each census tract (as opposed to independently modeling the count of pedestrian injuries by severity level). The data for our analysis is drawn from a 2009 pedestrian crash database from the Manhattan region of New York City. Several groups of census tract-based risk factors are considered in the empirical analysis based on earlier research. The empirical analysis sheds light on both engineering as well as behavioral countermeasures to reduce the number of pedestrian-vehicle crashes by severity of these crashes.

Authors	Theodore Mansfield, Office of the Secretary of Transportation (OST) Dana Peck, Carnegie Mellon University Daniel Morgan, U.S. Department of Transportation Barbara Mccann, Office of the Secretary of Transportation (OST) Paul Teicher, Office of the Secretary of Transportation (OST)
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05093
Paper Title	Effects of Roadway and Built Environment Characteristics on Pedestrian Fatality Risk: A National Assessment at the Neighborhood Scale
Abstract	Characteristics of the transportation system and built environment contribute to pedestrian fatality risks, including vehicular traffic and land-use characteristics associated with higher pedestrian activity. We combined data from FHWA, NHTSA, EPA, and the Census Bureau and performed regression modeling to explore associations between transportation system and built environment characteristics and pedestrian fatalities at Census tract scale across the contiguous United States. In urban tracts, we found an especially strong association between traffic on non-access-controlled principal arterial roadways and pedestrian fatalities (0.27 additional annual pedestrian fatalities per 100,000 persons per 1,000 VMT/mi^2 increase in traffic density); traffic on other facility types have significant, but weaker, associations. We also found strong associations between employment density in transportation and warehousing, retail, and food and accommodation services sectors and pedestrian fatalities. In rural tracts, we found associations between traffic density on most facility types and employment density in retail and food and accommodation services sectors. Finally, we compared our model to the High Injury Network in Los Angeles, CA. Nearly half (45%) of observed fatalities were identified by both methods, while some fatalities were identified by only one (26% by our model and 18% by the High Injury Network). This work shows that traffic on certain roadway facility types and employment in certain sectors have especially strong associations with pedestrian fatality risk. More broadly, we illustrate how leveraging cross-disciplinary data in novel ways can support prospective, risk-based assessments of pedestrian fatality risks and support integrated and systemic approaches to transportation safety.

Authors	Edna Aguilar, George Washington University Samer Hamdar, George Washington University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05147
Paper Title	Estimating the Effects of Environmental Conditions, Built Environment, and Traffic Behavioral Factors on Pedestrian and Bicyclist Safety in Washington, D.C.
Abstract	Cycling and walking as modes of transportation are on the rise in many major cities. Similarly, pedestrian and bicyclist collisions with motorized vehicles are also on the rise. This calls for the need to identify the factors that may cause collisions, both to improve bicyclist and pedestrian safety and to encourage more individuals to use active modes of transportation. Using a structural equation model, this paper estimates the impact of environmental conditions, road characteristics, and zonal traffic behavior on bicyclist and pedestrian collisions in Washington, DC. The zonal traffic behavior component was captured by using the Vision Zero Safety App, an online platform that allows users to report on a number of transportation safety issues. For pedestrian safety, results showed that traffic signals, intersections, bus stops and bike lanes decrease safety. For bicyclists, bike lanes improve safety whereas major arterial roads decrease it. For both bicyclists and pedestrians, adverse weather conditions and zones with high reporting on safety issues (as a surrogate performance measure of such zones) were associated with an increase in safety.

Authors	Amir Jamali, Montana State University Yiyi Wang, Montana State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05549
Paper Title	Analysis of Pedestrian Crashes Injury Severity for Rural and Small Urban Areas
Abstract	Pedestrian safety remains a key issue due to the disproportionate number of pedestrian injuries and fatalities in rural and small urban areas. This study applies two statistical models (i.e., ordered logit and multinomial logit) and one dataming appraoch (i.e., CART) to: 1) identify the contributing factors associated with pedestrian–vehicle injury severity levels and 2) compare the CART model with statistical models in order to evaluate the effectiveness of data mining approaches. The result showed that the MNL outperformed the ORL, which was perhaps due to increased flexibility of MNL specification model than ORL. In addition, the CART model performed slightly better than the two statsitical models. This might be attributed to the fact that the CART model does not assume any predefined underlying relationship between dependent and independent variables, which results in a more flexible model specification. Results showed that in rural and small urban areas pedestrian fatality risk increases in areas with higher intersection density, population density, share of residential and commercial areas, percentage of individuals educated to bachelor or college, and when the crash occurred in dark hours and spring season. In contrast, the pedestrian fatality decreases in areas with higher number of driveways, centerline mile, share of undeveloped areas, employment density, percentage of male residents, percentage of individuals educated to bachelor and graduate levels, and areas where warning sign is present.

Authors	Nutan Teketi, Talbert & Bright, Inc. Srinivas Pulugurtha, University of North Carolina, Charlotte Ajinkya Mane, University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05552
Paper Title	Modeling Pedestrian Crashes at Midblock Locations
Abstract	This paper focuses on identifying factors and developing pedestrian crash estimation models for midblock locations. Seventy midblock locations were identified in the city of Charlotte, North Carolina to capture data and develop as well as validate the pedestrian crash estimation models. The number of pedestrian crashes over a four-year period (2013 - 2016), within a 0.25-mile buffer around each selected midblock location, was used as the dependent variable. Road network characteristics, transit network characteristics, demographic characteristics, and land use characteristics captured within a 0.5-mile buffer around each midblock location were used as the independent variables. Data for 55 midblock locations was considered for developing six pedestrian crash estimation models using SPSS statistical analysis software, while data for the remaining 15 midblock locations was considered for validating the developed pedestrian crash estimation models. The best model was selected based on the goodness-of-fit statistics and validation results. The presence of crosswalk marking and the number of transit stops have a positive effect on pedestrian crashes at midblock locations. Land uses like multi-family, retail and single-family attached also have a positive effect on pedestrian crashes at midblock locations. The findings from the pedestrian crash estimation models can be used by practitioners to proactively plan and improve pedestrian safety.

Authors	Amir Jamali, Montana State University Yiyi Wang, Montana State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05575
Paper Title	Pedestrian Crash Hotspot Identification Using Two-Step Floating Catchment Area Method and Machine Learning Tools for Rural and Small Urban Areas
Abstract	The crash hotspots identification is a primary step in traffic safety program. It provides a list of prioritized locations for further investigation, which contributes to recognize the crash causes and specifies the effective countermeasures. This study utilized the two-step floating catchment area (2SFCA) method, which has been widely used in medical fields, to identify high risk locations in rural and small urban areas. The 2SFCA method can account simultaneously for spatial heterogeneity, crash severity level and pedestrian exposure. This study used common grid cells for both crash locations and pedestrian areas rather than using a predefined administrative boundary because crash locations influence area is limited to neighboring blocks. The Moran's I test showed there was significant spatial dependence among grid cells. The results confirmed this methodology performed perfectly to identify crash prone locations and reduce the errors associated with simple hotspot identification methods. In addition, this study used K-Nearest Neighbor (KNN) algorithm, which is a non-parametric machine learning technique, to estimate pedestrian exposure. The results revealed that K-NN showed improvement over the statistical models (i.e., negative binomial, zero inflated, and finite mixture) due to evaluation criteria. The proposed methodology can be used in safety programs to enhance the roadway network safety for traffic network users.

Authors	Lakshmi Prasanna Srirangam Srinivas Pulugurtha, University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05593
Paper Title	Modeling Pedestrian Crashes at Intersections Near Light Rail Transit Stations and Comparing Before–After Patterns
Abstract	The focus of this paper is two-fold - 1) to research and identify factors that influence pedestrian safety at intersections within the vicinity of light rail transit (LRT) stations, and, 2) to examine the change in crash patterns at these intersections before and after the operation of LRT service. Pedestrian crashes at 71 randomly selected intersections, within a vicinity of 0.25 miles (402 m) around fifteen LRT stations in Charlotte, North Carolina, were analyzed to understand factors associated with pedestrian safety at these intersections near LRT stations. Geographical Information System (GIS) software was used to overlay shapefiles related to pedestrian crash data, road network and intersection characteristics on buffers around the selected intersections to capture data and conduct analysis. Generalized linear pedestrian crash estimation model (based on negative binomial distribution) was developed and validated to understand the relationship between road network characteristics and pedestrian crashes at the intersections near LRT stations. Speed limit, the number of bus stops and pedestrian signal are statistically significant predictor variables that influence pedestrian safety at the intersections near LRT stations.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05742
Paper Title	Predicting the Likelihood of Aging Pedestrian Severe Crashes Using Dirichlet Random-Effect Bayesian Logistic Regression Model
Abstract	There is ample literature on factors that contribute to the injury severity of pedestrian-vehicle crashes. Nevertheless, coupled with a continuous growing aging population, there is limited information addressing predictors that influence the injury severity of pedestrian-vehicle crashes involving older pedestrians. As such, this study developed an injury severity model with improved prediction accuracy, and hence identified the risk factors that influence the severity of aging pedestrians. In particular, the Dirichlet random-effect logistic model (DRL) was used to account for unobserved heterogeneity across crash data. Unlike the conventional parametric random-effect logistic model (CRL), which assumes that the heterogeneity of data varies across individual observations, the approach applied herein is flexible, imposing a belief that the DRL can recognize clusters of unobserved heterogeneity of crash observations. Various predictive capability indicators were utilized to compare the basic logistic (BL), CRL, and DRL model performances. The DRL model outperformed the BL and CRL models in all performance metrics used. The accuracy of the DRL was found to be 90% versus 83% and 68% for CRL and BL models, respectively. Moreover, seven variables were found to significantly influence the severity of aging pedestrians at the 95% Bayesian Credible Interval. These variables include pedestrian age, alcohol involvement, first harmful event, vehicle movement, shoulder type, posted speed, and traffic volume. It is envisioned that the findings of this study can provide a better understanding of the contributing factors to the transportation agencies, which can assist in devising traffic crash risk reduction strategies, especially for elder pedestrians.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-06535
Paper Title	Bayesian Approach to Model Pedestrian Crashes at Signalized Intersections with Measurement Errors in Exposures
Abstract	This paper investigated the effects of site conditions of signalized intersections on pedestrian-vehicle crash frequency, using the crash count-data from 288 signalized intersections in Hong Kong in a 3-year period from 2010 to 2012. The site condition data include geometric characteristics, traffic characteristics and built environment characteristics. The traffic and pedestrian volumes at intersection-level across the 3-year period were collected and estimated as exposure terms in the model. The measurement errors of the traffic and pedestrian volumes were taken into account in the estimation of the predictive model. The full Bayesian method was adopted to estimate the effects of explanatory variables. Pedestrian exposure at intersection-level was found essential in predicting the frequency of pedestrian-vehicle crash, otherwise false alarm would be given from the misleading model estimates. Measurement errors were found exist among the traffic and pedestrian volumes. It was also found that presence of pedestrian signal and presence of park or playground at land of leisure use would significantly reduce the occurrence of pedestrian-vehicle crashes, while presence of curb parking and presence of ground-level shop would increase the pedestrian crash frequency.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-01751
Paper Title	Multimodal Safety Assessment of an Urban Intersection by Video Analysis of Bicycle, Pedestrian, and Motor Vehicle Traffic Conflicts and Violations
Abstract	This paper demonstrates the diagnosis of bicycle safety issues and evaluation of proposed improvements at a major intersection in Vancouver, British Columbia using automated traffic conflict analysis. Traditional road safety analysis has often been conducted using historical collision records. However, limitations associated with collision data have motivated the development of complementary proactive techniques for road safety analysis. Recently, there has been significant interest in using traffic conflicts to analyze safety which has been strengthened by the availability of automated traffic conflict analysis tools. Automated computer vision techniques are used to extract and analyze traffic conflicts from video data. Traffic conflict indicators, such as time to collision and post-encroachment time, are used to identify safety issues based on the frequency and severity of conflicts. Spatial and temporal non-conforming behavior patterns are also analyzed. The intersection safety diagnosis reveals that the main sources of bicycle and motor vehicle conflicts are associated with failure to yield at bicycle crossings of on- and off-ramps, and vehicle red-light and stop-bar violations. A new intersection design is evaluated for its expected ability to address the identified safety issues.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05351
Paper Title	Characteristics of Vehicle–Bicycle Crashes and Near Crashes Using Naturalistic Driving Data
Abstract	Although motor vehicles are being equipped with increasingly sophisticated active safety systems, the fatality rate of cyclists in the U.S. continues to increase (1). Active safety systems such as pre-collision autonomous braking systems, which detect and autonomously brake in the event of an impending bicycle collision, could be a solution to this growing problem (6). This study examined the SHRP-2 naturalistic driving study database of bicycle crashes and near-crashes to categorize and determine if active safety systems could prevent such incidents. Bicycle and the vehicles paths were examined, as well as the driver's reaction, the duration the bicyclists were visible, and the speed of the bicyclists. In the 30 cases provided by the SHRP-2 database, the most prevalent vehicle-bicycle incidents occurred when the bicycle traveled straight across the path of the vehicle or when the vehicle turned left across the path of the bicyclist. The average time visible was dependent on the path and speed of the bicyclist. The bicyclists traveling in the direction of traffic were visible for longer than the bicyclists traveling across the path of the vehicle. In almost three-fourths of the cases (73%) the bicyclist was visible for longer than one second. For autonomous braking to work, bicyclists need to be detectable with enough time for crash preventative actions to be initiated. While there are many factors, the time visible indicates that in 73% of the cases, pre-collision autonomous braking had the potential to decrease the severity of the crash or avoid the crash altogether.

Authors	Harold Stanislaw, California State University, Stanislaus
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05774
Paper Title	Metrics for Naturalistic Studies of Safety-Relevant Interactions Between Motor Vehicles and an Instrumented Bicycle
Abstract	Interactions between bicycles and motor vehicles are most commonly studied using a bicycle that is ridden in traffic and fitted with ultrasonic sensors that measure the lateral distance with which vehicles pass the bicycle. However, an alternative is to rely entirely on video cameras that record the view ahead, behind, and to the side of the bicycle as it interacts with motor vehicles. A bicycle equipped in this manner can record not just lateral passing distance, but also such information as the speed of an approaching vehicle, and the distance at which a motor vehicle turns in front of the bicycle. This paper proposes several variables that relate to bicycle safety during interactions with motor vehicles, and describes how they can be measured using a system that is entirely video-based. Technological solutions are also described for several challenges that arise when processing and scoring the videos.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-03065
Paper Title	Safety Investigation of Nonmotorized Crashes in the City of Huntsville, Alabama, Using Count Regression Models
Abstract	While walking and cycling can be enjoyable, there is a potential safety risk associated with these modes, especially when interacting with automobiles. This study contributes to the safety of non-motorized transportation by applying and comparing three zero-inflated count models for each of bike and pedestrian crashes, specifically the zero-inflated negative binomial (ZINB) and the zero-inflated Poisson (ZIP). Note that the ZINB was examined with two different variance types, which were the standard ZINB and the modified one including a different variance estimator. In this study, sociodemographic (e.g., school enrollment and number of households), traffic (e.g., traffic volume and speed limit), and infrastructure or built environment variables (e.g., sidewalk length) were used. Five-year bike and pedestrian crashes (2010 through 2014) in 368 traffic analysis zones (TAZs) in the city of Huntsville, Alabama were used. The performance of the six fitted count models was compared based on the prediction performance and goodness-of-fit statistics. The prediction accuracy have included the mean absolute deviance (MAD) and the mean square prediction error (MSPE). The standard ZINB outperformed the corresponding ZINB type and the ZIP one for both bike and pedestrian crashes (especially in the relatively higher MAD and MSPE estimates, which represents higher prediction performance). The fitted regression models for both bike and pedestrian crashes in Huntsville showed that there was an increase in crashes with the increase in traffic volume, number of households, and number of retails. The results of the fitted count models are deemed useful for decision makers to identify and predict high-risk zones for bicyclists and pedestrian crashes in a city or county, and in other areas having similar traffic and sociodemographic characteristics.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-00382
Paper Title	Occurrence and Severity of Crashes Involving Vulnerable Road Users: An Integrated Spatial and Temporal Analysis
Abstract	Pedestrians and cyclists, often called vulnerable road users (VRUs), are more likely to be injured in road crashes as they are more exposed to risk. It is estimated that each year 1.2 million road users lose their lives on the world's road crashes with half of them being VRUs. This situation has a dramatical impact in terms of health and economical development and costs to governments, when low- and middle-income countries lose approximately 3% of their GDP. The analysis of road crashes registrations and the development of predictive models to identify areas with higher risk could be a crucial step to improve road safety and sustainable urban mobility. The main objective of this paper is to find temporal and spatial patterns of crashes between motor vehicles-VRUs based on severity, in order to implement a model that estimates the probability of occurrence of a crash involving VRUs. For that purpose, crashes data from three cities in Portugal with different characteristics were examined. Crashes were georeferenced and blackspots were identified considering injury severity. Although georeferencing is often a method of identifying potential risk areas, it is not associated with time and injury severity. The proposed model is defined as a Multinomial logistic regression model (MLR) with pedestrians and cyclists as a response variable. The findings from this study highlighted target variables that may influence number and severity of crashes between motor vehicle and VRUs. The developed MLR models revealed that VRU gender and age, as well as weather conditions, are statistically significant. Pedestrians and cyclists, often called vulnerable road users (VRUs), are more likely to be injured in road crashes as they are more exposed to risk. It is estimated that each year 1.2 million road users lose their lives on the world's road crashes with half of them being VRUs. This situation has a dramatical impact in

terms of health and economical development and costs to governments, when low- and middle-income countries lose approximately 3% of their GDP. The analysis of road crashes registrations and the development of predictive models to identify areas with higher risk could be a crucial step to improve road safety and sustainable urban mobility.
The main objective of this paper is to find temporal and spatial patterns of crashes between motor vehicles-VRUs based on severity, in order to implement a model that estimates the probability of occurrence of a crash involving VRUs. For that purpose, crashes data from three cities in Portugal with different characteristics were examined. Crashes were georeferenced and blackspots were identified considering injury severity. Although georeferencing is often a method of identifying potential risk areas, it is not associated with time and injury severity. The proposed model is defined as a Multinomial logistic regression model (MLR) with pedestrians and cyclists as a response variable.
The findings from this study highlighted target variables that may influence number and severity of crashes between motor vehicle and VRUs. The developed MLR models revealed that VRU gender and age, as well as weather conditions, are statistically significant.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-02980
Paper Title	Bicyclist-Involved Crashes on Roadway Segments in New York City: A Spatial Analysis of Injury Severity
Abstract	With increasing popularity of bicycling, bike lane networks are expended in urban areas. Moreover, bicycling safety has gained continuing attention. However, most research on bicycling crash data focus on crash frequency, while limited literature is about injury severity. Among papers related to bicyclist-involved crash injury severity, only few of them consider bike lane. Using bicyclist-involved crash data in New York City, this study explores correlates of bicyclist-involved crash injury severities with a spatial concern of safety effects of bike lanes. These correlates may vary spatially due to spatial heterogeneity (i.e. geographic and socio-demographic diversity) within the whole city. Hence, Geographically Weighted Regression method is applied to uncover spatial variation in associations between injury severities and contributing factors. The global model (Ordered Logistic Regression) and the local models (Geographically Weighted Ordered Logistic Regression) are fitted. The modeling results of both global model and local models indicate that associations between bike lane related explanatory variables (i.e. the four bike lane types, number of bike lane on roadway segments) and injury severities are not significant. Averagely, summer time, heavy-duty vehicle, motorist, and multi-family elevator buildings are associated with higher probability of moderate, severe, or fatal injury. Fundamentally, the assumption of stationary associations in the global model does not fully hold in space. The results of local models reveal the spatial patterns of correlates. Maps of spatial varying coefficients visualize their spatial variation. Therefore, the local models considering regional situation could provide more information to guide safety improvement.

Authors	Dan Wan, City College of New York Camille Kamga, City College of New York Jun Liu, University of Texas, Austin
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-02988
Paper Title	Injury Severity of Bicyclist-Involved Crashes at Intersections: A Comparative Study in New York City
Abstract	Since bicycling is becoming increasingly popular in cities, bicycling safety has become a growing societal concern. While most research focuses on the frequency of bicyclist-involved crashes, the correlates of injury severity are under-explored. Through studying injury severity in crashes that occurred at intersections in NYC, this study addresses the question of whether bike lanes mitigate the injury severity in bicyclist-involved crashes. Geo-referenced crash data was used with crashes grouped by their location at intersections with bike lanes and without bike lanes. Four types of bike lanes were studied: a) Protected bicycle paths with an access point, (b) Bicycle lanes, (c) Shared lanes, and (d) Signed routes. Simple statistics show that crashes at intersections with two or more types of bike lanes have the largest share of fatal or severe injuries. Multi-level ordered logistic models were developed to better understand the injury

severity correlations. Modeling results indicate that the bike lane type has no significant association with injury severity in bicyclist-involved crashes, while factors such as time of year and types of motor vehicle involved in crashes are significantly linked to injury severity. Crashes during summer seem to have a 1.7% higher chance of resulting in fatal or severe injury at intersections with bike lanes. The involvement of heavy-duty vehicles (buses or trucks) is linked to a 7.4% increased probability of a fatality or severe injury at intersections with bike lanes. The results offer insights into bicycling planning, interaction design, and future research directions, which are extensively discussed in this paper.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-03480
Paper Title	Analyzing the Injury Severity Sustained by Nonmotorists at Midblock Considering Nonmotorists' Precrash Behavior
Abstract	Non-motorized travel is being considered as one of the most beneficial transportation modes. However, pedestrians are often exposed to a higher risk of injury and fatality in traffic crashes. Compared to other road users, non-motorists like pedestrians have shorter travel range but face a higher risk of fatal and severe injury at midblock. In addition, there are few reported studies that investigated the impact of non-motorists' pre-crash behavior on injury severities. To examine the risk factors of non-motorist injury severity at midblock, 8-year crash-related data from the GES system are explored based on the mixed logit model, including time characteristics, crash features, environmental conditions, roadway attributes, nonmotorists' characteristics and their pre-crash behaviors. The results show that five parameters tend to have mixed effects on injury severities, including speed limit between 30 and 55 mph, night time, right side collision, and hit-and-run on the incapacitating injury, as well as no action of motorists on the non-incapacitating injury. Moreover, heavy and light truck, three or more lanes, dark not lighted and age 65 are found to increase the likelihood of fatal injury, while the impacts of left side collision and age below 25 decrease the likelihood of fatality. After controlling for these factors, nonmotorists' pre-crash behaviors such as darting or running into the road, activities in the roadway, and improper passing are also found to have a significant impact on severity outcomes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05083
Paper Title	Investigating Cyclist–Pedestrian Interactions at Bus Stops and Nonsignalized Intersections Using a Distance–Velocity Model and Speed Measures Derived from Video Data
Abstract	As walking and cycling flows increase in urban areas, cyclist-pedestrian interactions also increase at road facilities such as crosswalks at non-signalized intersections and bus stops located along segregated cycle tracks. Cyclist yielding compliances at these locations can be low which could deteriorate pedestrian safety and comfort. To investigate pedestrian safety at these locations, this study introduces a framework using cyclists' distance, speed and yielding maneuver information at the time of pedestrian occurrence and crossing derived from video data. The distance-to-crosswalk and speed of the cyclist are used to classify the cyclist's situation at pedestrian occurrences into three categories: i) where the cyclist cannot make a full stop; ii) where the ability to yield depends on the reaction time; and iii) where the cyclist can stop to yield. Cyclist crossing speeds at the crosswalk are also analyzed. A case study involving several crosswalk locations on cycle tracks from Montreal, Canada, was conducted. Video data was collected and video-based tracking techniques were used to extract cyclist speed and distance information. Results allow for microscopic analysis and provide insight into cyclist-pedestrian interactions. The factors that contribute to the low yielding compliance of cyclists and the

impact of marking, and road grade on cyclist behavior are explored. This safety analysis could inform policy on bicycle yielding enforcement and bicycle braking system standards.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-00058
Paper Title	How Is Driving Volatility Related to Intersection Safety in a Connected-Vehicles Environment?
Abstract	*The emerging connected and automated vehicles (CAV) technology provides a promising opportunity for investigating intersection safety more from a proactive perspective.* Driving volatility captures the extent of variations in instantaneous driving decisions when a vehicle is being driven. This study develops a fundamental understanding of microscopic driving volatility and how it relates to unsafe outcomes at intersections. Using real-world connected vehicle data from the Safety Pilot Model Deployment in Ann Arbor, Michigan, intersection-specific volatility indices are calculated for 116 intersections by analyzing more than 62 million real-world Basic Safety Messages transmitted between thousands of instrumented vehicles. The large-scale CAV data is then linked to detailed intersection data containing crashes, traffic exposure, and other geometric features. By using coefficient of variation of speed as a relative measure of driving volatility, descriptive analysis is performed to spot differences between driving volatility at signalized and un-signalized intersections. Then, in-depth statistical analysis is conducted separately for all intersections and signalized intersections only. Given the important methodological concern of unobserved heterogeneity, hierarchical fixed- and random-parameter Poisson and Poisson log-normal models are estimated under a Full Bayesian Gibbs sampling setting. For all intersections, a one-percent increase in driving volatility is associated with a 0.37 percent increase in crash frequency. Importantly, the relationship between driving volatility and crash frequency is more pronounced for signalized intersections. Several of the exogenous factors are found to be normally distributed random parameters, suggesting that the effects of such variables vary across different intersections. The practical implications of the findings are discussed.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-00060
Paper Title	How Driving Volatility in Time to Collision Relates to Crash Severity in a Naturalistic Driving Environment
Abstract	The sequence of instantaneous driving decisions and its variations, known as driving volatility, can be a leading indicator of unsafe driving practices. The research issue is to characterize volatility in instantaneous driving decisions in longitudinal and lateral direction and to seek an understanding of how driving volatility relates to crash severity. By using a unique real-world naturalistic driving database from the SHRP 2, a test set of 671 crash events featuring around 0.2 million temporal samples of real-world driving are analyzed. Based on different driving performance measures, 16 different volatility indices are created. The volatility indices are then linked with individual crash events including information on crash severity, drivers' pre-crash maneuvers and behaviors, secondary tasks and durations, and other factors. As driving volatility prior to crash involvement can have different components, an in-depth analysis is conducted using the aggregate as well as segmented (based on time to collision) real-world driving data. To account for the issues of observed and unobserved heterogeneity, fixed and random parameter ordered models with heterogeneity in parameter means are estimated. The findings suggest that greater driving volatility (both in longitudinal and lateral direction) prior to crash occurrence increases the likelihood of police reportable or severe crash events. Importantly, compared to the effect of volatility in longitudinal acceleration on crash outcomes, the effect of volatility in longitudinal deceleration is significantly greater in magnitude. Methodologically, the random parameter models with heterogeneity-in-means significantly outperformed both the fixed parameter and random parameter counterparts. The relevance of the findings to the development of proactive behavioral countermeasures for drivers is discussed.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-00590
Paper Title	Real-Time Crash Risk Analysis of Urban Arterials Incorporating Bluetooth, Weather, and Adaptive Signal Control Data
Abstract	Real-time safety analysis has become a hot research topic as it can reveal the relationship between real-time traffic characteristics and crash occurrence more accurately, and these results could be applied to improve active traffic management systems and enhance safety performance. Most of the previous studies have been applied to freeways and seldom to arterials. Therefore, this study attempts to examine the relationship between crash occurrence and real-time traffic and weather characteristics based on four urban arterials in Central Florida. Considering the substantial difference between the interrupted traffic flow on urban arterials and the free flow on freeways, the adaptive signal phasing was also introduced in this study. Bayesian conditional logistic models were developed by incorporating the Bluetooth, adaptive signal control, and weather data, which were extracted for a period of 20 minutes (four 5-minute interval) before the time of crash occurrence. Model comparison results indicate that the model based on 5-10 minute interval dataset is the most appropriate model. It reveals that the average speed, upstream volume, and rainy weather indicator were found to have significant effects on crash occurrence. Furthermore, both Bayesian logistic and Bayesian random effects logistic models were developed to compare with the Bayesian conditional logistic model, and the Bayesian conditional logistic model was found to be much better than the other two models. These results are important in real-time safety applications in the context of Integrated Active Traffic Management.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-00800
Paper Title	Safety Analytics for Integrating Crash Frequency and Real-Time Risk Modeling for Expressways
Abstract	To find crash contributing factors, there have been numerous crash frequency and real-time safety studies, but such studies have been conducted independently. Until this point, no researcher has simultaneously analyzed crash frequency and real-time crash risk to test whether integrating them could better explain crash occurrence. Therefore, this study aims at integrating crash frequency and real-time safety analyses using expressway data. A Bayesian integrated model and a non-integrated model were built: the integrated model linked the crash frequency and the real-time models by adding the logarithm of the estimated expected crash frequency in the real-time model; the non-integrated model independently estimated the crash frequency and the real-time crash risk. The results showed that the integrated model outperformed the non-integrated model, as it provided much better model results for both the crash frequency and the real-time models. This result indicated that the added component, the logarithm of the expected crash frequency, successfully linked and provided useful information to the two models. This study uncovered few variables that are not typically included in the crash frequency analysis. For example, the average daily standard deviation of speed, which was aggregated based on speed at 1-minute intervals, had a positive effect on crash frequency. In conclusion, this study suggested a methodology to improve the crash frequency and real-time models by integrating them, and it might inspire future researchers to understand crash mechanisms better.

Authors	Rod Turochy, Auburn University Nicholas Jehn, Auburn University Wesley Zech, Auburn University Jeffrey LaMondia, Auburn University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-00866
Paper Title	Analysis of Work-Zone Crash Reports to Determine Factors Associated with Crash Severity
Abstract	Highway work zones present an environment that leads to opportunities for traffic crashes that may not otherwise occur. To investigate the severity of work zone-related crashes and relationships between severity and other crash variables, a database of 5,410 work zone-related crashes that occurred in Alabama from 2007-2014 was developed. The database includes information from traffic crash reports, project traffic control inspector reports, and supporting documentation from contractors. The full range of variables included in the crash reports was reduced to a manageable set of 16 independent variables whose relationships to crash severity were then explored. This analysis involved the development of an ordered probit regression model and examination of frequency distributions. The five most statistically significant variables that affect crash severity were found to be Primary Contributing Factor, Manner of Crash, First Harmful Event, Highway Classification, and Work Zone Type. Specific factors that had a highly statistically significant effect on severity include evening and overnight time periods, open country locale, rain, no-passing zones, Federal and State highways, two-lane highways, head-on, rollover, and angle crashes, pedestrian and bicyclist involvement, single-vehicle crashes, excessive speed, improper lane use, and the presence of work on the shoulder or median.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-00980
Paper Title	Analyzing Highly Volatile Driving Trips and Associated Factors
Abstract	Volatile driving, characterized by fluctuations in speed and accelerations and aggressive lane changing/merging, is known to contribute to transportation crashes. To fully understand driving volatility with the intention of reducing it, the objective of this study is to identify its key correlates, while focusing on highly volatile trips. First, a measure of driving volatility based on vehicle speed is applied to trip data collected in the California Household Travel Survey during 2012-2013. Specifically, the trips containing driving cycles (N=62839 trips) were analyzed to obtain driving volatility. Second, correlations of volatility with the trip, vehicle, and person level variables were quantified using Ordinary Least Squares and quantile regression models. The results of the 90th percentile regression (which distinguishes the 10% highly volatile trips from the rest) show that trips taken by pickup trucks, hatchbacks, convertibles, and minivans are less volatile when compared to the trips taken by sedans. Moreover, longer trips have less driving volatility. In addition, younger drivers are more volatile drivers than old ones. Overall, the results of this study are reasonable and beneficial in identifying correlates of driving volatility, especially in terms of understanding factors that differentiate highly volatile trips from other trips. Reductions in driving volatility have positive implications for transportation safety. From a methodological standpoint, this study is an example of how to extract useful (volatility) information from raw vehicle speed data and use it to calm down drivers and ultimately improve transportation safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-01562
Paper Title	Crash and Near-Crash Risk Assessment of Distracted Driving and Engagement in Secondary Tasks: A Naturalistic Driving Study
Abstract	Distracted driving behavior is a perennial safety concern that affects not only the vehicle's occupants but other road users as well. Distraction is typically caused by engagement in secondary tasks and other activities such as manipulating objects and passenger interaction among many others. This study provides an in-depth analysis for the increased crash/near-crash risk associated with different secondary tasks using the largest real-world naturalistic driving dataset (SHRP2 Naturalistic Driving Study). Several statistical and data mining techniques are developed to analyze the distracted driving and crash risk. First, a bivariate probit model is constructed to investigate the relationship between the engagement in a secondary task and safety-critical events likelihood. Subsequently, two different techniques are implemented to quantify the increased crash/near-crash risk due to involvement in a particular secondary task. The first technique uses the baseline-category logits model to estimate the increased crash risk in terms of conditional odds ratios. The second technique uses the a priori association rule mining algorithm to reveal the risk associated with each secondary task in terms of support, confidence and lift indexes. The results indicate that reaching for objects, manipulating objects, reading, and cell phone texting are the highest crash risk factors among various secondary tasks. Recognizing the effect of different secondary tasks on traffic safety in a real-world environment helps legislators enact laws that reduce crashes resulting from distracted driving, as well as enables government officials to make informed decisions regarding the allocation of available resources to reduce roadway crashes and improve traffic safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-02283
Paper Title	Multiscale Crash Analysis: A Case Study of Integrating FARS, Maryland's Crash Data, and Montgomery County's Traffic Violation Data
Abstract	Road safety is a serious issue raising increased public concerns. In this paper, we analyze road safety with an integration of multi-source data on multiple scales. As a case study, we consider three datasets, including the nationwide Fatality Analysis Reporting System (FARS), the statewide traffic crashes in Maryland (MDCrash), and the countywide traffic violations in Montgomery County, MD (MoCoVio). For data integration, we first exploit basic common characteristics among all the datasets. The time interval statistics of the datasets are found stable and can be modeled into parametric statistical distributions. We then check essential features of the datasets corresponding to road safety and the relationship among them. We also compare the patterns of six common risk factors across all the three datasets. It is found that despite the difference in the features of the datasets, the patterns of DUI/DWI are very similar. Next, we explore practical values of the multiple data integration on road crash analysis. The crash risk patterns extracted from data fusion is shown to be rather valuable. By identifying determinant risk factors in the patterns, we can better understand the effects of other risk factors. In addition, conditional risk matrix can be computed from data integration to measure the probability of the injury levels and to evaluate the impact of each individual risk factor on injuries. Finally, we conduct a multi-source data integration to discover the safety factors for pedestrians, where we obtain temporal patterns from FARS but acquire spatial patterns from the traffic crash and violation data. The results indicate that, in comparison with only using FARS, integrating multiple data has the power of showing more insights of the patterns on risk factors for traffic crashes, which allows us to not only better optimize limited resources but also realize countermeasures for reducing traffic crashes and enhancing road safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-02753
Paper Title	Improving Animal–Vehicle Collision Data for the Strategic Application of Mitigation
Abstract	Millions of animal-vehicle collisions (AVCs) occur every year. Although successful types of mitigation have been well documented over the past two decades, decision makers rely on reliable crash data to identify problem areas and determine the magnitude of the problem. Although the literature shows that AVCs are underrepresented in police report data, more detailed analyses are needed to determine the scale. Quality and cost evaluations of deer-vehicle collision (DVC) data in Virginia were conducted that illustrate an AVC underreporting phenomenon that is a problem nationwide. According to deer carcass removal records, the number of DVCs in the evaluated areas was up to 8.5 times greater than what was documented in police reports, and DVCs were the most frequent type of collision in many areas. The underrepresentation of DVCs results in missed opportunities for mitigation and understates the costs of these collisions. DVCs were found to be six times costlier on average than what was indicated from police report data. They are the fourth costliest of the 14 major collision types in Virginia, averaging more than $533 million per year. The findings demonstrate the need to prioritize the systematic collection of carcass removal data. The increasing use of handheld devices among transportation maintenance staff to track road maintenance activities is an ideal opportunity to collect this information. Reliable data can be used to target areas for mitigation strategically, which can yield large benefits in road safety and accident cost reduction.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-03029
Paper Title	An Improved Methodological Framework Based on Probe Vehicle Data for Detecting Secondary Crashes
Abstract	Secondary crashes that occur on roadways frequently interrupt traffic operations. These non-recurrent incidents are often considered as a critical performance indicator in assessing traffic incident management programs. A number of methods have focused on the detection of these crashes either based on the static (with fixed spatiotemporal thresholds) or dynamic (e.g., queuing models and speed contour maps) approaches. However, the use of these approaches is often limited by their requirements for detailed incident records, special assumptions, unique model structures, etc. This paper aims to develop a new analysis framework to support the determination of secondary crashes. The proposed framework focuses on leveraging probe vehicle data to quantify secondary crashes. The key component of the framework is built upon the support vector clustering (SVC) method to detect the impact area of a primary crash and determine secondary crashes within it. Its performance is tested based on both simulation and an actual probe dataset. The results show that the SVC-based approach can correctly identifying more than eighty percent of the crashes, even under a low penetration rate (e.g., five percent) of probe vehicles. The increases in the penetration rate will further improve its performance. For practical implementation, there is no need to obtain probe data with very high penetration rate.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-04956
Paper Title	Big Data Approach of Crash Prediction
Abstract	Traditional crash prediction models use roadway geometric design features, traffic control types, and annual average daily traffic volumes, etc. as inputs to predict the annual crashes of a facility. These models are known as safety performance functions. Developing these models requires careful sampling of crash sites from different locations and advanced statistical techniques; using them requires prior knowledge of the facility and often local calibrations. The big data approach of crash prediction is based on predictive analytics. It predicts what will happen in the future by analysing the rich historical data, recognizing the patterns of how it happened in the past, and applying that pattern or trend to predict future events. This method requires ready access to multi-year state-wide or regional crash history data, but doesn't require prior knowledge of the facility. The underpinning of this approach is that the environment that induced the crash events remains stable over the time-period considered. The outcomes of many natural events, such as annual precipitation or animal migration, can be predicted by this method. The annual traffic crashes in an area is a type of natural event that falls into the above category, and therefore has repeatable and predictable patterns. This paper presents a big data approach of predicting the annual crashes of an area centred on user specified locations. Once the big historical dataset of a region is properly prepared, it encompasses the comprehensive crash histories of every facility within its boundary. This paper presents an auto searching algorithm that enables the crash prediction of any facility within the region be generated on the fly. This method is inherently area based, however, by adjusting the searching criteria, the result can converge to an intersection or a roadway segment. A major advantage of this approach is that it naturally considers the influences of nearby facilities.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-06666
Paper Title	Evaluation of Driving Performance in Relation to Crashes on an Expressway Using Naturalistic Driving Data
Abstract	Innovative crash prediction methods aimed at minimizing the dependence on crash data is being researched upon by many across the world. The major component of any such research involves the identification of parameters that are crucial in estimating safety. The majority of the studies consider geometrical parameters or proximity measures to assess the safety of a road. Though these parameters bear relation with the crashes and represent the safety to a certain extent, it overlooks the driver behavior which is a major crash causal factor. The present study aims at evaluating the driving performance measures, namely lateral and longitudinal accelerations corresponding to g-force, a measure of acceleration force. The study uses naturalistic driving data to estimate the driver performance parameters and analyses it with respect to the geometry of the section. The results are compared with the historical crash data to evaluate its reliability in estimating safety. The results show that lateral acceleration is able to represent the safety better than the other parameters considered.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-01687
Paper Title	Understanding the Effects of Trip Patterns on Spatially Aggregated Crashes with Large-Scale Taxi GPS Data
Abstract	The primary objective of this study was to investigate how trip pattern variables extracted from large-scale taxi GPS data contribute to the spatially aggregated crashes in urban areas. Data were collected from the City of New York in the United States. The following five types of data were collected: crash data, large-scale taxi GPS data, road network attributes, land use features and social-demographic data. A data-driven modeling approach based on Latent Dirichlet Allocation (LDA) was proposed for discovering hidden trip patterns from a taxi GPS dataset, and with the LDA approach a total of 50 trip patterns were identified. The collected data and the identified trip patterns were further aggregated into167 ZIP Code Tabulation Areas (ZCTA). Random forest technique was used to identify the factors that contributed to total, PDO and fatal-plus-injury crashes in the selected ZCTAs during the study period. Geographically weighted regression (GWR) models were then developed to establish a relationship between the crashes and the contributing factors selected by the random forest technique. Comparative analyses were conducted to compare the performance of the GWR models that considered traditional traffic exposure variables only, trip pattern variables only, and both traditional exposure and trip pattern variables. The model specification results suggest that the trip pattern variables significantly affected the crash counts in the selected ZCTAs. The results of the comparative analyses suggest that the models that considered both the traditional traffic exposure and the trip pattern variables had the best goodness-of-fit in terms of the highest R2 and lowest AICc values. Based on these results, the authors argue that incorporating the trip pattern information extracted from taxi GPS data benefits the spatial analysis of crashes, and taxi GPS data have potential to serve as new data sources for roadway safety analyses.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Poster Session 523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-05956
Paper Title	Using Microsimulation to Evaluate the Impact of Automated Vehicles on Safety Performance of Signalized Intersections
Abstract	Automated vehicles (AVs) are expected to offer great societal benefits by potentially reducing crashes. It is important to understand these impacts and to examine how this understanding may affect the planning of roadways and roadway improvements. Signalized intersections are of particular interest in this regard since the safety of these sites is particularly impacted by driving behavior, which, even in conventional vehicles, can be influenced by the presence of AVs. The study uses micro-simulation to generate simulated traffic conflicts as indicators of potential crashes, and models that relate crashes to conflicts, to examine the expected safety of signalized intersections in Toronto, Canada in the presence of automated vehicles at various penetration levels. In addition, the effect on crashes of introducing three hypothetical left turn treatments was also evaluated. The results indicate that intersection safety may improve in the presence of AVs. However, the safety effects of treatments may be reduced compared to the effects with no AVs. The implication is that the imminent introduction of AVs should be considered in developing priorities for future intersection improvements.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Lectern Session 552
Session Title	SHRP 2 Safety Data: Researchers' Perspectives and Some Analysis Results
Paper Number	P18-21120
Paper Title	A Researcher's Perspective on Using the SHRP 2 NDS Data
Abstract	Dr. Hallmark will provide her perspective on using the NDS data for safety research.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Lectern Session 552
Session Title	SHRP 2 Safety Data: Researchers' Perspectives and Some Analysis Results
Paper Number	18-01100
Paper Title	Assessing Curve Severity and Crash Rates at Horizontal Curves on Rural Two-Lane Highways Using SHRP 2 Safety Data
Abstract	Horizontal curves are associated with a disproportionate number of severe crashes, particularly on two-lane rural highways. Factors that influence horizontal curve safety are speed compliance, geometric features of the curve, sight distance, and traffic volume. Many efforts have been placed to improve curve safety and efficiency; however, in many previous studies the curve safety and operational characteristics were analyzed separately. With the development of the SHRP2 program and related technologies, data and emerging approach are available for analyst to incorporate curve operational characteristics into safety. The main objective of this study is to simultaneously assess curve severity and crash rates at horizontal curves using operating characteristics and safety data, respectively. For this purpose, the SHRP2 roadway information data (RID) and naturalistic driving data (NDS) were used. Curve operating information was extracted from the NDS data and geometric features were obtained from the RID data, and both were merged with 8-year crash data, also obtained from the RID data. The severity of each curve was calculated by four methods, and the curve severity was compared with the severity based on crash rates. The results of the computational analysis suggest that for the higher curve severity categories, curve severity (which is related to side friction demand and tolerance) is positively associated with crash rate. Safety analysts and roadway agencies are recommended to consider using SHRP2 data and curve severity assessment methods for addressing horizontal curve safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Lectern Session 552
Session Title	SHRP 2 Safety Data: Researchers' Perspectives and Some Analysis Results
Paper Number	18-01012
Paper Title	Using Naturalistic Driving Study Data to Evaluate the Effects of Intersection Balance on Driver Behavior at Partial Cloverleaf Interchange Terminals
Abstract	Past studies showed that poor intersection balances at partial cloverleaf (parclo) interchange terminals significantly impact traffic safety and sight distance of drivers making left turns to entrance ramps. Some state traffic agencies have recommended a “balance” guideline that the length between the left-turn stop line on crossroads to the middle of the intersection should not be greater than 60% of the entire length of the intersection. However, a scarcity of research exists on how the balance of an intersection affects driver behavior, which has been identified as a critical contributing factor to intersection-related crashes. This study utilizes the Naturalistic Driving Study (NDS) data to evaluate the effects of intersection balance on driver behavior at parclo interchange terminals. It demonstrates statistical characteristics and overall trends of driver speed, acceleration/deceleration rates, and risk perception with the changing of intersection balances. Conclusions provide guidance on optimal intersection balance design that may help drivers make smoother and safer transitions from crossroads to entrance ramps at parclo interchange terminals.

Authors	Richard Porter, VHB
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20))
Session Number	Lectern Session 552
Session Title	SHRP 2 Safety Data: Researchers' Perspectives and Some Analysis Results
Paper Number	P18-20919
Paper Title	A Researcher's Perspective on the Application of SHRP 2 Safety Data for Safety Analysis and Evaluation Studies
Abstract	Dr. RJ Porter will share his perspective on the application of SHRP2 safety data for safety analysis and evaluation and the opportunities he sees for the highway safety community. He will discuss his experiences with both the NDS and RID data.

Authors	Dominique Lord, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25) Standing Committee on Safety Data, Analysis and Evaluation (ANB20) Standing Committee on Geometric Design (AFB10) Standing Committee on Operational Effects of Geometrics (AHB65)
Session Number	Poster Session 574
Session Title	Highway Safety Manual 2: A Sneak Preview
Paper Number	P18-21220
Paper Title	NCHRP 17-58: Safety Prediction Models for Six-Lane and One-Way Urban and Suburban Arterials
Abstract	

Authors	John Ivan, University of Connecticut
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25) Standing Committee on Safety Data, Analysis and Evaluation (ANB20) Standing Committee on Geometric Design (AFB10) Standing Committee on Operational Effects of Geometrics (AHB65)
Session Number	Poster Session 574
Session Title	Highway Safety Manual 2: A Sneak Preview
Paper Number	P18-21221
Paper Title	NCHRP 17-62: Improved Prediction Models for Crash Types and Crash Severities (Urban and Suburban Arterials)
Abstract	

Authors	John Ivan, University of Connecticut
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25) Standing Committee on Safety Data, Analysis and Evaluation (ANB20) Standing Committee on Geometric Design (AFB10) Standing Committee on Operational Effects of Geometrics (AHB65)
Session Number	Poster Session 574
Session Title	Highway Safety Manual 2: A Sneak Preview
Paper Number	P18-21319
Paper Title	NCHRP 17-62: Improved Prediction Models for Crash Types and Crash Severities (Two-Lane and Multilane)
Abstract	

Authors	John Ivan, University of Connecticut
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25) Standing Committee on Safety Data, Analysis and Evaluation (ANB20) Standing Committee on Geometric Design (AFB10) Standing Committee on Operational Effects of Geometrics (AHB65)
Session Number	Poster Session 574
Session Title	Highway Safety Manual 2: A Sneak Preview
Paper Number	P18-21320

Paper Title	NCHRP 17-62: Improved Prediction Models for Crash Types and Crash Severities (Special Procedures)
Abstract	

Authors	Erin Ferguson, Kittelson & Associates, Inc. (KAI)
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25) Standing Committee on Safety Data, Analysis and Evaluation (ANB20) Standing Committee on Geometric Design (AFB10) Standing Committee on Operational Effects of Geometrics (AHB65)
Session Number	Poster Session 574
Session Title	Highway Safety Manual 2: A Sneak Preview
Paper Number	P18-21222
Paper Title	NCHRP 17-70: Development of Roundabout Crash Prediction Models and Methods (Intersection Level)
Abstract	

Authors	Erin Ferguson, Kittelson & Associates, Inc. (KAI)
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25) Standing Committee on Safety Data, Analysis and Evaluation (ANB20) Standing Committee on Geometric Design (AFB10) Standing Committee on Operational Effects of Geometrics (AHB65)
Session Number	Poster Session 574
Session Title	Highway Safety Manual 2: A Sneak Preview
Paper Number	P18-21318
Paper Title	NCHRP 17-70: Development of Roundabout Crash Prediction Models and Methods (Leg and Planning Level)
Abstract	

Authors	Raghavan Srinivasan, University of North Carolina, Chapel Hill
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25) Standing Committee on Safety Data, Analysis and Evaluation (ANB20) Standing Committee on Geometric Design (AFB10) Standing Committee on Operational Effects of Geometrics (AHB65)
Session Number	Poster Session 574
Session Title	Highway Safety Manual 2: A Sneak Preview
Paper Number	P18-21223
Paper Title	NCHRP 17-72: Update of Crash Modification Factors for the Highway Safety Manual
Abstract	

Authors	Mohsen Kamrani, University of Tennessee, Knoxville Ramin Arvin, University of Tennessee, Knoxville Asad Khattak, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-00089
Paper Title	What Measures of Driving Volatilities Best Explain Crash Frequency at Intersections?
Abstract	While the term “volatility” is commonly used in finance, the emergence of high frequency connected and automated vehicles (CAV) data provides the opportunity to define and explore the concept of “driving volatility.” As volatility and other measures of dispersion and variation can be computed through different ways, in this paper, several measures of driving volatility are defined and calculated using vehicles’ instantaneous speed, acceleration, and jerk at 116 intersections from Michigan Safety Pilot connected vehicle (CV) data. These volatilities represent newly available surrogate measures of safety. Volatility data are integrated with intersection historical crash and inventory data to investigate what measures of driving volatility are associated with crash frequencies at these intersections. First, the data was error-checked and verified for accuracy. Given that crash frequency is count data, fixed and random parameter Poisson

regression models are estimated. According to the modeling results, three measures of driving volatility are found to be positively associated with the number of the crashes at intersections. Other correlated and significant variables are average annual daily traffic, signalization, and 4-legged intersections. The identified measures of volatilities can be used to locate intersections with high driving volatilities, i.e., hot-spots where the crashes are waiting to happen. Therefore, pro-active safety countermeasures can be considered to reduce drivers' volatility, making the intersections safer.

Authors	Chen Wang, Southeast University Jingxin Xia, Southeast University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-00189
Paper Title	Developing a New Spatial Unit for Macroscopic Safety Evaluation Based on Traffic Flow Homogeneity: A Ratio Cut Minimization Method
Abstract	This paper developed a new spatial unit for macroscopic safety evaluation based on traffic flow homogeneity. A Ratio Cut (RC) minimization method was introduced, which can partition an undirected graph into multiple clusters, ensuring a high similarity within a cluster while keeping large differences among clusters. Based on the RC method, the central area of Kunshan (Suzhou) was partitioned into multiple sub-regions (i.e. the RC-based spatial unit), using daily traffic density as a similarity measure. Bayesian Poisson lognormal models with CAR priors were developed for three different spatial aggregation units: Ratio-Cut (RC), Traffic Analysis Zone (TAZ), and Census Tract (CT). Microwave data (30s interval) were collected and aggregated into traffic flow variables. Planning-based data and crash data were also collected for spatial crash modeling purpose. According to modeling results, the RC-based model generally outperformed the other two models, in terms of model fit and model estimates. Especially for model estimates, the RC-based model performed reasonable traffic flow effects on traffic safety, while the other two appeared to suffer from ecological fallacy (for CT) and atomic fallacy (for TAZ). The strength of Bayesian methods overcame the potential over-fitting issue caused by relatively sparse detector data and limited research area. In general, the proposed partitioning method needs to be considered for macroscopic safety evaluation, based on which active traffic control and management strategies for regional safety improvement can be proposed. Moreover, since traffic flow is time-dependent, the proposed spatial unit also shows the potential for dynamic macroscopic safety evaluation.

Authors	Ahmed Osama, University of British Columbia Tarek Sayed, University of British Columbia Emanuele Sacchi, University of Saskatchewan
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01280
Paper Title	A Novel Technique to Identify Hot Zones for Active Commuters Crashes
Abstract	This paper presents an approach to identify and rank accident-prone (hot) zones for active transportation modes. The approach aims at extending the well-known empirical Bayes (EB) potential for safety improvement (PSI) method to cases where multiple crash modes are modeled jointly (multivariate modeling). In this study, crash modeling was pursued with a multivariate model incorporating spatial effects and using the full Bayes (FB) technique. Cyclist and pedestrian crash data for the city of Vancouver (British Columbia, Canada) were analyzed for 134 traffic analysis zones (TAZs) to detect active transportation hot zones. The hot zones identification (HZID) process was based on the estimation of the Mahalanobis distance, which can be considered an extension to the PSI method in the context of multivariate analysis. In addition, a negative binomial model was developed for cyclist and pedestrian crashes, where the EB PSI for each mode crash was quantified. The cyclist and pedestrian PSIs were combined to detect active transportation hot zones. Overall, the Mahalanobis distance method is found to outperform the PSI method in terms of results' consistency; and inconsistency is observed between the hot zones identified using both approaches.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01486
Paper Title	Safety Evaluation of Change in Posted Speed Limit from 65 to 70 mph on Rural Virginia Interstate System
Abstract	Effective July 1, 2010, the Virginia Department of Transportation (VDOT) increased the maximum allowable posted speed limit on interstates and similar facilities from 65 mph to 70 mph, after an engineering study. As a result, VDOT performed engineering studies on selected rural interstates posted at 65 mph. Subsequently, by November 2010, VDOT increased the speed limit from 65 to 70 mph for approximately 670 centerline miles of select rural interstates. There is a need to understand the safety and operational effects of increasing posted speed limits from 65 to 70 mph. This paper presents the results of an Empirical Bayes before-after study. The analysis was based on four years of data before and after the increase in posted speed limit, focusing on total, injury, run-off-road, and truck-related crashes. SPFs were estimated and used to account for changes in traffic volume. Comparison segments were used to develop annual adjustment factors, account for regional differences, and identify underlying crash trends in the period before the increase in speed limit. The study considered both aggregate and disaggregate effects. At the aggregate level, the results indicate no increase in any of the focus crash types after the increase in posted speed limit. Focusing on sites without other changes, which are most indicative of the impacts of the increased speed limit, the increased speed limit did not change (i.e. increase or decrease) any of the crash types. The disaggregate analysis provides further insight into the circumstances where the change in posted speed limit had more and less pronounced impacts. Specifically, the disaggregate analysis showed that segment type (base or interchange) influenced the safety impact where there was an increase in all crash types except injury crashes for interchange segments. The disaggregate analysis also showed that roadway improvements (e.g., rumble strip installation/reinstallation, pavement resurfacing activity, guardrail, pavement markings, and various warning signage) may help to offset the safety impact of increasing the posted speed limit.

Authors	Paul Durdin, Abley Transportation Consultants Ltd. Colin Brodie, New Zealand Transport Agency Raja Abeysekera, Transport for NSW Robyn Gardener, Accident Compensation Corporation Carl O'Neil, Abley Transportation Consultants Ltd. Dale Harris, Interpret Geospatial Solutions
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01591
Paper Title	Vehicle Speed and Risk Modeling of Horizontal Curves
Abstract	With more than half of all fatal and serious crashes on high-speed roads occurring on horizontal curves, managing the safety of road users traversing horizontal curves is a major issue confronted by road agencies globally. Traditional methods of detecting safety issues tend to involve geospatial analysis of crash data to highlight blackspots and reveal crash trends. Whilst these approaches enable horizontal curves with an established safety problem to be identified, they miss curves with an inherent high level of risk where few crashes have occurred in the past. This paper presents a geospatial risk prediction methodology that models vehicle speeds along high-speed road corridors and assesses the safety risk of horizontal curves based curve approach speed and curve radii. Results show that injury crash rates on horizontal curves classified as high-risk using the methodology are approximately 95% higher than other horizontal curves and 450% higher than straight road segments. These findings demonstrate that the horizontal curve risk assessment methodology is a strong indicator of underlying safety risk. Building off this methodology, a prioritization process was developed to identify corridors with the highest risk of curve crashes. This process established that the highest ranked 10% of corridors by length had a curve-related injury crash rate that was 97% higher than the next highest ranked 15% of corridors. This proactive approach of identifying high-risk corridors is helping road agencies across Australasia target their efforts at a comparatively small proportion of the network where a disproportionately large amount of risk exists.

Authors	Saif Alarifi, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida Xuesong Wang, Tongji University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01739
Paper Title	Exploring the Effect of Different Neighboring Structures on Spatial Hierarchical Joint Crash Frequency Models
Abstract	Corridor safety analysis is a primary interest of many safety studies. Corridors contain mainly intersections and roadway segments. Having both components while analyzing corridors in addition to corridor-level variables in a hierarchical joint model would provide a comprehensive understanding of the existing corridor safety problems. Also, spatial correlation presence among road entities along corridors is probably high especially if distance between the road entities is not large. Therefore, it is crucial to consider the spatial effect in the model. However, this data structure is relatively new, and the best spatial weight matrix for this hierarchical spatial joint model is worthy of investigation. Therefore, this study aims to estimate a hierarchical Poisson-lognormal (HPLN) joint model with spatial effects and explore the effect of different neighboring structures. A total of thirteen HPLN joint models have been estimated, and these models are the HPLN joint model with corridor random effect and twelve HPLN joint models with spatial effects. Four types of conceptualization of spatial relationships were considered: (1) adjacency-based, (2) adjacency-route, (3) distance-order, and (4) distance-based spatial weight features. The results show the importance of incorporating the spatial effect in the model. It was found that having joint model is important since one of the best models is the adjacency-based first-order model, where the feeding road entities in addition to the directly adjacent road entity of the same type as the road entity of interest are considered. Lastly, the results confirm the importance of spatial autocorrelation between road entities along the same corridor.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-02200
Paper Title	Utilizing Partial Least Squares Path Modeling to Analyze Crash Risk Contributing Factors for Shanghai Urban Expressway System
Abstract	The urban expressway systems are playing key roles in the metropolitan transportation system. However, frequent crash occurrences have significantly influenced the traffic operations and travel reliability. It is vital to understand the crash occurrence mechanisms and further improve traffic safety. Emerging studies have been conducted to unveil the relationships between crash risk contributing factors and crash outcomes with the advanced traffic sensing data. However, current results could mainly shed some lights on the correlation effects between traffic flow parameters and crash occurrence. In this study, we aimed at analyzing the confounding impacts of crash risk contributing factors and their causal relationships with crash occurrence through Partial Least Squares (PLS) Path Modeling approach. Crash data and traffic data from Shanghai urban expressway system were utilized. Firstly, potential crash risk contributing factors were summarized based on the literatures. Then, Random Forest (RF) model was adopted to rank the variable importance, and a total of six contributing factors were selected and used as inputs entered the PLS Path Modeling development procedure. Finally, the best PLS Path Modeling structures were identified, and crash occurrence scenarios and turbulent impacts on traffic flow parameters were concluded based on the analysis results.

Authors	Richard Amoh-Gyimah, Monash University Majid Sarvi, University of Melbourne Meead Saberi, Monash University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-02234
Paper Title	Application of Random Parameter Macroscopic Safety Models for Hot Zone Identification: A Case for Melbourne, Australia
Abstract	This study uses random parameter negative binomial model (RPNB) for crash risk hot zone identification. Potential for Safety Improvement (PSI) is adopted as a measure of the crash risk. Using road crash data from Melbourne, Australia (2010-2012), safety performance functions (SPFs) are developed for total, serious injury, minor injury, and pedestrian and bicycle crashes. The SPFs are developed at two different spatial aggregation levels for comparison. Three screening categories are also developed from the PSI for the hot zone screening. A comparison of the identified hot zones with different spatial aggregation shows significant differences in their spatial distribution. The location of the identified hot zones from one spatial aggregation does not necessarily match with similar locations in the other spatial aggregation level. However, both spatial units indicate the presence of hot zones that requires attention and treatment to improve safety. Overall, the study demonstrates an application of random parameter macroscopic safety models and PSI measures to identify hot zones in a large metropolitan area.

Authors	Chengcheng Xu, Southeast University Shuoyan Xu, Southeast University Pan Liu
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-02662
Paper Title	Predicting the Occurrence Time of Secondary Crashes on Freeways Using Bayesian Random-Parameters Accelerated Failure Time Model
Abstract	This paper aimed to investigate the effects of real-time traffic flow conditions on the duration between secondary and primary crashes. The crash and traffic flow data were obtained from the I-5N freeway for five years. The Bayesian random-parameters AFT model was then developed to link the duration between secondary and primary crashes with real-time traffic conditions, geometric characteristics and primary crash characteristics. The results showed that the real-time traffic conditions after the primary crash occurrence significantly affect the duration between secondary and primary crashes. The contributing traffic variables include traffic volume variation, detector occupancy variation, and difference in occupancy between upstream and downstream stations. In addition, the primary crash occurrence time, and geometric factors also affect the duration. The evaluation results showed that the developed model has satisfactory prediction accuracy in the duration between secondary and primary crashes, and has the potential to be used for predicting the secondary crash occurrence time. The evaluation results also indicated that the inclusion of random parameters greatly increase the prediction accuracy. The results of this study revealed how traffic flow conditions after the occurrence of the primary crash affects the until-secondary-crash duration on freeways. The developed model can be used to develop effective and timely incident management strategies for secondary crash prevention.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-02721
Paper Title	Impacts of Speed Variations on Freeway Crashes by Severity and Transportation Mode
Abstract	Speed variations are identified as potentially important predictors of freeway crash rates, but their impacts on crashes are not entirely understood. Existing findings tend to be inconsistent possibly because of the different definitions for speed variations, different crash type consideration or different modelling and data aggregation approaches. This study explores the relationships of speed variations with crashes on a freeway section. Crashes split by vehicle type (heavy and light vehicles) and by severity level (killed/serious injury and slight injury crashes) are aggregated based on the similarities of the conditions just before their occurrence (condition-based approach) and modelled using Multivariate Poisson lognormal regression. The models control for speed variations along with other traffic and weather variables as well as their interactions. Speed variations are expressed as two separate variables namely the standard deviations of speeds within the same lane and between lanes over a five-minute interval. The results, similar for all crash types (by coefficient significance and sign), suggest that crash rates increase as the within lane speed variations raise, at higher traffic volumes. Crashes are also triggered by the presence of higher between lane speed variations. Higher speeds coupled with higher volume and high speed variation between lanes also increase the crash likelihood. Overall, the results suggest that combinations of traffic characteristics play an important role in crash occurrences rather than their individual effects. Identification of these specific crash prone conditions could improve our understanding of crash risk and would support the development of more efficient countermeasures.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-03009
Paper Title	Revisiting Hit-and-Run Crashes: A Geospatial Modeling Method
Abstract	Hit-and-run crashes often delay emergency response and may result in increasing/secondary harms/damages to the victims involved in the crash. Almost all states in United States have laws regarding hit-and-run crashes. Previous studies have extensively explored the stationary correlates of hit-and-run crashes. In order words, the relationships between associated factors and hit-and-run are constant in all over the study region (e.g., a state or country), resulting in uniform strategies/recommendations (to prevent hit-and-run behavior) for the entire region. However, hit-and-run crashes (perhaps all traffic crashes) involve complex mechanisms between driver and driving/traffic environment which are likely influenced by the diverse social and geographic contexts. In addition, hit-and-run can be a societal concern, because of not only its consequences to victims but also negative impacts on safety cultures in local communities. Therefore, it may be more appropriate to understand the local correlates of hit-and-run crashes and specify strategies/recommendations to local communities or corridors. This study revisited hit-and-run crashes through a geo-spatial modeling approach, specifically, Geographically Weighted Regression (GWR) using geo-referenced crash data from Southeast Michigan Council of Governments. The data cover all types of motor vehicle crashes (N= 138,529) that occurred in Southeast Michigan, including 20,813 hit-and-run crashes. This study presented the results from both traditional regression and GWR models. GWR model results can be mapped in spatial domain, and the maps offer visual insights about the spatially varying correlates of hit-and-run crashes, which are not available from previous studies. Results from traditional binary logit model are generally consistent with findings in previous studies. For example, hit-and-run was more likely to occur on weekends or during nighttime (especially without street lights on).Driving under impairment (DUI) was bonded with a higher likelihood of hit-and-run. GWR models also uncovered spatially varying correlates of hit-and-run. For example, crashes in northwest of Detroit metropolitan area were associated with an even greater hit-and-run

	likelihood than those in other parts in this area. In addition, the local socio-economic factors were included in the analysis. Results show that hit-and-run was more likely to occur in census tracts with a higher unemployment rate, a lower household income, a smaller portion of college-educated population and a greater population density. The study demonstrates a way of making sense of geo-referenced traffic safety data. Geo-spatial modeling method is useful for prioritizing specific geographic regions/corridors for traffic safety improvements, which outperforms traditional modeling techniques.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-04815
Paper Title	Evaluating the Impact of Raising Speed Limit on Urban Freeways Using Mixed-Effects Negative Binomial Regression
Abstract	Numerous statistical approaches have been used in establishing the safety impacts associated with raising posted speed limit, especially on highways. These approaches range from simple naïve before and after study to more advanced statistical approaches which control for exposure and other confounding factors. In this study, mixed effects negative binomial regression was used in quantifying the changes in fatal, incapacitating and non-incapacitating (KAB) crashes, total crashes and road departure crashes after raising the posted speed limit in some of Michigan urban freeways. This method was preferred as it offers the ability to control for individual random effects which vary across the freeway corridors, intra-cluster correlation of crashes between corridors or segments that are nested in the same corridor, overdispersion in crash data and time effect. The importance of these factors was demonstrated by comparing the estimation results of mixed effects negative binomial model and standard negative binomial model. The standard negative binomial model underestimated the impact of speed limit on KAB and total crashes while compensating for the missing variables, namely time effect and random effects. The results from mixed effects negative binomial regression showed a net increase in KAB crashes, total crashes and road departure crashes after raising the speed limit. The effect of raising speed limit was more pronounced on curved freeway segments compared to straight freeway segments. Therefore, the design standards for horizontal curve, vertical curve and other geometric features should be thoroughly assessed to ensure that they meet required standards for the proposed speed limit changes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-05331
Paper Title	Traffic Incident Prediction Using Wavelet-Based Feature Extraction and Artificial Neural Networks
Abstract	The availability of huge traffic-related data enables us to evaluate and analyze the sources of traffic congestion and accidents in a systematic manner. Several researchers have explored ways to exploit the boom in data availability for improving traffic safety and efficiency. In this paper, we present an approach that explores the prediction of accidents using wavelet decomposition-based denoising and then applying artificial neural network (ANN) for prediction of these features. The ANN-based pattern recognition methodology is constructed in order to determine the underlying factors associated with collisions. We utilized the accident data for the county of Los Angeles, which were collected between 2009 and 2013, to develop the proposed methodology. The preliminary results of this study were encouraging; however, it requires further investigation into the topic to improve the reliability of the prediction model.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-05564
Paper Title	MOE-Based Safety Performance Functions for Signalized Intersections: A Tool for Safety Evaluations in TIAs and Traffic Studies
Abstract	Evaluating roadway safety is a challenging task due to the lack of collision data and indeterminate relationship between the exposure variables and collision events. To evaluate safety, some researchers use Poisson and Negative Binomial modelling structures to develop exposure based Safety Performance Functions (SPFs) that account for the statistical characteristics of collision data. Some studies explored using conflict field observations and others investigated the use of conflict estimates generated from simulation software to study safety. Many practitioners use SPFs due to the availability of data, easiness to use, and reliability. Using conflict observations is relatively expensive and using conflict estimates from modelling software is yet an unproven methodology. On the other hand, the relationship between detailed operational measures and their relationship to safety seems to be understudied. This study is intended to provide practitioners with a tool to evaluate safety using commercial software such as Synchro. SPFs were developed to evaluate the relationship between measures of operational performance and safety at arterial roadway intersections. Operational performance was evaluated using Synchro, which reports on delays, queues, vehicle stops, v/c ratios, actuated signal performance, and other measures of performance. In this study, Model parameters for Synchro were based on the City of Calgary guidelines. SPFs using peak hour collision data between 2010-2014 at 76 intersections were developed. Operational measures were developed based on peak traffic volumes (AM, Mid-Day, and PM) and on-site signal timing plans. Modelling attempts covered collisions by severity and type, in addition to roadway snow related collisions.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-05685
Paper Title	Use of Multivariate Dirichlet Process Mixture Spatial Model to Estimate Active Transportation-Related Crash Counts
Abstract	The current study contributes to the safety literature by presenting a dedicated research for comprehensive analysis of multivariate Dirichlet process mixture spatial model for estimation of pedestrian and bicycle crash counts. This study focuses on the active transportation at Traffic Analysis Zone (TAZ) level by developing a semi-parametric model that accounted for the unobserved heterogeneity by combining the strengths of incorporating multivariate specification to accommodate correlation among crash modes, spatial random effects for the impact of neighboring TAZs, and Dirichlet process mixture for random intercept. Three alternate models, one Dirichlet while two parametric, were also developed for comparison based on different criteria. Bicycle and pedestrian crashes shared three influential variables: the positive correlation of K12 student enrollment, the bike-lane density, and the percentage of arterial roads. The heterogeneity error term demonstrated the presence of statistically significant correlation among the bicycle and pedestrian crashes while the spatial random effect term exhibited the absence of a significant correlation, which might explain the slightly inferior performances associated with the spatial models. The Dirichlet models were consistently superior to non-Dirichlet ones under all evaluation criteria. Moreover, the Dirichlet models exhibited the capability to identify the latent distinct subpopulations and suggested that the normal assumption of intercept associated with traditional parametric models does not hold true for the TAZ level crash dataset of the current study.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-05889
Paper Title	Multimodal Crash Frequency Modeling: Multivariate Space-Time Models with Alternate Spatiotemporal Interactions
Abstract	Enhancement of safety for all transportation mode users plays an essential role in the implementation of multimodal transportation systems. Compared with crash prediction models dedicated to motorized mode users, the use of these models has been considerably scarce in the multimodal literature. To fill this research gap, the authors aim to develop and evaluate three multivariate space-time models with different temporal trends and spatiotemporal interactions. The model estimates justified the use of mode-varying coefficients for explanatory variables as the impact of these factors varied across different crash modes. Largely a similar set of influential covariates was generated by the three models which indicate their robustness. However, notable differences were observed from the assessment of goodness-of-fit criteria employed in the study. The model with time-varying spatial random effects demonstrated superior performance under various prediction-related criteria. Nonetheless, due to the significant increase in the effective number of parameters that were utilized for model development, this model was inferior to competing models at deviance information criterion (DIC). The results also revealed the effectiveness of various random effects in capturing the unobserved heterogeneity that escapes the covariates.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-06270
Paper Title	Accident Risk Prediction Based on Driving Behavior Feature Learning Using Cart and Xgboost
Abstract	This study aims to assess and predict accident risk from instantaneous driving behavior. A novel accident risk prediction method is developed based on surrogate accident risk assessment and feature learning of driving behaviors. Risk Index is proposed based on surrogate risk indicators, which is feasible to measure potential accident risks with three levels. Besides, surrogate accident risk assessment also provides sufficient instances to capture various driving behavior features, which are helpful to identify early pre-collision signals and trigger factors of impending accidents. Driving behavior features and corresponding risk levels are extracted from vehicle movement trajectory. A total of 50 features involving driving behaviors are extracted and Classification and Regression Tree (CART) is applied to select the key features for risk identification. Seventeen key features are selected according to tree-based learning of driving behavior features and surrogate risk levels. Accident risk prediction model is established and trained using eXtreme Gradient Boosting (XGBoost). The findings suggest that accidents involving vehicle collisions can be evaluated and predicted based on driving behavior feature learning. The ensemble method combined with XGBoost and CART is a creative and feasible way to achieve reliable prediction. Based on the identification of risky behavior features, accident risk level and likelihood are able to be inferred and predicted before accident happen. Targeted proactive accident prevention solutions are also discussed for potential application, which are both necessary and valuable.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Poster Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-03131
Paper Title	An Exploration of Contributing Factors Related to Driver Errors on Highway Segments
Abstract	A significant portion of crashes occur on highway segments, with more than 90 percent of crashes associated with driver errors. To avoid a crash, a driver needs to detect a hazard, make safe driving maneuvers, and execute them properly. Driver error at any of these sequential phases may lead to a crash; therefore, it is necessary to identify the contributing factors and assess their influence on driver behavior. To assist this investigation, a multinomial probit model was employed to study driver errors reported in a crash in rural and urban areas. The modeling results identified many highway geometric features, traffic conditions, roadway events, and driver characteristics as statistically related to different types of driver mistakes. Following the extensive list of explanatory variables, their impact expressed as the marginal effect was discussed within each error category. This exercise helps to gain broader understanding of similar or varying effects of explanatory variables across different error categories. The new information of the errors preceding to a crash can help researchers and safety professionals to better understand when, where, and how drivers made mistakes that lead to a crash and to develop cost-effective countermeasures to prevent them.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-00065
Paper Title	Development of Safety Performance Functions for Tennessee: Unobserved Heterogeneity and Functional Form Analysis
Abstract	To facilitate the implementation of the Highway Safety procedures in the state of Tennessee, the main objectives of this study are to apply HSM predictive models for rural two-lane, two-way roads, compute calibration factors and crash rates, and explore the need of developing Tennessee-specific Safety Performance Functions (SPFs). For the development of SPFs, several functional forms are considered in Poisson and Poisson-gamma modeling frameworks. Using five years (2011-2015) crash, traffic, and road inventory data, fixed- and random-parameter count data models are developed that accounts for important methodological concerns of unobserved heterogeneity and omitted variable bias. Using validation dataset, the calibrated and uncalibrated HSM SPFs and eight new Tennessee-specific SPFs are then compared for out-of-sample prediction accuracies. A state-wide calibration factor of 2.48 is estimated, suggesting that rural two-lane, two-way road segment crashes are at least 1.48 times greater than what HSM SPF predicts. Significant variation in four different regions in Tennessee is observed with calibration factors ranging between 2.02 and 2.77. Among all the SPFs considered, fully specified Tennessee-specific random parameter Poisson SPF outperformed all competing SPFs in forecasting out-of-sample crashes on rural two-lane, two-way road segments. The best-fit random parameter SPF relates mean crash frequency to annual average daily traffic, segment length, shoulder width, lane width, speed limit, and the presence of passing lanes. Significant heterogeneity is observed in the effects of traffic exposure-related factors on crash frequency. The study demonstrates how heterogeneity based models can be used by practitioners for obtaining more accurate crash predictions.

Authors	Ahmed Farid, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-00109
Paper Title	Transferring and Calibrating Safety Performance Functions Among Multiple States
Abstract	Safety performance functions (SPFs), which are statistical regression models, by predicting traffic crash counts by crash type, severity and facility type, aid traffic engineers in the process of identifying high frequency crash locations. Developing SPFs requires the collection and processing of traffic, crash, road design and other characteristics data. Jurisdiction agencies may choose not to develop their own SPFs and cut down on their resources by adopting SPFs provided by the national Highway Safety Manual (HSM). The HSM also provides a technique to calibrate the HSM's SPFs to the specific jurisdiction's conditions. Yet, the technique is subject to criticism. This study is aimed at exploring the transferability of SPFs of Florida, Ohio, Illinois, Minnesota, California, Washington and North Carolina's rural divided multilane highway segments. The SPFs are negative binomial (NB) models as are those provided by the HSM. We address the fault of instinctively applying the HSM's SPFs to a particular locality without verifying whether the SPFs are transferable to the locality and compare different states. Remarkably, it is found that Ohio, Illinois, Minnesota and California's SPFs are mutually transferable for specific crash categories. In addition, in this study, two calibration techniques are proposed as alternatives to that of the current HSM. One of proposed techniques is shown to be more accurate than the HSM's.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-00618
Paper Title	Exploration of Macrolevel Effects for Segment and Intersection Crash Modeling
Abstract	It is acknowledged that crash occurrence at segments and intersections could be affected by multilevel factors. Omission of important explanatory variables could result in biased and inconsistent parameter estimates. This paper contributes to the literature on traffic safety research for segments and intersections by examining the macro-level effects which are always excluded or ignored. A Bayesian hierarchical model is proposed to incorporate the macro-level factors including not only macro-level explanatory variables but also total segment- and intersection-crash counts aggregated based on zones. In addition, a joint modeling structure is adopted to investigate the spatial autocorrelation between intersection and their connecting segments. The proposed model is evaluated by comparing it with its three counterparts: a model considering micro-level factors only, one hierarchical model considering macro-level effects with random effect terms only, and one hierarchical model considering macro-level effects with explanatory variables based on zones. The results indicate that the models considering macro-level effects outperform the road entity crash models. In addition, the proposed model has improved performance, which validates the concept of considering macro-level effects through both explanatory variables and total crashes based on zones. In addition, significant spatial autocorrelation could be found between intersections and their connecting segments, supporting the modeling structure to analyze crashes at various types of road entities. Finally, the proposed model provides more valuable insights about the crash occurrence at segments and intersections by revealing both micro- and macro-level factors.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-00658
Paper Title	A Novel Approach for Calibrating Safety Performance Functions
Abstract	Safety performance functions (SPFs) are statistical regression models used for estimating crash counts by roadway facility classification. They are required in the process of assessing the effectiveness of safety countermeasures provided for hazardous crash sites in before-after analyses. Roadway agencies may opt to develop jurisdiction specific SPFs or borrow them from the national Highway Safety Manual (HSM) provided by the American Association of State Highway and Transportation Officials. In addition, the HSM suggests a simple technique to calibrate its SPFs to specific jurisdictions. A more recent calibration technique is similar to that of the HSM with a minor modification, also known as the calibration function. In this research, we develop SPFs for rural divided multilane highway segments for total crashes in seven states. The states are Florida, Ohio, Illinois, Minnesota, California, Washington and North Carolina. We also calibrate each SPF to all states using the HSM calibration method. Furthermore, we propose a combination of the HSM calibration method with hierarchical clustering. According to the goodness of fit results, our proposed calibration method is superior to the HSM's and the calibration function.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-00981
Paper Title	Methods Assessment and Recommended Practice for Estimating the Safety Effects of Multiple Treatments
Abstract	Crash modification factors (CMFs) are one tool to estimate the expected safety effects of a given treatment. One practical limitation is that treatments may be considered in combination, but most CMFs represent the effect of a single treatment. Ideally, the analyst would use a CMF for the combination treatment of interest, but relatively few CMFs have been developed for combination treatments, and it would take a tremendous effort to develop CMFs for all likely combinations of treatments. Combining individual CMFs is one alternative to developing CMFs for every possible treatment combination, but there is limited guidance on the application of multiple CMFs. The predictive method from the first edition of the Highway Safety Manual shows that CMFs can be multiplied to estimate the combined effect of multiple treatments, assuming the treatments are independent. It further notes that limited research exists regarding the independence assumption. Further research and guidance is needed to help practitioners estimate the expected safety effects when multiple treatments are considered at the same location. This paper presents several potential methods for combining multiple CMFs and the associated strengths and limitations. A methodology is developed and then applied to test the accuracy of these methods. The method hinges on the development of high-quality CMFs for the two individual treatments in question as well as the CMF for the combined treatment. CMFs were developed and presented in a companion paper. The results of the methods assessment provide a solid foundation for recommending methods for combining multiple CMFs.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-02091
Paper Title	Highway Safety Manual Calibration: Assessing Alternate Definitions of the Calibration Factor
Abstract	The publication of the Highway Safety Manual (HSM) in 2010 established crash frequency prediction as the essential safety measure for safety studies. However, given that the models were developed using a single state data, the HSM recommends calibration of the prediction models using data from the jurisdiction where they will be applied. This calibration process has been conducted in several states and many questions have been raised as a result. This paper is intended to investigate different definitions and criteria for the calibration factors and provide recommendations for practitioners on which definition to use. In addition to the calibration factors in the HSM and previously published definitions, three other calibration factor equations are proposed and compared using multiple goodness of fit measures. Whereas each definition may outperform others in certain measures, in this study, it is recommended to use the definition that maximizes the likelihood between predicted and observed crashes. The idea is to follow the same concept in both state-specific SPF development and calibration process, which is maximizing the likelihood of predicted and observed crashes.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-02744
Paper Title	Calibrating Safety Performance Functions for Four-Leg Signalized Intersections in New York City: Application of Geographically Weighted Regression
Abstract	Traditional Safety Performance Functions (SPFs) in Highway Safety Manual (HSM) for intersections are developed at jurisdiction levels. They are usually calibrated by using local data to have localized SPFs at state level. However, the fixed parameters of traditional SPFs may ignore significant spatial variation of key factors' impacts. This could result in biased or invalid inferences. By using geo-referenced crash data, this study proposed Geographically Weighted Negative Binomial Regression (GWNBR) models to consider intersections' spatial heterogeneity. Geo-referenced crash data at 2404 four-leg signalized intersections in New York City was used. Local SPFs (GWNBR models) estimating non-stationary parameters and traditional SPFs (NBR models) estimating fixed parameters are built for single-vehicle crash frequency and multi-vehicle crash frequency, respectively. GWNBR models passed non-stationarity tests, which implies that their parameters vary substantially in space. Comparisons between GWNBR models and NBR models were conducted using log-likelihood, Pseudo-R 2, and AIC. Results show that the GWNBR models outperform the NBR models. Spatial varying GWNBR model parameters were mapped to visualize them. The GWNBR model results provide better understanding of associations between roads' Annual Average Daily Traffic (AADTs) and crash frequencies. For transportation agencies, this method can provide a way to localize traditional SPFs. And for safety practitioners, the proposed models can provide more accurate crash frequency predictions to develop appropriate safety improvements.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-02939
Paper Title	Transferability Study of Urban Arterial Safety Performance Functions Between Shanghai and Guangzhou
Abstract	Shanghai, China, has developed a series of safety performance functions (SPFs) to analyze crash contributing factors and identify hazardous locations for the purpose of safety improvements. However, many other cities in China, such as Guangzhou have not developed local models due to lack of reliable safety data. This paper focuses on investigating the transferability of SPFs among similar cities, so jurisdictions without SPFs can more quickly conduct safety analyses. To this end, data on urban arterials in Shanghai and Guangzhou were collected, including crash data, geometric design features and traffic characteristics. Negative-binomial-based SPFs were developed separately for the cities during peak and off-peak hours. Then, model estimation results were transferred from one city to the other for crash prediction, and the prediction performance was evaluated. Results showed that local models could yield higher prediction accuracy than the transferred models. The results of likelihood ratio tests, conducted to evaluate model transferability between Guangzhou and Shanghai, suggested that the models could not be transferred directly. In order to improve transferability, the models were multiplied by calibration factors. The peak-hour models became transferable, but the off-peak models were still not transferable. To solve this problem, pooled data, composed of all Shanghai samples and various proportions of Guangzhou samples, were used to develop SPFs for transfer to Guangzhou. When over 50% Guangzhou samples were used in the pooled data, the models during both peak and off-peak hours became transferable. Findings from this paper prove that SPF models have the potentiality and possibility to transfer to other similar cities when appropriate methods are adopted to improve transferability.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-04325
Paper Title	Exploring the Transferability of Cross-Country Safety Performance Functions for Urban Arterials with Pooled Data
Abstract	Safety performance functions (SPFs) identify crash contributing factors and identify crash hotspots for the purpose of safety improvements. The U.S. Highway Safety Manual (HSM) provides a series of SPFs for various roadway facilities, developed using data from multiple states. In states without local jurisdiction-based SPFs, it is common practice to adopt national SPFs for crash prediction and safety improvement. However, the HSM SPFs transfer work has not been conducted to China where the traffic safety analysis is in its initial phase. With the foundation of U.S. traffic safety work, this study therefore aims to investigate the transferability of HSM SPFs to China, and how they might be improved to be transferred to China. Using the road design, traffic volume, and crash data of four-leg signalized intersections, four-lane and multi-lane (6-10 lanes) divided urban arterials in the downtown areas of Orlando, Florida, and Shanghai, SPFs were developed separately for the two cities using negative binomial models. Pooled datasets were further created by combining different proportions of Shanghai samples into Orlando samples to estimate SPFs. A transfer index was estimated using log-likelihood to evaluate the transferability of the SPFs. Results showed that the separate SPFs were not transferable between the two cities. Pooled data consisting of all Orlando samples and 50% of Shanghai samples made SPFs for four-leg signalized intersections and multi-lane road segments on urban arterials transferable to Shanghai, and when the proportion of Shanghai samples increased to 75% in the pooled data, SPFs for four-lane divided road segments also became transferable. Recommendations for better general SPF transferability to China are suggested.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-04969
Paper Title	HSM Calibration Factor, Calibration Function, or Jurisdiction-Specific Safety Model: How to Choose the Approach?
Abstract	There are various ways in which a transportation agency can approach safety prediction. One could calibrate the Highway Safety Manual, calibrate it using factors by ranges of exposure variable, calibrate it using a function, or develop jurisdiction-specific models. Various tradeoffs are involved in deciding on which approach to undertake, including minimum sample size, data required, data processing, modeling, statistical expertise, labor involved, and accuracy of estimate. To aid an agency in this decision, a comprehensive case study involving urban freeway four-lane segments (FU4) in Missouri is presented along with a discussion of general tradeoffs. HSM calibration was performed over the entire range of predictor variable values and by AADT and segment length ranges. For calibration functions, regression modeling was performed, and calibration function forms were explored using AADT and segment length as additional predictor variables. Using 160 FU4 segments, Missouri specific Safety Performance Functions (SPF) were developed. Cumulative Residuals (CURE) plots were used for comparative analysis of all model approaches. For calibration functions and SPFs, the inverse overdispersion and log-likelihood were evaluated in addition to the CURE plots. The results showed that calibration by AADT ranges outperformed all other calibration factors and functions proposed. The jurisdiction-specific SPF had similar accuracy as fully loaded and calibrated HSM models while not requiring the extensive data collection and processing of freeway-related Crash Modifications Factors. Agencies should consider developing jurisdiction-specific SPFs because it only requires the inclusion of two predictor variables (i.e., AADT and length), reducing data collection efforts and statistical modeling complexity.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-06245
Paper Title	Bicyclist Safety Performance Functions for Road Segments in a U.S. City
Abstract	Safety Performance Functions (SPFs) are able to estimate the relationship between collisions and exposure by accounting for the non-linear relationship between exposure and risk. While SPFs have been comprehensively developed for motor-vehicles, there is a need to further develop bicycle-specific SPFs. This paper uses data from eight years (2006-2013) in Boulder, Colorado to create the first bicycle-specific SPFs for roadway segments in a U.S. city that utilizes bicycle exposure. Such SPFs can help prioritize projects and inform the transportation decision-making process and future editions of the Highway Safety Manual. In this analysis, a negative-binomial model with log link was used to predict annual non-fatal motorist-bicyclist crashes on road segments per mile. The analysis shows that motor vehicle volume is a leading factor associated with more crashes between motor vehicles and bicyclists. Bicyclist exposure, population density, and percent retail land use are also predictive. The analysis also suggests that bicyclist exposure, at least in Boulder, Colorado, can be modeled as either bicycle volume or a combination of percent of road segment with a bike lane and pedestrian volume. While it is unlikely that pedestrian volume would be known and not bicycle volume, there may be cases where this surrogate for bicycle volume may be useful. However, results should not be interpreted to indicate that bicycle lanes cause crashes. The bike lane measure is likely a surrogate for bicyclist exposure.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 575
Session Title	Highway Safety Performance
Paper Number	18-06548
Paper Title	Safety Performance Functions for Divided Four-Lane Intercity Highway Under Heterogeneous Traffic Flow
Abstract	Inter-city/rural highway contributes to majority of crashes on four-lane divided highways in India, a developing country. According to recent statistics, 54% of the crashes occurred on inter-city highways in the country in the year 2016. Default Safety Performance Functions (SPFs) in the Highway Safety Manual (HSM) are site-specific and need local calibration for application in other countries. In order to adapt the SPF developed by the HSM, calibration factors were estimated for four-lane divided inter-city highway as well as for un-signalised three and four-legged intersections using the Interactive Highway Design Model (IHSDM). Further the study was carried out to develop site-specific SPF based on local site data using count data modeling approach. The study was carried out on a inter-city highway in plain and rolling terrain and operating under heterogeneous traffic flow. The database used for the analysis includes the geometric design, traffic and exposure characteristics, crash characteristics and other features of the roadway. For safety analysis, the highway was segmented based on fixed length and pavement surface characteristics. Validation of the developed models have been performed based on prediction performance and cross validation. Best fit models were identified based on these results and Akaike's Information Criterion (AIC). Results from calibration studies indicated that the HSM under-predicts crashes both in the case of segment and intersection safety analysis. The developed SPFs are found to be capable of predicting/evaluating the safety level more accurately on multi-lane divided segments compared to that of calibrated HSM models.

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Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 723
Session Title	Case Studies of Performance-Based Analysis of Geometric Design
Paper Number	P18-21361
Paper Title	Incorporating Predictive Safety Analysis into Freeway Design Decision Making in the Environmental Impact Study Process
Abstract	A high-traffic freeway corridor connecting the entirety of Reno, Nevada is currently being significantly redesigned. Locally known as "the Spaghetti Bowl", the corridor, which includes the system interchange for Interstates 80 and 580, as well as fifteen miles of surrounding freeway mainline, is notorious for extreme congestion and high crash frequencies throughout. In particular, the original design of the system interchange, constructed from 1969 to 1971, is unable to process the level of traffic volumes experienced by the corridor during rush periods, causing highly variable traffic speeds. As a result, some weaving sections display more than twice the average statewide crash rate of comparable freeways, with an overrepresentation of rear-end crashes, both severe and non-severe. The Nevada Department of Transportation (NDOT), the agency responsible for the corridor, has begun Phase 1 engineering for the Spaghetti Bowl and has elected to incorporate predictive analysis of safety performance into their design decision-making considerations, along with more common considerations of economic, traffic, structural, societal, and environmental impact. These methods, based on Part C of the American Association of State Highway and Transportation Officials' (AASHTO) Highway Safety Manual (HSM), utilize a freeway safety performance modeling tool called the Enhanced Interchange Safety Analysis Tool (ISATe). The tool requires inputs of freeway segment and ramp geometry configurations as well as annual average daily traffic volumes (AADT) throughout the study area. ISATe models freeway corridors based on these user inputs and generates predicted safety performance results in terms of crash frequencies by severity for each element of the study area. For the Reno Spaghetti Bowl modernization project, this predictive tool is being utilized to produce results for the freeway mainline, system interchange, and service interchange ramps on all proposed design alternatives as well as the no-build scenario, using a design year of 2040. Due to data limitations, the ISATe models have not been calibrated, so results will not be adjusted for regional safety characteristics. Therefore, these results are being used exclusively to determine the relative safety performance of the freeway and interchange design alternatives, ultimately comparing them to the performance of a no-build scenario. This process offers an invaluable look into the effects of various design elements on motorist safety, such as interchange design, lane configuration, and curve geometry, empowering NDOT to incorporate substantive safety

performance into their decision-making for the project. It is anticipated that the quantitative results of this analysis will play a significant role in the final design selection process, taking place in early 2018.

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Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 723
Session Title	Case Studies of Performance-Based Analysis of Geometric Design
Paper Number	P18-21362
Paper Title	Making the Case for Safer Design Alternatives: Innovative Techniques for Presenting Operational and Safety Benefits to the Public
Abstract	This poster will explore a case study of roadway widening and discuss several innovative performance measures that were used to showcase the benefits of progressive design choices on the safety and operational performance of the corridor in a quantitative yet accessible manner. A suburban jurisdiction outside Nashville, TN was looking to add capacity a three-lane US Highway with continuous left-turn lane carrying 18,900 vehicles per day. Widening alternatives under consideration included a 5-lane open cross-section, a 4-lane median-divided section, and a 4-lane roundabout corridor. During the public outreach stage, community stakeholders and elected officials raised concerns about the roundabout and median-divided alternatives on the basis of property impacts and perceived operational deficiencies. To address these concerns, City staff and the consultant team developed several performance metrics and exhibits to highlight the safety and operational benefits of these design concepts, including: • A corridor-wide comparison of mainline delay versus side-street delay, showing that while implementing access management would slightly impact mainline delay and travel time, concentrating left turns at roundabout- and signal-controlled intersections would significantly improve side-street performance; • Conflict point diagrams and tabulations to show the crash risk of different design choices; and • Projected future crashes using Highway Safety Manual methodology, showing the forecasted safety benefits or detriments of specific geometric design decisions, both corridor-wide and at spot locations. This poster will discuss these and other performance metrics and show how they were presented to the public as part of a three-pronged comparison of operational, safety, and physical impacts. This approach enabled the City Board to make a direct, fair comparison of all alternatives from a quantitative standpoint by presenting safety benefits on even footing with the travel time and delay values that they were accustomed to seeing.

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Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 723
Session Title	Case Studies of Performance-Based Analysis of Geometric Design
Paper Number	P18-21363
Paper Title	Colorado I-225/I-25 Ramp Reconfiguration and Restriping Alternatives: Safety Analysis Using IHSDM
Abstract	Colorado Interstate 225 (I-225) is a north-south freeway between Interstate 70 (I-70) to the north and I-25 to the south, which provides major access to the cities of Denver and Aurora. The Colorado Department of Transportation (CDOT), in cooperation with the Federal Highway Administration (FHWA) completed a 2014 Planning and Environmental Linkages (PEL) study for Southbound (SB) I-225 between Yosemite Street and I-25, south of Denver (see Figure 1). The purpose of the I-225 PEL was to develop and evaluate transportation improvements to reduce congestion and enhance the safety of SB I-225. In 2016, a safety analysis of the existing condition (Scenario 1) and two proposed alternatives (Scenarios 2 & 3) was conducted by CDOT with assistance from the FHWA Geometric Design Lab (GDL). Safety impacts of the proposed changes to SB I-225 were evaluated, including: • Adding a Lane: to an existing 2-lane section of SB I-225 on the approach to its junction with I-25 (Scenarios 2 and 3).

- Narrowing the Shoulders: Right-of-way limitations require a narrowing of both right and left shoulders on SB I-225, approaching its junction with I-25 (Scenarios 2 and 3).
- Reconfiguring ramps to reduce weaving-related safety concerns:
  - ☐Eliminating the movement from a southbound Denver Tech Center (DTC) Boulevard on-ramp to southbound I-25; and extending the ramp to merge with an "I-225 Southbound to I-25 Northbound" system ramp (Scenarios 2 and 3).
  - ☐Eliminating a southbound I-225 off-ramp to DTC Boulevard; adding a southbound I-225 on ramp from Yosemite Street; and connecting a collector-distributor (C-D) road to SB I-225 (Scenario 3).

The Crash Prediction Module (CPM) of FHWA's Interactive Highway Safety Design Model (IHSDM) was used to apply Highway Safety Manual (HSM) Part C predictive methods to perform the I-225 / I-25 safety analysis. The study also investigated the impacts on the local urban street network.

CDOT anticipates that construction of the selected re-striping alternative will begin in late 2017. The proposed presentation will document results of the safety analysis and discuss how they were used by CDOT to select a preferred solution.

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Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 723
Session Title	Case Studies of Performance-Based Analysis of Geometric Design
Paper Number	P18-21364
Paper Title	Quantitative Road Safety Assessment of Staging Options for the Rehabilitation of a Complex Interchange
Abstract	This poster discussed a comparative evaluation of expected road safety performance associated with construction staging options for the rehabilitation of a complex interchange. The tools and techniques applied to this evaluation included the following: • FHWA Complex Interchange Tool (CIT) • FHWA Surrogate Safety Analysis Model (SSAM) • FHWA Enhanced Interchange Analysis Tool (ISATe) In carrying out our assessment of the proposed staging options, safety performance was evaluated and quantified by each tool individually using its unique methodology. In the next step, a "lines of evidence" approach was applied to combine the findings into an integrated synthesis to identify links between critical design features and operational elements of the facility. By carrying out this type of analysis, we develop a technically sound and defensible rationale for our findings and recommendations. The main objectives of this poster are to: • Present available tools to quantify interchange safety performance • Present the unique methodology behind each tool • Highlight the capabilities and limitations of tools • Underline the Lines of Evidence approach, used to overlap the independent conclusions from each toolset with purpose to develop a technically sound and defensible rationale for our recommendations, but also to indicate areas of design with potential for road safety improvements.

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Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 723
Session Title	Case Studies of Performance-Based Analysis of Geometric Design
Paper Number	P18-21365
Paper Title	Using Microsimulation to Evaluate Safety and Operational Implications of Newer Roundabout Layouts for European Road Networks
Abstract	Standard" roundabouts, for example those designed in some European countries, can often be characterized by low levels of safety or capacity. Given the proliferation of newer layouts, it is of interest to explore whether design practices could be improved by capitalizing on the experience gained internationally. Some layouts of interest are already in frequent use (hamburger, dumb-bell), while some

	are recent and have only been implemented in a few countries (i.e. turbo, double-lane), and others are still at the development phase (i.e. flower, target). Operational aspects of some of these designs have been explored previously but there is a need to compare both the operational and safety performance to that of standard roundabouts. The objective of this paper is to evaluate the safety and operational implications of various potential alternatives to the standard roundabouts that proliferate in Europe and elsewhere. Microsimulation is used to simulate traffic operations at roundabout layout alternatives at the same levels of V/C ratio and also at the same traffic flow. Operational performance measures include common level of service parameters, while measures of safety are based initially on time to collision (TTC) values. Threshold values of TTC were then applied in defining conflicts that are then used for crash based safety evaluation by applying crash-conflict models estimated in published research. Interesting insights are revealed, suggesting that the newer layouts should be considered where warranted by cost-benefit considerations.

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Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 723
Session Title	Case Studies of Performance-Based Analysis of Geometric Design
Paper Number	P18-21366
Paper Title	Implementation of Data-Driven Safety Analysis in Georgia DOT Districts 1, 2, and 5
Abstract	Consistent with the Federal Highway Administration's Data Driven Safety Analysis (DDSA) initiative, the state-of-the-art analysis techniques from the Highway Safety Manual (HSM) have been integrated into management of the Georgia Department of Transportation's (GDOT) safety program. This included the development of a system-wide safety analysis database comprised of all federal aid roadways in GDOT Districts 1, 2 and 5. Roadway inventory data, historical traffic volume data and surrounding land use data were combined with three years of historical traffic crash data using a geographic information system. This system-wide database was used to identify roadway facilities for potential safety improvement projects based upon the Empirical Bayes methodology outlined in the HSM, including the development of jurisdictional calibration factors and default distributions. The system-wide database was also used to develop reference data for specific facility types to aid in diagnosis and treatment selection. Additionally, the results of the system-wide analysis also provide opportunities to identify the need for systemic treatments within the federal aid highway system in GDOT Districts 1, 2 and 5. Ultimately, continued development of the system-wide database will provide improved reference data, calibration factors and default distributions as more precise roadway inventory data becomes available. The focus of this poster will be to summarize how this data has been applied within transportation projects in Georgia. The poster will include several case studies demonstrating the benefits and issues associated with applying this approach. These case studies will include examples of how DDSA has been integrated into GDOT's traffic engineering studies, intersection control evaluations and road safety audits.

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Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 723
Session Title	Case Studies of Performance-Based Analysis of Geometric Design
Paper Number	P18-21367
Paper Title	Planning-Level Safety Performance Evaluation of Extended Freeway Alternatives Using IHSDM in Arizona
Abstract	The Federal Highway Administration (FHWA) and Arizona Department of Transportation (ADOT) are conducting the environmental review process for the Interstate 11 (I-11) Corridor from Nogales to Wickenburg, Arizona. The I-11 corridor has been identified by previous studies as a critical piece of multimodal infrastructure that would diversify, support, and connect the economies of Arizona and Nevada. The corridor is expected to improve regional mobility, and to enhance access to the high capacity transportation network to support economic vitality.

The I-11 study area extends approximately 280 miles from Nogales to Wickenburg, traversing five counties, 14 municipalities, and four tribal communities. The alternative selection process consisted of a robust evaluation process that used public and agency input as well as various transportation performance, environmental, community and economic development, and other planning information to help identify opportunities and constraints. This process resulted in three build corridor alternatives that incorporate all recommended options selected for advancement to the next phase.
The safety performance evaluation of the 2035 No Build and the three alternatives was performed using the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) predictive methods for freeways and interchanges. The analysis was conducted using the Interactive Highway Safety Design Model (IHSDM). The IHSDM includes crash prediction capabilities for facility types as specified in Part C of the HSM. Application of the IHSDM for a planning level study of this magnitude proved to be a very effective tool to model alternatives efficiently while applying the HSM predictive methods.
This poster will provide a high-level overview of the project, details of the safety performance evaluation, lessons learned of applying IHSDM and HSM methods in a planning study, and will highlight the importance of making informed decisions using a performance-based approach.

Authors	Zhoutong Jiang, University of Illinois, Urbana Champaign Khair Jadaan, University of Jordan Yanfeng Ouyang, University of Illinois, Urbana Champaign
Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 723
Session Title	Case Studies of Performance-Based Analysis of Geometric Design
Paper Number	P18-21368
Paper Title	Harmonizing Design Speed Versus Operating Speed Based on Safety Performance
Abstract	Current geometric design of roadway elements is based primarily on the design speed, which may be unrelated to the posted speed limit and/or the actual operating speed. When the actual operating speed on the roads exceeds the design speed, which is common on rural highways, the roadway design may become problematic from a safety point of view. Most of the current design policy does not address such a discrepancy, and hence new design methods based on speed harmonization might be necessary to improve roadway safety. To quantify the relationship between design speed, operating speed, and select economic strategies to improve roadway safety, we developed a new framework that considers the relationship between design speed and operating speed, the safety impacts of various geometric elements, as well as the economic benefits of various strategies for roadway safety improvement. The integrated modeling framework includes sequential modules for (1) geometric design simulation based on current engineering design practice/manuals, (2) operating speed profile prediction for the geometric roadway designs, (3) crash rate prediction and speed consistency level evaluation based on the speed profile, and quantification of safety improvement benefits using methods from the Highway Safety Manual, (4) benefit-cost analysis for roadway safety improvements based on economic evaluation of crash rate reduction and construction cost. Numerical examples were conducted to demonstrate the applicability of the proposed models. All models were programmed into an Excel VBA-based computer tool to facilitate decision making. The outcome of this project may be suitable for implementation in a wide range of application contexts.

Authors	Suliman Gargoum, University of Alberta
Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 723
Session Title	Case Studies of Performance-Based Analysis of Geometric Design
Paper Number	P18-21369
Paper Title	Exploring the Impacts of the Failure to Meet Stopping Sight Distance Requirements on Existing Highways
Abstract	One important element of highway design is ensuring that the available sight distance (ASD) on a highway meets driver needs. For instance, if the ASD at any point on a highway is less than the distance required to come to a complete stop after seeing a hazard (i.e. Stopping Sight Distance (SSD)), the driver will not be able to stop in time to avoid a collision. SSD is function of a number of variables which vary depending on the driver, the vehicle driven and surface conditions; examples of such variables include a driver's

perception reaction time or PRT (i.e. the time required by the driver to perceive and react to a hazard) and the deceleration rate of the vehicle.

Most design guides including AASHTO recommend deterministic values for PRT and deceleration rates. This research effort explores the extent to which ASD on highways satisfies SSD requirements in AASHTOs design guide. The research first develops MATLAB and Python codes to automatically estimate the ASD on highway point cloud data collected using Light Detection and Ranging (LiDAR) remote sensing technology. The developed algorithms are then used to estimate ASD on seven different crash prone segments in the Province of Alberta, Canada and the ASD is compared to the required SSD on each highway. The results show that, when compared to AASHTO's SSD requirements, up to 6% of the analyzed segments do not meet the requirements.

In an attempt to explore the effects of such design limitations on safety, the research also explores crash rates in noncompliant regions (i.e. regions that do not provide sufficient SSD) and compares them to crash rates in compliant regions. On average, it was found that noncompliant regions experience crash rates that just over 2 times higher than compliant regions.

Authors	David McDonald, Hanson Professional Services, Inc.
Sponsoring Committee	Standing Committee on Operational Effects of Geometrics (AHB65) Standing Committee on Highway Safety Performance (ANB25)
Session Number	Poster Session 723
Session Title	Case Studies of Performance-Based Analysis of Geometric Design
Paper Number	P18-21630
Paper Title	How Might Connected Vehicles and Autonomous Vehicles Influence Geometric Design? - Best of the 5th Urban Street Symposium
Abstract	

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. 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:

- Generalized Additive & Piecewise Linear Count Data Models (Wali et al; 18-00064)
- Multivariate model incorporating spatial effects using the Full bayes method with Mahalanobis distance (Osama et al; 18-01280)
- Empirical Bayes using traditional and generalized negative binomial regression (Yang at al; 18-01388)
- Quantile and graphical methods for determining optimal sliding window and increment lengths in network screening (Zhang et al; 18-01974)
- Random parameter macroscopic safety models (Amoh-Gyimah et al; 18-02234)
- Geographically weighted regression method (Liu et al 18-03009)
- Zero-inflated negative binomial and zero inflated poisson model (Shirani et al. 18-03065)
- Two-step floating catchment area method with machine learning tools (Jamali and Wang; 18-05575)
- Logistic regression (Wang et al; 18-00738)
- Point Density Estimation (PDE), Kriging, Inverse Distance Weighted (IDW), and Spline (Mohammadianamiri et al; 18-01655)
- Safety performance functions and empricial bayes methods (Ambros et al; 18-02011
- Hotspot identification by considering single and multivehicle crashes separately (Wang et al; 18-02533
- Dynamic programming-based screening (Lee et al; 18-05114)
- Crash Frequency, Equivalent Property Damage Only (EPDO), Relative Severity Index, Excess Predicted Average Crash Frequency using Method of Moment, and Cross Sectional Analysis (CSA) methods (Wang et al; 18-05210)
- Pedestrian safety indicator threshold (Abou-Senna et al; 18-05479)

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

- Rural two-lane roads (Wali et al; 18-00064)
- Freeway segments (Wang et al; 18-02533) (Lee et al; 18-05114)
- Urban roads of different types ((Wang et al; 18-05210)
- Pedestrian and bicycle crashes for a city (Osama et al; 18-01280) (Shirani et al. 18-03065)
- Pedestrian crashes in rural and small urban areas (Jamali and Wang; 18-05575)
- Pedestrian and bicycle crashes at intersections and segments in a state (Wang et al; 18-00738)
- Animal vehicle collisions (Yang et al; 18-01388)
- Total, serious injury, minor injury, and pedestrian and bicycle crashes in a city (Amoh-Gyimah et al; 18-02234)
- Hit and run crashes (Liu et al; 18-03009)
- Network screening at a country level (Ambros et al; 18-02011)

Authors	Behram Wali, University of Tennessee, Knoxville Asad Khattak, University of Tennessee, Knoxville Xiaobing Li, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-00064
Paper Title:	Exploring Nonlinear Dependencies in Correlates of Roadway Crashes: Application of Generalized Additive and Piecewise Linear Count Data Models
Abstract:	For practical considerations, Annual Average Daily Traffic (AADT) and segment length are often used as the main correlates for predicting crash frequencies on segments. Typically, a linear or simple non-linear dependence of crash frequencies on traffic exposure related factors is assumed which may not realistically represent the underlying complexity embedded in crash data, generated by physical and social elements of transportation systems. The objective of the current study is to investigate and quantify the extent of nonlinear dependencies of crash frequency on traffic exposure related factors. Using rural two-lane two-way crash data in Tennessee, Negative Binomial Generalized Additive Models (NBGAMs) models are developed for estimating total crashes and total injury crashes. Then, the advanced nonlinear modeling framework is connected to practice by utilizing the knowledge generated by NBGAMs in simpler Piecewise Linear Negative Binomial (PLNB) models. Additional data on important correlates are collected and incorporated in NBGAM and PLNB frameworks to address the issue of omitted variables. The modeling results show that the relationship between crash frequencies (total crashes and total injury crashes) and AADT is clearly non-linear. Importantly, the non-linear dependency of crash frequencies on segment length is even more complex. As compared to negative binomial models, the goodness-of-fit statistics indicate the significant potential of NBGAMs and PLNB models in approximating complex non-linear relationships, whereas the gains in prediction accuracy for PLNB models are approximately similar (and in some cases better) than NBGAMs. Important practical implications of results are presented with respect to rural two-lane two-way road safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01280
Paper Title	A Novel Technique to Identify Hot Zones for Active Commuters Crashes
Abstract	This paper presents an approach to identify and rank accident-prone (hot) zones for active transportation modes. The approach aims at extending the well-known empirical Bayes (EB) potential for safety improvement (PSI) method to cases where multiple crash modes are modeled jointly (multivariate modeling). In this study, crash modeling was pursued with a multivariate model incorporating spatial effects and using the full Bayes (FB) technique. Cyclist and pedestrian crash data for the city of Vancouver (British Columbia, Canada) were analyzed for 134 traffic analysis zones (TAZs) to detect active transportation hot zones. The hot zones identification (HZID) process was based on the estimation of the Mahalanobis distance, which can be considered an extension to the PSI method in the context of multivariate analysis. In addition, a negative binomial model was developed for cyclist and pedestrian crashes, where the EB PSI for each mode crash was quantified. The cyclist and pedestrian PSIs were combined to detect active transportation hot zones. Overall, the Mahalanobis distance method is found to outperform the PSI method in terms of results' consistency; and inconsistency is observed between the hot zones identified using both approaches

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01388
Paper Title	Modeling Animal–Vehicle Collisions Using Empirical Bayes Method Based on the Negative Binomial Models
Abstract	Two common types of animal-vehicle collision data (reported animal-vehicle collision (AVC) data and carcass removal data) are usually collected and recorded by the transportation management agencies today. Previous studies have found that these two datasets often demonstrate different characteristics. To accurately identify the dangerous animal-vehicle collision sites, it is important to compare the Empirical Bayesian (EB) estimates using these two datasets. The objective of this study is to compare the differences in hotspot identification and the effect of explanation variables between carcass removal and reported AVCs. To complete the objective, both the traditional negative binomial (NB) model and the generalized negative binomial (GNB) are applied in calculating the EB estimates using the animal accident data collected on ten highways in Washington State. The important conclusions can be summarized as follows: (1) the explanatory variables have different effects on the occurrence of carcass removal and reported AVC data. (2) The ranking results from EB estimates when using the carcass removal and reported AVC data differ significantly.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01974
Paper Title	The Optimal Sliding Window Length and Increment Length for Identifying Hazardous Road Segments
Abstract	In recent years, Europe and U.S have widely adopted sliding window method to identify hazardous road segments, because this way can be easily operated and coded. However, when sliding window method is used, if the length of sliding window or increment is inappropriate, there will be two common problems: hazardous road segments are omitted or exaggerated. This paper aims to investigate the optimal lengths of sliding window and increment. The influence of lengths of sliding window and increment on the identification results of hazardous road segments is disscussed, and the optimal window lengths and increment lengths are determined by using quantile method and graphic method in this paper. Two methods are tested to prove their reliability in a novel and more practical way. Research indicates that different lengths of sliding window should correspond to different identification criteria; the longer sliding window length is, the greater possibility of exaggerating hazardous road segments will have; the bigger increment length is, the greater possibility of omitting hazardous road segments will have; and in respect of determination of the optimal length of sliding window and increment by using quantile method, the optimal combination is that increment length is half of the window length. Findings of this paper show that both quantile method and graphic method are feasible to optimize the traditional sliding window method and when the window length is smaller, the graphic method is more reliable than quantile method.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-02234
Paper Title	Application of Random Parameter Macroscopic Safety Models for Hot Zone Identification: A Case for Melbourne, Australia
Abstract	This study uses random parameter negative binomial model (RPNB) for crash risk hot zone identification. Potential for Safety Improvement (PSI) is adopted as a measure of the crash risk. Using road crash data from Melbourne, Australia (2010-2012), safety performance functions (SPFs) are developed for total, serious injury, minor injury, and pedestrian and bicycle crashes. The SPFs are developed at two different spatial aggregation levels for comparison. Three screening categories are also developed from the PSI for the hot zone screening. A comparison of the identified hot zones with different spatial aggregation shows significant differences in their spatial distribution. The location of the identified hot zones from one spatial aggregation does not necessarily match with similar locations in the other spatial aggregation level. However, both spatial units indicate the presence of hot zones that requires attention and treatment to improve safety. Overall, the study demonstrates an application of random parameter macroscopic safety models and PSI measures to identify hot zones in a large metropolitan area.

Authors	Jun Liu, University of Texas, Austin Asad Khattak, University of Tennessee, Knoxville Cong Chen, USF Center for Urban Transportation Research Dan Wan, City College of New York Jiaqi Ma, University of Cincinnati Jia Hu, Tongji University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-03009
Paper Title	Revisiting Hit-and-Run Crashes: A Geospatial Modeling Method
Abstract	Hit-and-run crashes often delay emergency response and may result in increasing/secondary harms/damages to the victims involved in the crash. Almost all states in United States have laws regarding hit-and-run crashes. Previous studies have extensively explored the stationary correlates of hit-and-run crashes. In order words, the relationships between associated factors and hit-and-run are constant in all over the study region (e.g., a state or country), resulting in uniform strategies/recommendations (to prevent hit-and-run behavior) for the entire region. However, hit-and-run crashes (perhaps all traffic crashes) involve complex mechanisms between driver and driving/traffic environment which are likely influenced by the diverse social and geographic contexts. In addition, hit-and-run can be a societal concern, because of not only its consequences to victims but also negative impacts on safety cultures in local communities. Therefore, it may be more appropriate to understand the local correlates of hit-and-run crashes and specify strategies/recommendations to local communities or corridors. This study revisited hit-and-run crashes through a geo-spatial modeling approach, specifically, Geographically Weighted Regression (GWR) using geo-referenced crash data from Southeast Michigan Council of Governments. The data cover all types of motor vehicle crashes (N= 138,529) that occurred in Southeast Michigan, including 20,813 hit-and-run crashes. This study presented the results from both traditional regression and GWR models. GWR model results can be mapped in spatial domain, and the maps offer visual insights about the spatially varying correlates of hit-and-run crashes, which are not available from previous studies. Results from traditional binary logit model are generally consistent with findings in previous studies. For example, hit-and-run was more likely to occur on weekends or during nighttime (especially without street lights on).Driving under impairment (DUI) was bonded with a higher likelihood of hit-and-run. GWR models also uncovered spatially varying correlates of hit-and-run. For example, crashes in northwest of Detroit metropolitan area were associated with an even greater hit-and-run likelihood than those in other parts in this area. In addition, the local socio-economic factors were included in the analysis. Results show that hit-and-run was more likely to occur in census tracts with a higher unemployment rate, a lower household income, a smaller portion of college-educated population and a greater population density. The study demonstrates a way of making sense of geo-referenced traffic safety data. Geo-spatial modeling method is useful for prioritizing specific geographic regions/corridors for traffic safety improvements, which outperforms traditional modeling techniques.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-03065
Paper Title	Safety Investigation of Nonmotorized Crashes in the City of Huntsville, Alabama, Using Count Regression Models
Abstract	While walking and cycling can be enjoyable, there is a potential safety risk associated with these modes, especially when interacting with automobiles. This study contributes to the safety of non-motorized transportation by applying and comparing three zero-inflated count models for each of bike and pedestrian crashes, specifically the zero-inflated negative binomial (ZINB) and the zero-inflated Poisson (ZIP). Note that the ZINB was examined with two different variance types, which were the standard ZINB and the modified one including a different variance estimator. In this study, sociodemographic (e.g., school enrollment and number of households), traffic (e.g., traffic volume and speed limit), and infrastructure or built environment variables (e.g., sidewalk length) were used. Five-year bike and pedestrian crashes (2010 through 2014) in 368 traffic analysis zones (TAZs) in the city of Huntsville, Alabama were used. The performance of the six fitted count models was compared based on the prediction performance and goodness-of-fit statistics. The prediction accuracy have included the mean

absolute deviance (MAD) and the mean square prediction error (MSPE). The standard ZINB outperformed the corresponding ZINB type and the ZIP one for both bike and pedestrian crashes (especially in the relatively higher MAD and MSPE estimates, which represents higher prediction performance). The fitted regression models for both bike and pedestrian crashes in Huntsville showed that there was an increase in crashes with the increase in traffic volume, number of households, and number of retails. The results of the fitted count models are deemed useful for decision makers to identify and predict high-risk zones for bicyclists and pedestrian crashes in a city or county, and in other areas having similar traffic and sociodemographic characteristics.

Authors	Amir Jamali, Montana State University Yiyi Wang, Montana State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05575
Paper Title	Pedestrian Crash Hotspot Identification Using Two-Step Floating Catchment Area Method and Machine Learning Tools for Rural and Small Urban Areas
Abstract	The crash hotspots identification is a primary step in traffic safety program. It provides a list of prioritized locations for further investigation, which contributes to recognize the crash causes and specifies the effective countermeasures. This study utilized the two-step floating catchment area (2SFCA) method, which has been widely used in medical fields, to identify high risk locations in rural and small urban areas. The 2SFCA method can account simultaneously for spatial heterogeneity, crash severity level and pedestrian exposure. This study used common grid cells for both crash locations and pedestrian areas rather than using a predefined administrative boundary because crash locations influence area is limited to neighboring blocks. The Moran's I test showed there was significant spatial dependence among grid cells. The results confirmed this methodology performed perfectly to identify crash prone locations and reduce the errors associated with simple hotspot identification methods. In addition, this study used K-Nearest Neighbor (KNN) algorithm, which is a non-parametric machine learning technique, to estimate pedestrian exposure. The results revealed that K-NN showed improvement over the statistical models (i.e., negative binomial, zero inflated, and finite mixture) due to evaluation criteria. The proposed methodology can be used in safety programs to enhance the roadway network safety for traffic network users.

Authors	Yi Wang, Portland State University Christopher Monsere, Portland State University Chen Chen, Oregon State University Haizhong Wang, Oregon State University
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00738
Paper Title	Development of a Crash Risk Scoring Tool for Pedestrian and Bicycle Projects in Oregon
Abstract	Methods for identifying and prioritizing high-crash locations for safety improvements are generally crash-based. There are fewer reported crashes involving non-motorized users and in most states, reported crashes must involve a motor vehicle. This means that minor, non-injury events are not reported and those crashes that are reported, tend to be more severe. Selecting projects based only on crash performance is sometimes limiting for these crash types and predicting where these crashes will occur next is also a challenging task. An alternative to crash-based selection is to develop risk-based criteria and methods. This paper presents the results of a research effort to develop a risk-scoring method with weights derived from data for use in project screening and selection in Oregon. To develop the risk model, data were collected from 188 segments and 184 intersections randomly selected on both state and non-state roadways. Geometric, land use, volume, and crash data were collected from Google Earth, EPA's Smart Location Database and the ODOT crash database from 2009-2013. The sample included 213 bicycle and pedestrian crashes on the segments and 238 at intersections. Logistic regression models were developed and the outputs used to create pedestrian and bicycle risk-scoring tools for segments and intersections. The risk-scoring tool was applied to safety projects identified in the 2015 All Roads Transportation Safety (ARTS) project lists from Oregon. The risk scores for the case study applications aligned reasonably well with the project's benefit-costs estimates.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-01655
Paper Title	Hotspot Identification in an Urban Network: A Comparison Among Four Different Techniques
Abstract	Knowing where clusters of accidents occur would provide us great occasion to figure out the real causes of them and the processes occurring in these areas. However, it can be really difficult to realize and evaluate the real patterns latent in the crash database and identify the locations that require further consideration. Since now, several studies have been conducted on this issue; however, all principles and techniques used in this process are still not fully realized. In this regard and within this study, different types of hotspot identification methods consisted of Point Density Estimation (PDE), Kriging, Inverse Distance Weighted (IDW), and Spline have been developed and evaluated and subsequently compared using a particular index called Prediction Accuracy Index (PAI). Also, four categories of accident risk were defined to label different locations of the map as high, medium, low and no accident risk. The accident data for this research were collected from the database of police information technology center of Mashhad, Iran that includes 40,096 accidents recorded within 3 years (from March 21, 2012 to March 21, 2015). Results indicated that, based on the amount of PAI, IDW is the most accurate method followed by Spline, PDE, and Kriging. The present paper showed that although PAI is a useful index to find the accuracy of each method for hotspot detection, more considerations are required to be taken into account for the assessment of the efficiency of a method.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02011
Paper Title	Safety Screening of Czech Core Road Network
Abstract	Czech motorways and national roads present the core road network, which is critical in terms of ensuring operation and maintenance, as well as safety. In this context, there was an interest in safety screening of Czech core road network. Consistently with state-of-the-art literature, this necessitated developing safety performance functions for all types of network elements (road segments, intersections, interchanges, etc.), and using them to identify and rank hotspots. Unlike a number of similar international studies, which usually dealt only with a selected road category, the study focused on the whole network, including intersections and interchanges. The authors conducted own traffic survey, collected and processed all necessary data, and used them to develop 7 safety performance functions. These not only enabled identification of hotspots, but also interpretation of effect of statistically significant risk factors. Obtained results were mostly consistent with literature, for example as to the effects of exposure variables; on the other hand, several variables did not have sufficiently significant effect or yielded unexpected results, for example regarding the effects of traffic control devices.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02533
Paper Title	Hotspot Identification for Freeways Considering Difference in Single- and Multiple-Vehicle Crashes
Abstract	Previous studies found that the spatial distributions of Single-vehicle (SV) and Multi-vehicle (MV) crashes are quite different, but there has not been much research on hotspots identification considering differences in SV and MV crashes. This study identified hotspots of SV, MV and total crashes separately, using road design data, traffic operational data and crash data collected from a 45-km freeway segment in Shanghai. Full Bayes Poisson Lognormal regression models were developed for SV, MV and total crashes and the potential for safety improvement (PSI) was used to rank hotspots. Model estimation results showed that the significant influencing factors vary in different crash types. Hotspots identification results demonstrated that hotspots of SV crashes are quite different from MV crashes. For example, only three of the top ten hotspots were shared by both SV and MV crashes. Additionally, hotspots of total crashes have a higher consistency with MV crashes than with SV crashes, indicating that a majority of SV crash hotspots may be ignored if total crashes are used to identify hotspots. These conclusions prove the necessity to differentiate SV and MV crashes for hotspot identification and conducting road safety management.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05114
Paper Title	High Collision Concentration Location Identification Method Based on Optimization Technique
Abstract	High Collision Concentration Location (HCCL) identification approach based on the highest number of excessive collisions included within the limited covered length of hotspots has been proposed in this paper. A bi-criteria optimization model is created to maximize Potential for Safety Improvement (PSI) and to minimize the covered length by detected sites after considering the bias that can be introduced in the model due to the regression-to-the-mean phenomenon. The model is solved using Dynamic Programming-based Screening (DPS) techniques. The algorithm is computationally feasible to the size of historic collision data and applied to two freeways sites in San Francisco, California. The performance of the proposed model has also been compared with Sliding Moving Window (SMW) and Continuous Risk Profile (CRP) methods are compared to the DPS. Findings indicate that DPS can outperform both SMW and CRP in selecting sites with maximum PSI per unit distance.

Authors	Kai Wang, Connecticut Transportation Safety Research Center Shanshan Zhao, University of Connecticut John Ivan, University of Connecticut ISHRAQ RAYEED AHMED Eric Jackson, University of Connecticut
Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05210
Paper Title	Evaluation of Hot-Spot Identification Methods for Municipal Roads
Abstract	Estimating crash prediction models and applying the Empirical Bayesian approach in identifying hot spots for roads under municipal jurisdiction is often challenging due to the lack of traffic count data. This study presents five hot spot identification (HSID) methods in which AADT information is not required (*i.e.* crash frequency (CF), equivalent property damage only (EPDO), relative severity index (RSI), excess predicted average crash frequency using method of moments (MOM) and cross sectional analysis (CSA)), to identify hot spots for road segments under municipal jurisdiction in Connecticut. The segments were categorized into eleven homogenous groups based on the roadway geometric characteristics. The five HSID methods were applied to all segments in each roadway group separately and across the entire State for a systemic analysis. Four quantitative tests (*i.e*. site consistency test (SCT), method consistency test (MCT), total rank difference test (TRDT) and total score test (TST)) were used to compare the performance of the five HSID methods. The results indicate that the MOM outperforms others in identifying hot spots for urban one-way arterials, urban one-way local roads, urban two-lane two-way local roads, urban multilane two-way arterials, and urban multilane two-way collectors; the CF outperforms others for rural arterials and collectors, rural local roads, urban one-way collectors, urban two-lane two-way arterials, urban two-lane two-way collectors and urban multilane two-way local roads, and the CSA performs best in all of the five HSID methods in identifying and ranking the roadway hot spots for all roadway groups together.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05479
Paper Title	Safety Prioritization Tool for Sidewalk and Bike-Lane Gaps
Abstract	Pedestrian sidewalks and bicycle lanes in Florida are not continuous, and there is a concern among planners and engineers in the FDOT that these gaps constitute discontinuity of flow and are potentially posing threats to pedestrian and bicycle safety. Before these agencies attempt to develop a prioritization program to decide on which gaps need to be addressed, it was logical to carry out an analysis that investigates the correlation between safety and sidewalk/bicycle-lane gaps. The previous research concluded that absence of sidewalk along roadway segments is one of the main factors that have a significant impact on the expected number of pedestrian crashes at a specific location. This paper builds on the previous task's results to develop a safety prioritization tool to address the gaps. The developed tool takes into account the above-mentioned parameters as well as other pedestrian-related activity variables and proximity to generators using land use, income, and auto ownership data. The prioritization method was based on a multi-criterion ordinal ranking of the parameters of five main modules, using a scoring system that combines all criteria weights then aggregates them into a single indicator. The five main modules comprise roadway and traffic data, socioeconomic data, land use data, transit, and crash data. The need for roadway segment safety improvement was ranked according to its roadway pedestrian safety indicator (RPSI) threshold and categorized into five categories. The Sidewalk/Bike-Lane Gaps Safety Prioritization Tool (SBLPT) has the capability to generate sidewalk/bike-lane gap maps that can be viewed in Google Earth ®.

4 Safety Performance Functions

Mohamed Abdel-Aty, Qing Cai, Ahmed Farid, University of Central Florida (UCF)

Studies involving safety performance functions (SPFs) are intended to model crash counts, also known as frequencies, as functions of crash contributing factors and to infer the influences of the factors on such counts. The subcommittee identified forty-three papers, which are classified as those pertaining to the use of SPFs. The manuscripts may be classified by the type of roadway facility analyzed, type of crashes analyzed, whether vehicle or pedestrian/bicyclist crashes, methodological framework implemented, and pratical applications.

Many studies have been conducted for **non-motorist crash analysis** (18-00123, 18-01759, 18-02977, 18-02980, 18-03065, 18-04741, 18-05593, 18-05685, and 18-06535). When it comes to the **classification of the manuscripts by roadway facility**, several papers study crash counts on segments from different perspectives such as weather impact on freeway crashes (18-01509), effects of pavement surface roughness (18-02152), impact of speed variations on freeway crashes (18-02721), and bicycle safety (18-02980). Some studies conduct analysis at intersections. For example, in the study, 18-04956, crash counts at an interchange, a signalized intersection and a rural two-lane road are predicted. In manuscript, 18-06535, pedestrian crashes are analyzed at signalized intersections while in the study, 18-05593, pedestrian crashes are modeled at both signalized and un-signalized intersections. In two other studies (18-04583 and 18-05552), pedestrian crashes at mid-block locations are investigated. In addition to analyzing crashes on segments and intersections separately, a study (18-01739) explores the effect of corridors containing intersections and segments by using a spatial hierarchical joint model. Furthermore, integrated models are proposed to estimate SPFs at the microscopic (segments and intersections) and macroscopic (zones) levels simultaneously (18-00109 and 18-00658).

Other than the categorization of the research papers by roadway facility and crash type, it is crucial to discuss the various **innovative methodologies** implemented by the research teams composing the papers. The paper 18-00058 develops negative binomial generalized additive models to analyze total crashes and total injury crashes. Additionally, the unobserved heterogeneity was considered in several studies by implementing random parameters models (18-02152, 18-02234, 18-04741, and 18-03189). In the study 18-05071 multiple count modeling methods are employed with the spatial heterogeneity effects considered. Similarly, the research team of the study 18-05889 implemented three Bayesian Poisson log-normal models each with different configuration of time trend characteristics and interactions. The interactions are of spatial and temporal features. In the manuscript 18-05331 use of a joint approach uniting the neural network model with wavelet analyses for crash count prediction is documented. In another manuscript 18-03528 the authors used multivariate adaptive regression splines (MARS) for modeling crash frequencies. The study 18-04562 uses the

geographically weighted Poisson (GWP) model to examine the influence of land use trends on crash counts. Mixed effects negative binomial (NB) regression (18-04815) is used for evaluating fluctuations in crash counts by severity when posted speed limits are increased. Time series random parameter NB regression (18-05263) is also employed for predicting traffic crashes and it is found that monthly traffic volumes, among other features, has a considerable impact on monthly crash counts. In addition, a multivariate Dirichlet process mixture spatial regression model is used for predicting non-motorist crashes as well (18-05685). Furthermore, different modeling technologies have been proposed for modeling crash counts by collision types (18-01509, 18-02152, 18-02721, and 18-02952). It is critical to note the aspects that distinguish the study 18-05685. The authors of the study utilized big data to estimate crash frequencies by discerning the contributing factors that lead to crashes instead of implementing an SPF. This is a paradigm shift in the approach to predicting crash frequencies.

Lastly, the papers suggested **several application approaches** such as identification of hot zones (18-01280, 18-02234, and 18-02533), prediction of future traffic safety (18-01759, 18-02293, and 18-06727), screening of sites for animal-vehicle collisions (18-01388), correlation of crash frequency and real-time risk modeling for expressways (18-00800), effects of driving volatilities on crash risk at intersections (18-00058 and 18-00089), and transferability of SPFs (18-00144 and 18-00618).

Information on the research papers in which SPFs are implemented is presented as follow.

Authors	Akinfolarin Abatan, Iowa State University Peter Savolainen, Iowa State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	575
Session Title	Highway Safety Performance
Paper Number	18-00011
Paper Title	How is Driving Volatility Related to Intersection Safety in a Connected Vehicles Environment?
Abstract	The emerging connected and automated vehicles (CAV) technology provides a promising opportunity for investigating intersection safety more from a proactive perspective. Driving volatility captures the extent of variations in instantaneous driving decisions when a vehicle is being driven. This study develops a fundamental understanding of microscopic driving volatility and how it relates to unsafe outcomes at intersections. Using real-world connected vehicle data from the Safety Pilot Model Deployment in Ann Arbor, Michigan, intersection-specific volatility indices are calculated for 116 intersections by analyzing more than 62 million real-world Basic Safety Messages transmitted between thousands of instrumented vehicles. The large-scale CAV data is then linked to detailed intersection data containing crashes, traffic exposure, and other geometric features. By using coefficient of variation of speed as a relative measure of driving volatility, descriptive analysis is performed to spot differences between driving volatility at signalized and un-signalized intersections. Then, in-depth statistical analysis is conducted separately for all intersections and signalized intersections only. Given the important methodological concern of unobserved heterogeneity, hierarchical fixed- and random-parameter Poisson and Poisson log-normal models are estimated under a Full Bayesian Gibbs sampling setting. For all intersections, a one-percent increase in driving volatility is associated with a 0.37 percent increase in crash frequency. Importantly, the relationship between driving volatility and crash frequency is more pronounced for signalized intersections. Several of the exogenous factors are found to be normally distributed random parameters, suggesting that the effects of such variables vary across different intersections. The practical implications of the findings are discussed.

Authors	Emira Rista, Texas A&M Transportation Institute Timothy Barrette, Texas A&M Transportation Institute Peter Savolainen, Iowa State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	575
Session Title	Highway Safety Performance
Paper Number	18-00013
Paper Title	Safety Performance of Median U-Turns on Urban Boulevards
Abstract	Congestion continues to be a primary concern on urban and suburban road corridors. This is particular true at high-volume intersections, where left-turning vehicles introduce pronounced operational and safety issues. High left-turn volumes are generally difficult to accommodate at traditional signalized intersections and, as such, alternative intersection designs have become a viable alternative to mitigate issues related to both safety and operations. Median U-turn (MUT) intersections are one example of such an alternative intersection design, where direct left-turns from the major and/or minor road approaches are eliminated. Drivers must turn right through the primary at-grade intersection and then execute a U-turn downstream of the intersection in order to complete a left-turn maneuver. While the operational advantages of MUTs are well established, the safety impacts have been relatively under researched. This study examines the safety performance of corridors where MUTs are present along four-, six-, and eight-lane urban arterials. Random effects negative binomial regression models are estimated to examine the impacts of MUTs on the safety performance of the primary intersections, as well as the adjacent road segments where the left-turning traffic is diverted. The results show the presence of MUTs and the prohibition of left turns are associated with significantly fewer crashes at the intersection-level. On a segment-level, crashes are found to increase with the density of MUTs, though these increases are less pronounced as compared to the reductions experienced at intersections. Ultimately, the results provide empirical support for the continuing installation of MUTs.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring and Refining Methods in Highway Safety
Paper Number	18-00058
Paper Title	How is Driving Volatility Related to Intersection Safety in a Connected Vehicles Environment?
Abstract	The emerging connected and automated vehicles (CAV) technology provides a promising opportunity for investigating intersection safety more from a proactive perspective. Driving volatility captures the extent of variations in instantaneous driving decisions when a vehicle is being driven. This study develops a fundamental understanding of microscopic driving volatility and how it relates to unsafe outcomes at intersections. Using real-world connected vehicle data from the Safety Pilot Model Deployment in Ann Arbor, Michigan, intersection-specific volatility indices are calculated for 116 intersections by analyzing more than 62 million real-world Basic Safety Messages transmitted between thousands of instrumented vehicles. The large-scale CAV data is then linked to detailed intersection data containing crashes, traffic exposure, and other geometric features. By using coefficient of variation of speed as a relative measure of driving volatility, descriptive analysis is performed to spot differences between driving volatility at signalized and un-signalized intersections. Then, in-depth statistical analysis is conducted separately for all intersections and signalized intersections only. Given the important methodological concern of unobserved heterogeneity, hierarchical fixed- and random-parameter Poisson and Poisson log-normal models are estimated under a Full Bayesian Gibbs sampling setting. For all intersections, a one-percent increase in driving volatility is associated with a 0.37 percent increase in crash frequency. Importantly, the relationship between driving volatility and crash frequency is more pronounced for signalized intersections. Several of the exogenous factors are found to be normally distributed random parameters, suggesting that the effects of such variables vary across different intersections. The practical implications of the findings are discussed.

Authors	Behram Wali, University of Tennessee, Knoxville Asad Khattak, University of Tennessee, Knoxville Xiaobing Li, University of Tennessee, Knoxville
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-00058
Paper Title	Exploring Nonlinear Dependencies in Correlates of Roadway Crashes: Application of Generalized Additive and Piecewise Linear Count Data Models
Abstract	For practical considerations, Annual Average Daily Traffic (AADT) and segment length are often used as the main correlates for predicting crash frequencies on segments. Typically, a linear or simple non-linear dependence of crash frequencies on traffic exposure related factors is assumed which may not realistically represent the underlying complexity embedded in crash data, generated by physical and social elements of transportation systems. The objective of the current study is to investigate and quantify the extent of nonlinear dependencies of crash frequency on traffic exposure related factors. Using rural two-lane two-way crash data in Tennessee, Negative Binomial Generalized Additive Models (NBGAMs) models are developed for estimating total crashes and total injury crashes. Then, the advanced nonlinear modeling framework is connected to practice by utilizing the knowledge generated by NBGAMs in simpler Piecewise Linear Negative Binomial (PLNB) models. Additional data on important correlates are collected and incorporated in NBGAM and PLNB frameworks to address the issue of omitted variables. The modeling results show that the relationship between crash frequencies (total crashes and total injury crashes) and AADT is clearly non-linear. Importantly, the non-linear dependency of crash frequencies on segment length is even more complex. As compared to negative binomial models, the goodness-of-fit statistics indicate the significant potential of NBGAMs and PLNB models in approximating complex non-linear relationships, whereas the gains in prediction accuracy for PLNB models are approximately similar (and in some cases better) than NBGAMs. Important practical implications of results are presented with respect to rural two-lane two-way road safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-00089
Paper Title	What Measures of Driving Volatilities Best Explain Crash Frequency at Intersections?
Abstract	While the term “volatility” is commonly used in finance, the emergence of high frequency connected and automated vehicles (CAV) data provides the opportunity to define and explore the concept of “driving volatility.” As volatility and other measures of dispersion and variation can be computed through different ways, in this paper, several measures of driving volatility are defined and calculated using vehicles’ instantaneous speed, acceleration, and jerk at 116 intersections from Michigan Safety Pilot connected vehicle (CV) data. These volatilities represent newly available surrogate measures of safety. Volatility data are integrated with intersection historical crash and inventory data to investigate what measures of driving volatility are associated with crash frequencies at these intersections. First, the data was error-checked and verified for accuracy. Given that crash frequency is count data, fixed and random parameter Poisson regression models are estimated. According to the modeling results, three measures of driving volatility are found to be positively associated with the number of the crashes at intersections. Other correlated and significant variables are average annual daily traffic, signalization, and 4-legged intersections. The identified measures of volatilities can be used to locate intersections with high driving volatilities, i.e., hot-spots where the crashes are waiting to happen. Therefore, pro-active safety countermeasures can be considered to reduce drivers’ volatility, making the intersections safer.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	575
Session Title	Highway Safety Performance
Paper Number	18-00109
Paper Title	Transferring and Calibrating Safety Performance Functions Among Multiple States
Abstract	Safety performance functions (SPFs), which are statistical regression models, by predicting traffic crash counts by crash type, severity and facility type, aid traffic engineers in the process of identifying high frequency crash locations. Developing SPFs requires the collection and processing of traffic, crash, road design and other characteristics data. Jurisdiction agencies may choose not to develop their own SPFs and cut down on their resources by adopting SPFs provided by the national Highway Safety Manual (HSM). The HSM also provides a technique to calibrate the HSM's SPFs to the specific jurisdiction's conditions. Yet, the technique is subject to criticism. This study is aimed at exploring the transferability of SPFs of Florida, Ohio, Illinois, Minnesota, California, Washington and North Carolina's rural divided multilane highway segments. The SPFs are negative binomial (NB) models as are those provided by the HSM. We address the fault of instinctively applying the HSM's SPFs to a particular locality without verifying whether the SPFs are transferable to the locality and compare different states. Remarkably, it is found that Ohio, Illinois, Minnesota and California's SPFs are mutually transferable for specific crash categories. In addition, in this study, two calibration techniques are proposed as alternatives to that of the current HSM. One of proposed techniques is shown to be more accurate than the HSM's.

Authors	Michael Rodriguez, Smart Growth America Samuel Sklar, Smart Growth America Heather Zaccaro, Smart Growth America
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-00123
Paper Title	Dangerous by Design, Statistically Speaking: Pedestrian Fatalities and Ubran Design
Abstract	There were 46,149 pedestrian fatalities resulting from automobile-pedestrian crashes in the U.S. from 2005 to 2014. While the transportation literature has explored various factors related to fatal crashes, this analysis fills a gap with an emphasis on pedestrian fatalities. We constructed a dataset from the Fatality Analysis Reporting System (FARS), the EPA Smart Location Database, and the Census ACS to assess the factors that explain the incidence of pedestrian fatalities at the Census Block Group level. For our analysis, we examined the metropolitan Washington, D.C. region from 2005 to 2014. We ask: to what extent do measurements of urban design influence the prevalence of pedestrian fatalities? We identify infrastructure, demographic, and geographic variables to specify our models. We then conducted Poisson, zero-inflated Poisson (ZIP), negative binomial (NB), and zero-inflated negative binomial (ZINB) regressions to test the relationship, and find the NB model to be the most appropriate. We also test for sensitivities by including and excluding pedestrian fatalities on interstate and other highways. Our findings show that the density of auto-oriented roadways was associated with more pedestrian fatalities; while the density of pedestrian-oriented roadways was associated with fewer pedestrian fatalities. Residential density was also associated with fewer pedestrian fatalities. Third, we find that wealthier areas would expect fewer pedestrian fatalities, while areas with more people of color would expect more pedestrian fatalities. These findings support the conclusion that urban design – the type of roadway infrastructure provided - matters in the prevalence of pedestrian fatalities.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00144
Paper Title	Integrating Macro- and Microlevel Safety Analyses: A Bayesian Approach Incorporating Spatial Interaction
Abstract	Crash frequency analysis is a crucial tool to investigate transportation safety problems. Traditionally, crash frequency analyses have been undertaken at the macro- and micro-levels, independently. If conducted in the same study area, the macro- and micro-level crash analyses should investigate the same crashes but by aggregating the crashes at different levels. Hence, the crash counts at the two levels should be correlated and integrating macro- and micro-level crash frequency analyses in one modeling structure might have the ability to better explain crash occurrence by realizing the effects of both macro- and micro-level factors. This study proposes a Bayesian integrated spatial crash frequency model, which links the crash counts of macro- and micro-levels based on the spatial interaction. In addition, the proposed model considers the spatial autocorrelation of different types of road entities (i.e., segments and intersections) at the micro-level with a joint structure. Two independent non-integrated models for macro- and micro-levels were also estimated separately and compared with the integrated model. The results indicated that the integrated model can provide better model performance for estimating macro- and micro-level crash counts, which validates the concept of integrating the models for the two levels. Also, the integrated model provides more valuable insights about the crash occurrence at the two levels by revealing both macro- and micro-level factors. It is expected that the proposed integrated model can help practitioners implement more reasonable transportation safety plans and more effective engineering treatments to proactively enhance safety.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	575
Session Title	Highway Safety Performance
Paper Number	18-00618
Paper Title	Exploration of Macrolevel Effects for Segment and Intersection Crash Modeling
Abstract	It is acknowledged that crash occurrence at segments and intersections could be affected by multilevel factors. Omission of important explanatory variables could result in biased and inconsistent parameter estimates. This paper contributes to the literature on traffic safety research for segments and intersections by examining the macro-level effects which are always excluded or ignored. A Bayesian hierarchical model is proposed to incorporate the macro-level factors including not only macro-level explanatory variables but also total segment- and intersection-crash counts aggregated based on zones. In addition, a joint modeling structure is adopted to investigate the spatial autocorrelation between intersection and their connecting segments. The proposed model is evaluated by comparing it with its three counterparts: a model considering micro-level factors only, one hierarchical model considering macro-level effects with random effect terms only, and one hierarchical model considering macro-level effects with explanatory variables based on zones. The results indicate that the models considering macro-level effects outperform the road entity crash models. In addition, the proposed model has improved performance, which validates the concept of considering macro-level effects through both explanatory variables and total crashes based on zones. In addition, significant spatial autocorrelation could be found between intersections and their connecting segments, supporting the modeling structure to analyze crashes at various types of road entities. Finally, the proposed model provides more valuable insights about the crash occurrence at segments and intersections by revealing both micro- and macro-level factors.

Authors	Ahmed Farid, University of Central Florida Mohamed Abdel-Aty, University of Central Florida Jaeyoung Lee, University of Central Florida
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	575
Session Title	Highway Safety Performance
Paper Number	18-00658
Paper Title	A Novel Approach for Calibrating Safety Performance Functions
Abstract	Safety performance functions (SPFs) are statistical regression models used for estimating crash counts by roadway facility classification. They are required in the process of assessing the effectiveness of safety countermeasures provided for hazardous crash sites in before-after analyses. Roadway agencies may opt to develop jurisdiction specific SPFs or borrow them from the national Highway Safety Manual (HSM) provided by the American Association of State Highway and Transportation Officials. In addition, the HSM suggests a simple technique to calibrate its SPFs to specific jurisdictions. A more recent calibration technique is similar to that of the HSM with a minor modification, also known as the calibration function. In this research, we develop SPFs for rural divided multilane highway segments for total crashes in seven states. The states are Florida, Ohio, Illinois, Minnesota, California, Washington and North Carolina. We also calibrate each SPF to all states using the HSM calibration method. Furthermore, we propose a combination of the HSM calibration method with hierarchical clustering. According to the goodness of fit results, our proposed calibration method is superior to the HSM's and the calibration function.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring and Refining Methods in Highway Safety
Paper Number	18-00800
Paper Title	Safety Analytics for Integrating Crash Frequency and Real-Time Risk Modeling for Expressways
Abstract	To find crash contributing factors, there have been numerous crash frequency and real-time safety studies, but such studies have been conducted independently. Until this point, no researcher has simultaneously analyzed crash frequency and real-time crash risk to test whether integrating them could better explain crash occurrence. Therefore, this study aims at integrating crash frequency and real-time safety analyses using expressway data. A Bayesian integrated model and a non-integrated model were built: the integrated model linked the crash frequency and the real-time models by adding the logarithm of the estimated expected crash frequency in the real-time model; the non-integrated model independently estimated the crash frequency and the real-time crash risk. The results showed that the integrated model outperformed the non-integrated model, as it provided much better model results for both the crash frequency and the real-time models. This result indicated that the added component, the logarithm of the expected crash frequency, successfully linked and provided useful information to the two models. This study uncovered few variables that are not typically included in the crash frequency analysis. For example, the average daily standard deviation of speed, which was aggregated based on speed at 1-minute intervals, had a positive effect on crash frequency. In conclusion, this study suggested a methodology to improve the crash frequency and real-time models by integrating them, and it might inspire future researchers to understand crash mechanisms better.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01280
Paper Title	A Novel Technique to Identify Hot Zones for Active Commuters Crashes
Abstract	This paper presents an approach to identify and rank accident-prone (hot) zones for active transportation modes. The approach aims at extending the well-known empirical Bayes (EB) potential for safety improvement (PSI) method to cases where multiple crash modes are modeled jointly (multivariate modeling). In this study, crash modeling was pursued with a multivariate model incorporating spatial effects and using the full Bayes (FB) technique. Cyclist and pedestrian crash data for the city of Vancouver (British Columbia, Canada) were analyzed for 134 traffic analysis zones (TAZs) to detect active transportation hot zones. The hot zones identification (HZID) process was based on the estimation of the Mahalanobis distance, which can be considered an extension to the PSI method in the context of multivariate analysis. In addition, a negative binomial model was developed for cyclist and pedestrian crashes, where the EB PSI for each mode crash was quantified. The cyclist and pedestrian PSIs were combined to detect active transportation hot zones. Overall, the Mahalanobis distance method is found to outperform the PSI method in terms of results' consistency; and inconsistency is observed between the hot zones identified using both approaches.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01388
Paper Title	Modeling Animal–Vehicle Collisions Using Empirical Bayes Method Based on the Negative Binomial Models
Abstract	Two common types of animal-vehicle collision data (reported animal-vehicle collision (AVC) data and carcass removal data) are usually collected and recorded by the transportation management agencies today. Previous studies have found that these two datasets often demonstrate different characteristics. To accurately identify the dangerous animal-vehicle collision sites, it is important to compare the Empirical Bayesian (EB) estimates using these two datasets. The objective of this study is to compare the differences in hotspot identification and the effect of explanation variables between carcass removal and reported AVCs. To complete the objective, both the traditional negative binomial (NB) model and the generalized negative binomial (GNB) are applied in calculating the EB estimates using the animal accident data collected on ten highways in Washington State. The important conclusions can be summarized as follows: (1) the explanatory variables have different effects on the occurrence of carcass removal and reported AVC data. (2) The ranking results from EB estimates when using the carcass removal and reported AVC data differ significantly.

Authors	Kai Wang, Connecticut Transportation Safety Research Center Shanshan Zhao, University of Connecticut Eric Jackson, University of Connecticut
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01509
Paper Title	Multivariate Poisson Lognormal Modeling of Weather-Related Crashes on Freeways
Abstract	Adverse weather conditions are one of the primary causes of motor vehicle crashes. To identify the contributing factors to crashes during adverse weather conditions and recommend cost-effective countermeasures, it is necessary to develop reliable crash prediction models to estimate weather-related crash frequencies. To account for the crash count variations among different adverse weather conditions, crash types and crash severities for both rain- and snow-related crashes, crash data on freeways was collected from the State of Connecticut, and crash prediction models were developed to estimate crash counts by crash type and severity for each weather condition. To account for the potential correlations among crash type and severity counts due to the common unobserved factors, the Integrated Nested Laplace Approximation (INLA) Multivariate Poisson Lognormal (MVPLN) models were developed to simultaneously estimate weather-related crashes counts by crash type and severity. To verify the model prediction ability, Univariate Poisson Lognormal (UPLN) models were estimated and compared with the MVPLN models. The results show that the impacts of crash contributors vary not only among different adverse weather conditions, but also among different crash types and severities. The crash types and severities are shown to be highly correlated and the model comparison verifies that the MVPLN models significantly improve the model prediction accuracy compared with the UPLN models. Therefore, the MVPLN model is recommended to provide more unbiased parameter estimates when estimating weather-related crashes by crash type and severity.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01739
Paper Title	Exploring the Effect of Different Neighboring Structures on Spatial Hierarchical Joint Crash Frequency Models
Abstract	Corridor safety analysis is a primary interest of many safety studies. Corridors contain mainly intersections and roadway segments. Having both components while analyzing corridors in addition to corridor-level variables in a hierarchical joint model would provide a comprehensive understanding of the existing corridor safety problems. Also, spatial correlation presence among road entities along corridors is probably high especially if distance between the road entities is not large. Therefore, it is crucial to consider the spatial effect in the model. However, this data structure is relatively new, and the best spatial weight matrix for this hierarchical spatial joint model is worthy of investigation. Therefore, this study aims to estimate a hierarchical Poisson-lognormal (HPLN) joint model with spatial effects and explore the effect of different neighboring structures. A total of thirteen HPLN joint models have been estimated, and these models are the HPLN joint model with corridor random effect and twelve HPLN joint models with spatial effects. Four types of conceptualization of spatial relationships were considered: (1) adjacency-based, (2) adjacency-route, (3) distance-order, and (4) distance-based spatial weight features. The results show the importance of incorporating the spatial effect in the model. It was found that having joint model is important since one of the best models is the adjacency-based first-order model, where the feeding road entities in addition to the directly adjacent road entity of the same type as the road entity of interest are considered. Lastly, the results confirm the importance of spatial autocorrelation between road entities along the same corridor.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-01759
Paper Title	Integrated Modeling Approach for Nonmotorized Mode Trips and Crashes in the Framework of Transportation Safety Planning
Abstract	In the recent decade, considerable efforts have been made to incorporate traffic safety into long-term transportation plans (LTTPs), which is often termed transportation safety planning (TSP). Although some researchers have attempted integrate transportation plans and safety by adopting transportation planning data (e.g., trip generation) for estimating traffic crash frequency at the macroscopic level, no studies have attempted to develop trip and safety models in one structure simultaneously. We suggest a Bayesian integrated multivariate modeling approach for estimating trips and crashes of non-motorized modes (i.e., walking and cycling). The American Housing Survey (AHS) data were collected from the U.S. Census Bureau and were used for the proposed approach. In the first part of proposed model, the probabilities of choosing walking and cycling modes were estimated, and the estimated probabilities were converted to trips by multiplying the number of sampled households. In the second part, the estimated trips are fed into crash prediction models (or safety performance functions) as an exposure variable. The modeling result revealed many contributing factors for pedestrian/bicycle trips and crashes. Also, we accounted for possible shared unobserved features between pedestrian and bicycle trips, and between pedestrian and bicycle crashes by adopting a multivariate structure. In addition, it was found that the crash models with the estimated exposures outperform those with the observed exposures. It is expected that integrated modeling approach for trips and crashes in this study will provide great insights into the future directions of TSP.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	359
Session Title	Lessons Learned in Safety Management: A Time to Reflect—Hybrid Session
Paper Number	18-01775
Paper Title	In-Depth Investigation of Factors That Contributed to the Decline in Fatalities from 2008 to 2012 in the United States
Abstract	Between 2005 and 2011, peak to trough, the number of traffic fatalities in the United States declined by 11,031, from 43,510 in 2005 to 32,479 in 2011. Most of the dramatic decline occurred from 2008 to 2012 which also coincided with the great economic recession and aftermath. The objective of this study is to provide a multidisciplinary analysis of the relative influence of the types of factors that contributed to this decline in the number of highway fatalities and fatality rates from 2008 to 2012. Two basic approaches were used to analyze the factors that were associated with the drop in traffic fatalities. The first approach developed a set of count models, using negative binomial models to examine the associations between predictors and raw fatality counts. The second approach, which is used to validate the first approach, used a log-change regression model, to examine the association between the change in predictor variables in one year with the change in the outcome variable (traffic fatalities) in the following year. The most significant contributors to the drop in traffic fatalities were the substantial increase in teen and young adult unemployment, decreased in beer consumption, and reduction in GDP/capita income. Vehicle design improvements also contributed to the decline significantly, as did the decline in rural vehicle-miles traveled (VMT) and increased strictness of DUI laws. State highway spending was not a significant contributor to the drop; the effect of changes in infrastructure was likely more cumulative and longer term. Changes in safety belt use rates and fuel prices were not significant contributors to the decline because they did not change much over the period.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring and Refining Methods in Highway Safety
Paper Number	18-02152
Paper Title	Comparative Analysis of Safety Impacts of Pavement Surface Roughness at Two-Lane and Multilane Highways: Accounting for Heterogeneity and Seemingly Unrelated Correlation Across Crash Severities
Abstract	For purposes of project evaluation, safety audits, and project appraisal, highway agencies seek to establish the relationship between road safety and road-related factors including pavement condition. In addition, agencies show interest in measuring and comparing the strength of the safety influence of pavement surface roughness across the different highway classes. To this end, this paper estimates random-parameters seemingly-unrelated negative binomial regression (RPSUNB) models to account for the unobserved heterogeneity and correlation in the crash frequency across three levels of crash severity. Also, univariate negative binomial models were estimated for both highway classes for the purposes of comparison with the RPSUNB models. It was found that at multi-lane highways, the pavement condition generally has a far more significant impact on the number of crashes compared to two-lane highways. This result could be due to the effect of risk compensation where drivers offset the safety hazard associated with inherently less safe situations by driving more carefully. For both highway classes, a number of traffic and road geometric covariates were found to significantly influence the number of crashes of various severities. In addition, the RPSUNB models outperform their univariate counterparts, thus confirming the efficacy of the former in addressing seemingly-unrelated correlation among the three severity levels. In sum, the paper throws more light on the effects of pavement roughness on highway crashes and establishes that the influence of this crash factor differs significantly across two-lane and multi-lane roads. The results can be useful in road safety audits, evaluation of the safety impacts of past or anticipated projects that improve in pavement condition, and assessing the safety consequences of delayed pavement rehabilitation.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-02234
Paper Title	Application of Random Parameter Macroscopic Safety Models for Hot Zone Identification: A Case for Melbourne, Australia
Abstract	This study uses random parameter negative binomial model (RPNB) for crash risk hot zone identification. Potential for Safety Improvement (PSI) is adopted as a measure of the crash risk. Using road crash data from Melbourne, Australia (2010-2012), safety performance functions (SPFs) are developed for total, serious injury, minor injury, and pedestrian and bicycle crashes. The SPFs are developed at two different spatial aggregation levels for comparison. Three screening categories are also developed from the PSI for the hot zone screening. A comparison of the identified hot zones with different spatial aggregation shows significant differences in their spatial distribution. The location of the identified hot zones from one spatial aggregation does not necessarily match with similar locations in the other spatial aggregation level. However, both spatial units indicate the presence of hot zones that requires attention and treatment to improve safety. Overall, the study demonstrates an application of random parameter macroscopic safety models and PSI measures to identify hot zones in a large metropolitan area.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02293
Paper Title	Stratified Crash Fatality Prediction Models for Developing Targeted Safety Strategies
Abstract	In South Korea, the Korea Transportation Safety Authority (KTSA) conducts the Special Traffic Safety Culture Investigation (STSCI) every year to assist local governments in promoting road safety. To address the issue of diversity, the local agencies were grouped into four regions by administrative district unit and offered region-specific safety promotion strategies. However, it is unclear if such a classification truly reflects the underlying differences that contribute to safety. The goal of this study is to identify the most relevant attributes that affect the safety performance of local agencies so that targeted safety promotion strategies can be recommended. To accomplish the goal, latent class cluster-based negative binomial regressions were applied for a comprehensive list of factors such as demographics, socio-economic features, roadway conditions, traffic violations and road user driver behavior; resulting in seven latent class clusters of local governments. The following indexes were found to significantly and strongly affect crash fatalities in the clusters: rate of wearing helmet, rate of pedestrian's signal compliance, the number of unlicensed driving violations, total paved road length, province, ratio of male to female, and population density. Further, stratified NB regression models were developed to identify statistically significant factors for predicting fatal crashes within each cluster. These cluster-specific features allow the KTSA to design targeted strategies for effective safety promotion.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02533
Paper Title	Hotspot Identification for Freeways Considering Difference in Single- and Multiple-Vehicle Crashes
Abstract	Previous studies found that the spatial distributions of Single-vehicle (SV) and Multi-vehicle (MV) crashes are quite different, but there has not been much research on hotspots identification considering differences in SV and MV crashes. This study identified hotspots of SV, MV and total crashes separately, using road design data, traffic operational data and crash data collected from a 45-km freeway segment in Shanghai. Full Bayes Poisson Lognormal regression models were developed for SV, MV and total crashes and the potential for safety improvement (PSI) was used to rank hotspots. Model estimation results showed that the significant influencing factors vary in different crash types. Hotspots identification results demonstrated that hotspots of SV crashes are quite different from MV crashes. For example, only three of the top ten hotspots were shared by both SV and MV crashes. Additionally, hotspots of total crashes have a higher consistency with MV crashes than with SV crashes, indicating that a majority of SV crash hotspots may be ignored if total crashes are used to identify hotspots. These conclusions prove the necessity to differentiate SV and MV crashes for hotspot identification and conducting road safety management.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-02721
Paper Title	Impacts of Speed Variations on Freeway Crashes by Severity and Transportation Model
Abstract	Speed variations are identified as potentially important predictors of freeway crash rates, but their impacts on crashes are not entirely understood. Existing findings tend to be inconsistent possibly because of the different definitions for speed variations, different crash type consideration or different modelling and data aggregation approaches. This study explores the relationships of speed variations with crashes on a freeway section. Crashes split by vehicle type (heavy and light vehicles) and by severity level (killed/serious injury and slight injury crashes) are aggregated based on the similarities of the conditions just before their occurrence (condition-based approach) and modelled using Multivariate Poisson lognormal regression. The models control for speed variations along with other traffic and weather variables as well as their interactions. Speed variations are expressed as two separate variables namely the standard deviations of speeds within the same lane and between lanes over a five-minute interval. The results, similar for all crash types (by coefficient significance and sign), suggest that crash rates increase as the within lane speed variations raise, at higher traffic volumes. Crashes are also triggered by the presence of higher between lane speed variations. Higher speeds coupled with higher volume and high speed variation between lanes also increase the crash likelihood. Overall, the results suggest that combinations of traffic characteristics play an important role in crash occurrences rather than their individual effects. Identification of these specific crash prone conditions could improve our understanding of crash risk and would support the development of more efficient countermeasures.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-02952
Paper Title	A Joint Econometric Approach for Modeling Crash Counts by Collision Type
Abstract	In recent years, there is growing recognition that common unobserved factors that influence crash frequency by one attribute level are also likely to influence crash frequency by other attribute levels. The most common approach employed to address the potential unobserved heterogeneity in safety literature is the development of multivariate crash frequency models. The current study proposes an alternative joint econometric framework to accommodate for the presence of unobserved heterogeneity – referred to as joint negative binomial-multinomial logit fractional split (NB-MNLFS) model. Furthermore, the study undertakes a first of its kind comparison exercise between the most commonly used multivariate model (multivariate random parameter negative binomial model) and the proposed joint approach by generating an equivalent log-likelihood measure. The empirical analysis is based on the zonal level crash count data for different collision types from the state of Florida for the year 2015. The model results highlight the presence of common unobserved effect affecting the two components of the joint model as well as the presence of parameter heterogeneity. The equivalent log-likelihood and goodness of fit measures clearly highlight the superiority of the proposed joint model over the commonly used multivariate approach.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-02977
Paper Title	How Does Rainfall Affect Pedestrian–Vehicle Crashes?
Abstract	The safety of walking activity has been a primary concern for researchers and authorities, who have developed numerous studies, particularly dedicated to the interaction between pedestrians and vehicles. Nonetheless, very few studies have focused on the impact of meteorological conditions on pedestrian-vehicle crashes. The present study aims to improve knowledge on this subject, considering mixed effects representing different phenomena associated to meteorological conditions. For this purpose, the city of Porto, Portugal, was selected as case study. First, a Poisson regression model was applied to evaluate the impact of precipitation on pedestrian-vehicle crashes, considering the daily precipitation, the lagged effects associated with the past-accumulated precipitation and the type of road. In a second model, an offset term named “all crashes” was added, allowing the evaluation of the relative risk of occurrence of pedestrian-vehicle crashes in comparison with all the other types of crashes for the same meteorological conditions. The results from both models support the following conclusions: (i) the number of pedestrian-vehicle crashes increase during rainfall, however the contribution of this type of crashes to the overall crash risk decreases; (ii) wet-monthly periods increase the pedestrian-vehicle crash risk, even when compared to the risk of all other crashes; (iii) 7-day periods of accumulated rainfall decrease the risk of pedestrian-vehicle crashes compared to all crashes; (iv) the road type affects differently the pedestrian-vehicle crash risk, maintaining the same trend when compared to all crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-02980
Paper Title	Bicyclist-Involved Crashes on Roadway Segments in New York City: A Spatial Analysis of Injury Severity
Abstract	With increasing popularity of bicycling, bike lane networks are expended in urban areas. Moreover, bicycling safety has gained continuing attention. However, most research on bicycling crash data focus on crash frequency, while limited literature is about injury severity. Among papers related to bicyclist-involved crash injury severity, only few of them consider bike lane. Using bicyclist-involved crash data in New York City, this study explores correlates of bicyclist-involved crash injury severities with a spatial concern of safety effects of bike lanes. These correlates may vary spatially due to spatial heterogeneity (i.e. geographic and socio-demographic diversity) within the whole city. Hence, Geographically Weighted Regression method is applied to uncover spatial variation in associations between injury severities and contributing factors. The global model (Ordered Logistic Regression) and the local models (Geographically Weighted Ordered Logistic Regression) are fitted. The modeling results of both global model and local models indicate that associations between bike lane related explanatory variables (i.e. the four bike lane types, number of bike lane on roadway segments) and injury severities are not significant. Averagely, summer time, heavy-duty vehicle, motorist, and multi-family elevator buildings are associated with higher probability of moderate, severe, or fatal injury. Fundamentally, the assumption of stationary associations in the global model does not fully hold in space. The results of local models reveal the spatial patterns of correlates. Maps of spatial varying coefficients visualize their spatial variation. Therefore, the local models considering regional situation could provide more information to guide safety improvement.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-03065
Paper Title	Safety Investigation of Nonmotorized Crashes in the City of Huntsville, Alabama, Using Count Regression Models
Abstract	While walking and cycling can be enjoyable, there is a potential safety risk associated with these modes, especially when interacting with automobiles. This study contributes to the safety of non-motorized transportation by applying and comparing three zero-inflated count models for each of bike and pedestrian crashes, specifically the zero-inflated negative binomial (ZINB) and the zero-inflated Poisson (ZIP). Note that the ZINB was examined with two different variance types, which were the standard ZINB and the modified one including a different variance estimator. In this study, sociodemographic (e.g., school enrollment and number of households), traffic (e.g., traffic volume and speed limit), and infrastructure or built environment variables (e.g., sidewalk length) were used. Five-year bike and pedestrian crashes (2010 through 2014) in 368 traffic analysis zones (TAZs) in the city of Huntsville, Alabama were used. The performance of the six fitted count models was compared based on the prediction performance and goodness-of-fit statistics. The prediction accuracy have included the mean absolute deviance (MAD) and the mean square prediction error (MSPE). The standard ZINB outperformed the corresponding ZINB type and the ZIP one for both bike and pedestrian crashes (especially in the relatively higher MAD and MSPE estimates, which represents higher prediction performance). The fitted regression models for both bike and pedestrian crashes in Huntsville showed that there was an increase in crashes with the increase in traffic volume, number of households, and number of retails. The results of the fitted count models are deemed useful for decision makers to identify and predict high-risk zones for bicyclists and pedestrian crashes in a city or county, and in other areas having similar traffic and sociodemographic characteristics.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-03189
Paper Title	Analyzing Crash Frequency in Freeway Tunnels: A Correlated Random Parameters Approach
Abstract	The majority of past road safety studies focused on open road segments while only a few focused on tunnels. Moreover, the past tunnel studies produced some inconsistent results about the safety effects of the traffic patterns, the tunnel design, and the pavement conditions. The effects of these conditions therefore remain unknown, especially for freeway tunnels in China. The study presented in this paper investigated the safety effects of these various factors utilizing a four-year period (2009 to 2012) of data as well as three models: 1) a random effects negative binomial model (RENB), 2) an uncorrelated random parameters negative binomial model (URPNB), and 3) a correlated random parameters negative binomial model (CRPNB). Of these three, the results showed that the CRPNB model provided a better goodness-of-fit and offered more insights into the factors that contribute to tunnel safety. The CRPNB was not only able to allocate the part of the otherwise unobserved heterogeneity to the individual model parameters but also was able to estimate the cross-correlations between these parameters. Furthermore, the study results showed that traffic volume, tunnel length, proportion of heavy trucks, curvature, and pavement rutting were associated with higher frequencies of traffic crashes, while the distance to the tunnel wall, distance to the adjacent tunnel, distress ratio, IRI, and friction coefficient were associated with lower crash frequencies. In addition, the effects of the heterogeneity of the proportion of heavy trucks, the curvature, the rutting depth, and the friction coefficient were identified and their inter-correlations were analyzed.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Part 1, Session 523)
Paper Number	18-03528
Paper Title	Parametric and Nonparametric Approaches in Developing Crash Prediction Models for Rural Mountainous Freeways: A Case Study in Wyoming
Abstract	Researchers have extensively used crash prediction models to quantify safety performance of various roadway facilities. This study compares between Multivariate Adaptive Regression Splines (MARS), which is a recently adopted nonparametric data-mining technique, with Negative Binomial (NB) model in predicting crashes on a unique 402-mile rural mountainous freeway corridor in Wyoming. I-80 is a vital corridor running in the southern part of Wyoming that was selected as one of the three sites for the regional connected vehicle pilots. This study serves as a baseline investigation of safety performance of a connected vehicle pilot deployment corridor. Crash prediction models for different severity levels (total crashes, Fatal and Injury, and PDO crashes) were developed. Seven years of crashes from 2010 to 2016 were utilized in the analysis. Homogeneous segmentation method was used to segment the study corridor. Results showed that the MARS model out performed the NB model. The developed MARS models were considered as better crash prediction models, given the lower AIC values. MARS model has the capability to handle nonlinear relationships between the predictors and the response variable. Furthermore, it automatically identifies the significant variables and interactions term. The relationship between crash counts and variables used in prediction are usually nonlinear. Therefore, using MARS model is recommended as a good technique to develop crash prediction models.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-04562
Paper Title	Investigating the Impacts of Land Use Patterns on Traffic Safety at Traffic Analysis Zone Level
Abstract	This study aimed to investigate how land-use pattern affects the crash frequency at the traffic analysis zone (TAZ) level. Traffic, road network, land use, population and crash data were collected from Los Angeles County, California in 2014. K-means clustering analysis was first conducted to divide land use at each TAZ into five different patterns. Geographically weighted Poisson regression (GWPR) models were then developed to investigate the associations between crash counts and land use patterns. Traffic flow, road and demographic characteristics were compared across the five land-use patterns to identify the underlying phenomena that made certain land-use patterns more hazardous than others. Separate GWPR models were further developed for each land-use pattern to identify how traffic, road network and demographic characteristics affect crash frequencies in different land-use patterns. The results of this study indicated that land-use combinations at TAZs can be divided into different patterns using land-use mix and proportions of different land-use types, and that each land-use combination can be assigned with a certain safety level. The effects of contributing factors on crash frequency are different across different land-use patterns. The Bayesian discriminant analysis was finally conducted to identify land-use patterns given land-use data at TAZ level. Cross-validation results indicated that the developed method can accurately identify land-use patterns.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-04583
Paper Title	Analyzing the Impact of Median Treatments on Bicyclist and Pedestrian Safety
Abstract	In response to a disproportionately high number of pedestrian and bicyclist crashes related to illegal mid-block crossings, Maryland Department of Transportation's State Highway Administration (SHA) implemented various median treatments and safety enhancement countermeasures at identified high-frequency bicyclist/pedestrian crash locations. While median treatments are generally perceived as effective and beneficial, this study seeks to quantify their impact. The research team collected required data and applied trend analysis and statistical analysis (Empirical Bayes methods) to assess the effectiveness of installed safety countermeasures. The trend analysis focused on the general crash trend for different types of crashes. Statistical modeling methods were employed to link bicycle and pedestrian crashes to median treatments and other influencing variables. The Empirical Bayes methods separated the effect of median treatments from the effects of other factors. To investigate public opinion of median treatments and pedestrian/bicycle safety, on-site pedestrian and bicyclist surveys were conducted at study locations. The surveys were supplemented with business and community interest group interviews. The results shed light on the socio-demographic factors that may influence attitudes toward the installed median treatments. Results of the trend analysis showed that treatment sites experienced lower or similar crash rates for all crash types after the treatment, while control sites experience higher crash rates during the same period. The statistical analysis showed a significant reduction in total crash rates and fatalities because of the treatments. Survey results showed that more than 50% of pedestrians and bicyclists are likely to cross roads mid-block, but median treatments are effective in discouraging it.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-04741
Paper Title	A Model for the Analysis of Pedestrian Injury Counts by Severity Level
Abstract	We propose in this paper a spatial random coefficients flexible multivariate count model to examine, at the spatial level of a census tract, the number of pedestrian injuries by injury severity level. Our model, unlike many other macro-level pedestrian injury studies in the literature, explicitly acknowledges that risk factors for different types of pedestrian injuries can be very different, as well as accounts for unobserved heterogeneity in the risk factor effects. We also recognize the multivariate nature of the injury counts by injury severity level within each census tract (as opposed to independently modeling the count of pedestrian injuries by severity level). The data for our analysis is drawn from a 2009 pedestrian crash database from the Manhattan region of New York City. Several groups of census tract-based risk factors are considered in the empirical analysis based on earlier research. The empirical analysis sheds light on both engineering as well as behavioral countermeasures to reduce the number of pedestrian-vehicle crashes by severity of these crashes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Part 1, Session 523)
Paper Number	18-04815
Paper Title	Evaluating the Impact of Raising Speed Limit on Urban Freeways Using Mixed-Effects Negative Binomial Regression
Abstract	Numerous statistical approaches have been used in establishing the safety impacts associated with raising posted speed limit, especially on highways. These approaches range from simple naïve before and after study to more advanced statistical approaches which control for exposure and other confounding factors. In this study, mixed effects negative binomial regression was used in quantifying the changes in fatal, incapacitating and non-incapacitating (KAB) crashes, total crashes and road departure crashes after raising the posted speed limit in some of Michigan urban freeways. This method was preferred as it offers the ability to control for individual random effects which vary across the freeway corridors, intra-cluster correlation of crashes between corridors or segments that are nested in the same corridor, overdispersion in crash data and time effect. The importance of these factors was demonstrated by comparing the estimation results of mixed effects negative binomial model and standard negative binomial model. The standard negative binomial model underestimated the impact of speed limit on KAB and total crashes while compensating for the missing variables, namely time effect and random effects. The results from mixed effects negative binomial regression showed a net increase in KAB crashes, total crashes and road departure crashes after raising the speed limit. The effect of raising speed limit was more pronounced on curved freeway segments compared to straight freeway segments. Therefore, the design standards for horizontal curve, vertical curve and other geometric features should be thoroughly assessed to ensure that they meet required standards for the proposed speed limit changes.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-04956
Paper Title	Big Data Approach of Crash Prediction
Abstract	Traditional crash prediction models use roadway geometric design features, traffic control types, and annual average daily traffic volumes, etc. as inputs to predict the annual crashes of a facility. These models are known as safety performance functions. Developing these models requires careful sampling of crash sites from different locations and advanced statistical techniques; using them requires prior knowledge of the facility and often local calibrations. The big data approach of crash prediction is based on predictive analytics. It predicts what will happen in the future by analysing the rich historical data, recognizing the patterns of how it happened in the past, and applying that pattern or trend to predict future events. This method requires ready access to multi-year state-wide or regional crash history data, but doesn't require prior knowledge of the facility. The underpinning of this approach is that the environment that induced the crash events remains stable over the time-period considered. The outcomes of many natural events, such as annual precipitation or animal migration, can be predicted by this method. The annual traffic crashes in an area is a type of natural event that falls into the above category, and therefore has repeatable and predictable patterns. This paper presents a big data approach of predicting the annual crashes of an area centred on user specified locations. Once the big historical dataset of a region is properly prepared, it encompasses the comprehensive crash histories of every facility within its boundary. This paper presents an auto searching algorithm that enables the crash prediction of any facility within the region be generated on the fly. This method is inherently area based, however, by adjusting the searching criteria, the result can converge to an intersection or a roadway segment. A major advantage of this approach is that it naturally considers the influences of nearby facilities.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05057
Paper Title	Developing a Global Road Safety Model
Abstract	Road accidents constitute a major social problem in modern societies, with road traffic injuries being estimated to be the eighth leading cause of death globally. The need for action based on evidence based policy making becomes more and more pronounced. In this context, this paper presents SafeFITS, a global road safety model, developed for the United Nations Economic Committee for Europe, which is based on global historical road safety data (72 indicators for 130 countries) and may serve as a road safety decision making tool for three types of policy analysis, i.e. intervention, benchmarking and forecasting analysis. A hierarchical conceptual framework of five layers of the road safety system is suggested (namely, economy and management, transport demand and exposure, road safety measures, road safety performance indicators, and road safety outcomes), and a dedicated database was developed with various road safety indicators for each layer. A two-step approach was opted for the purposes of the research, including the calculation of composite variables and then their introduction in a regression model, and the development of a model on the basis of short-term differences, accumulated to obtain medium- and long-term forecasts. The model developed has overall satisfactory performance and acceptable prediction errors, and preliminary validation provided encouraging results. Its usage might be proved highly useful for testing road safety policies, taking however into account the model limitations, mostly related to data availability and accuracy, and the recommendations for its optimal use.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Part 1, Session 523)
Paper Number	18-05071
Paper Title	Comprehensive Assessment of Temporal Treatments in Crash-Prediction Models
Abstract	Even though a fairly large number of crash prediction models that address the serial correlations have been proposed, the comprehensive comparison of such temporal treatments under different criteria is lacking in the literature. The current study aims to fill this gap by developing nine groups of methodological approaches based on different ways of addressing temporal correlations. Moreover, three types of models were proposed for each group in terms of spatial dependency. Finally, ten different assessment criteria were utilized for the evaluation purpose. All models and performance-checking criteria applied to eight years of county-level crash counts in California. The modeling results illustrated that the space-time models consistently enhanced the precision associated with the intercepts. The serial and spatial correlations also appeared to be statistically significant. In terms of model complexity, the models with spatial correlations outperformed the ones without considering spatially structured heterogeneity, and the models accounting for the temporal dependency revealed more benefits compared with those without temporal treatments. The opposite trends were found by prediction-pertinent criteria based on the aggregation results, even though the first-order autoregressive process space-time models with spatiotemporal interaction claimed the first place of prediction in most cases. The correlation analysis among all ten criteria illustrated that the efficiency in reducing the effective number of parameters tended to have larger impacts on the value of deviance information criterion than did the mean deviance, which demonstrated the statistically significant correlations with all other prediction-related measures.

Authors	Shanshan Zhao, University of Connecticut Kai Wang, Connecticut Transportation Safety Research Center Chenhui Liu, Iowa State University Eric Jackson, University of Connecticut
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Part 1, Session 523)
Paper Number	18-05263
Paper Title	Freeway Crash Analysis Considering Monthly Variation in Traffic Volumes and Weather Conditions Using Time-Series Random Effect Negative Binomial Models
Abstract	The research investigated the effects of monthly traffic and weather conditions on traffic crash counts and considered the correlations between these factors. Time series random effect negative binomial models were estimated for total crashes, major types of crashes (front-to-rear, sideswipe-same-direction, and fixed-object), severe crashes (i.e., fatal and injury crashes) and non-injury crashes (i.e., property-damage-only crashes). Major findings are that variations in monthly traffic volumes, roadway geometry, and weather conditions explain much of the variations in monthly traffic crashes. Higher monthly traffic volumes, narrower inside or outside shoulder widths, lower temperature, more heavy fog days, increased snowfall, and lower wind speed were found to be associated with higher monthly crashes. Time series effect exists in the panel monthly data for most types of crashes. Taking into account this effect improves model estimation results. When the raw weather measures are highly correlated, using dimension reduction techniques helps to extract more interpretable weather factors. By considering the interaction effects between traffic volumes and weather components, additional findings were found. Compared to high traffic volume freeways, low traffic volume freeways are more influenced by snowfall and less affected by temperature. The findings of this research could help researchers and general readers gain better understanding of the effects of monthly weather conditions on freeway crashes and give engineers practical guidelines on improving freeway safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Part 1, Session 523)
Paper Number	18-05331
Paper Title	Traffic Incident Prediction Using Wavelet-Based Feature Extraction and Artificial Neural Networks
Abstract	The availability of huge traffic-related data enables us to evaluate and analyze the sources of traffic congestion and accidents in a systematic manner. Several researchers have explored ways to exploit the boom in data availability for improving traffic safety and efficiency. In this paper, we present an approach that explores the prediction of accidents using wavelet decomposition-based denoising and then applying artificial neural network (ANN) for prediction of these features. The ANN-based pattern recognition methodology is constructed in order to determine the underlying factors associated with collisions. We utilized the accident data for the county of Los Angeles, which were collected between 2009 and 2013, to develop the proposed methodology. The preliminary results of this study were encouraging; however, it requires further investigation into the topic to improve the reliability of the prediction model.

Authors	Nutan Teketi, Talbert & Bright, Inc. Srinivas Pulugurtha, University of North Carolina, Charlotte Ajinkya Mane, University of North Carolina, Charlotte
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05552
Paper Title	Modeling Pedestrian Crashes at Midblock Locations
Abstract	This paper focuses on identifying factors and developing pedestrian crash estimation models for midblock locations. Seventy midblock locations were identified in the city of Charlotte, North Carolina to capture data and develop as well as validate the pedestrian crash estimation models. The number of pedestrian crashes over a four-year period (2013 - 2016), within a 0.25-mile buffer around each selected midblock location, was used as the dependent variable. Road network characteristics, transit network characteristics, demographic characteristics, and land use characteristics captured within a 0.5-mile buffer around each midblock location were used as the independent variables. Data for 55 midblock locations was considered for developing six pedestrian crash estimation models using SPSS statistical analysis software, while data for the remaining 15 midblock locations was considered for validating the developed pedestrian crash estimation models. The best model was selected based on the goodness-of-fit statistics and validation results. The presence of crosswalk marking and the number of transit stops have a positive effect on pedestrian crashes at midblock locations. Land uses like multi-family, retail and single-family attached also have a positive effect on pedestrian crashes at midblock locations. The findings from the pedestrian crash estimation models can be used by practitioners to proactively plan and improve pedestrian safety.

Authors	Ahmed Abdelnaby, Hatch Corporation Yasser Hassan, Carleton University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Part 1, Session 523)
Paper Number	18-05564
Paper Title	MOE-Based Safety Performance Functions for Signalized Intersections: A Tool for Safety Evaluations in TIAs and Traffic Studies
Abstract	Evaluating roadway safety is a challenging task due to the lack of collision data and indeterminate relationship between the exposure variables and collision events. To evaluate safety, some researchers use Poisson and Negative Binomial modelling structures to develop exposure based Safety Performance Functions (SPFs) that account for the statistical characteristics of collision data. Some studies explored using conflict field observations and others investigated the use of conflict estimates generated from simulation software to study safety. Many practitioners use SPFs due to the availability of data, easiness to use, and reliability. Using conflict observations is relatively expensive and using conflict estimates from modelling software is yet an unproven methodology. On the other hand, the relationship between detailed operational measures and their relationship to safety seems to be understudied. This study is intended to provide practitioners with a tool to evaluate safety using commercial software such as Synchro. SPFs were developed to evaluate the relationship between measures of operational performance and safety at arterial roadway intersections. Operational performance was evaluated using Synchro, which reports on delays, queues, vehicle stops, v/c ratios, actuated signal performance, and other measures of performance. In this study, Model parameters for Synchro were based on the City of Calgary guidelines. SPFs using peak hour collision data between 2010-2014 at 76 intersections were developed. Operational measures were developed based on peak traffic volumes (AM, Mid-Day, and PM) and on-site signal timing plans. Modelling attempts covered collisions by severity and type, in addition to roadway snow related collisions.

Authors	Lakshmi Prasanna Srirangam, 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	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05593
Paper Title	Modeling Pedestrian Crashes at Intersections Near Light Rail Transit Stations and Comparing Before–After Patterns
Abstract	The focus of this paper is two-fold - 1) to research and identify factors that influence pedestrian safety at intersections within the vicinity of light rail transit (LRT) stations, and, 2) to examine the change in crash patterns at these intersections before and after the operation of LRT service. Pedestrian crashes at 71 randomly selected intersections, within a vicinity of 0.25 miles (402 m) around fifteen LRT stations in Charlotte, North Carolina, were analyzed to understand factors associated with pedestrian safety at these intersections near LRT stations. Geographical Information System (GIS) software was used to overlay shapefiles related to pedestrian crash data, road network and intersection characteristics on buffers around the selected intersections to capture data and conduct analysis. Generalized linear pedestrian crash estimation model (based on negative binomial distribution) was developed and validated to understand the relationship between road network characteristics and pedestrian crashes at the intersections near LRT stations. Speed limit, the number of bus stops and pedestrian signal are statistically significant predictor variables that influence pedestrian safety at the intersections near LRT stations.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Part 1, Session 523)
Paper Number	18-05685
Paper Title	Use of Multivariate Dirichlet Process Mixture Spatial Model to Estimate Active Transportation-Related Crash Counts
Abstract	The current study contributes to the safety literature by presenting a dedicated research for comprehensive analysis of multivariate Dirichlet process mixture spatial model for estimation of pedestrian and bicycle crash counts. This study focuses on the active transportation at Traffic Analysis Zone (TAZ) level by developing a semi-parametric model that accounted for the unobserved heterogeneity by combining the strengths of incorporating multivariate specification to accommodate correlation among crash modes, spatial random effects for the impact of neighboring TAZs, and Dirichlet process mixture for random intercept. Three alternate models, one Dirichlet while two parametric, were also developed for comparison based on different criteria. Bicycle and pedestrian crashes shared three influential variables: the positive correlation of K12 student enrollment, the bike-lane density, and the percentage of arterial roads. The heterogeneity error term demonstrated the presence of statistically significant correlation among the bicycle and pedestrian crashes while the spatial random effect term exhibited the absence of a significant correlation, which might explain the slightly inferior performances associated with the spatial models. The Dirichlet models were consistently superior to non-Dirichlet ones under all evaluation criteria. Moreover, the Dirichlet models exhibited the capability to identify the latent distinct subpopulations and suggested that the normal assumption of intercept associated with traditional parametric models does not hold true for the TAZ level crash dataset of the current study.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Part 1, Session 523)
Paper Number	18-05889
Paper Title	Multimodal Crash Frequency Modeling: Multivariate Space-Time Models with Alternate Spatiotemporal Interactions
Abstract	Enhancement of safety for all transportation mode users plays an essential role in the implementation of multimodal transportation systems. Compared with crash prediction models dedicated to motorized mode users, the use of these models has been considerably scarce in the multimodal literature. To fill this research gap, the authors aim to develop and evaluate three multivariate space-time models with different temporal trends and spatiotemporal interactions. The model estimates justified the use of mode-varying coefficients for explanatory variables as the impact of these factors varied across different crash modes. Largely a similar set of influential covariates was generated by the three models which indicate their robustness. However, notable differences were observed from the assessment of goodness-of-fit criteria employed in the study. The model with time-varying spatial random effects demonstrated superior performance under various prediction-related criteria. Nonetheless, due to the significant increase in the effective number of parameters that were utilized for model development, this model was inferior to competing models at deviance information criterion (DIC). The results also revealed the effectiveness of various random effects in capturing the unobserved heterogeneity that escapes the covariates.

Authors	Si Qi Xie, University of Hong Kong Pengpeng Xu, University of Hong Kong S.C. Wong, University of Hong Kong
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-06535
Paper Title	Bayesian Approach to Model Pedestrian Crashes at Signalized Intersections with Measurement Errors in Exposures
Abstract	This paper investigated the effects of site conditions of signalized intersections on pedestrian-vehicle crash frequency, using the crash count-data from 288 signalized intersections in Hong Kong in a 3-year period from 2010 to 2012. The site condition data include geometric characteristics, traffic characteristics and built environment characteristics. The traffic and pedestrian volumes at intersection-level across the 3-year period were collected and estimated as exposure terms in the model. The measurement errors of the traffic and pedestrian volumes were taken into account in the estimation of the predictive model. The full Bayesian method was adopted to estimate the effects of explanatory variables. Pedestrian exposure at intersection-level was found essential in predicting the frequency of pedestrian-vehicle crash, otherwise false alarm would be given from the misleading model estimates. Measurement errors were found exist among the traffic and pedestrian volumes. It was also found that presence of pedestrian signal and presence of park or playground at land of leisure use would significantly reduce the occurrence of pedestrian-vehicle crashes, while presence of curb parking and presence of ground-level shop would increase the pedestrian crash frequency.

Authors	Mouyid Islam, USF Center for Urban Transportation Research Dante Perez-Bravo, CH2M Kimberly Kolody, CH2M
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	575
Session Title	Highway Safety Performance
Paper Number	18-06727
Paper Title	Freeway Safety Evaluation: A Quantitative Approach Using Highway Safety Manual to Informed Decisions
Abstract	Performance-based design in the form of operation and safety in the freeway system plays a significant role in alternative evaluation process. Moreover, performance-based design consistent with Highway Safety Manual is getting more accepted and adopted by the highway agency since it sets specific goals in meeting safety targets that lead to meet performance criteria. Nebraska Department of Roads (NDOR) sets targets by using the systematic safety assessment on design modifications. The application of Highway Safety Manual (HSM) in the safety assessment of freeway alternatives focusing on Metropolitan Travel Improvement Study (MTIS) provides a new direction for making informed decisions at the agency level. With that in mind, this study was conducted with the objectives to perform: (1) safety performance evaluation of alternatives in the MTIS by applying ISATe; (2) safety performance evaluation of design exceptions; and (3) qualitative safety performance evaluation of sub-options as part of sensitivity analysis for design year 2040. This paper focuses on a performance-based approach to compare safety performance of alternatives and provides information to assist safety professionals, designers, planners, and policy makers at state and local levels in making informed decisions. Finally, this study highlights some of the challenges of using predictive tool recommend by HSM in real applications.

5 Crash Severity Prediction

Alfonso Montella and Filomena Mauriello, University of Naples Federico II

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

The subcommittee identified forty papers dealing with crash severity prediction. The 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, and 41 in 2017), highliting how this issue is becoming important for the scientific community.

These papers are scattered across various sessions, with most papers presented at the poster sessions 394 Advanced Analysis to Improve Nonmotorized Transportation Safety (Monday, 1:30 PM – 3:15 PM) and 834 The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Wednesday, 10:15 AM – 12:00 PM).

From a **methodological perspective**, several approaches were used. Most studies used discrete outcome models treating injury severity as either a nominal or ordered variable.

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

- Multinomial logit model (Jamali and Wang, 18-05549; Kitali et al., 18-05472; Salum et al., 18-06463; Vilaca et al., 18-00382; Yang et al., 18-03042);
- Random parameters logit model (Bahrololoom et al., 18-04070; Dong et al., 18-03480; Haleem et al., 18-00073; Khan and Khattak, 18-05356; Kitali et al., 18-05472; Islam and Benjamin, 18-00975; Li et al., 18-06244; Mesa Arango et al., 18-04655; Wali et al., 18-02266; Wang et al., 17-05464; Wu et al., 18-06297);
- Latent class logit model (Li et al., 18-06244);
- Dirichlet random-effect logistic model (DRL) (Kitali et al., 18-05472);
- Fractional multinomial logit model (Stipancic et al., 18-02836);
- Linearised spatial logit model ();
- Skewed logit model ();
- Probit model (); and
- Dirichlet random parameters binary probit model (Kitaly et al., 18-06389);
- Finite-mixture random parameters model (Li et al., 18-06210).

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

- Ordered logit model (Jamali and Wang, 18-05549; Wali et al., 18-00060; Wan et al., 18-02980);
- Geographically weighted ordered logit model (Wan et al., 18-02980);

- Random parameters ordered logit model (Russo, 17-00941; Taylor et al., 18-02290; Wali et al., 18-00060);
- Random parameter ordered logit model with heterogeneity-in-means (Wali et al., 18-00060);
- Multi-level ordered logit model (Wan et al., 18-02988);
- Generalized ordered logit model (Rouholamin and Zhou, 18-00509);
- Mixed generalized ordered response model (Balan and Paleti, 18-02227);
- Ordered probit model (Fountas et al., 18-0327; Turochy et al., 18-00866; Uddin and Ahmed, 18-01119; Uddin and Huynh, 18-04409; Ye and Wang, 18-05926; Zhou et al., 18-04007);
- Random parameters ordered probit model (Fountas et al., 18-0327; Uddin and Ahmed, 18-01119; Uddin and Huynh, 18-04409; Wang et al., 18-05178);
- Correlated random parameters ordered probit model (Fountas et al., 18-0327);
- Mixed generalized ordered response probit model (MGORP) (Osman et al., 18-05160); and
- Generalized ordered probit model (Anarkooli et al., 18-06609).

Some papers used **data mining techniques**, such as Artificial Neural Networks-Multi-Layer Perceptron (ANN-MLP) (Yang et al., 18-03042), Artificial Neural Networks-Radial Basis Function (ANN-RBF) (Yang et al., 18-03042), Bayesian Networks (Mohammadianamiri et al., 18-02088; Zhou et al., 18-04007), Classification And Regression Trees (CART) (Eustace et al., 18-05958; Jamali and Wang, 18-05549), Chi-square Automatic Interaction Detector (CHAID) (Hezaveh et al., 18-01507), Support Vector Machine models (SVM) (Mohammadianamiri et al., 18-02088; Yang et al., 18-03042), and Support Vector Machine-Polynomial (Yang et al., 18-03042).

Some papers used **machine learning tools**, such as a deep learning framework (Das et al., 18-04840), a deep learning approach built upon the convolutional neural network (Yang et al., 18-03042), C4.5, instance based (IB), and random forest (RF) machine learning models (Mafi et al., 18-03427).

Some studies investigated the performance of **models combining safety safety performance functions and crash severity functions**. Avelar et al. (18-00495) compared two alternative methods for developing safety performance functions for severe crashes: a direct estimation of severe crashes using frequency models, and the combination of safety performance functions for total crashes combined and crash severity functions. Xu et al. (18-01354) used the quantile selection model as a methodological alternative for analyzing crash rate and severity at different levels. Anarkooli et al. (18-06609) used a two-stage modeling approach, estimating the total crash counts by a heterogeneous negative binomial (HTNB) regression and the severity level by a generalized ordered probit model.

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

- Environmental factors (Dong et al., 18-03480; Fountas et al., 18-0327; Hezaveh et al., 18-01507; Islam and Benjamin, 18-00975; Kitaly et al., 18-06389; Mesa Arango et al., 18-04655; Osman et al., 18-05160; Rouholamin and Zhou, 18-00509; Turochy et al., 18-00866; Uddin and Ahmed, 18-01119; Uddin and Huynh, 18-04409; Vilaca et al., 18-00382; Wan et al., 18-02980, 18-02988; Xu et al., 18-01354; Zhou et al., 18-04007);
- Highway characteristics (Das et al., 18-04840; Dong et al., 18-03480; Eustace et al., 18-05958; Fountas et al., 18-0327; Haleem et al., 18-00073; Hezaveh et al., 18-01507; Islam and Benjamin, 18-00975; Khan and Khattak, 18-05356; Kitali et al., 18-05472; Mesa Arango et al., 18-04655; Salum et al., 18-06463; Turochy et al., 18-00866; Uddin and Ahmed, 18-01119; Uddin and Huynh, 18-04409; Wali et al., 18-02266; Wan et al., 18-02980, 18-02988; Wang et al., 15-05178; Xu et al., 18-01354; Zhou et al., 18-04007);
- Road users' characteristics and behaviour (Bahrololoom et al., 18-04070; Dong et al., 18-03480; Eustace et al., 18-05958; Hezaveh et al., 18-01507; Islam and Benjamin, 18-00975; Khan and Khattak, 18-05356; Kitali et al., 18-05472, 18-06389; Osman et al., 18-05160; Rouholamin and Zhou, 18-00509; Salum et al., 18-06463; Taylor et al., 18-02290; Turochy et al., 18-00866; Uddin and Ahmed, 18-01119; Uddin and Huynh, 18-04409; Vilaca et al., 18-00382; Wali et al., 18-00209, 18-02266; Wang et al., 15-05178; Zhou et al., 18-04007);
- Roadside features (Osman et al., 18-05160; Rouholamin and Zhou, 18-00509);
- Traffic control devices (Bahrololoom et al., 18-04070; Eustace et al., 18-05958; Hezaveh et al., 18-01507; Kitali et al., 18-05472; Mesa Arango et al., 18-04655; Uddin and Ahmed, 18-01119; Wali et al., 18-00060, 18-00209, 18-02266; Wang et al., 15-05178; Xu et al., 18-01354);
- Traffic characteristics (Bahrololoom et al., 18-04070; Fountas et al., 18-0327; Haleem et al., 18-00073; Khan and Khattak, 18-05356; Kitali et al., 18-05472, 18-06389; Osman et al., 18-05160);
- Vehicle characteristics (Dong et al., 18-03480; Osman et al., 18-05160; Rouholamin and Zhou, 18-00509; Taylor et al., 18-02290; Uddin and Ahmed, 18-01119; Uddin and Huynh, 18-04409; Wali et al., 18-00209; Wan et al., 18-02980, 18-02988 ; Zhou et al., 18-04007); and
- Workzone characteristics (Turochy et al., 18-00866; Yang et al., 18-03042;).

The papers investigated also **specific road users** (with most papers focused on vulnerable road users) and **vehicle types**, such as:

- Cyclists (Bahrololoom et al., 18-04070; Vilaca et al., 18-00382; Wali et al., 18-00209, 18-02266; Wan et al., 18-02980, 18-02988);
- Motorcyclits (Das et al., 18-04840; Salum et al., 18-06463);
- Older drivers (Rouholamin and Zhou, 18-00509);
- Pedestrians (Dong et al., 18-03480; Hezaveh et al., 18-01507; Jamali and Wang, 18-05549; Kitali et al., 18-05472; Uddin and Ahmed, 18-01119; Wali et al., 18-00209;); and
- Trucks (Eustace et al., 18-05958; Khan and Khattak, 18-05356; Taylor et al., 18-02290 ; Uddin and Huynh, 18-04409).

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Sponsoring Committee	Standing Committee on Highway/Rail Grade Crossings (AHB60)
Session Number	324
Session Title	Analysis of Safety Concerns at Highway-Rail Grade Crossings
Paper Number	18-00209
Paper Title	Injury Severity Analysis of Pedestrian and Bicyclist Trespassing Crashes at Noncrossings: Application of Predictive Text Analytics
Abstract	Non-motorists involved in rail-trespassing crashes are usually more vulnerable to receiving serious or fatal injuries. Previous research has used tabular data from for understanding factors contributing to injury outcomes of non-motorists in train involved collisions. However, police reported crash narratives which are usually overlooked can provide useful and unique contextual crash-specific information regarding factors associated with injury outcomes. The main objective of this study is to harness the rapid advancements in more sophisticated qualitative analysis procedures for identifying thematic concepts in unstructured crash narrative data. By using ten-year (2006-2015) non-motorist non-crossing trespassing injury data obtained from the FRA, statistical procedures and advanced machine learning text analytics are applied to extract unique information on contributory factors of trespassers' injury outcomes. The key concepts are systematically categorized into trespasser, injury, train, medical, and location related factors. A total of 13 unique variables are extracted from the thematic concepts that are not present in traditional tabular crash data. The analysis reveals a positive statistically significant association between presence of crash narrative and trespasser's injury outcome. Compared to crashes with minor injuries, crashes involving major and fatal injuries are more likely to be reported with crash narratives. Important findings are that trespassers with confirmed suicides, trespassers wearing headphones, or talking on cell are more likely to receive fatal injuries. Among other factors identified, trespassers under alcohol influence, trespasser hit by commuter train, and advance warnings by engineer are associated with severe trespasser injury outcomes. Practical implications and future research directions are discussed.

Authors	M. Majbah Uddin, University of South Carolina Fahim Ahmed, University of South Carolina
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-01119
Paper Title	Analysis of Pedestrian Injury Severity in Motor Vehicle Crashes in Ohio
Abstract	This paper investigates factors contributing to the pedestrian injury severity resulting from motor vehicle crashes in Ohio. It uses the crash data from the Highway Safety Information System, from 2009 to 2013. The explanatory factors include the pedestrian, driver, vehicle, crash, and roadway characteristics. Both fixed- and random-parameters ordered probit models of injury severity (where possible outcomes are major, minor, and possible/no injury) were estimated; the random-parameters model captures possible unobserved effects related to factors not present in the data. The model results indicate that being older pedestrian (65 and over), younger driver (less than 24), driving under influence (DUI), being struck by truck, dark-unlighted roadways, six lane roadways, and speed limit of 40 mph and 50 mph were associated with more severe injuries to the pedestrians. Conversely, older driver (65 and over), passenger car, crash occurring in urban locations, daytime traffic off-peak (10 AM to 3:59 PM), weekdays, and daylight condition were associated with less severe injuries. This study also provides specific safety recommendations so that effective countermeasures could be developed and implemented by the policy makers, which in turn will improve overall highway safety.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-01507
Paper Title	Pedestrian Crashes in Tennessee: A Data Mining Approach
Abstract	In Tennessee, annually about 1000 people die in traffic crashes; the crash statistics sources indicate a falling pattern in traffic fatalities over time. However, pedestrian crashes are increasing, and the number of pedestrians' fatalities increased from 80 in 2011 to 118 in 2015, mimicking national trends. Data from Tennessee Integrated Traffic Analysis Network (TITAN) were used to investigate traffic crashes between 2011 to 2015. Findings indicated that odds of death and injury for the pedestrians in a traffic crash were respectively 1 in 17 and 2.6; these odds for drivers were respectively 1 in 555 and 1 in 20. CHAID analysis was used in this study to investigate the relation between crash severity of the pedestrians, pedestrian characteristic (e.g., age, gender), road characteristic (e.g., intersection type, number of lanes), and other environmental factors (e.g., weather). Results of the CHAID analysis indicated that the most key factors that predict pedestrian crash severity were the post Speed limit, Light Condition, Pedestrian Age, area designated code, pedestrian under the influence, intersection type, road curvature, and relation to the road. Results were discussed in the context of the road safety.

Authors	Amir Jamali, Montana State University Yiyi Wang, Montana State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05549
Paper Title	Analysis of Pedestrian Crashes Injury Severity for Rural and Small Urban Areas
Abstract	Pedestrian safety remains a key issue due to the disproportionate number of pedestrian injuries and fatalities in rural and small urban areas. This study applies two statistical models (i.e., ordered logit and multinomial logit) and one dataming appraoch (i.e., CART) to: 1) identify the contributing factors associated with pedestrian–vehicle injury severity levels and 2) compare the CART model with statistical models in order to evaluate the effectiveness of data mining approaches. The result showed that the MNL outperformed the ORL, which was perhaps due to increased flexibility of MNL specification model than ORL. In addition, the CART model performed slightly better than the two statsitical models. This might be attributed to the fact that the CART model does not assume any predefined underlying relationship between dependent and independent variables, which results in a more flexible model specification. Results showed that in rural and small urban areas pedestrian fatality risk increases in areas with higher intersection density, population density, share of residential and commercial areas, percentage of individuals educated to bachelor or college, and when the crash occurred in dark hours and spring season. In contrast, the pedestrian fatality decreases in areas with higher number of driveways, centerline mile, share of undeveloped areas, employment density, percentage of male residents, percentage of individuals educated to bachelor and graduate levels, and areas where warning sign is present.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-02266
Paper Title	Influence of Type of Traffic Control on Injury Severity in Bicycle–Motor Vehicle Crashes at Intersections
Abstract	Many studies have identified factors that contribute to bicycle-motor vehicle (BMV) crashes, but little is known about determinants of cyclist injury severity under different traffic control measures at intersections. Preliminary analyses of 5,388 police-reported BMV crash data for 2002-2014 from Queensland, Australia revealed that cyclist injury severity differed according to whether the intersection had a stop/give way sign, traffic signals or no traffic control. Therefore, separate mixed logit models of cyclist injury severity (fatal/hospitalized, medically treated, and minor injury) were estimated. Despite similar distributions of injury severity across the 3 types of traffic control, more factors were identified as influencing cyclist injury severity at stop/give way controlled intersections than at signalized intersections or intersections with no traffic control. Increased injury severity for riders aged 40-49 and 60+ and those not wearing helmets were the only consistent findings across all traffic control types, although the effect of not wearing helmets was smaller at uncontrolled intersections. Cyclists who were judged to be at fault were more severely injured at stop/give way and signalized intersections. Speed zone influenced injury severity only at stop/give way signs and appears to reflect differences in intersection design, rather than speed limits per se. While most BMV crashes occurred on dry road surface, wet road surface was associated with an increased cyclist injury severity at stop/give way intersections. The results of this study will assist transport and enforcement agencies in developing appropriate mitigation strategies to improve the safety of cyclists at intersections.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05742
Paper Title	Predicting the Likelihood of Aging Pedestrian Severe Crashes Using Dirichlet Random-Effect Bayesian Logistic Regression Model
Abstract	There is ample literature on factors that contribute to the injury severity of pedestrian-vehicle crashes. Nevertheless, coupled with a continuous growing aging population, there is limited information addressing predictors that influence the injury severity of pedestrian-vehicle crashes involving older pedestrians. As such, this study developed an injury severity model with improved prediction accuracy, and hence identified the risk factors that influence the severity of aging pedestrians. In particular, the Dirichlet random-effect logistic model (DRL) was used to account for unobserved heterogeneity across crash data. Unlike the conventional parametric random-effect logistic model (CRL), which assumes that the heterogeneity of data varies across individual observations, the approach applied herein is flexible, imposing a belief that the DRL can recognize clusters of unobserved heterogeneity of crash observations. Various predictive capability indicators were utilized to compare the basic logistic (BL), CRL, and DRL model performances. The DRL model outperformed the BL and CRL models in all performance metrics used. The accuracy of the DRL was found to be 90% versus 83% and 68% for CRL and BL models, respectively. Moreover, seven variables were found to significantly influence the severity of aging pedestrians at the 95% Bayesian Credible Interval. These variables include pedestrian age, alcohol involvement, first harmful event, vehicle movement, shoulder type, posted speed, and traffic volume. It is envisioned that the findings of this study can provide a better understanding of the contributing factors to the transportation agencies, which can assist in devising traffic crash risk reduction strategies, especially for elder pedestrians.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-00382
Paper Title	Occurrence and Severity of Crashes Involving Vulnerable Road Users: An Integrated Spatial and Temporal Analysis
Abstract	Pedestrians and cyclists, often called vulnerable road users (VRUs), are more likely to be injured in road crashes as they are more exposed to risk. It is estimated that each year 1.2 million road users lose their lives on the world's road crashes with half of them being VRUs. This situation has a dramatical impact in terms of health and economical development and costs to governments, when low- and middle-income countries lose approximately 3% of their GDP. The analysis of road crashes registrations and the development of predictive models to identify areas with higher risk could be a crucial step to improve road safety and sustainable urban mobility. The main objective of this paper is to find temporal and spatial patterns of crashes between motor vehicles-VRUs based on severity, in order to implement a model that estimates the probability of occurrence of a crash involving VRUs. For that purpose, crashes data from three cities in Portugal with different characteristics were examined. Crashes were georeferenced and blackspots were identified considering injury severity. Although georeferencing is often a method of identifying potential risk areas, it is not associated with time and injury severity. The proposed model is defined as a Multinomial logistic regression model (MLR) with pedestrians and cyclists as a response variable. The findings from this study highlighted target variables that may influence number and severity of crashes between motor vehicle and VRUs. The developed MLR models revealed that VRU gender and age, as well as weather conditions, are statistically significant.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-02980
Paper Title	Bicyclist-Involved Crashes on Roadway Segments in New York City: A Spatial Analysis of Injury Severity
Abstract	With increasing popularity of bicycling, bike lane networks are expended in urban areas. Moreover, bicycling safety has gained continuing attention. However, most research on bicycling crash data focus on crash frequency, while limited literature is about injury severity. Among papers related to bicyclist-involved crash injury severity, only few of them consider bike lane. Using bicyclist-involved crash data in New York City, this study explores correlates of bicyclist-involved crash injury severities with a spatial concern of safety effects of bike lanes. These correlates may vary spatially due to spatial heterogeneity (i.e. geographic and socio-demographic diversity) within the whole city. Hence, Geographically Weighted Regression method is applied to uncover spatial variation in associations between injury severities and contributing factors. The global model (Ordered Logistic Regression) and the local models (Geographically Weighted Ordered Logistic Regression) are fitted. The modeling results of both global model and local models indicate that associations between bike lane related explanatory variables (i.e. the four bike lane types, number of bike lane on roadway segments) and injury severities are not significant. Averagely, summer time, heavy-duty vehicle, motorist, and multi-family elevator buildings are associated with higher probability of moderate, severe, or fatal injury. Fundamentally, the assumption of stationary associations in the global model does not fully hold in space. The results of local models reveal the spatial patterns of correlates. Maps of spatial varying coefficients visualize their spatial variation. Therefore, the local models considering regional situation could provide more information to guide safety improvement.

Authors	Dan Wan, City College of New York Camille Kamga, City College of New York Jun Liu, University of Texas, Austin
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-02988
Paper Title	Injury Severity of Bicyclist-Involved Crashes at Intersections: A Comparative Study in New York City
Abstract	Since bicycling is becoming increasingly popular in cities, bicycling safety has become a growing societal concern. While most research focuses on the frequency of bicyclist-involved crashes, the correlates of injury severity are under-explored. Through studying injury severity in crashes that occurred at intersections in NYC, this study addresses the question of whether bike lanes mitigate the injury severity in bicyclist-involved crashes. Geo-referenced crash data was used with crashes grouped by their location at intersections with bike lanes and without bike lanes. Four types of bike lanes were studied: a) Protected bicycle paths with an access point, (b) Bicycle lanes, (c) Shared lanes, and (d) Signed routes. Simple statistics show that crashes at intersections with two or more types of bike lanes have the largest share of fatal or severe injuries. Multi-level ordered logistic models were developed to better understand the injury severity correlations. Modeling results indicate that the bike lane type has no significant association with injury severity in bicyclist-involved crashes, while factors such as time of year and types of motor vehicle involved in crashes are significantly linked to injury severity. Crashes during summer seem to have a 1.7% higher chance of resulting in fatal or severe injury at intersections with bike lanes. The involvement of heavy-duty vehicles (buses or trucks) is linked to a 7.4% increased probability of a fatality or severe injury at intersections with bike lanes. The results offer insights into bicycling planning, interaction design, and future research directions, which are extensively discussed in this paper.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-03480
Paper Title	Analyzing the Injury Severity Sustained by Nonmotorists at Midblock Considering Nonmotorists' Precrash Behavior
Abstract	Non-motorized travel is being considered as one of the most beneficial transportation modes. However, pedestrians are often exposed to a higher risk of injury and fatality in traffic crashes. Compared to other road users, non-motorists like pedestrians have shorter travel range but face a higher risk of fatal and severe injury at midblock. In addition, there are few reported studies that investigated the impact of non-motorists' pre-crash behavior on injury severities. To examine the risk factors of non-motorist injury severity at midblock, 8-year crash-related data from the GES system are explored based on the mixed logit model, including time characteristics, crash features, environmental conditions, roadway attributes, nonmotorists' characteristics and their pre-crash behaviors. The results show that five parameters tend to have mixed effects on injury severities, including speed limit between 30 and 55 mph, night time, right side collision, and hit-and-run on the incapacitating injury, as well as no action of motorists on the non-incapacitating injury. Moreover, heavy and light truck, three or more lanes, dark not lighted and age 65 are found to increase the likelihood of fatal injury, while the impacts of left side collision and age below 25 decrease the likelihood of fatality. After controlling for these factors, nonmotorists' pre-crash behaviors such as darting or running into the road, activities in the roadway, and improper passing are also found to have a significant impact on severity outcomes.

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Sponsoring Committee	Standing Committee on Visibility (AND40)
Session Number	429
Session Title	Lighting, Visibility, and Safety
Paper Number	18-05178
Paper Title	Exploring the Impacts of Street Illuminance on Nighttime Crash Severity in Roadway Segments Using a Random Parameter Ordered Probit Model
Abstract	Nighttime crashes are over-represented on the US highway system. Roadway lighting, providing additional visibility by supplementing vehicle headlights, has been identified as an effective countermeasure to improve nighttime safety. However, the effect of street lighting illuminance in reducing the injury severity of nighttime crashes on roadway segments is not well-documented. This study aimed to investigate the effect of street lighting illuminance, rather than the presence of street lighting, on nighttime crash severity on roadway segments. Illuminance data were collected in the Tampa Bay area in Florida from 2012–2014 using the Advanced Lighting Measurement System and four years of crash data (2011–2014). A random parameter ordered probit model was developed based on the collected data for addressing the unobserved heterogeneity issue in the sample. The major conclusions include the following: (1) a medium illuminance level (0.4–0.8 fc) compared to a low illuminance level (<0.4 fc) can significantly reduce the injury severity of nighttime crashes; (2) a high illuminance level (>0.8 fc) has no significant influence on the injury severity of nighttime crashes compared to a medium illuminance level, but its effect is random (63.7% increase in injury severity and 23.7% decrease); (3) the involvement of vulnerable road users (pedestrians, bicyclists, motorcyclists) and aggressive driving are the first and second most significant factors contributing to severe injury (fatal or incapacitating) in nighttime crashes; and (4) other significant factors include injured party gender, driver age (at fault), crash type, roadway speed limit, lane configuration, pavement friction, etc.

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Sponsoring Committee	Standing Committee on Artificial Intelligence and Advanced Computing Applications (ABJ70)
Session Number	385
Session Title	Artificial Intelligence and Machine Learning Tools for Estimation, Detection, and Prediction Applications in Transportation
Paper Number	18-02088
Paper Title	Predicting Crash Severity Based on Its Related Collision Type Using Five Data Mining Techniques
Abstract	Modeling techniques such as discrete choice and data mining can be used to predict the severity of a collision based on related factors. The discrete choice is regarded as a regression technique, which has its own model assumptions and predefined relationships between dependent and independent variables. This study seeks to predict crash severity using three data mining classification techniques. Five different data mining techniques including Bayesian Network, Artificial Neural Networks-Multi-Layer Perceptron (ANN-MLP), Artificial Neural Networks-Radial Basis Function (ANN-RBF), Support Vector Machine (SVM)-Polynomial and Support Vector Machine (SVM)-Sigmoid were developed and subsequently compared to determine which one displays the best performance. A total of 4,566 collisions on roadway segments in Mashhad, Iran that occurred in 2014 were modeled using SPSS MODELER software. Accuracy, error, and area under the curve (AUC) were used to evaluate the selected techniques, and ANN-RBF displayed the best performance among the proposed data mining algorithms. This result may be rooted in the fact that RBFs can be optimized fully, which is not only fast but does not suffer from problems such as local minima which plague MLP training techniques. Furthermore, among the variables used in the modeling process, traffic flow parameters exerted the greatest impact on the development of crash severity prediction models. The results also show that modeling collision severity based on its probable type is an effective approach in which countermeasures can be proposed more efficiently.

Authors	Lacramioara Balan, Old Dominion University Rajesh Paleti, Old Dominion Universit
Sponsoring Committee	Standing Committee on Statistical Methods (ABJ80)
Session Number	264
Session Title	Research Advances in Statistical and Econometric Methods
Paper Number	18-02227
Paper Title	A Modified Mixed Generalized Ordered Response Model to Handle Misclassification in Injury Severity Data
Abstract	Traditional crash databases that record police-reported injury severity data are prone to misclassification errors. Ignoring these errors in discrete ordered response models used for analyzing injury severity can lead to biased and inconsistent parameter estimates. In this study, mixed generalized ordered response (MGOR) model that quantifies misclassification rates in the injury severity variable and adjusts the bias in parameter estimates due to misclassification was developed. The model was used to analyze misclassification rates in police-reported injury severity of the 2014 General Estimates System (GES) data. The model uncovered 32% misclassification rate in the non-incapacitating severity category. Also, comparative analysis with the MGOR model that ignores misclassification not only has lower data fit but also considerable bias both in the parameter and elasticity estimates. The model developed in this study can be used to analyze misclassification errors in ordinal response variables in other empirical contexts.

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Sponsoring Committee	Standing Committee on Artificial Intelligence and Advanced Computing Applications (ABJ70)
Session Number	385
Session Title	Artificial Intelligence and Machine Learning Tools for Estimation, Detection, and Prediction Applications in Transportation
Paper Number	18-03042
Paper Title	A Deep Learning Approach to Predict Severity Levels of Work Zone Crashes
Abstract	Aging infrastructure and increased traffic volume put more pressure on highway maintenance and upgrading. This unavoidably leads to an increasing number of work zones present on highways. Consequently, these work zones often create a hazardous roadway environment to road users. In order to help transportation agencies identify more appropriate countermeasures for crash risk mitigation in work zones, more comprehensive studies on the work zone safety issues related to crash occurrences and their corresponding outcomes are needed. Other than crash occurrence analysis, previous research mainly sought to use statistical models to examine the causal relationship between potential risk factors and work zone crash severity. However, very few of them examined the predictive performance of the deployed models. In light of this issue, this paper contributes to the field by introducing a deep learning approach to predict the severity levels of work zone crashes. The deep learning approach built upon the convolutional neural network was established. A numerical study that uses massive work zone crash data obtained from a State crash database was conducted to test the predictive capability of the proposed approach. Compared with two baseline approaches (logistic regression and support vector machine), the proposed method achieved improved performance. The implications of the sensitivity analysis on the impact of several key parameters are also discussed to facilitate implementing the proposed approach for predicting work zone crash severity.

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Sponsoring Committee	Standing Committee on Transportation in the Developing Countries (ABE90)
Session Number	198
Session Title	Traffic Management and Safety in China and Kenya
Paper Number	18-04655
Paper Title	Influence of Socioeconomic Conditions in Crash Injury Severity for an Urban Area in a Developing Country
Abstract	First paper including macroeconomic conditions in an econometric framework to understand urban crash injury severity (CIS) in a developing country. Macroeconomic indicators approximate unique socioeconomic conditions of developing countries that are important to understanding CIS. A unique dataset of crashes in Medellin, Colombia (developing country), between 2009 and 2016 is analyzed. A comprehensive literature review illustrates previous approaches to understand CIS. Both classic and novel macroeconomic variables are analyzed with a multinomial logit (MNL) model with random parameters. Results show macroeconomic indicators influence CIS. Other covariates include geometry, traffic control, pavement, time, crash-specific, and environmental attributes. Several policy implications are proposed and discussed based on the results.

Authors	Waleed Khan, University of Nebraska, Lincoln Aemal Khattak, University of Nebraska, Lincoln
Sponsoring Committee	Standing Committee on Highway/Rail Grade Crossings (AHB60)
Session Number	324
Session Title	Analysis of Safety Concerns at Highway-Rail Grade Crossings
Paper Number	18-05356
Paper Title	Injury Severity of Truck Drivers in Crashes at Highway–Rail Grade Crossings in the United States
Abstract	The physical and operational characteristics of large trucks distinguish them from other types of vehicles in terms of facility design needs and safety requirements. A critical node in the surface transportation network is the at-grade intersection of highways and rails because it represents a conflict point between different modes of transportation. The topic of truck safety at highway-rail grade crossings (HRGCs) is important because of unique characteristics of these vehicles and the potential severity of crash outcomes at HRGCs. The main objective of this research is to identify factors related to different injury severity levels of truck/truck-trailer drivers in crashes reported at HRGCs. This study utilized a mixed Logit model to investigate injury severity of those drivers and relied on eight years (2007-2014) of Federal Railroad Administration (FRA) HRGC crash and inventory data involving trucks/truck-trailers (n=2664 crashes). Results showed that truck drivers' injuries in crashes reported at HRGCs were positively associated with train speed, when train struck the road user (truck/trailer), when the driver "went around crossing gates", older drivers, crashes reported in rural areas and crashes at minimum crossing angle of 60-90 degrees. Presence of crossbucks, gates, track obstructions, and HRGCs located within 500 feet of a highway were associated with less severe driver injuries. The paper provides recommendations for safety improvements at HRGCs and recommendations for future research.

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Sponsoring Committee	Standing Committee on Motorcycles and Mopeds (ANF30)
Session Number	291
Session Title	New Technologies and Methods in Motorcycle Safety—Hybrid Session
Paper Number	18-06463
Paper Title	Factors Influencing the Severity of Motorcycle Crashes in Dar es Salaam
Abstract	Motorcycles are a common mode of transportation in low and middle-income countries. Tanzania, in particular, has experienced an increased use of motorcycles in the last decade. In Dar es Salaam, motorcycles provide door-to-door travel, and often operate where more conventional services are uneconomical or physically impossible to maneuver. Although motorcycles play a crucial role in improving mobility in the city, they have several safety issues. This study focuses on identifying factors influencing severity of motorcycle crashes. From 2013-2016, a total of 784 motorcycle crashes were extracted from the Tanzania police force records. The severity categories were fatality, severe injury, minor injury, and property damage only. A multinomial logit analysis was performed. The following factors were found to increase the probability of a fatality: speeding, driving under influence, head-on impact type, presence of horizontal curves, reckless riding, during off peak hours, violations, and riding without helmets. The results indicate that crashes occurring on weekdays, during peak hours, at intersections, rear-end impact type, in daylight, on street roads, and under clear weather conditions decrease the probability of a fatality. However, minor injuries and property damage only crashes are associated with crashes occurring during peak hours, at intersections, at street roads, and failure to yield right-of-way. 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.

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Sponsoring Committee	Standing Committee on Transportation Safety Management (ANB10)
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00509
Paper Title	Single-Vehicle Crashes on Rural Two-Lane Highways and Injury Severity: Does the Age Matter?
Abstract	Single-vehicle crashes on rural two-lane highways impose a considerable risk to road users due to their higher severity outcome compared to other crashes on these facilities. Furthermore, considerable variation in the severity among various age groups (young, middle-aged, and older drivers) has been noticed, corroborating the need for analyzing age-classified data. Crash data from Alabama was compiled and classified based on the age group. For each age class, a generalized ordered logit model was developed to identify the effect of various variables on injury severity. This model can consider ordered nature of severity as well as provide flexibility in calculating the parameter estimates. Driver gender, seatbelt use, damage to the vehicle, driving on county roads, hitting a fixed object and animal, and speeding were found to be significant in all developed models. Intoxication is a significant factor that affects injury severity for young drivers. Time of day also significantly affects the injury severity for older drivers. Vehicle age and driving with invalid license were not found to affect injury severity for older drivers, while they affected the other age groups. It was shown that some factors have significant effect on the injury severity for all age groups while others have varying effect across different age groups. The results of this study highlight the importance of considering separate injury severity models for different age groups, specifically separating older drivers from others, as the difference among older drivers and others are substantial.

Authors	Samuel Taylor Brendan Russo, Northern Arizona University Emmanuel James, Northern Arizona University
Sponsoring Committee	Standing Committee on Truck and Bus Safety (ANB70)
Session Number	458
Session Title	Truck and Bus Safety Research
Paper Number	18-02290
Paper Title	A Comparative Analysis of Factors Affecting the Frequency and Severity of Freight-Involved and All-Vehicle Crashes on a Major Freight Corridor Freeway
Abstract	Traffic crashes cost society billions of dollars each year as a result of property damage, injuries, and fatalities. Additionally, traffic crashes have a negative impact on mobility, as they are a primary cause of non-recurring delay. With the Interstate 10 corridor between the ports of Los Angeles and Houston being one of the most vital links for goods movement across the United States, safety and mobility along this freeway, particularly for freight traffic, are of significant concern. This study, which utilized six years of crash data from the state of Arizona, explores factors affecting the frequency and severity of crashes along the Arizona portion of the I-10 corridor, with a particular focus on freight-related crashes. The safety performance along the I-10 is analyzed through the development of crash frequency and severity prediction models using integrated crash, roadway, traffic, and environmental data. Negative binomial and ordered logit models, with the incorporation of random parameters, were estimated to provide a detailed understanding of factors associated with freight-involved crashes and how they compare to non-freight crashes in terms of frequency and severity. The results showed that several roadway- crash-, vehicle-, and person-related variables were associated with the frequency and/or severity of crashes along the study corridor. These findings provide important insights which can be used to develop or plan countermeasures aimed at improving the safety and efficiency of freight travel, which may include new ITS technologies, and targeted educational and enforcement campaigns.

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Sponsoring Committee	Standing Committee on Truck and Bus Safety (ANB70)
Session Number	458
Session Title	Truck and Bus Safety Research
Paper Number	18-04409
Paper Title	Factors Influencing Injury Severity of Crashes Involving HAZMAT Trucks
Abstract	This paper investigates factors affecting injury severity of crashes involving HAZMAT large trucks. It uses the crash data in the state of California from the Highway Safety Information System, from 2005 to 2011. The explanatory factors include the occupant, crash, vehicle, roadway, environmental, and temporal characteristics. Both fixed- and random-parameters ordered probit models of injury severity (where possible outcomes are major, minor, and no injury) were estimated; the random-parameters model captures possible unobserved effects related to factors not present in the data. The model results indicate that the occupants being male, truck drivers, crashes occurring in rural locations, under dark-unlighted, under dark-lighted conditions, and on weekdays were associated with increased probability of major injuries. Conversely, the older occupants (age 60 and over), truck making a turn, rear-end collision, collision with an object, crashes occurring on non-interstate highway, higher speed limit highway (≥ 65 mph), and flat terrain were associated with decreased probability of major injuries. This study has identified factors that explain injury severities of crashes involving HAZMAT, and as such, it could be used by policy makers and transportation agencies to improve HAZMAT transport, and thus, the overall highway safety.

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Sponsoring Committee	Standing Committee on Truck and Bus Safety (ANB70)
Session Number	458
Session Title	Truck and Bus Safety Research
Paper Number	18-05958
Paper Title	Classification Tree Modeling of Factors Impacting Severity of Truck-Related Crashes in Ohio
Abstract	Large truck safety is a very crucial aspect of the overall safety of the transportation system. Records show that in the United States and in the state of Ohio large trucks are over-represented in fatal and serious injury crashes. Recognizing this alarming impact of large truck-related crashes in the overall transportation safety, this study attempts to identify strongly important factors that increase the risk of injuries/fatalities due to large truck-related crashes. The study used truck-related crash data from Ohio for two and half years (July 2013-December 2015). The classification tree model was used in analyzing the data. It was determined that the strongly important factors of large truck-related crash severity are collision type, posted speed limit, collision event, speed-related, and intersection-related. These kind of crashes can be reduced by drivers abiding to driving laws and law enforcement strategies to ensure driving laws are followed.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-00060
Paper Title	How Driving Volatility in Time to Collision Relates to Crash Severity in a Naturalistic Driving Environment
Abstract	The sequence of instantaneous driving decisions and its variations, known as driving volatility, can be a leading indicator of unsafe driving practices. The research issue is to characterize volatility in instantaneous driving decisions in longitudinal and lateral direction and to seek an understanding of how driving volatility relates to crash severity. By using a unique real-world naturalistic driving database from the SHRP 2, a test set of 671 crash events featuring around 0.2 million temporal samples of real-world driving are analyzed. Based on different driving performance measures, 16 different volatility indices are created. The volatility indices are then linked with individual crash events including information on crash severity, drivers' pre-crash maneuvers and behaviors, secondary tasks and durations, and other factors. As driving volatility prior to crash involvement can have different components, an in-depth analysis is conducted using the aggregate as well as segmented (based on time to collision) real-world driving data. To account for the issues of observed and unobserved heterogeneity, fixed and random parameter ordered models with heterogeneity in parameter means are estimated. The findings suggest that greater driving volatility (both in longitudinal and lateral direction) prior to crash occurrence increases the likelihood of police reportable or severe crash events. Importantly, compared to the effect of volatility in longitudinal acceleration on crash outcomes, the effect of volatility in longitudinal deceleration is significantly greater in magnitude. Methodologically, the random parameter models with heterogeneity-in-means significantly outperformed both the fixed parameter and random parameter counterparts. The relevance of the findings to the development of proactive behavioral countermeasures for drivers is discussed

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-00866
Paper Title	Analysis of Work-Zone Crash Reports to Determine Factors Associated with Crash Severity
Abstract	Highway work zones present an environment that leads to opportunities for traffic crashes that may not otherwise occur. To investigate the severity of work zone-related crashes and relationships between severity and other crash variables, a database of 5,410 work zone-related crashes that occurred in Alabama from 2007-2014 was developed. The database includes information from traffic crash reports, project traffic control inspector reports, and supporting documentation from contractors. The full range of variables included in the crash reports was reduced to a manageable set of 16 independent variables whose relationships to crash severity were then explored. This analysis involved the development of an ordered probit regression model and examination of frequency distributions. The five most statistically significant variables that affect crash severity were found to be Primary Contributing Factor, Manner of Crash, First Harmful Event, Highway Classification, and Work Zone Type. Specific factors that had a highly statistically significant effect on severity include evening and overnight time periods, open country locale, rain, no-passing zones, Federal and State highways, two-lane highways, head-on, rollover, and angle crashes, pedestrian and bicyclist involvement, single-vehicle crashes, excessive speed, improper lane use, and the presence of work on the shoulder or median.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-06389
Paper Title	Evaluating Factors Influencing the Severity of Three-Plus Multiple-Vehicle Crashes Using Real-Time Traffic Data
Abstract	Multiple-vehicle crashes involving at least two vehicles constitute over 70% of fatal and injury crashes in the U.S. Moreover, multiple-vehicle crashes involving three or more vehicles are usually more severe compared to the crashes involving only two vehicles. This study focuses on developing three plus multiple-vehicle crash severity models for a freeway section using real-time traffic data and crash data for the years 2014 to 2016. The study corridor is a 111-mile section on I-4 in Orlando, Florida. Crash injury severity was classified as a binary outcome (fatal/severe injury and minor/no injury crashes). For the purpose of identifying the reliable relationship between the 3+ severe multiple-vehicle crashes and the identified explanatory variables, a Binary probit model with Dirichlet random parameter was used. More specifically, Dirichlet random parameter model was introduced to account for unobserved heterogeneity in the crash data. The probit model was implemented using a Bayesian framework and the ratios of the Monte Carlo errors were evaluated to achieve parameter estimation convergence. The following variables were found significant at the 95% Bayesian Credible Interval: logarithm of average vehicle speed, logarithm of average equivalent 10-minute hourly volume (EHV), logarithm of standard deviation of EHV, alcohol involvement, lighting condition, and number of vehicle involved in multiple-vehicle crashes. Further analysis involved analyzing the posterior probability distributions of these significant variables. The study findings can be used to associate certain traffic conditions with severe injury crashes involving multiple vehicles, and can help develop effective crash injury reduction strategies based on real-time traffic data.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety
Paper Number	18-02836
Paper Title	Network Screening for Large Urban Road Networks: Using GPS Data and Surrogate Measures to Model Crash Frequency and Severity
Abstract	Crash frequency and injury severity are independent dimensions of road safety which should be considered in the network screening process. Traditional screening techniques model crashes using regression and historical crash data, making them intrinsically reactive. In response, surrogate safety measures (SSMs) have become a popular alternative. The purpose of this paper is to develop a mixed-multivariate model for crash frequency and severity by incorporating GPS-derived SSMs as predictive variables. SSMs based on vehicle manoeuvres and traffic flow were extracted from GPS data collected in Quebec City, Canada. The mixed multivariate outcome is estimated using two models. First, crash frequency is modelled using a Full Bayes Spatial Negative Binomial model estimated using the Integrated Nested Laplace Approximation approach. Second, crash severity is integrated through a fractional Multinomial Logit model. Third, the results are combined to generate crash counts at each severity level and rank sites based on crash cost per trip. The crash frequency model was shown to be accurate at the network scale, with all proposed SSMs statistically significant at 95 % confidence and the direction of their effect consistent with previous research. In the crash severity model, fewer variables were significant, yet the direction of the effect of all significant variables was again consistent with previous research. Rankings generated using the mixed multivariate model were 95 % correlated to the crash data rankings. The ability to prioritize sites based on GPS data and SSMs rather than historical crash data represents a substantial contribution to the field of road safety.

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Sponsoring Committee	Standing Committee on Motorcycles and Mopeds (ANF30)
Session Number	554
Session Title	Motorcycle and Moped Crash Studies
Paper Number	18-04840
Paper Title	Using Deep Learning in Severity Analysis of At-Fault Motorcycle Rider Crashes
Abstract	Motorcyclists are vulnerable highway users. Unlike passenger vehicle occupants, motorcycle riders do not have either protective structural surrounding or the advanced restraints, which are mandatory safety features in cars and light trucks. Per vehicle mile traveled, motorcyclist fatalities occurred 27 times more frequently than passenger car occupant fatalities in traffic crashes. Additionally, there were 4,976 motorcycle crash-related fatalities in the U.S. in 2014—more than twice the number of motorcycle rider fatalities that occurred in 1997. Countless research efforts on motorcycle crash data have been conducted to understand the contributing factors that influence severity of crashes. However, the number of crashes is still at an unacceptable level, which is evident by the sharp rise of motorcycle-involved fatalities in the last 15 years. This shows that, in addition to current efforts, research needs to be conducted with additional resources and in newer directions. Deep Learning is an excellent tool in mapping a high-multidimensional input into a smaller multidimensional output. The current study contributes to the existing injury severity modeling literature by developing a deep learning framework, named as DeepScooter, to predict motorcycle involved crash severities. The final model can predict severity types with 100% accuracy with training data, and with 94% accuracy with test data. The intensity of severities were found to be more likely associated with driver ejection, two way roadways with no physical separation, curved aligned roadways, and weekends. It is anticipited that the DeepScooter framework and the findings will provide significant contributions to the area of motorcycle safety.

Authors	Raul Avelar, Texas A&M Transportation Institute Karen Dixon, Texas A&M Transportation Institute Sruthi Ashraf, Texas A&M Transportation Institute
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	575
Session Title	Highway Safety Performance
Paper Number	18-00495
Paper Title	A Comparative Analysis on Performance of Severe Crash Prediction Methods
Abstract	The objective of this paper is to compare the performance and tradeoffs among two alternative analysis methods for developing crash prediction models for severe crashes: a direct estimation of severe crashes using frequency models, and a more indirect but popular approach of combining frequency of total crashes models and some form of Severity Distribution Functions (SDFs). The researchers conducted a comprehensive comparison of model methods to illustrate strengths and weaknesses of each alternative and to inform future research that intends to develop such models. An examination of the theoretical characteristics of the modeling approach is presented and discussed. The performance of the two modeling alternatives is compared using two different datasets. The results of those comparisons showed very similar performances by both techniques. Finally, a sensitivity analysis is presented to explore how the performance of these techniques vary by degree of dispersion and observed correlation levels of Total and KAB crashes with potential explanatory variables. The results from these analysis tended to favor the use of SDFs in combination with Total Crashes SPFs, as the prediction tended to show reduced dispersion under most conditions. However, performance of the KAB SPF model outperformed the combination of SDF and SPF for Total Crashes when KAB and non KAB crashes had a common predictor but with effects in opposite directions.

Authors	Samantha Islam, University of South Alabama Burton Benjamin, University of South Alabama
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	575
Session Title	Highway Safety Performance
Paper Number	18-00975
Paper Title	Comparative Analysis of Injury Severity Resulting from Rural Intersection Crashes Under Different Lighting Conditions in Alabama
Abstract	The research described in this paper explored the factors contributing to the injury severity resulting from rural intersection crashes in Alabama under different lighting conditions. Given the occurrence of a crash, separate random parameter logit models of injury severity (with possible outcomes of fatal, major, minor, and possible or no injury) were estimated for different lighting conditions: i. dark and ii. lighted (including daylight). The estimated models identified a variety of statistically significant factors influencing the injury severities resulting from crashes occurring under dark and lighted/daylight conditions. According to these models, some variables were found to be significant only in one model (dark or lighted/daylight) but not in the other one. For example, variables such as female drivers, presence of no opposing lane separations, and presence of stop signs were found significant only in the dark intersection model. On the other hand, variables such as old drivers, presence of signaling devices, and posted speed limit 40 mph or lower were found significant only in the lighted/daylight model. In addition, some variables (such as, driver under influence of alcohol, roadway curves, etc.) were found significant in both models. Estimation findings also showed that two parameters in each 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 paper discusses the effects of different variables on injury severities resulting from crashes at rural intersections under different lighting conditions and their possible explanations.

Authors	Sareh Bahrololoom, Monash University William Young, Monash University David Logan
Sponsoring Committee	Standing Committee on Bicycle Transportation (ANF20)
Session Number	781
Session Title	Cycling Safety and Comfort
Paper Number	18-04070
Paper Title	A Safe System-Based Investigation of Factors Influencing Bicycle Crash Severity in Victoria, Australia
Abstract	Safe System approach has been adopted in Australia and New Zealand to manage vehicles, road and roadside infrastructure, and speeds to eliminate death and serious injury as a consequence of road crashes. In Australia, one main focus of road safety professionals is applying Safe System principles to reduce the number of death and serious injuries resulting from bicycle crashes. This study examined the effect of factors associated with three pillars of the Safe System approach on bicycle crash severity in Victoria, Australia. These pillars include 'safe roads and roadsides', 'safe speeds' and 'safe road users'. The Victorian police-collected road crash information system (RCIS) database was used to conduct the analysis. A random parameter binary logit model was utilised to find out the effect of factors on bicycle crash severity. The results showed that traffic control and lighting condition were the 'safe roads and roadsides' related parameters influencing bicycle crash severity. Speed zone was also found as a significant factor under the 'safe speeds' pillar in the Safe System approach. Furthermore, bicyclist age, helmet use, intention (movement) and other road user intention (movement), were the other significant variables (i.e. related to 'safe road users' pillar) affecting the severity of bicycle crashes. The results also suggested that more in depth investigation of bicycle crash dynamics is required to achieve better understanding of the parameters influencing bicycle crash severity.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-00073
Paper Title	Comparing the Operational and Geometric Injury Severity Risk Factors on Rural Freeways in Different States in the United States
Abstract	This study compares the significant operational (e.g., the annual average daily traffic "AADT") and geometric (e.g., road surface condition and type) factors affecting crash injuries and fatalities on different rural freeways in the United States. Two case studies in the states of Montana and West Virginia are used. The study makes use of crashes on mainline (or basic) rural segments in both states. An uncommon variable explored is whether the crash involves "hit-and-run". The mixed logit model is applied, which offers a methodological flexibility to capture individual-specific heterogeneity while allowing the parameter estimates to randomly vary across the crash observations. The study uses three-year crash data (2011 to 2013) on rural freeway segments in Montana and West Virginia. Higher AADT was associated with a reduction in injuries and fatalities in both states, with West Virginia exhibiting a higher reduction (around 40%). Some variables were found significant in one state, but not in the other. For example, middle-age group had a reduction in injuries and fatalities in the Montana model; however, was not found significant in the West Virginia model. Furthermore, hit-and-run crashes were associated with lesser fatality likelihood compared to non-hit-and-run crashes in Montana. The results show that the significant factors of crash injury can vary for the same facility type (i.e., rural freeways) across different states. Thus, different crash injury severity models for different states are suggested instead of lumping all crashes in a single model. Potential countermeasures are included to reduce injuries and fatalities on rural freeway segments in both states.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01354
Paper Title	A Two-Step Quantile Selection Model for Safety Analysis at Signalized Intersections
Abstract	The simultaneous estimation of crash frequency and severity has been studied for years, but most methodologies have adopted mean regression models to estimate the parameters. This study presents the quantile selection model as a methodological alternative for analyzing crash rate and severity at different levels, focusing on addressing heterogeneity and endogeneity issues to identify the influencing factors at signalized intersections. A two-step estimation procedure is conducted in which the Heckman selection framework accounts for the endogenous relationship between crash rate and crash severity at different levels, and quantile regression estimates various quantiles of crash rate instead of mean regression and accounts for the heterogeneity attributed to unobserved factors. The quantile approach provides more comprehensive information about how influencing factors affect crash rate than the general Heckman selection model. The model uses 555 crash observations from 262 signalized intersections in the Hong Kong metropolitan area, integrated with information on traffic flow, geometric road design, road environment and traffic control. The proposed model reveals more detailed information in terms of different quantiles and improves the prediction accuracy.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-03237
Paper Title	Analysis of Accident Injury Severities Using a Time-Variant Correlated Random Parameters Ordered Probit Approach
Abstract	This paper employs a correlated random parameters ordered probit modeling framework to explore time-variant and time-invariant factors affecting injury-severity outcomes in single-vehicle accidents. The proposed approach extends traditional random parameters modeling, by accounting for possible correlations among the random parameters. On the basis of an unrestricted covariance matrix for the random parameters, the proposed framework can capture the combined effect of the unobserved factors – which are captured by the random parameters – on the injury-severity mechanism. The empirical analysis is based on traditional roadway-, traffic- and crash-specific information, and detailed weather and pavement surface disaggregate data, collected in the State of Washington, between 2011 and 2013. The results show that accident injury-severity outcomes are affected by a number of time-variant (ice thickness or water depth on pavement surface, sub-surface temperature) and time-invariant (roadway geometrics, and vehicle-, driver-, and collision-specific characteristics) factors, several of which result in statistically significant parameters – thus they have mixed effects on the injury-severity generation mechanism. The findings also present statistically significant correlation effects among the random parameters, which substantiates the appropriateness of the approach. The comparative assessment between the employed approach and its lower-order counterparts (i.e., fixed parameters, and uncorrelated random parameters ordered probit modeling approaches) shows that accounting for the unobserved heterogeneity interactions results not only in superior statistical performance (in terms of model's fit, and explanatory and prediction performance) but also in less biased and more consistent parameter estimates.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-03427
Paper Title	Machine Learning Methods to Analyze the Influence of Age and Gender on Driver Injury Severity
Abstract	Access to non-biased and accurate models capable of predicting the driver injury severity of collision events is vital for determining what safety measures should be implemented at intersections. Inadequate models can underestimate the potential for collision events to result in driver fatalities or injuries, which can lead to improperly assessing the safety criteria of an intersection. This study investigates how injury severity differs between drivers of various age and gender groups using cost-sensitive data mining models. Previous research efforts have used machine learning methods for predicting injury severity; however, these studies did not consider the consequences (cost) of incorrect predictions. This paper addresses this shortfall by considering the monetary cost of incorrect injury severity predictions when developing C4.5, instance based (IB), and random forest (RF) machine learning models. One model of each method was developed for four distinct cohorts of drivers (i.e. younger males, younger females, older males, and older females). Each model considered a selection of driver, vehicular, road/traffic, environmental, and crash parameters for determining if they significantly influenced driver injury severity. A five-year period of two-vehicle crash data collected at signalized intersections in the metropolitan area of Miami, Florida was used in the models. Results indicated that cost-sensitive learning classifiers were superior to regular classifiers at accurately predicting important injury severity classes. Among cost-sensitive models, RF outperformed C4.5 and IB models in predicting driver injury severity for four groups of drivers. The models displayed substantial differences in injury severity determinants across the age/gender cohorts.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-04007
Paper Title	Comparison of Two Methods to Explore Influence Factors of Crash Severity
Abstract	This paper seeks to identify factors that impact the level of crash severity with the intent of determining appropriate countermeasures to improve road safety. A total of 191,278 crash records from the Connecticut Crash Data Repository (CTCDR) between 2012 and 2013 were collected. 15 factors covering the crash, driver, vehicle, road, and environmental characteristics were studied in this paper. The severity of a crash can be classified in one of the following three levels: fatality, injury (no fatality) and property damage only (PDO). Two methodologies, namely, the ordered probit model and the Bayesian network model were applied to explore and assess factors which influence crash severity. The Tree Augmented Naive (TAN) Bayes Classifier was used to determine the structure of the Bayesian network and the maximum likelihood method was used to learn the parameters. Comparing the results of the two models, airbag status, collision type and number of vehicles involved are the most important variables in both models. Occupant protection system use and alcohol/drug use also greatly affect the crash severity. Some variables have different implications in the two models, such as driver's age and sex, route class and crash location (at or between intersections). These identified influence factors must be considered while planning, during the construction process, as well as in the operational management of road networks in order to reduce traffic accidents and the severity of injuries.

Authors	Mohamed Osman, University of Memphis Sabyasachee Mishra, University of Memphis Rajesh Paleti, Old Dominion University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-05160
Paper Title	Injury Severity Analysis of Commercially Licensed Drivers in Single-Vehicle Crashes: Accounting for Unobserved Heterogeneity and Age Group Differences
Abstract	This study analyzes the injury severity of commercially-licensed drivers involved in single-vehicle crashes. Considering the discrete ordinal nature of injury severity categories, the Mixed Generalized Ordered Response Probit (MGORP) modeling framework was adopted. Additional effects of the different drivers' age groups are taken into consideration through interaction terms. Unobserved heterogeneity of the different covariates is investigated through the rich structure of the MGORP model. The empirical analysis is conducted using four years of the Highway Safety Information System (HSIS) 6,247 commercially-licensed drivers' single-vehicle crashes in the state of Minnesota. The MGORP model elasticity effects indicates that key factors that increases the likelihood of severe crashes for commercially-licensed drivers across all age groups include: lack of seatbelt usage, collision with a fixed object, speeding, vehicle age of 11 or more years, wind, night time, and weekday. Also, the effects of several covariates were found to vary across different age groups.

Authors	Fan Ye, Ohio Northern University Yong Wang, Ohio Northern University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-05926
Paper Title	Performance Evaluation of Various Missing Data Treatments in Crash Severity Modeling
Abstract	Data quality, including record inaccuracy and missingness (incompletely recorded crashes and crash underreporting), has always been concerns in crash data analysis. Some efforts have been made to handle some specific aspect of crash data quality problems. Yet, there lacks a general investigation of the performance of different statistical methods to handle missing crash data. This paper is intended to explore and evaluate the performance of three missing data treatments (i.e., complete-case analysis, inverse probability weighting, and multiple imputation) in crash severity modeling using Ordered Probit model. By conducting analysis based on both simulated and real crash data, this paper suggests a decision of choosing the appropriate missing data treatment should be based on sample size and data missing rate. Meanwhile, it is recommended to use multiple imputation for incompletely recorded crash records and inverse probability weighting for unreported crashes, before applying crash severity models on crash data.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-06210
Paper Title	A Finite-Mixture Random Parameters Model for Exploring the Risk Factors on Driver Injury Severity of Low Visibility–Related Crashes
Abstract	Low visibility condition is found to be the most dangerous inclement weather event due to its highest fatality rate. A three-year crash dataset from 2010 to 2012 focusing on low visibility related crashes in four South Central states including Arkansas, Louisiana, Texas, and Oklahoma was adopted in this article to study the impacts of different variables on driver injury severity. In order to account for the unobserved heterogeneity within-class and varying across classes, a finite mixture random parameters model is developed in this study for analyzing the aforementioned dataset. After a careful balance, choosing normal distributions as priors for random parameters and classifying the dataset into two subtypes showed significant superiority than other models, and therefore were selected as the final model. Three parameters including rural (I), rural (F), and single vehicle (F) are found to be normally distributed across the observations. Other fixed parameters include the number of vehicles, light conditions, road surface, traffic controls, and driver characteristics. In addition, this paper also provides meaningful countermeasures and strategies on low visibility crashes for severe injury prevention.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-06244
Paper Title	An Empirical Assessment and Investigation of the Driver Injury Severities in Rain-Related Rural Single-Vehicle Crashes Using Mixed and Latent-Class Logit Models
Abstract	Due to slippery road surface together with the limited visibility, single-vehicle crash during rain, especially the one occurred in the rural area, is more likely to result in driver incapacitating injury or even fatality. A two-year crash dataset including all rain-related rural single-vehicle crashes in four South Central states, i.e., Texas, Arkansas, Oklahoma, and Louisiana, from 2011 to 2012 were selected in this paper to analyze the impacts of the risk factors on driver injury severity. Mixed multinomial logit model and latent class multinomial logit model were both developed using the same dataset. Several parsimony indices including AIC and BIC, as well as McFadden pseudo r-squared, are calculated for each model to evaluate their performances. Results showed that choosing normal distribution as the prior for random parameters could best increase goodness-of-fit of the mixed logit model. In addition, the two-class latent class model also showed superiority when compared to the three- and four-class models. Finally, a careful comparison between these two models was conducted, and the results indicated that the latent class logit model behaves better in analyzing the aforementioned dataset in this study. Model estimation results showed that curve, on grade, signal control, multiple lanes, pickup, straight, drug/alcohol impaired, and seat belt not used have adverse impacts on driver injury severity in the two models. On the other hand, wet, male, semi, and young have favorable effects on injury outcomes. This study provides insightful understandings of the effects of these attributes on rain-related single-vehicle crashes and beneficial references for developing effective countermeasures for severe crash prevention.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-06297
Paper Title	Examining Driver Injury Severity in Single-Vehicle Crashes: A Two-Step Study Using Cluster Analysis and Mixed Logit Model
Abstract	Single-vehicle crashes are more likely to result in severe driver injuries and fatalities. The heterogeneity among traffic crash data leads to biased model estimation results, which has been illustrated in previous studies. In this study, latent class clustering is employed to segment whole crash data into seven sub-datasets in order to reduce heterogeneity among crashes in each cluster. The mixed logit model, which is widely used in crash severity analysis, are developed to further examine the heterogeneity in the sub-datasets and identifying contributing factors of severity for specific driver groups. The results indicate that significant differences exist regarding contributing factors and their influence on driver injury severity between whole dataset model and cluster-based models. There are significant contributing factors (e.g. rural) only captured in cluster models, while their impacts on severity remain hidden or insignificant in whole dataset model due to data heterogeneity. Additionally, some contributing variables demonstrate the contrary influence on the same injury severity level between whole dataset model and cluster models. This study examines the necessity of cluster analysis before crash severity analysis to reduce the estimation result bias due to data heterogeneity and provides a better understanding of contributing factors and their impacts on driver injury severity in a single-vehicle crash.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-06609
Paper Title	Development and Evaluation of a Two-Stage Modeling Approach for Estimating Crash Frequency for Horizontal Curves on Two-Lane Rural Roads
Abstract	The Highway Safety Manual (HSM) procedures apply specific safety performance functions (SPFs) and crash modification factors (CMFs) appropriate for estimating the safety effects of design and operational changes to a roadway. Although the applicability of the SPFs and CMFs may significantly vary by crash severity, they are mainly based on total crash counts, with only limited consideration for crash severity. In an effort to fill this void while addressing some methodological issues, this study estimates the proportion of crashes for each severity level on curves – sites with a high propensity for severe crashes -- as a function of roadway-specific factors and traffic attributes, using a two-stage modelling approach. In this regard, using Highway Safety information System (HSIS) data for Washington state, a heterogeneous negative binomial (HTNB) regression model is estimated for total crash counts and then applied with a severity distribution function (SDF) developed by a generalized ordered probit model (GOP). Also, to evaluate the performance of the two-stage approach, a comparison is made with predictions directly obtained from estimated univariate SPFs for crash frequency by severity and also a fixed proportion method that has been suggested in the HSM. The results revealed that, while the two-stage approach and univariate approach adopt different procedures for model estimation, their prediction accuracies are similar, and both are superior to the fixed proportion method. In short, this study highlights the potential of the two-stage modelling approach in accounting for crash frequency variations by severity levels, at least for curved two-lane road sections.

6 Crash Modification Factors

Tarek Sayed and Ahmed Osama, University of British Columbia

This year, the subcommittee identified 23 papers dealing with crash modification factors (CMF) and did not identify any papers dealing with crash modification functions.

Almost all the papers employed the empirical Bayes approach (e.g., Goswamy et al., 18-03564; Srinivasan et al., 18-01803; Lyon et al., 18-00673). One study compared full Bayesian and empirical Bayesian analysis results (Appiah et al., 18-01468). Almost all the studies employed before-after techniques (e.g., Bryant et al., 18-00225; Appiah et al., 18-01468; Rahman et al., 18-06321). Only one study compared the before-after CMF results to the cross-sectional CMF results (i.e., Srinivasan et al., 18-01803). The safety impact of countermeasures was generally represented by changes in crash frequency and/or crash severity except one study that evaluated simulated traffic conflicts as a surrogate measure (Naik et al., 18-02755).

A before-after analysis with benefit-cost evaluation was applied in two studies (Himes et al., 18-03008; Rahman et al., 18-06321). One study developed adjustment factors to account for regional differences and identify underlying crash trends in the before period (Himes et al., 18-01486). Also, one study (Said et al., 18-04247) calibrated SPFs using default CMFs, and the results were compared with actual crash events.

The evaluated countermeasures included median cable barriers (Bryant et al., 18-00225), pavement edge drop-offs (Lyon et al., 18-00673), flashing yellow arrow (Srinivasan et al., 18-01803), edge line rumble stips (Himes et al., 18-03008), cable median barriers (Lan et al., 18-03788), alternative audible lane departure warning treatments (Wu et al., 18-01098), diverging diamond interchanges design (Walls, 18-06071), converting undivided four-lane to five-lane highways (Rahman et al., 18-06321), centerline rumble stips on curves (Babiceanu et al., 18-05020), pedestrian crossing enhancements (Monsere et al., 18-00737), among others.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-01486
Paper Title	Safety Evaluation of Change in Posted Speed Limit from 65 to 70 mph on Rural Virginia Interstate System
Abstract	Effective July 1, 2010, the Virginia Department of Transportation (VDOT) increased the maximum allowable posted speed limit on interstates and similar facilities from 65 mph to 70 mph, after an engineering study. As a result, VDOT performed engineering studies on selected rural interstates posted at 65 mph. Subsequently, by November 2010, VDOT increased the speed limit from 65 to 70 mph for approximately 670 centerline miles of select rural interstates. There is a need to understand the safety and operational effects of increasing posted speed limits from 65 to 70 mph. This paper presents the results of an Empirical Bayes before-after study. The analysis was based on four years of data before and after the increase in posted speed limit, focusing on total, injury, run-off-road, and truck-related crashes. SPFs were estimated and used to account for changes in traffic volume. Comparison segments were used to develop annual adjustment factors, account for regional differences, and identify underlying crash trends in the period before the increase in speed limit. The study considered both aggregate and disaggregate effects. At the aggregate level, the results indicate no increase in any of the focus crash types after the increase in posted speed limit. Focusing on sites without other changes, which are most indicative of the impacts of the increased speed limit, the increased speed limit did not change (i.e. increase or decrease) any of the crash types. The disaggregate analysis provides further insight into the circumstances where the change in posted speed limit had more and less pronounced impacts. Specifically, the disaggregate analysis showed that segment type (base or interchange) influenced the safety impact where there was an increase in all crash types except injury crashes for interchange segments. The disaggregate analysis also showed that roadway improvements (e.g., rumble strip installation/reinstallation, pavement resurfacing activity, guardrail, pavement markings, and various warning signage) may help to offset the safety impact of increasing the posted speed limit.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	Session 834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety
Paper Number	18-03826
Paper Title	Methods to Define Homogeneous Segments and Assign Crashes for Highway Safety Manual Applications
Abstract	The AASHTO Highway Safety Manual (HSM) presents a variety of methods for quantitatively estimating crash frequency. The HSM predictive methods require the roadway network to be divided into homogeneous segments and intersections. The characteristics used to specify homogeneity vary depending on facility type, and could include number of lanes, shoulder width, traffic volume, median type, and a host of other characteristics. Despite the complexity and potential impacts of segmentation, there is a dearth of detail in documented procedures to determine homogeneous segment termini. To fill this void, this paper focuses on automation methods to determine appropriate roadway homogeneous segment termini for different facility types discussed in the HSM. Methods include a Microsoft Excel spreadsheet method using Visual Basic to subdivide roadway segments into homogeneous segments as well as an application for GIS platforms using multi-criteria dynamic segmentation. Both methods have been applied in support of an extensive HSM calibration project for South Carolina Department of Transportation. The paper also includes a case study using an actual roadway segment from South Carolina to demonstrate how the proposed spreadsheet procedure can identify appropriate homogeneous segments. The benefits of using these automated methodologies are summarized and recommendations for future research are discussed.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-00225
Paper Title	Crash Modification Factors for Median Cable Barriers in Tennessee
Abstract	This paper developed Crash Modification Factors (CMF) for median cable barriers in Tennessee. Utilizing cable barriers installed from 2006 to 2010, the study used comparison group approach that considers crashes before and after the installation of cable barriers. Comparison segments were selected if they met criteria such as median width equal to the median width of the existing cable barrier segment plus or minus 10 feet, the segment length is equal to the cable barrier segment plus or minus 20 feet and the AADT is equal to that of the cable barrier segment plus or minus 1000 vpd. Using comparison group and screened median-related crashes only, CMF for fatal crashes was found to be 0.04, fatal and incapacitating injury 0.07, and 0.14 for fatal and all injury crashes combined.. These CMFs which translate into crash reduction percentages of 96% and 86% for fatal and fatal and all injuries combined respectively are comparable or slightly better compared to those obtained from other states. However, when all crashes within the cable segment were used (without screening median related), the CMF for fatal was found to be 0.46, and 1.18 for all crashes. This implies that installation of cable barriers in Tennessee significantly reduces fatal and severe injury crashes but increase minor PDO crashes (mainly those below $400). The developed CMFs responds to the intended benefits of the median cable barriers to prevent cross-median crashes which occurs when a vehicle leaves its travel way enters or crosses the median dividing the highway directional lanes and collides with vehicles in the opposite direction.

Authors	Craig Lyon, Persaud and Lyon Inc. Bhagwant Persaud, Ryerson University Eric Donnell, Pennsylvania State University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-00673
Paper Title	Safety Evaluation of the Safety Edge Treatment for Pavement Edge Drop-Offs on Two-Lane Rural Roads
Abstract	This study estimated crash modification factors (CMFs) for the SafetyEdge paving technique that is applied for the treatment of pavement edge drop-offs on two-lane rural highways. An empirical Bayes observational before-after evaluation based on installation data in Iowa, North Carolina, Ohio, Pennsylvania and Florida found that the SafetyEdge treatment was associated with statistically significant reductions in fatal and injury (FI), run-off-road (ROR), opposite direction (head-on and sideswipe), and drop-off-related crashes. The ROR CMF was also statistically significant for both horizontal curve and tangent sections. A disaggregate analysis examined the variation of the CMF for ROR with factors such as the travel lane width, traffic volume, presence of a horizontal curve, posted speed limit, and the pre-treatment ROR crash frequency. The results of that analysis indicated, for example, that the SafetyEdge paving technique appears to have a greater ROR safety benefit on two-lane rural roadway segments with average annual daily traffic volumes greater than 3,000 vehicles per day, relative to roadway segments with lower traffic volumes. A Crash Modification Function was calibrated with expected pre-treatment ROR crashes as the independent variable to simultaneously capture the relationship of the CMF for ROR crashes to multiple factors. An economic analysis found that the treatment is highly cost-effective.

Authors	Frank Gross, VHB Thanh Le, VHB Scott Himes, VHB
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-00981
Paper Title	Methods Assessment and Recommended Practice for Estimating the Safety Effects of Multiple Treatments
Abstract	Crash modification factors (CMFs) are one tool to estimate the expected safety effects of a given treatment. One practical limitation is that treatments may be considered in combination, but most CMFs represent the effect of a single treatment. Ideally, the analyst would use a CMF for the combination treatment of interest, but relatively few CMFs have been developed for combination treatments, and it would take a tremendous effort to develop CMFs for all likely combinations of treatments. Combining individual CMFs is one alternative to developing CMFs for every possible treatment combination, but there is limited guidance on the application of multiple CMFs. The predictive method from the first edition of the Highway Safety Manual shows that CMFs can be multiplied to estimate the combined effect of multiple treatments, assuming the treatments are independent. It further notes that limited research exists regarding the independence assumption. Further research and guidance is needed to help practitioners estimate the expected safety effects when multiple treatments are considered at the same location. This paper presents several potential methods for combining multiple CMFs and the associated strengths and limitations. A methodology is developed and then applied to test the accuracy of these methods. The method hinges on the development of high-quality CMFs for the two individual treatments in question as well as the CMF for the combined treatment. CMFs were developed and presented in a companion paper. The results of the methods assessment provide a solid foundation for recommending methods for combining multiple CMFs.

Authors	Zulqarnain H. Khattak, University of Virginia Michael Fontaine, Virginia Transportation Research Council
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-01498
Paper Title	Evaluating the Safety Effects of Span Wire to Mast Arm Signal Conversion
Abstract	The mast arm signal mounting configuration has often been assumed to provide greater conspicuity and visibility than span wire installations, but the impacts of this countermeasure on road safety have not been well established quantitatively. This paper's intent is to provide a comprehensive evaluation of safety effects of converting span wire installations to mast arm installations. An empirical Bayes before-after safety analysis was conducted using crash data for thirty intersections collected from the Virginia Department of Transportation (VDOT). A crash type analysis was also conducted to observe changes in crash type. The results indicate that the countermeasure creates no significant improvement in safety. Average crash modification factor (CMF) values of 0.97 and 0.98 were observed for total and fatal and injury crashes, but these CMFs were not statistically significant. While a reduction in the proportion of angle crashes was observed, the change was not statistically significant and the overall distribution of crashes did not change significantly after converting signal configurations from span wire to mast arm. While mast arm deployments may offer advantages in terms of maintenance costs and aesthetics, there does not appear to be a substantial safety benefit to these conversions.

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, UNC Highway Safety Research Center Kari Signor, University of North Carolina, Chapel Hill
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-01776
Paper Title	Crash Modification Factors for the Flashing Yellow Arrow Treatment at Signalized Intersections
Abstract	This paper presents the results of an evaluation of the flashing yellow arrow (FYA) treatment using data from signalized intersections in Nevada, North Carolina, Oklahoma, and Oregon. The evaluation method was an empirical Bayes before-after analysis. The treatments were divided into seven categories depending on the phasing system in the before period (permissive, protected-permissive, or protected), phasing system in the after period (FYA permissive or FYA protected-permissive), the number of roads where the FYA was implemented (one road or both roads), and the number of legs at the intersections (three or four). The first five treatment categories involved permissive or protected-permissive phasing in the before period. Intersections in these five treatment categories experienced a reduction in the primary target crashes under consideration: left-turn crashes and left turn with opposing through crashes. The reduction ranged from 15 to 50 percent, depending on the treatment category. Intersections in categories 6 and 7 had at least one protected left-turn phase in the before period, and after phasing had flashing yellow arrow protected-permissive left-turn phase without time of day operation (category 6) and with time of day operation (category 7). Consistent with results from previous studies, these intersections experienced an increase in left-turn and left turn with opposing through crashes. Agencies typically use categories 6 and 7 for capacity improvements rather than safety, but the implications for safety are important.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-01803
Paper Title	A Before–After Evaluation of the Realignment of Horizontal Curves on Rural Two-Lane Roads
Abstract	This study determined the crash modification factors (CMFs) associated with horizontal curve realignment using the before-after empirical Bayes method and compared the results from published CMFs from cross-sectional studies. This evaluation used data from rural, two-lane roads in California, North Carolina, and Ohio. The evaluation revealed a 68-percent reduction in total crashes, a 74-percent reduction in injury and fatal crashes, a 78-percent reduction in run-off-road and fixed object crashes, a 42-percent reduction in dark crashes, and an 80-percent reduction in crashes during dark, all of which were statistically significant at the 95-percent confidence level. The results pertain to a range of site characteristics, the most important of which is the range of before and after degree of curve. The average degrees of curve in the before and after periods were 18.1 (with a minimum of 3.2 and a maximum of 52.1) and 6.9 (with a minimum of 0.0 and a maximum of 16.3), respectively. The average central angle of the curves was approximately 42 degrees (with a minimum of 1 and a maximum of 117). The CMFs from this before-after evaluation are lower compared to CMFs estimated from two previous cross-sectional studies. There is a need for further research with a larger sample of sites to assess the reliability of the CMFs obtained from this before-after evaluation.

Authors	Scott Himes, VHB Frank Gross, VHB Kimberly Eccles, VHB Bhagwant Persaud, Ryerson University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-03008
Paper Title	Safety Evaluation of Edge Line Rumble Stripes (ELRS) on Rural, Two-Lane Horizontal Curves
Abstract	Edge line rumble strips (ELRS) are a variation of common shoulder rumble strips used to alert drowsy or distracted drivers when they are leaving the travel lane to the right. ELRS are installed with the edge line pavement marking placed directly over the rumble strip. Geometric, traffic, and crash data were obtained at treated rural, two-lane horizontal curves in Kentucky and Ohio. To account for potential selection bias and regression-to-the-mean, an empirical Bayes (EB) before-after analysis was conducted, utilizing reference groups of untreated rural horizontal curves with similar characteristics to the treated sites. The analysis also controlled for changes in traffic volumes over time and time trends in crash counts unrelated to the treatment. Due to a small sample for the reference group in Kentucky and a simultaneous statewide curve warning sign upgrade program in Ohio, alternative reference sites were utilized to account for annual trends. The results for Kentucky indicate statistically significant reductions for total, injury, run-off-road (ROR), and nighttime crashes, with crash modification factors (CMFs) of 0.75, 0.64, 0.74, and 0.63, respectively. The results for Ohio indicate statistically significant reductions for all crash types, with total, injury, ROR, nighttime, and nighttime ROR CMFs of 0.79, 0.79, 0.78, 0.75, and 0.74, respectively. The two States' results could not be combined due to the statewide curve signing program in Ohio. It is important to note that all crash types considered in this research exclude intersection-related and animal crashes. Benefit-cost (B/C) ratios were estimated to be 331 to 1 for Kentucky and 477 to 1 for Ohio. As a curve-specific treatment, the B/C ratio would likely be much smaller due to the higher installation cost; however, these results suggest that the treatment can be highly cost-effective.

Authors	Bo Lan, UNC Highway Safety Research Center Raghavan Srinivasan, University of North Carolina, Chapel Hill Daniel Carter, UNC Highway Safety Research Center Bhagwant Persaud, Ryerson University Kimberly Eccles, VHB
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-03788
Paper Title	Safety Evaluation of Cable Median Barriers in Combination with Rumble Strips on Divided Roads
Abstract	The empirical Bayes before–after method was used to evaluate the safety effectiveness of cable median barriers in combination with rumble strips on the inside shoulder of divided roads, using Illinois, Kentucky, and Missouri data. In Illinois and Kentucky, cable median barriers were introduced many years after the inside shoulder rumble strips were installed, while in Missouri, the inside shoulder rumble strips and cable barrier were implemented about the same time. Hence, the evaluation in Missouri estimated the combined safety effect of inside shoulder rumble strips and cable barriers, while the analysis in Illinois and Kentucky estimated the effect of cable barriers installed on roads with existing inside shoulder rumble strips. The combined Illinois and Kentucky results indicate approximately a 27% increase in total crashes, a 24% decrease in fatal, incapacitating, non-incapacitating, and possible injury crashes (KABC), a 22% decrease in in fatal, incapacitating, and non-incapacitating injury crashes (KAB), and a 48% decrease in head-on plus opposite-direction sideswipe crashes (used as a proxy for cross-median crashes). The results from Missouri for total and KABC crashes were very similar to the combined Illinois and Kentucky results. However, the reduction in cross-median crashes in Missouri was much more dramatic—showing a 96% reduction (based on cross-median indicator only) and an 88% reduction (based on cross-median indicator plus head-on). An economic analysis showed that this strategy is cost-beneficial.

Authors	Dalia Said, Cairo University Hend Asal, Cairo University
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-04247
Paper Title	Development of Local Safety Performance Functions for Egyptian Multilane Rural Divided Highways Based on Highway Safety Manual Procedure
Abstract	The Highway Safety Manual (HSM) provides several safety performance functions (SPFs), which are used to predict the expected average crash frequency on a roadway network given the geometric features, section length, and traffic volume. The HSM was developed in the US using road and crash data specific to the environment in the US. Every state was encouraged to develop locally derived models suitable for the local characteristics of roads and crashes. The objective of this paper is to assess the opportunity of adopting the HSM on rural multi-lane divided highways in Egypt. This project calibrated SPFs considering Egyptian road factors. The SPFs were first calibrated using the default Crash Modification Factors (CMFs), and the results were compared with the actual crash events. The results showed the need for a further step to develop locally derived SFPs using the Poisson-Gamma regression technique. The developed models describe the mean crash frequency as a function of natural logarithm of the annual average daily traffic and segment length. It was found that the curve density was the main geometric feature affecting crash occurrence on rural multi-lane divided roads. The study found that the results would help designers in regions of driver behavior different than the US to benefit from the HSM procedure and better select countermeasures to provide improved safety.

Authors	Simona Babiceanu, University of Virginia Michael Fontaine, Virginia Transportation Research Council
Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-05020
Paper Title	Examining the Safety Effect of Centerline Rumble Strips on Curves on Rural Two-Lane Roads
Abstract	The Virginia Department of Transportation (VDOT) has installed centerline rumble strips on a number of rural two-lane primary roads to reduce head-on and opposite direction sideswipe crashes. This paper calculated crash modification factors (CMF) for installing centerline rumble strips by applying the empirical Bayes methodology, with a focus on evaluating how the effectiveness varies by roadway curvature. Centerline rumble strips on curves with a design speed of less than 55 mph reduced total head-on, opposite direction sideswipe, and fixed objects, off-road crashes by 40% (CMF 0.60, standard error 0.16). Other analyses that examined the safety effect of centerline rumble strips as a function of curve design speed showed promising trends, but were inconclusive, most likely due to small sample sizes. When looking at tangent sections, a 32% decrease in total crashes (CMF 0. 68, standard error 0.11) and a 43% decrease in fatal and injury crashes (CMF 0.57, standard error 0.12) was observed. When examining all roads irrespective of curvature, the study found a 27% decrease in total head-on and opposite direction sideswipe crashes (CMF 0.73, standard error 0.10) and 29% decrease in fatal and injury crashes (CMF 0.71, standard error 0.12) for these types. All these reductions were significant at a 95% confidence level. Besides these main findings, CMFs for several other situations were produced that support the assertion that centerline rumble strips are a beneficial treatment for rural two-lane roads.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-05955
Paper Title	Evaluating the Safety Effectiveness of Variable Speed Limit: Before–After Study Utilizing Multivariate Adaptive Regression Splines
Abstract	Interstate 80 (I-80) is a vital freight corridor running in the southern part of Wyoming. As the corridor being selected as one of the three sites for Connected Vehicle Pilot Deployment Program, a baseline assessment of existing countermeasures is vital. The 402-mile freeway has four weather-based Variable Speed Limit (VSL) corridors totaling 147-mile. VSL systems are countermeasures that aim to improve road safety by providing different operating speeds based on existing weather and road conditions. A before-after study with Empirical Bayes (EB) was utilized to develop Crash Modification Factors (CMF) for the VSL. Crash prediction models are essential to estimate the safety effectiveness of the implemented countermeasures. Parametric Negative Binomial (NB) and non-parametric Multivariate Adaptive Regression Splines (MARS) were used to develop crash models in the before period. Crash models were developed for total crashes, fatal and Injury crashes (FI), and Property Damage Only (PDO) crashes. Comparisons between CMFs obtained from NB model and MARS model were conducted. Analyses were performed using crashes occurred on the 402-miles of I-80 corridor, in Wyoming. Six years of crashes in the before period from 2003 to 2008 were utilized in the analysis, in addition to five years in the after period from 2012 to 2016. Results showed that the VSL reduced all the investigated crash types by different percentages ranging between 26% to 67%. Developed CMFs using NB and MARS showed comparable results. CMFs developed using the NB model might provide a quick and easy method for practitioners. Yet, it provides reliable results.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-06071
Paper Title	Safety Evaluation of Diverging Diamond Interchanges Design for Intersections in Minnesota
Abstract	The installation of Diverging Diamond Interchanges (DDIs) has grown exponentially in the United States. There are limited real-world assessments of the safety benefits because the implementation of DDIs in the United States is relatively new. This study provides a project level safety effectiveness evaluation of two DDIs in Minnesota using two observational before-after evaluations. Before the implementation of the DDIs, both sites were classified as signalized intersections. The Naïve and Empirical Bayes (EB) before-after approaches were used to determine the safety savings of converting the signalized intersections into DDIs. Crash Modification Factors (CMF) were used to measure the safety effectiveness of the DDIs. Crash data and annual volume data from both sites before and after the DDI implementation was used in the analysis. The results indicate that the average CMF is 0.48 for the Naïve method and 0.42 for the EB method. The findings prove that the DDI design is a valid and reliable safety countermeasure.

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Sponsoring Committee	Standing Committee on Highway Safety Performance (ANB25) Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 575
Session Title	Highway Safety Performance
Paper Number	18-01440
Paper Title	Evaluating the Impact of Rumble Strips on Fatal and Injury Freeway Crashes
Abstract	Rumble strips are known as one of the most cost-effective treatments for preventing the road departure crashes. However, in recent years some studies have found controversial results indicating that rumble strips may in fact increase the number of more severe crashes. Although these effects are estimated to be very small, nonetheless it could cause a potential problem for the highway safety agencies using these treatments. In this paper authors have used robust and up-to-date data analysis tools to evaluate the impact of rumble strip presence on the fatal and injury crashes on freeways. For this purpose, authors have used the database used in one of the aforementioned studies. The results of the current study suggest that the rumble strips do in fact improve the safety outcomes in rural freeways. These findings are observed to be true for urban freeways as well however the effects are not statistically significant.
Session Number	Session 722
Session Title	Traffic Control Devices
Paper Number	18-01098
Paper Title	Safety Evaluation of Alternative Audible Lane Departure Warning Treatments in Reducing Traffic Crashes: An Empirical Bayes Observational Before–After Study
Abstract	Roadway departure crashes are a major contributor to traffic fatalities and injury. Rumble strips have been shown as an effective countermeasure in reducing roadway departure crashes. However, some roadway situations, for instance inadequate shoulder width or roadway surface depth, have limited the application of conventional milled or rolled in rumble strips. Alternative audible lane departure warning systems include profile (audible) pavement markings and preformed rumble bars have seen increased usage to overcome the limitations that exist with the milled rumble strips. So far, the safety effectiveness of these alternative audible lane departure warning systems has not been extensively assessed. The main purpose of this paper is to examine the safety effect of installing profile pavement markings and preformed rumble bars. Specifically, this study developed crash modification factors for these treatments that quantify the effectiveness in reducing single-vehicle-run-off-road (SVROR) and opposite-direction (OD) crashes. Traffic, roadway, and crash data at the treated sites on about 200 miles of rural two-lane highways in Texas were analyzed using empirical Bayes (EB) before-after analysis method. Safety performance functions from the *Highway Safety Manual* and Texas Highway Safety Design Workbook were used in the EB analysis. The results revealed a 21.3 percent reduction in all SVROR and OD crashes, and 32.5 to 39.9 percent reduction in fatal and injury SVROR and OD crashes after installing profile pavement marking and preformed rumble bars.

Authors	Justice Appiah, Virginia Transportation Research Council Frederick King, Virginia Transportation Research Council Michael Fontaine, Virginia Transportation Research Council Benjamin Cottrell, Virginia Department of Transportation
Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 722
Session Title	Traffic Control Devices
Paper Number	18-01468
Paper Title	Safety Effects of Flashing Yellow Arrows Used in Protected Permitted Phasing: Comparison of Full Bayes and Empirical Bayes Results
Abstract	Using the flashing yellow arrow (FYA) signal indication for the permissive portion of protected-permissive left-turn (PPLT) phasing has become an increasingly popular treatment for left-turn signals since drivers are believed to understand the FYA better than the traditional green ball indication. A before and after safety evaluation of deploying FYA at PPLT signals at 36 intersections in Virginia was conducted. Each of the study intersections had FYA for the permitted portion of the phase on at least one left-turn approach. The focus was on left-turns that operated in either the fully-protected mode or the protected-permissive mode (with green ball indication for the permissive portion) before being converted to PPLT operations with the FYA indication for the permissive portion. Crash records from before and after the activation of FYA were compared using both the full Bayes and empirical Bayes approaches. The results indicate that using the FYA signal indication instead of the green ball indication had a statistically significant effect in reducing overall frequency and severity of crashes. However, converting the left-turn mode from protected-only to PPLT with FYA was not beneficial from a safety perspective. For the intersections studied in this research, total crashes reduced by 12% following conversion from PPLT to PPLT-FYA and increased by 19% following conversion from protected-only to PPLT-FYA. The results also indicated that the full Bayes approach to safety effectiveness evaluation can, at a minimum, provide similar results to the well-established empirical Bayes approach.

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Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 722
Session Title	Traffic Control Devices
Paper Number	18-02755
Paper Title	Are Dilemma Zone Protection Systems Useful on High-Speed Arterials with Signal Coordination? A Case Study
Abstract	Driver behavior within the dilemma zone can be a major safety concern at high-speed signalized intersections, especially for heavy trucks. The Nebraska Department of Roads (NDOR) has developed and implemented an Actuated Advance Warning (AAW) dilemma zone protection system. The AAW system has been documented as being effective at improving traffic safety at isolated signalized intersections. However, the system is yet to be used at signalized intersections operating in the coordinated mode. This study assessed the potential deployment of the AAW system on arterials where the signals are closely spaced and operate in a coordinated mode. Traffic microsimulation and surrogate safety analyses were used to assess the potential safety and operational benefits. The analysis on conflicts indicated that, on average, there were 30%, 7% and 30% reductions in the number of rear-end, lane change and crossing conflicts when the AAW system was used. In terms of the relative productivity of the system – the number of vehicles that were processed during a specified analysis period revealed that there were generally more vehicles processed when the AAW system was not in place. Also, the overall link travel times were slightly higher when the system was in place. The results of this analysis can be a useful guide to NDOR and other agencies as they consider potential AAW deployments.

Authors	Michael Shea, University of Utah Juan Medina, University of Utah
Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	Session 722
Session Title	Traffic Control Devices
Paper Number	18-06742
Paper Title	Approach-Level Safety Comparison of Permitted-Protected and Protected Left-Turn Phasing to Flashing Yellow Arrows
Abstract	Since the introduction of flashing yellow arrow (FYA) indications in the MUTCD, transportation agencies have increasingly adopted this alternative to improve left-turn operations. However, it has not been until recently that agencies have accumulated enough data (both temporally and spatially) to conduct safety evaluations of FYA implementations for specific types of "before" left-turn phasing. Most past studies have focused on intersection-level crash analyses given the difficulties to obtain reliable crash data at the level of a single approach where the direction of travel, particularly for left turn movements, should be individually verified. This study aims at bridging research gaps by estimating the change in target (left-turn related) crash frequencies, specifically for approaches converted from a permissive-protected or a protected only left turn operation to a permissive-protected FYA indication. Safety performance functions for permissive-protected, protected only, and the FYA approaches are estimated. In addition, crash modification factors for converting permissive-protected to FYA, and for converting protected-only to FYA are presented. Results from this approach-level analysis support some of the findings from previous studies conducted at intersection-level.

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Sponsoring Committee	Standing Committee on Roadside Safety Design (AFB20)
Session Number	Session 845
Session Title	Analysis and Modeling of Roadway Departure Crashes
Paper Number	18-03564
Paper Title	Empirical Bayes Before and After Method to Evaluate Edge Treatment
Abstract	A drop-off between the edge of the paved roadway and the adjacent ground proves to be a serious concern for vehicles that drift-off the roadway. Pavement edge drop-off contribute to about 18% of rural run-off-the-road (ROR) crashes. The Safety Edge creates a fillet along the edge of the paved roadway which allows errant drivers to return safely to the roads. It has been promoted to reduce the frequency of rural roadway departure crashes. Little information is available regarding the actual effectiveness of Safety Edge. Although the treatment is low cost, agencies are interested in understanding its impacts to better program safety funds. The safety impact of the Safety Edge on rural 2-lane tangent roadways with asphalt pavement of speeds 45-55 mph was evaluated. A total of 340 miles of roadway were treated during the 2010-2011 construction season and 509 miles of control segments were identified. Eleven years (2004-2014) of roadway and traffic data and non-intersection crashes were used in the study. The study evaluated Crash Modification Factors for several injury combinations using observational before-after with empirical Bayes method. Target crashes were identified as any crash related to ROR action. Treatment showed reduction in total and PDO/unknown non-intersection crashes statistically significantly by 13-14%. More desirably total and PDO/unknown target crashes showed greater reduction of 15-18%, statistically significantly. The study illustrated positive safety effectiveness of Safety Edge especially for ROR crashes. It can be recommended to consider the safety effects of Safety Edge for different crash types with consideration of installation.

Authors	Christine Carrigan, Roadsafe LLC Malcolm Ray, Roadsafe LLC
Sponsoring Committee	Standing Committee on Roadside Safety Design (AFB20)
Session Number	Session 845
Session Title	Analysis and Modeling of Roadway Departure Crashes
Paper Number	18-01503
Paper Title	A Model of the Probability of a Cross-Median Crash When a Vehicle Fully Crosses the Median
Abstract	The consequences of cross-median crashes are often catastrophic but crashes into median barriers can also be severe. Wide medians provide traversable space where vehicles can recover or stop but sometimes even wide medians can be crossed over. Determining if a median barrier is needed at a particular site involves balancing the risks associated with crossing completely over the median and striking a vehicle in the opposing lanes with the risks of an errant vehicle striking a median barrier. Median cross-over crashes can be viewed as a conditional probability model: first the vehicle must enter the median; second, the vehicle must cross completely over the median; third, a vehicle must be in the opposing lanes where it is struck and, finally, there is a chance of a severe or fatal injury if all these conditions are met. All the elements of this conditional probability model are documented in the literature except the third; the probability of a crash with an opposing-direction vehicle given that a vehicle has completely traversed the median. Estimating this probability is the subject of this paper.

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Sponsoring Committee	Standing Committee on Geometric Design (AFB10)
Session Number	Session 568
Session Title	Geometric Design Research and Graduate Student Poster Session
Paper Number	18-06321
Paper Title	Safety Performance Evaluation of Urban Undivided Four-Lane to Five-Lane Conversion in Louisiana
Abstract	In theory, urban five-lane highways with two way left turn lane (5T) are less safe compared with four-lane undivided highways (4U). Although critically-acclaimed road diet (three-lane highway with a two way left turn lane) remains the most prevalent cost-effective alternative to 4U, still some 4U highway segments have been converted to 5T with an aim to cope with the increasing left-turn traffic towards the roadside establishments without sacrificing the capacity. This study provides an extensive look to the safety performance of 4U to 5T conversion. A total of nine converted sites of different characteristics were evaluated using up to 7 years of crash data before and after conversion. The Empirical Bayes (EB) method was used with LaDOTD developed SPF and estimated temporal factors to avoid any potential regression-to-the-mean bias. The reduction of crashes was achieved in all the sites with an estimated overall CMF of 0.482 with a very small standard deviation of 0.001, indicating a total crash reduction of 51.8% after conversion. The relationship of annual crash reduction with driveway density shows a decreasing trend, which also illustrates that 4U to 5T conversion performs better in driveway densities ranged from 30 to 40 driveways per mile. Analysis by crash type shows substantial reduction of the predominant rear-end crashes on converted urban 5T highways. The very high benefit-cost ratio, 77, indicates that 4U to 5T conversion proves to be a very effective low-cost crash countermeasure for urban and suburban roadways with low to moderate AADT.

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Sponsoring Committee	Standing Committee on Pedestrians (ANF10)
Session Number	Session 576
Session Title	Innovative Research on Pedestrian Safety and Behavior
Paper Number	18-00737
Paper Title	An Analysis of the Safety Effectiveness of Pedestrian Crossing Enhancements in Oregon
Abstract	Over the last decade, the transportation agencies in Oregon have systematically enhanced many pedestrian crossing enhancements at mid-block locations with Rectangular Rapid Flashing Beacons (RRFBs), Flashing Yellow Beacons (Flash), and high visibility crosswalk markings (Hi-Vis). Enhancements often included the installation of refuge medians. This study explored the safety performance of these enhanced crossings, categorized by enhancement type. Data were collected on 191 crossings that included installation year, geometric features, surrounding land use, traffic volumes, and the number of crashes. Because pedestrian volume at the locations was unavailable, a pedestrian activity level variable was developed. Target crashes for analysis were identified as pedestrian and rear-end. The analysis of the before-after crash patterns showed a reduction in the pedestrian crash severity after the installation of the crosswalk enhancements. Risk ratios, calculated by the unadjusted crash frequency relative to the years of operation in each analysis category, were calculated. For pedestrian crashes, risk ratios increased with the number of lanes, posted speed, and estimated pedestrian activity level. Similar trends were observed for rear-end crashes. Due to sample size limitations, safety effectiveness was only estimated for the 19 RRFBs locations. Lack of pedestrian volumes limited the development of a safety performance function (SPF) for the pedestrian crash types. However, a rear-end crash SPF was estimated. Standard methods to estimate a crash modification factor (CMF) were attempted. The recommended CMF for pedestrian crashes is 0.64 +/- 0.26 using a simple before-after analysis and 0.93 +/- 0.22 for rear-end crashes using an empirical Bayes analysis.

7 Surrogate Measures of Safety

Thomas Hall, Cristhian Lizarazo, and Andrew Tarko, Purdue University
Matin Nabavi Niaki and Nicolas Saunier, Polytechnique Montreal

Forty-one papers utilizing surrogate measures of safety have been identified. Surrogate measures are used either as the primary approach to safety analysis or as a supplement to the more traditional crash-based approach in these papers.

Of the topics covered in the papers, **intersection safety**, **pedestrians and non-motorized traffic**, and **autonomous and connected vehicle technologies** stand out. Fifteen papers are related to **intersection safety** (Khattak et al., 18-00058; Wang et al., 18-00657; Cloutier et al., 18-01288; Amiridis et al., 18-01294; Puscar et al., 18-01751; Shah and Perumal, 18-02052; Paul et al., 18-02421; Stylianou et al., 18-03363; Stylianou and Dimitriou, 18-04602; Tan et al., 18-04827; Mishra et al., 18-04868; Fu et al., 18-05083; St-Aubin et al., 18-05438; Zhao et al., 18-05895; Granados et al., 18-05956). **Pedestrians and non-motorized traffic** are covered by twelve papers (Wang et al., 18-00657; Uzondu et al., 18-01206; Cloutier et al., 18-01288; Puscar et al., 18-01751; Wu et al., 18-01508; Shah and Perumal, 18-02052; Guo et al., 18-03174; Essa et al., 18-03468; Pascucci et al., 18-04364; Fu et al., 18-05083; Haus and Gabler, 18-05351; St-Aubin et al., 18-05438). Surrogate safety measures related to **autonomous and connected vehicle technologies** are examined in seven papers (Khattak et al., 18-00058; Rahman et al., 18-00846; Wu et al., 18-01064; Osman et al., 18-03927; He et al., 18-04931; Haus and Gabler, 18-05351; Granados et al., 18-05956).

Traffic conflicts are the most frequent basis for surrogate measures of safety, generally as the number of (severe) traffic conflicts, used this year in twenty-five papers (Wali et al., 18-00060; Hui et al., 18-00140; Kim et al., 18-00280; Wang et al., 18-00657; Saad et al., 18-00860; Vrielink et al., 18-00890; Wu et al., 18-01064; Uzondu et al., 18-01206; Haque et al., 18-01279; Cloutier et al., 18-01288; Amiridis et al., 18-01294; Wu et al., 18-01508; Puscar et al., 18-01751; Shah and Perumal, 18-02052; Mahmud et al., 18-02193; Paul et al., 18-02421; Wang et al., 18-02562; Stylianou et al., 18-03363; Essa et al., 18-03468; Pascucci et al., 18-04364; Stylianou and Dimitriou, 18-04602; Mishra et al., 18-04868; He et al., 18-04931; Haus and Gabler, 18-05351; Granados et al., 18-05956). **Time-to-collision (TTC)** and **post-encroachment time (PET)** are the most commonly used traffic conflict (severity) indicators (Wali et al., 18-00060; Wang et al., 18-00657; Vrielink et al., 18-00890; Wu et al., 18-01064; Haque et al., 18-01279; Puscar et al., 18-01751; Shah and Perumal, 18-02052; Paul et al., 18-02421; Wang et al., 18-02562; Stylianou et al., 18-03363; Essa et al., 18-03468; Pascucci et al., 18-04364; Stylianou and Dimitriou, 18-04602; Mishra et al., 18-04868; He et al., 18-04931; Granados et al., 18-05956). Additionally, Tan et al., 18-04827 and Zhao et al., 18-05895 analyze the **red-light running** behavior of drivers at signalized intersections.

Speed-related measures (including acceleration and deceleration) are also used by a number of researchers. Twenty papers use such measures (Khattak et al., 18-00058; Wali et al., 18-00060; Hui et al., 18-00140; Rahman et al., 18-00846; Kamrani et al., 18-00980; Dadashova et al., 18-01431; Wu et al., 18-01508; Paul et al., 18-02421; Stipancic et al., 18-02836; Yao et al., 18-03362; Essa et al., 18-03468; Zhao and Lee, 18-03619; Osman et al., 18-03927; Tselentis et

al., 18-04182; Pascucci et al., 18-04364; Tan et al., 18-04827; He et al., 18-04931; Fu et al., 18-05083; St-Aubin et al., 18-05438; Mathew and Charly, 18-06666).

In terms of data sources and analysis methods, various methods are utilized. **Field observations**, including video, GPS, or detector-collected data, are used in twenty papers (Hui et al., 18-00140; Wang et al., 18-00657; Uzondu et al., 18-01206; Haque et al., 18-01279; Cloutier et al., 18-01288; Amiridis et al., 18-01294; Puscar et al., 18-01751; Shah and Perumal, 18-02052; Stipancic et al., 18-02836; Guo et al., 18-03174; Stylianou et al., 18-03363; Essa et al., 18-03468; Zhao and Lee, 18-03619; Pascucci et al., 18-04364; Stylianou and Dimitriou, 18-04602; Tan et al., 18-04827; Mishra et al., 18-04868; Fu et al., 18-05083; St-Aubin et al., 18-05438; Zhao et al., 18-05895). **Simulation** methods and tools are implemented in a total of eleven papers. These methods include microsimulation (Kim et al., 18-00280; Rahman et al., 18-00846; Saad et al., 18-00860; Vrielink et al., 18-00890; Amiridis et al., 18-01294; Paul et al., 18-02421; Mishra et al., 18-04868; Granados et al., 18-05956) and driving simulators (Wu et al., 18-01064; Wu et al., 18-01508; Yao et al., 18-03362; Mishra et al., 18-04868). Data obtained through **naturalistic driving, travel surveys, and smartphones** is used in eleven papers (Khattak et al., 18-00058; Wali et al., 18-00060; Kamrani et al., 18-00980; Dadashova et al., 18-01431; Bakhit et al., 18-01562; Wang et al., 18-02562; Osman et al., 18-03927; Tselentis et al., 18-04182; He et al., 18-04931; Haus and Gabler, 18-05351; Mathew and Charly, 18-06666). Finally, three papers incorporate **machine and deep learning** techniques (Hui et al., 18-00140; Wang et al., 18-00657; Shah and Perumal, 18-02052).

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-00058
Paper Title	How Is Driving Volatility Related to Intersection Safety in a Connected-Vehicles Environment?
Abstract	The emerging connected and automated vehicles (CAV) technology provides a promising opportunity for investigating intersection safety more from a proactive perspective. Driving volatility captures the extent of variations in instantaneous driving decisions when a vehicle is being driven. This study develops a fundamental understanding of microscopic driving volatility and how it relates to unsafe outcomes at intersections. Using real-world connected vehicle data from the Safety Pilot Model Deployment in Ann Arbor, Michigan, intersection-specific volatility indices are calculated for 116 intersections by analyzing more than 62 million real-world Basic Safety Messages transmitted between thousands of instrumented vehicles. The large-scale CAV data is then linked to detailed intersection data containing crashes, traffic exposure, and other geometric features. By using coefficient of variation of speed as a relative measure of driving volatility, descriptive analysis is performed to spot differences between driving volatility at signalized and un-signalized intersections. Then, in-depth statistical analysis is conducted separately for all intersections and signalized intersections only. Given the important methodological concern of unobserved heterogeneity, hierarchical fixed- and random-parameter Poisson and Poisson log-normal models are estimated under a Full Bayesian Gibbs sampling setting. For all intersections, a one-percent increase in driving volatility is associated with a 0.37 percent increase in crash frequency. Importantly, the relationship between driving volatility and crash frequency is more pronounced for signalized intersections. Several of the exogenous factors are found to be normally distributed random parameters,

suggesting that the effects of such variables vary across different intersections. The practical implications of the findings are discussed.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-00060
Paper Title	How Driving Volatility in Time to Collision Relates to Crash Severity in a Naturalistic Driving Environment
Abstract	The sequence of instantaneous driving decisions and its variations, known as driving volatility, can be a leading indicator of unsafe driving practices. The research issue is to characterize volatility in instantaneous driving decisions in longitudinal and lateral direction and to seek an understanding of how driving volatility relates to crash severity. By using a unique real-world naturalistic driving database from the SHRP 2, a test set of 671 crash events featuring around 0.2 million temporal samples of real-world driving are analyzed. Based on different driving performance measures, 16 different volatility indices are created. The volatility indices are then linked with individual crash events including information on crash severity, drivers' pre-crash maneuvers and behaviors, secondary tasks and durations, and other factors. As driving volatility prior to crash involvement can have different components, an in-depth analysis is conducted using the aggregate as well as segmented (based on time to collision) real-world driving data. To account for the issues of observed and unobserved heterogeneity, fixed and random parameter ordered models with heterogeneity in parameter means are estimated. The findings suggest that greater driving volatility (both in longitudinal and lateral direction) prior to crash occurrence increases the likelihood of police reportable or severe crash events. Importantly, compared to the effect of volatility in longitudinal acceleration on crash outcomes, the effect of volatility in longitudinal deceleration is significantly greater in magnitude. Methodologically, the random parameter models with heterogeneity-in-means significantly outperformed both the fixed parameter and random parameter counterparts. The relevance of the findings to the development of proactive behavioral countermeasures for drivers is discussed.

Authors	Nancy Hui, University of Toronto Matthew Roorda, University of Toronto Eric Miller, University of Toronto
Sponsoring Committee	Standing Committee on Artificial Intelligence and Advanced Computing Applications (ABJ70)
Session Number	386
Session Title	Advanced Modeling, Recognition, and Classification Methods in Transportation Applications
Paper Number	18-00140
Paper Title	Identifying Multimodal Conflicts with Machine Learning
Abstract	This study explores the efficacy of using machine learning techniques to automatically identify traffic conflicts. Quantitative conflict identification methods are largely designed through observation of motorized vehicles only, and can report erroneous results when applied to users of non-motorized modes. A dataset of conflict and non-conflict events is constructed through analysis of video footage of a multimodal street. For each event, conflict indicators and parameters representing user mode, speed, and acceleration are calculated. Six machine learning classifiers are trained on 80% of the dataset: three classifiers were trained using only the conflict indicators, and three classifiers were trained using the full set of explanatory variables. Five of the six classifiers are more effective in identifying conflicts than the threshold-based conflict identification technique, suggesting that the structure of machine learning classifiers presents advantages over conventional indicator thresholds in conflict identification. Furthermore, the classifiers trained on the full set of explanatory variables performed better during conflict identification than classifiers excluding mode, speed, and acceleration in their set of potential explanatory variables. This suggests that user mode, speed, and acceleration influence interaction severity.

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Sponsoring Committee	Standing Committee on Access Management (AHB70)
Session Number	284
Session Title	Quantifying Benefits and Impacts of Access Management
Paper Number	18-00280
Paper Title	Using the Surrogate Safety Assessment Model for Evaluating Safety Impacts of Access Management Alternatives
Abstract	In a traditional safety impact analysis, it is necessary to have crash data on existing roadway conditions and a few years must pass before accumulating additional crash data to evaluate the safety impact of an improvement. This is a time-consuming approach and there remains uncertainty in the crash data integrity. The Surrogate Safety Assessment Model (SSAM) was developed for resolving these issues. With SSAM, a conflict analysis is performed in a simulated environment. A planned improvement alternative is modeled and no physical installation of the alternative is needed. This study evaluated if SSAM can be used to assess the safety of a highway segment in terms of the number and type of conflicts and to compare the safety effects of multiple access management alternatives. An evaluation of the effect of converting a two-way left-turn lane (TWLTL) into a raised median on a section of an urban street was performed using SSAM working on VISSIM simulation's trajectory files. The analysis showed that a raised median would be much safer than a TWLTL median for the same level of traffic volume with approximately 32 to 50 percent reduction in the number of crossing conflicts. The analysis showed that about 34,000 to 38,000 veh/day would be the demand level where the median conversion is recommended for the four-lane study section. The study concluded that the combination of a simulation software program with SSAM could be a viable, surrogate analysis approach for evaluating and comparing the safety effects of multiple access management alternatives.

Authors	BoChen Wang, Jiangsu University YuQuan Zhu, Jiangsu University Yan Shen, Jiangsu University Qingchao Liu, Jiangsu University
Sponsoring Committee	Standing Committee on Artificial Intelligence and Advanced Computing Applications (ABJ70)
Session Number	385
Session Title	Artificial Intelligence and Machine Learning Tools for Estimation, Detection, and Prediction Applications in Transportation
Paper Number	18-00657
Paper Title	Traffic Conflict Detection of Vehicle and Nonmotorized Vehicle at Intersection Based on Deep Learning
Abstract	With the rapid development of urbanization, the safety of road intersections has been widely concerned. This paper presents an automated vision-based road user conflict detection system, which can provide more effective data for traffic safety diagnosis. The system can achieve the high-precision detection, classification and tracking of the road users by using the state-of-art deep convolution neural network and the MOT technology, and finally the potential traffic conflict events are identified by LSTM based trajectory prediction techniques and TTC indicator. The system was experimented on a typical intersection of Nanjing, where the conflict between vehicles and non-motor vehicles (PTW and bicycles) was detected and their safety conditions at the intersections were evaluated. The results showed that the method based on deep learning can better adapt to the conflict detection of complex intersection, and the safety of the intersection can be effectively analyzed by this method.

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Sponsoring Committee	Standing Committee on Intelligent Transportation Systems (AHB15)
Session Number	755
Session Title	Connected and Automated Vehicle Systems in Complex Transportation Systems
Paper Number	18-00846
Paper Title	Understanding the Highway Safety Benefits of Different Approaches of Connected Vehicles in Reduced-Visibility Conditions
Abstract	This study evaluated the effectiveness of Connected Vehicle (CV) technologies in adverse visibility conditions using microscopic traffic simulation. Traffic flow characteristics deteriorate significantly in reduced visibility conditions resulting in high crash risks. This study applied CV technologies on a segment of Interstate I-4 in Florida to improve the traffic safety under fog conditions. Two types of CV approaches (i.e., connected vehicles without platooning (CVWPL) and connected vehicles with platooning (CVPL)) were applied to reduce the crash risk in terms of three surrogate measures of safety: the standard deviation of speed, the standard deviation of headway, and rear-end crash risk index (RCRI). This study implemented Vehicle-to-Vehicle (V2V) communication technologies of CVs to acquire real-time traffic data using the microsimulation software VISSIM. A car following model for both CV approaches was used with an assumption that the CVs would follow this car following behavior in fog conditions. The model performances were evaluated under different CV market penetration rates (MPRs). The results showed that both CV approaches improved safety significantly in fog conditions as MPRs increase. To be more specific, the minimum MPR should be 30% in order to provide significant safety benefits in terms of surrogate measures of safety for both CV approaches over the base scenario (non-CV scenario). In terms of surrogate safety measures, CVPL significantly outperformed CVWPL when MPRs were equal or higher than 50%. The results also indicated a significant improvement in the traffic operation characteristics in terms of average speed.

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Sponsoring Committee	Standing Committee on Congestion Pricing (ABE25) Standing Committee on Managed Lanes (AHB35)
Session Number	379
Session Title	Analyzing the Effectiveness of Congestion Pricing and Managed Lanes
Paper Number	18-00860
Paper Title	Access Design Safety Analysis for Managed Lanes Including Accessibility Level and Weaving Length
Abstract	On expressways, Managed Lanes (MLs) have emerged as an effective dynamic traffic management strategy. MLs have been successfully implemented as an important facility in improving traffic mobility and in generating revenue for transportation agencies. Most of the previous studies of the MLs have only explored the safety impact of the whole MLs segments, without considering the safety effects of the access design. In this study, scenarios were built and tested with microsimulation to specify the safest accessibility level and to decide on the sufficient weaving length near access zones. The studied accessibility level varied from one to three accessibility levels along the network. The weaving length was defined as the distance per lane change to use the access zones from or to the ramps. The findings indicated that the conflict rate on MLs were 48% and 11% lower than that of General Purpose Lanes (GPLs) in the peak and the off-peak periods, respectively. A log-linear model was developed with estimation of odds multipliers for investigating the factors that affect the traffic conflicts in the studied segment. The result of the conflict frequency analysis suggested that one accessibility level was the safest option in the 9-miles network. The length of 1,000 feet per lane change was shown to be the safest weaving length near access zones. Additionally, a weaving length of 600 feet per lane change was not recommended. The findings of this study represent a further step towards improving access design of MLs.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-00890
Paper Title	Assessing Traffic Safety of Dutch Weaving Sections: Validation of the Surrogate Safety Assessment Model Combined with VISSIM
Abstract	Dutch road designers and safety experts are searching for more quantitative methods to evaluate the safety of a (proposed) road design than the current expert judgement method. An alternative would be to determine safety of Dutch weaving sections using VISSIM micro-simulation models in combination with the Surrogate Safety Assessment Model (SSAM). SSAM calculates the number of conflicts (i.e. observable situations in which two or more road users approach each-other resulting in a potential collision risk) that occurred in a micro-simulation model using the surrogate safety measures TTC and PET. In this research it is assessed whether this number of conflicts observed from VISSIM microsimulation models using SSAM is representing safety (crash rate) of Dutch weaving sections. Nine Dutch weaving sections were selected and ranked based on four criteria: (I) the crash rate, (II) the conflict rate calculated from VISSIM-simulations using SSAM, (III) the number of crashes expected by the crash prediction model developed by Iliadi et al. (1), and (IV) the judgement of road safety experts. To validate the conflict rate ranking, the Spearman Rank Correlation Coefficient was calculated between these rankings. The correlation of between the crash rate and conflict rate ranking indicates a reasonable, but nonsignificant, fit. In a sensitivity analysis the effects of some micro-simulation settings, conflict analysis thresholds and the calibration method are assessed. Although different than expected, extending the calibration process resulted in a weaker correlation. Hence care should be taken when using VISSIM/SSAM conflict rates as (only) safety-predictor of Dutch weaving sections.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-00980
Paper Title	Analyzing Highly Volatile Driving Trips and Associated Factors
Abstract	Volatile driving, characterized by fluctuations in speed and accelerations and aggressive lane changing/merging, is known to contribute to transportation crashes. To fully understand driving volatility with the intention of reducing it, the objective of this study is to identify its key correlates, while focusing on highly volatile trips. First, a measure of driving volatility based on vehicle speed is applied to trip data collected in the California Household Travel Survey during 2012-2013. Specifically, the trips containing driving cycles (N=62839 trips) were analyzed to obtain driving volatility. Second, correlations of volatility with the trip, vehicle, and person level variables were quantified using Ordinary Least Squares and quantile regression models. The results of the 90th percentile regression (which distinguishes the 10% highly volatile trips from the rest) show that trips taken by pickup trucks, hatchbacks, convertibles, and minivans are less volatile when compared to the trips taken by sedans. Moreover, longer trips have less driving volatility. In addition, younger drivers are more volatile drivers than old ones. Overall, the results of this study are reasonable and beneficial in identifying correlates of driving volatility, especially in terms of understanding factors that differentiate highly volatile trips from other trips. Reductions in driving volatility have positive implications for transportation safety. From a methodological standpoint, this

	study is an example of how to extract useful (volatility) information from raw vehicle speed data and use it to calm down drivers and ultimately improve transportation safety.
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Sponsoring Committee	Standing Committee on User Information Systems (AND20)
Session Number	428
Session Title	User Information Needs for Connected Vehicle Environments and Automation
Paper Number	18-01064
Paper Title	Effects of Connected-Vehicle Warning Systems on Rear-End Crash Avoidance Behavior Under Fog Conditions
Abstract	More rear-end crashes could occur when driving under reduced visibility conditions. The connected-vehicle crash warning system can help drivers be aware of the imminent situations ahead and take timely crash avoidance action(s). This study provides a driving simulator study to evaluate the effectiveness of the Head-up Display warning system as well as the audio warning system on drivers' crash avoidance performance when the lead vehicle makes an emergency stop under fog conditions. Drivers' throttle release time, brake transition time, perception response time, brake reaction time, minimum time-to-collision, and maximum brake pedal pressure are assessed for the analysis. According to the results, the crash warning system can help decrease drivers' reaction time and reduce the probability of rear-end crashes. In addition, the effects of fog level and drivers' characteristics including gender and age are also investigated in this study. The findings of this study are helpful for the designers of rear-end crash warning systems to enhance the effectiveness of the system's application under fog conditions.

Authors	Chinebuli Uzondu, University of Leeds Samantha Jamson, Institute of Transportation Studies (ITS) Frank Lai, University of Leeds
Sponsoring Committee	Standing Committee on Transportation in the Developing Countries (ABE90)
Session Number	382
Session Title	Public Transport, Safety and Management, E-bikes and Bikesharing, and Nonmotorized Transportation in Developing Countries
Paper Number	18-01206
Paper Title	Investigating Unsafe Behaviors in Traffic Conflict Situations: An Observational Study
Abstract	Although road users are aware of the possible risks of engaging in unsafe behaviours while driving, they continue to do so. These behaviours often contribute to traffic incidents and crashes involving them and other road users. This study set out to analyse the effect of road user type, location and time of day on unsafe driving behaviours observed in traffic conflict situations. Data were collected by road side observation at three different locations in the Eastern part of Nigeria using the Traffic Conflict Technique (TCT). This approach was adopted to overcome the inherent problems associated with reliable, inadequate and accessible crash data in Nigeria. In total 946 traffic conflicts were observed and statistical testing showed that drivers were involved in one or more unsafe behaviours prior to these conflicts. Of all unsafe behaviours observed, the incorrect use of indicators (13.3%) and tailgating (11.5%) were found to be the most prevalent, while road user type, location and time of day were found to be statistically associated with unsafe behaviours such as passenger scouting and picking/dropping of passengers. Tricycle drivers were significantly more likely to engage in unsafe behaviours than vehicle drivers, drivers are also more likely to engage in unsafe behaviours on straight roads. Additionally, a greater number of these unsafe behaviours were observed during the peak periods. It is recommended that better road infrastructure, more effective regulations and enforcement, and proper road safety education could help improve traffic safety in Nigeria.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-01279
Paper Title	Head-On Crash Probability Estimation on Two-Lane Undivided Highway from Vision-Based Classified Trajectory
Abstract	This paper endeavors to develop a model that estimates head-on crash probability from classified vehicle trajectory. The model formulation considered: (1) drivers' overtaking decision (OD); and (2) time-to-collision (TTC) on two-lane undivided highway. Drivers' overtaking decision was modeled using nonlinear random parameter multivariate binary logistic regression. It considered variables related to both traffic (i.e. vehicle speed and spacing) and drivers' characteristics (i.e. aggressiveness). In contrast, TTC was determined using a new formulation that considered the dynamic acceleration of the vehicles in addition to the vehicular speed and spacing. Incorporation of two new parameters, i.e. overtaking importance factor (OIF) and crash frequency parameter (CFP) enabled the estimation of crash probability combining OD and TTC. Background subtraction technique along with Kalman filter was used to obtain vehicle trajectories from real-time video. Variable inputs required for calibrating the OD model were generated by constructing adjacency matrices among the vehicles. Exploiting these inputs, Metropolis-Hastings algorithm was applied to obtain calibrated parameters of the OD model for different types of vehicle. Calibration result showed that subject vehicle speed and the subject-opposing spacing are the most significant variables influencing the overtaking decision on two-lane undivided highway. Besides, the maximum head-on crash probability for different types of vehicles was determined and it was found that bus has maximum crash probability. Finally, the nomographs established in this paper ensures easy determination of the crash probability.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-01288
Paper Title	Bound to Happen? An Empirical Example of the Relationship Between Pedestrian Collisions and Interaction Rates at Intersections
Abstract	Background: Research on surrogate measures of safety suggests that traffic conflict or interaction indicators, are relevant to study collisions before they actually happen. Accordingly, several studies were able to predict collisions using safety performance functions that included traffic conflict measures as a predictor. However, simple empirical evidence of the relationship between conflict or interaction measures and actual collisions are limited, especially in the pedestrian collision literature. Objective: This paper provides an assessment of the relationships between reported collisions involving pedestrians (within a 5 and a 10-year period) and interaction rates based on field observation of street crossing behavior, at selected urban intersections (n=60). Methods: Data from a naturalistic observational study of pedestrian street crossing behavior was used to compute interaction rates (n= 4286 observations) at intersections with 25 or more observations. Collisions over a 10-year period (2003-2012, n=358 pedestrian collisions) were mapped and pooled at the same intersections to evaluate the relationship between the two. Descriptive analysis and Spearman correlation were performed. Results: We found a positive and significant relationship between collisions (all-years) and interaction rates (Spearman's coefficient between 0.329 and 0.340). This seems to be particularly the case on larger arterial roads. Conclusions: Our analysis shows that interaction rates as measured by observations at street intersections are significant correlates of actual pedestrian collisions, but correlation coefficient were small. This means that further development of conflict or interaction measures could potentially provide early information on the safety performance of intersection modifications without having actual pedestrians injured.

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Sponsoring Committee	Standing Committee on Traffic Signal Systems (AHB25)
Session Number	645
Session Title	Advances in Traffic Signal Timing Methodologies
Paper Number	18-01294
Paper Title	Development of Left-Turn Phasing Decisions Combining Simulated Traffic Conflicts and Historical Crashes
Abstract	A fundamental objective of traffic signal operations is the development of phasing plans that reduce delays while maintaining a high level of safety. One issue of concern is the treatment of left-turn phasing, which can operate as a protected movement, a permitted movement yielding to conflicting traffic, or a combination protected-permitted movement. Protected-only movements can improve safety of the turning movement, but they can also increase delays and congestion at intersections. Most states use criteria for left-turn phasing selection based on a threshold crash values and do not account for traffic volumes or intersection features that may influence crash frequency. This research leverages conflict points as an indicator of potential safety estimation to assist in the selection of the left-turn phasing and relates them to historical crash records. Prediction models of potential conflicts were developed through microsimulation for 200 existing intersections; hourly volume data resulted in approximately 2,300 hours of observations. The number of left-turn-related conflicts was obtained through SSAM and related to the number of crashes at each intersection. The proposed models offer a simple but realistic approach for determining the boundary conditions that influence safety when left-turn decisions are required. The models can be used to develop nomographs, which practicing traffic engineers can use for left-turn phasing decisions.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-01431
Paper Title	Exploring the Effects of Important Predictors of Ramp Speeding Behavior
Abstract	Traditional measures of speed obtained through traffic observations are not based on detailed information about the related drivers and vehicles. Data from naturalistic studies, such as SHRP2 - NDS, can mitigate this issue by combining the key data on driver, roadway and speeding behavior. The objective of this study is to assess drivers' speeding behaviors on the freeway ramps as the function of the ramp design, trip summary, and driver characteristics. The data analysis provides insights into various spatial and temporal factors. To conduct the data analysis authors have implemented time series reduction, matching and clustering methods to define a new speeding behavior response variable denoted as driving States. Using the resulting response variable and the three groups of predictors, authors have conducted neural network analysis to identify the most influential predictors and their effects on the speeding behavior of drivers during on-ramp and off-ramp travels. Results of speeding behavior on freeway ramps indicate that the speed choice at these locations is indeed a complex process and is mainly influenced by the temporal and traffic conditions. Personal characteristics of drivers also were found to influence speed choice in these locations.

Authors	Jiawei Wu, University of Central Florida Essam Radwan, University of Central Florida Hatem Abou-Senna, University of Central Florida
Sponsoring Committee	Standing Committee on Pedestrians (ANF10)
Session Number	576
Session Title	Innovative Research on Pedestrian Safety and Behavior
Paper Number	18-01508
Paper Title	Pedestrian–Vehicle Conflicts Prediction Model Based on Driver's Avoidance Pattern at the Midblock Crossings
Abstract	In recent years, traffic agencies have begun to place emphasis on the importance of pedestrian safety. In the United States, nearly 70,000 pedestrians were reported injured in 2015. Although the number only account for 3% of all the people injured in traffic crashes, the number of pedestrian fatalities is still around 15% of total traffic fatalities. This study mainly focused on investigating driver's avoidance pattern towards pedestrian-vehicle conflict at midblock crossings and developing the pedestrian-vehicle conflict prediction model by using the driving simulator. The driving simulator experiment was conducted to simulate the pedestrian-vehicle conflict under different potential risk factors at midblock crossings. Fifty-nine participants finished the experiment. Based on the results, typical examples of drivers' deceleration rate and the distance to crosswalk during the avoidance time period were summarized, which exhibited a clear drivers' avoidance pattern during the vehicle pedestrian conflicts. Then, the pedestrian-vehicle conflict prediction model was developed to predict the minimum distance between the vehicle and the pedestrian. Finally, the relative absolute error was used to validate the prediction model and the results indicate that the pedestrian-vehicle conflict prediction model has a good prediction performance.

Authors	Peter Bakhit, Louisiana State University BeiBei Guo, Louisiana State University Sherif Ishak, University of Alabama, Huntsville
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-01562
Paper Title	Crash and Near-Crash Risk Assessment of Distracted Driving and Engagement in Secondary Tasks: A Naturalistic Driving Study
Abstract	Distracted driving behavior is a perennial safety concern that affects not only the vehicle's occupants but other road users as well. Distraction is typically caused by engagement in secondary tasks and other activities such as manipulating objects and passenger interaction among many others. This study provides an in-depth analysis for the increased crash/near-crash risk associated with different secondary tasks using the largest real-world naturalistic driving dataset (SHRP2 Naturalistic Driving Study). Several statistical and data mining techniques are developed to analyze the distracted driving and crash risk. First, a bivariate probit model is constructed to investigate the relationship between the engagement in a secondary task and safety-critical events likelihood. Subsequently, two different techniques are implemented to quantify the increased crash/near-crash risk due to involvement in a particular secondary task. The first technique uses the baseline-category logits model to estimate the increased crash risk in terms of conditional odds ratios. The second technique uses the a priori association rule mining algorithm to reveal the risk associated with each secondary task in terms of support, confidence and lift indexes. The results indicate that reaching for objects, manipulating objects, reading, and cell phone texting are the highest crash risk factors among various secondary tasks. Recognizing the effect of different secondary tasks on traffic safety in a real-world environment helps legislators enact laws that reduce crashes resulting from distracted driving, as well as enables government officials to make informed decisions regarding the allocation of available resources to reduce roadway crashes and improve traffic safety.

Authors	Federico Puscar, University of British Columbia Tarek Sayed, University of British Columbia Alexander Bigazzi, University of British Columbia Mohamed Zaki, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-01751
Paper Title	Multimodal Safety Assessment of an Urban Intersection by Video Analysis of Bicycle, Pedestrian, and Motor Vehicle Traffic Conflicts and Violations
Abstract	This paper demonstrates the diagnosis of bicycle safety issues and evaluation of proposed improvements at a major intersection in Vancouver, British Columbia using automated traffic conflict analysis. Traditional road safety analysis has often been conducted using historical collision records. However, limitations associated with collision data have motivated the development of complementary proactive techniques for road safety analysis. Recently, there has been significant interest in using traffic conflicts to analyze safety which has been strengthened by the availability of automated traffic conflict analysis tools. Automated computer vision techniques are used to extract and analyze traffic conflicts from video data. Traffic conflict indicators, such as time to collision and post-encroachment time, are used to identify safety issues based on the frequency and severity of conflicts. Spatial and temporal non-conforming behavior patterns are also analyzed. The intersection safety diagnosis reveals that the main sources of bicycle and motor vehicle conflicts are associated with failure to yield at bicycle crossings of on- and off-ramps, and vehicle red-light and stop-bar violations. A new intersection design is evaluated for its expected ability to address the identified safety issues.

Authors	Harsh Shah, Indian Institute of Technology, Bombay Vedagiri Perumal, Indian Institute of Technology, Bombay
Sponsoring Committee	Standing Committee on Transportation in the Developing Countries (ABE90)
Session Number	735
Session Title	Pedestrian Safety in Colombia, India, and Tanzania
Paper Number	18-02052
Paper Title	Proactive Pedestrian Safety Evaluation at Unsignalized Intersections in India Using Surrogate Safety Measures
Abstract	The safety evaluation using reactive approach (conventional method) requires crash data of several years. However, in developing country like India, the reliability and accuracy of the available accident data are highly questionable. Hence more effective and proactive safety evaluation technique is required. Therefore, the objective of this work is to propose proactive surrogate safety measures based methodology to quantify pedestrian safety at the unsignalized intersections in India. The main advantage of the proximal safety indicator is the incorporation of the conflicts more frequently than the actual accidents, which results in the effective, statistically significant and reliable proximal measure of traffic safety. The Post Encroachment Time(PET) is used as a proximal safety indicator in this study. The required pedestrian-vehicle conflicts were extracted manually from the videographic survey conducted at an unsignalized intersection. The conflicts were grouped as highly severe conflict, severe conflict, and normal conflict according to the behavior of the participants of the conflicts (pedestrian & vehicle). For each type of the vehicle class, the threshold PET values of each conflict group (highly severe conflict, severe conflict, and normal conflict) were obtained using Support Vector Machine algorithm. This paper describes the effect of vehicle type and the vehicle approaching speed on the severity of the conflict under non-lane based mix traffic condition. Additionally, it also sets the threshold PET values for highly severe conflict, severe conflict, and normal conflict which can be used for the prediction of the severity of the conflict at unsignalized intersections in India.

Authors	S.M. Sohel Mahmud, University of Queensland Luis Ferreira, University of Queensland Md. Shamsul Hoque, Bangladesh University Ahmad Tavassoli, University of Queensland
Sponsoring Committee	Standing Committee on Transportation in the Developing Countries (ABE90)
Session Number	382
Session Title	Public Transport, Safety and Management, E-bikes and Bikesharing, and Nonmotorized Transportation in Developing Countries
Paper Number	18-02193
Paper Title	Prioritizing Hazardous Road Sections Using Surrogate Safety Measures: A Count Data Modeling Application in a Heterogeneous Traffic Environment
Abstract	Road safety continues to be a major concern in developing countries and the major causes of road crashes need to be established before mitigation measures can be applied. The study reported here is aimed at identifying those sections of a road which are most likely to be at risk. A new model is put forward to predict the most hazardous sections using surrogate safety measures, considering the problems related to the reporting and recording of the crash data. The paper demonstrates an alternative technique to identify traffic conflicts using combined surrogate indicators. Acknowledging the limited resources and facilities in developing countries, this conflict identification method provides a relatively simple way to define traffic conflicts in heterogeneous traffic environments. The study explored the use of fixed and random parameter Poisson models as an alternative methodological approach to relate the factors affecting the number and probability of conflicts. The partial effect of individual independent variables were estimated to gain a better insight of their impact. The results shows that the model can predict the number and the probability of potential conflicts for a particular number of trips, as well as prioritize road sections according to their likelihood of safety level. The model provides a less expensive alternative to the collection of historical crash data in order to identify hazardous road locations or black spots on two-lane two-way highway of developing countries.

Authors	Madhumita Paul, Indian Institute of Technology, Roorkee Tarun Pakhariya, Indian Institute of Technology, Roorkee Indrajit Ghosh, Indian Institute of Technology, Roorkee
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Part 1, Session 523)
Paper Number	18-02421
Paper Title	Traffic Calming and Management-Based Safety Enhancement at Unsignalized Intersection Using Microsimulation
Abstract	Unsignalized intersection presents the highest amount of serious potential conflicts between road users. Safety at such intersections is a worldwide concern, especially in the developing countries like India where unsignalized intersections essentially function as uncontrolled ones due to the high prevalence of indiscipline traffic maneuverability. Recently, there has been a growing interest in using microsimulation models for the safety assessment of any road network by analyzing vehicle trajectories and estimating proximal safety indicators. Hence, the aim of this study is to enhance safety at four unsignalized intersections located at National Capital Region (NCR), India using the widely used microsimulation model PTV VISSIM. Initially, safety evaluation has been carried out using two proximal indicators, Post Encroachment Time (PET) and Conflicting speed. Later, several traffic calming and management measures have been utilized in order to improve the safety of the selected study sites in VISSIM. Consequently, their effect on base mean PET is obtained using an add-in software Surrogate Safety Assessment Model (SSAM). The study results show that increase in overall traffic volume, reduction in heavy vehicle volume, increase in grade up to 4 percent gradient have resulted into increased safety level at the selected intersections. Speed calming measures such as speed humps and speed tables are also found to be effective by increasing safety at selected intersections. The present study shows that integration of proximal safety indicator in conjunction with traffic simulation model identifies different efficient traffic calming and management measures in order to increase the safety of traffic networks.

Authors	Xuesong Wang, Tongji University Minming Yang, Tongji University Meixin Zhu, Tongji University
Sponsoring Committee	Standing Committee on Traffic Flow Theory and Characteristics (AHB45)
Session Number	775
Session Title	Traffic Flow Theory and Characteristics, Part 3 (Part 1, Session 522; Part 2, Session 573; Part 4, Session 832)
Paper Number	18-02562
Paper Title	An Exploration of Cut-In Behavior and Gap Acceptance Using Shanghai Naturalistic Driving Data
Abstract	Cut-in maneuvers are dangerous lane changes that may result in traffic conflicts or crashes. The maneuvers affect the safety gap between vehicles and may adversely affect automated vehicle operations and safety. To comprehensively explore cut-in behavior, 4,734 cut-in events in China were extracted from the Shanghai Naturalistic Driving Study. The data were used to analyze the characteristics of cut-in behavior, including purposes, turn signal usage, duration and urgency. Cut-in duration and gap acceptance distributions were quantified and an exploratory gap model was developed to promote a broader understanding of cut-in behavior in Shanghai. The results showed that 1) cut-in behavior is relatively dangerous and risky with smaller time to collision than normal lane change, and more than 50% of cut-ins are motivated by a slow preceding vehicle; 2) almost half of Chinese drivers did not use a turn signal when cutting-in, which is indicative of poor driving habits and an aggressive driving style; 3) unlike a typical lane change, cut-ins have a shorter duration as well as a smaller lag gap. A lognormal distribution and Generalized Extreme Value distribution produced the best fit for the cut-in duration and lag gap respectively; 4) road type, relative speed, and following vehicle's acceleration are important factors that might influence drivers' lag gap acceptance. This paper extends the exploration and development of lane change theory and its applications. The results indicate social norms and behavior are influenced by culture and other countries should consider calibrating assumptions about cut-in behavior based on local data sources.

Authors	Joshua Stipancic, McGill University Luis Miranda-Moreno, McGill University Nicolas Saunier, École Polytechnique de Montréal Aurelie Labbe, HEC Montreal
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-02836
Paper Title	Network Screening for Large Urban Road Networks: Using GPS Data and Surrogate Measures to Model Crash Frequency and Severity
Abstract	Crash frequency and injury severity are independent dimensions of road safety which should be considered in the network screening process. Traditional screening techniques model crashes using regression and historical crash data, making them intrinsically reactive. In response, surrogate safety measures (SSMs) have become a popular alternative. The purpose of this paper is to develop a mixed-multivariate model for crash frequency and severity by incorporating GPS-derived SSMs as predictive variables. SSMs based on vehicle manoeuvres and traffic flow were extracted from GPS data collected in Quebec City, Canada. The mixed multivariate outcome is estimated using two models. First, crash frequency is modelled using a Full Bayes Spatial Negative Binomial model estimated using the Integrated Nested Laplace Approximation approach. Second, crash severity is integrated through a fractional Multinomial Logit model. Third, the results are combined to generate crash counts at each severity level and rank sites based on crash cost per trip. The crash frequency model was shown to be accurate at the network scale, with all proposed SSMs statistically significant at 95 % confidence and the direction of their effect consistent with previous research. In the crash severity model, fewer variables were significant, yet the direction of the effect of all significant variables was again consistent with previous research. Rankings generated using the mixed multivariate model were 95 % correlated to the crash data rankings. The ability to prioritize sites based on GPS data and SSMs rather than historical crash data represents a substantial contribution to the field of road safety.

Authors	Yanyong Guo, University of British Columbia Tarek Sayed, University of British Columbia Mohamed Zaki, University of British Columbia
Sponsoring Committee	Standing Committee on Motorcycles and Mopeds (ANF30)
Session Number	291
Session Title	New Technologies and Methods in Motorcycle Safety—Hybrid Session
Paper Number	18-03174
Paper Title	Analysis of the Lateral Distance Between Two Wheelers and Automobiles During Overtaking at Shared Traffic Facility
Abstract	There is a growing interest in analyzing lateral interactions between two wheelers and automobiles due to the significant influence of the interactions on traffic performance and safety. This paper examines the lateral distance between two wheelers and automobiles during overtaking at a shared traffic street. A video-based computer vision technique is used to track road-users, collect their trajectories, and measure the lateral distance. A full Bayesian logit model is developed to investigate the factors that may affect the likelihood of two wheelers to accept the critical lateral distance. The analysis results show that (a) the average lateral distance between two wheelers and automobiles is 1.542 m; (b) the lateral distance for bicycles is significantly larger than that for e-bikes and e-scooters; (c) the lateral distance follows a best-fitted Gamma distribution; (d) 90% of lateral distance exceeds 1.1 m. Further results from the full Bayesian logit model show that: (1) the two wheelers type, the evasive action manner, the occurrence of a platoon of moving two wheelers, and two wheelers' yaw rate ratio are significantly positively related to the probability of two wheelers accepting the critical lateral distance; (2) the presence of heavy vehicles and the speed difference between two wheelers and the interacting automobiles are negatively associated with the above probability.

Authors	Yao Yao, University of Leeds Oliver Carsten, University of Leeds Daryl Hibberd, Institute for Transport Studies
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-03362
Paper Title	Explore the Relationship Between Risk Perception, Speed Limit Credibility, and Compliance with Speed Limit
Abstract	The study aims to investigate the relationship between risk perception and compliance with speed limit, between speed limit credibility and driver's compliance with speed limit, and between risk perception and speed limit credibility in a given rural single carriageway road and roadside environment. To achieve the aim, the speed limit credibility, subjective risk perception and compliance with speed limit are measured separately in given rural single carriageway road and roadside environment situations. Speed limit credibility is measured by speed limit rating score using a picture questionnaire. Subjective risk perception is measured by risk rating in an automated car driving simulator for a given speed and road environment. Speed limit compliance is measured by percentage of driving time below speed limit in the simulated manual driving task for the given speed limit and road environment. Multilevel regression and logistic regression analysis demonstrate that higher risk perception has a positive influence on compliance with speed limit. Credible speed limit has a positive influence on speed limit compliance. Higher risk perception has a negative influence on speed limit credibility.

Authors	Katerina Stylianou, University of Cyprus Loukas Dimitriou, University of Cyprus Mohamed Abdel-Aty, University of Central Florida
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	834
Session Title	The Search for a Better Way, Part 2: Exploring and Refining Methods in Highway Safety (Part 1, Session 523)
Paper Number	18-03363
Paper Title	Development of a Spatiotemporal Hybrid Conflict Severity Indicator on Urban Network
Abstract	Traffic safety usually relies on crash frequency or severity and therefore the most recent research has focused on the analysis of historical crash data. However, in most cases these data are faced with organization problems, quality issues or under-reporting. Thus, an alternative approach to road safety analysis is the use of surrogate safety measures such as traffic conflicts which can easily be identified through general traffic data. Relying upon traffic conflict techniques and safety hierarchy, this study provides the development of a Conflict Severity Index (CSI) based on the closeness in time and in space. The innovative feature of this study is the application of statistical techniques used in crash severity analysis, to conflict severity data. The analytical approach selected is discrete choice modelling, which represents a well-established technique in the statistical analysis of crash severity. Traffic data for conflict observations were collected from Inductive Loop Detectors (ILD) at several locations in the urban network of Nicosia, Cyprus. Results of the CSI showed that conflict severity is higher when positive speed difference is higher and spacing between vehicles is smaller. Three discrete choice models were developed for conflict severity: multinomial logit model; nested logit model and ordered probit model. All models showed the significance of location in the network, speed difference, headway and speed standard deviation, however the ordered probit model provided the best fit to the observed conflict data. The proposed methodology can be used as a support decision tool for evaluating urban traffic safety in real time.

Authors	Mohamed Essa, University of British Columbia Mohamed Hussein Tarek Sayed, University of British Columbia
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-03468
Paper Title	Behavioral and Safety Analysis of Pedestrian–Bike Shared Space of Robson Street in Vancouver
Abstract	The main objective of this paper is to conduct a road-user behavior and safety analysis of the operation of the pedestrian-bike shared space of Robson Street in Vancouver. The analysis is conducted using video-data, collected by the City of Vancouver during the summer of 2016. Automated video analysis techniques were used to detect different road users and extract their trajectories from video scenes. Afterwards, the extracted trajectories were used to estimate the speed distributions of different categories of road users, and analyze the interactions (conflicts) between them in order to assess their safety. An investigation of the effect of introducing a bike-dismount sign at both ends of the shared space on both the percentage of cyclists' compliance with the sign and the frequency of pedestrian-bike interactions is provided. Finally, the relationship between the speed of both pedestrians and bikes and the density of the shared space were investigated in order to develop speed-density relationships in such a shared space environment. The results show that the percentage of bike dismounts increased from 17% to 36% after placing the sign. The traffic conflict analysis shows a reduction of 34% in the pedestrian-bike conflict rate after placing the sign, which indicates an improvement in safety. The average and standard deviations of the pedestrian and bike speeds were found to be (1.12 ± 0.05 m/s) and (2.95 ± 1.80 m/s), respectively. In addition, two models were developed to investigate the speed-density relationships of pedestrians and bikes. Both models showed good fit to the data, with R-squared values of 0.73 and 0.80, respectively. The results obtained in this paper can be useful in providing insights into understanding the operational and safety performance of pedestrian-bike shared space environments.

Authors	Peibo Zhao, University of Windsor Chris Lee, University of Windsor
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-03619
Paper Title	Analysis of Discretionary Lane Change Collision Risk Using Individual Vehicle Trajectories
Abstract	Although lane-change collisions have frequently occurred, there are relatively fewer studies on lane-change collision risk compared to rear-end collision risk. Also, most studies on lane-change collision risk focused on the collision between the lane-changing vehicle (LCV) and the trailing vehicle in the target lane (TV). Thus, this study comprehensively analyzes risk of lane-change collisions between the LCV and both lead and trailing vehicles in the target lane - LV and TV, respectively. Lane-change collision risk was measured using the crash potential index (CPI) with the modified deceleration to avoid crashes (DRAC) which accounts for driver's reaction time. CPIs were computed using individual vehicle trajectories from a 640-m segment of the US-101 freeway in Los Angeles, U.S.A. CPIs were separately computed for collision between LCV and TV (LCV-TV) and collision between LCV and LV (LCV-LV) based on the vehicles' lateral positions during lane changes. CPIs were also separately computed for sideswipe and rear-end collisions. It was found that CPIs were consistently higher for sideswipe collision than rear-end collision for LCV-TV. It was also found that CPIs for cars were higher when they change lane before trailing heavy vehicles than trailing cars in the target lane. Moreover, CPIs were consistently higher for LCV-TV than LCV-LV. This study provides insights into better understanding of lane-change collision risk for the LCV with surrounding vehicles by collision type.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-03927
Paper Title	Crash and Near-Crash Prediction from Vehicle Kinematics Data: A SHRP 2 Naturalistic Driving Study
Abstract	This study introduces a crash/near-crash prediction model developed from vehicle kinematics data. The study hypothesis is that vehicles experience significant turbulence in their kinematics before involvement in crashes/near-crashes. To test this hypothesis, the SHRP2 NDS vehicle kinematics data (speed, longitudinal acceleration, lateral acceleration, yaw rate, and pedal position) are utilized. The data are first prepared based on two approaches: Euclidean point and similarity matrix. In the first approach, several algorithms are trained and comparatively analyzed including K Nearest Neighbor (KNN), Random Forest, Support Vector Machine (SVM), Decision Trees, Gaussian Neighborhood, Adaptive Boost (AdaBoost), Multilayer Perceptron (MLP), and Quadratic Discrimination Analysis (QDA), whereas the kernel SVM algorithm is tested in the second approach. Initial testing indicates that AdaBoost outperforms all other methods in the Euclidean point approach. Sensitivity analysis is accordingly performed using AdaBoost and the kernel SVM models to determine the optimal prediction horizon length (the time period before which a crash/near-crash can be predicted) and turbulence horizon length (the time period over which crash/near-crash related changes in vehicle kinematics take place). The results reveal that both models have considerably reliable prediction accuracy around 90% at one-second prediction horizon and four-second turbulence horizon. It is consequently believed that such time window allows for capturing the crash/near-crash related variations in vehicle kinematics. The achieved high prediction accuracy is promising for crash avoidance systems in the emerging autonomous vehicle technology.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-04182
Paper Title	Comparative Evaluation of Driving Efficiency Using Smartphone Data
Abstract	The objective of this paper is to provide a solid framework for the comparative evaluation of driving efficiency based on Data Envelopment Analysis (DEA). The analysis considers each driver as a Decision Making Unit (DMU) and aims to provide a relative efficiency measure to compare different drivers based on their driving performance. The last is defined based on a set of driving analytics (e.g. distance travelled, speed, accelerations, braking, cornering and smartphone usage) collected using an innovative data collection scheme, which is based on the continuous recording of personalized driving behavior analytics in real time, using smartphone device sensors. Efficiency is examined in terms of speed limit violation, driving distraction, aggressiveness and safety on urban, rural and highway road and in an overall model. DEA models are identifying the most efficient drivers that lie on the efficiency frontier and act as peers for the rest of the non-efficient drivers. The proposed methodological framework is tested on data from fifty-six (56) drivers during a 7-months driving experiment. Findings help distinguish the most efficient drivers from those that are less efficient. Moreover, the efficient level of inputs and outputs that should be reached by each one of the less-efficient and non-efficient drivers to switch to the efficiency frontier and become efficient is identified. Results also provide a potential for classification of the driving sample based on drivers' comparative efficiency. The main characteristics of the most and less efficient drivers are consequently analyzed and presented herein. The impact of this methodology lies on the fact that most common inefficient driving practices are identified (aggressive, risky driving etc.) and driving behavior is comparatively evaluated and analyzed.

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Sponsoring Committee	Standing Committee on Pedestrians (ANF10)
Session Number	576
Session Title	Innovative Research on Pedestrian Safety and Behavior
Paper Number	18-04364
Paper Title	Should I Stay or Should I Go? A Discrete Choice Model for Pedestrian–Vehicle Conflicts in Shared Space
Abstract	When streets are designed according to the shared space principle, road user are encouraged to interact spontaneously with each other for negotiating the space. These interaction mechanisms do not follow clearly defined traffic rules but rather psychological and social principles related to aspects of safety, comfort and time pressure. However, these principles are hard to capture and to quantify, thus making it difficult to simulate the behavior of road users. This work investigates traffic conflict situations between pedestrians and motorized vehicles, with the main objective to formulate a discrete choice model for the identification of the proper conflict solving strategy. A shared space street in Hamburg, Germany, with high pedestrian volumes is used as a case study for model formulation and calibration. Conflict situations are detected by an automatic procedure of trajectory prediction and comparison. Standard evasive actions are identified, both for pedestrians and vehicles, by observing behavioral patterns. A set of potential parameters, which may affect the choice of the evasive action, is formulated and tested for significance. These include geometrical aspects, like distance and speed of the conflicting users, as well as conflict-specific ones, like time to collision. A multinomial logit model is finally calibrated and validated on real situations. The developed approach is realistic and ready for implementation in motion models for shared space or any other less organized traffic environment.

Authors	Katerina Stylianou, University of Cyprus Loukas Dimitriou, University of Cyprus
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-04602
Paper Title	Explanatory Analysis of Rear-End Conflicts in Urban Networks Using Bayesian Networks
Abstract	Crash analysis and modeling studies have provided insightful information on crash contributing factors and the methodologies utilized provide evidence that they could also be beneficial for conflict analysis, as traffic conflict data share similar traits with crash data. In this study a Bayesian Network (BN) is estimated to comprehensively analyze rear-end conflict likelihood in an urban network, using dissagregate vehicle-by-vehicle data and the Time to Collision (TTC) indicator to identify conflicts. The variables imported in the BN include (i) individual driver characteristics (e.g. speed); (ii) traffic operational characteristics (e.g. volume); and (iii) general characteristics (e.g. weather conditions). The inference analyses of the BN conducted to quantify the contributions of the variables affecting rear-end conflict likelihood in the urban network, showed that rear-end conflict likelihood could be increased when the involved vehicles are of different type, when the speed of the following vehicle is higher than the speed of the leading vehicle, when individual speed is high when the individual headway is small, with higher coefficient of variation of speed values, when the type of intersection nearest of the measuring point was a priority intersection, when the carriageway was of dual design and when it was rainy. It was also shown that rear-end conflict likelihood increases during congestion and free flow traffic. The findings of this study could be further developed to provide a good understanding on contributing factors to possible crashes in the urban network.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-04827
Paper Title	Real-Time Prediction of Vehicle Trajectories for Proactively Identifying Risky Driving Behaviors at High-Speed Intersections
Abstract	A 3s of flashing green indication followed by a 3s of yellow indication is commonly implemented at rural high-speed intersections in many Chinese cities. Such a long phase transition time leads to heterogeneous decision-making of pass or stop at the end of green phase for approaching drivers. Therefore, risky driving behaviors such as red-light running, abrupt stop, and aggressive pass are more likely to occur at these intersections. Proactive identification of risky behaviors can facilitate dilemma zone mitigation and on-board safety altering strategies. In this study, a real-time vehicle trajectory prediction method is proposed to help proactively identifying risky behaviors during the phase transition intervals at high-speed intersections. Two cases are considered and treated differently in the proposed method: one is the single vehicle case and the other is the following vehicle case. The adaptive Kalman Filter (KF) model and the K-Nearest Neighbor model are integrated to predict the single vehicles' trajectories. Meanwhile, the adaptive KF model and the Intelligent Driver Model are fused to predict the following vehicles' trajectories. The proposed models are calibrated and validated using 1, 281 vehicle trajectories, collected at three rural high-speed intersections in Shanghai. Results indicate that the Root Mean Square Error between the predicted trajectories and the actual trajectories is 5.02m for the single vehicles and 2.33m for the following vehicles, respectively. The proposed method is further applied to predict risky behaviors, including red light running, abrupt stop, aggressive pass, speeding pass and aggressive following. Results show that the overall prediction accuracy is 95.1% for the single vehicle case and 96.2% for the following vehicle case.

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Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-04868
Paper Title	Safety Evaluation of Unsignalized Intersection Using Hybrid Approach Involving Emperical and Simulation Data Sources
Abstract	This research aims at developing a safety assessment methodology of un-signalized intersection under heterogeneous traffic conditions using proximal-safety concept. For this, the Post Encroachment Time (PET) measure at different approaches of the intersection was extracted manually from the recorded traffic video of a representative un-signalized intersection in Surat, India. The effect of temporal variations of traffic conditions on PET values for the field configuration was obtained from the microscopic simulation software and the driving behavior for varying intersection configuration was obtained from the driving simulator. The data from these three sources were analyzed to estimate the crash frequency and to explain the crash type of un-signalized intersection. The Generalized Extreme Value (GEV) was found to be the best-fitted distribution for explaining the temporal variations observed in PET values. It was observed that traffic volume has a prominent effect on the likelihood of crash occurrence. The likelihood of crash during morning hours was found to be around 6%, which increased to 17% during evening hours due to increase in traffic volume. A sensitivity analysis was conducted for studying the effect of variations in traffic composition, speed and driving behavior using a well-validated simulation model. Different intersection configurations were studied using driving simulator to analyze the potential crash types for selected traffic maneuvers at un-signalized intersections. Based on PET values, the right-angled collision was found to be the most critical crash type with prominent crash probability.

Authors	Zhaoxiang He, University of Wisconsin, Milwaukee Xiao Qin, University of Wisconsin, Milwaukee Pan Liu MD ABU SAYED, No Organization
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-04931
Paper Title	Assessing Surrogate Safety Measures Using a Safety Pilot Method Deployment (SPMD) Data Set
Abstract	Emerging data sources such as Safety Pilot Model Deployment (SPMD) provide a great opportunity to gain a better understanding of collision mechanisms and to develop novel safety metrics. The SPMD program was a comprehensive data collection effort under real-world conditions in Ann Arbor, Michigan, covering over 73 lane-miles and including approximately 3,000 pieces of onboard vehicle equipment and 30 pieces of roadside equipment. In-vehicle data (e.g.: speed, location) collected by SPMD program can potential be an important supplement to traditional crash data oriented safety analysis. The goal of this study was to assess roadway link-level surrogate safety measures using the vehicle trajectory data from SPMD. The study's objectives included: 1) developing a framework to process the SPMD dataset using Big Data Analytics; 2) converting raw vehicle motion data from SPMD to surrogate safety measures; and 3) analyzing the statistical relationship between crash records and calculated safety index. The statistical models showed that time to collision (TTC) outperforms modified time to collision (MTTC) and deceleration rate to avoid collision (DRAC) in terms of its goodness of fit and statistically significant variables. The findings are promising in that augmenting safety analysis with surrogate measures and vehicle performance (i.e. speed and brake duration from connected vehicles) improves the overall model performance. Such information is vital for safety analysis, especially in the absence of detailed roadway and traffic data.

Authors	Ting Fu, McGill University David Beitel, McGill University Bismarck Ledezma-Navarro, McGill University Seyed Amir Zahabi, McGill University Nicolas Saunier, École Polytechnique de Montréal Luis Miranda-Moreno, McGill University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB 20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05083
Paper Title	Investigating Cyclist–Pedestrian Interactions at Bus Stops and Nonsignalized Intersections Using a Distance–Velocity Model and Speed Measures Derived from Video Data
Abstract	As walking and cycling flows increase in urban areas, cyclist-pedestrian interactions also increase at road facilities such as crosswalks at non-signalized intersections and bus stops located along segregated cycle tracks. Cyclist yielding compliances at these locations can be low which could deteriorate pedestrian safety and comfort. To investigate pedestrian safety at these locations, this study introduces a framework using cyclists' distance, speed and yielding maneuver information at the time of pedestrian occurrence and crossing derived from video data. The distance-to-crosswalk and speed of the cyclist are used to classify the cyclist's situation at pedestrian occurrences into three categories: i) where the cyclist cannot make a full stop; ii) where the ability to yield depends on the reaction time; and iii) where the cyclist can stop to yield. Cyclist crossing speeds at the crosswalk are also analyzed. A case study involving several crosswalk locations on cycle tracks from Montreal, Canada, was conducted. Video data was collected and video-based tracking techniques were used to extract cyclist speed and distance information. Results allow for microscopic analysis and provide insight into cyclist-pedestrian interactions. The factors that contribute to the low yielding compliance of cyclists and the impact of marking, and road grade on cyclist behavior are explored. This safety analysis could inform policy on bicycle yielding enforcement and bicycle braking system standards.

Authors	Samantha Haus, Virginia Polytechnic Institute and State University Hampton Gabler, Virginia Polytechnic Institute and State University
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	394
Session Title	Advanced Analysis to Improve Nonmotorized Transportation Safety
Paper Number	18-05351
Paper Title	Characteristics of Vehicle–Bicycle Crashes and Near Crashes Using Naturalistic Driving Data
Abstract	Although motor vehicles are being equipped with increasingly sophisticated active safety systems, the fatality rate of cyclists in the U.S. continues to increase (1). Active safety systems such as pre-collision autonomous braking systems, which detect and autonomously brake in the event of an impending bicycle collision, could be a solution to this growing problem (6). This study examined the SHRP-2 naturalistic driving study database of bicycle crashes and near-crashes to categorize and determine if active safety systems could prevent such incidents. Bicycle and the vehicles paths were examined, as well as the driver's reaction, the duration the bicyclists were visible, and the speed of the bicyclists. In the 30 cases provided by the SHRP-2 database, the most prevalent vehicle-bicycle incidents occurred when the bicycle traveled straight across the path of the vehicle or when the vehicle turned left across the path of the bicyclist. The average time visible was dependent on the path and speed of the bicyclist. The bicyclists traveling in the direction of traffic were visible for longer than the bicyclists traveling across the path of the vehicle. In almost three-fourths of the cases (73%) the bicyclist was visible for longer than one second. For autonomous braking to work, bicyclists need to be detectable with enough time for crash preventative actions to be initiated. While there are many factors, the time visible indicates that in 73% of the cases, pre-collision autonomous braking had the potential to decrease the severity of the crash or avoid the crash altogether.

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Sponsoring Committee	Standing Committee on Traffic Control Devices (AHB50)
Session Number	722
Session Title	Traffic Control Devices
Paper Number	18-05438
Paper Title	Speed at Partially and Fully Stop-Controlled Intersections
Abstract	Conversion of "two-way stop" intersections into "four-way stop"/"all-way stop" intersections is a popular road safety counter-measure typically deployed in dense, urban environments. This is not surprising, given pedestrian concerns with crossing increasingly congested uncontrolled approaches and given how relatively cost-effective it is to install stop signs and update road markings in order to convert from partial to full stop-controlled. However, this practice sometimes contradicts existing traffic control guides, especially if different design warrants address conflicting needs: for example, when increasing safety at the expense of capacity. To further understand the safety impact of partial and full-stop control, nearly 65,000 road users at 77 Montréal stop-controlled and uncontrolled approaches are studied by instrumenting each intersection so as to collect high-resolution approach trajectories, thereby profiling the approach of all motorists with and without the presence of pedestrians. The study determines, among other things, that stop location varies considerably between intersections and reveals a mean minimum speed of 11.5 km/h at stop-controlled approaches and possible prevalence of the "rolling-stop". Fully stop-controlled intersections are found to have a further decrease in speed of 3 km/h, suggesting that existing stops might benefit from full stop-control, but the greatest benefit of conversion lies with the conversion of uncontrolled approaches.

Authors	Li Zhao, University of Nebraska, Lincoln Laurence Rilett, University of Nebraska, Lincoln Jianan Zhou, University of Nebraska, Lincoln
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-05895
Paper Title	Using High-Fidelity Vehicle Trajectory Data for Safety Analyses: A Case Study
Abstract	Vehicle trajectory data provide detailed information on driving behavior. They are useful in a variety of areas such as modeling of car-following, lane-changing, and gap acceptance. To date, obtaining video-based vehicle trajectories has been attempted by many researchers. However, this research identified a number of challenges, including image quality and high manual labor costs. Consequently, video-based vehicle trajectory data and its use have been limited. This paper introduces a high-definition, low-cost radar-based data collection system to track individual vehicles as they approach an intersection. The data collection system, developed the by Nebraska Transportation Center, consists of Wavetronix Smartsensor Advance, Wavetronix Smartsensor HD, and digital cameras. Micro-level (i.e., second by second) vehicle speed profiles were collected at two test beds: (1) a highway-rail grade crossing equipped with signal-warning flashers and automatic gates, and (2) a highway-highway intersection equipped with advance signal-warning flashers. The speed profiles are used to investigate how a driver reacts, in a detailed process, to the activated warning system at each of the test beds. Safety surrogate measures such as gate violation and red-light running (i.e., violation of traffic law) are studied to indicate the relationship between the start of the traffic control equipment and driver behaviors. It is concluded that the radar-based speed profiles provide better and more comprehensive data for study safety impacts of driver behavior on an approach lane to critical interests such as highway-highway intersections and highway-rail grade crossings.

Authors	Maria Espinosa Granados, CIMA+ Bhagwant Persaud, Ryerson University Thanushan Rajeswaran, Ryerson University Taha Saleem, UNC Highway Safety Research CenterYang Cheng, University of Wisconsin, Madison
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-05956
Paper Title	Using Microsimulation to Evaluate the Impact of Automated Vehicles on Safety Performance of Signalized Intersections
Abstract	Automated vehicles (AVs) are expected to offer great societal benefits by potentially reducing crashes. It is important to understand these impacts and to examine how this understanding may affect the planning of roadways and roadway improvements. Signalized intersections are of particular interest in this regard since the safety of these sites is particularly impacted by driving behavior, which, even in conventional vehicles, can be influenced by the presence of AVs. The study uses micro-simulation to generate simulated traffic conflicts as indicators of potential crashes, and models that relate crashes to conflicts, to examine the expected safety of signalized intersections in Toronto, Canada in the presence of automated vehicles at various penetration levels. In addition, the effect on crashes of introducing three hypothetical left turn treatments was also evaluated. The results indicate that intersection safety may improve in the presence of AVs. However, the safety effects of treatments may be reduced compared to the effects with no AVs. The implication is that the imminent introduction of AVs should be considered in developing priorities for future intersection improvements.

Authors	Tom Mathew, Indian Institute of Technology, Bombay Anna Charly, Indian Institute of Technology, Bombay
Sponsoring Committee	Standing Committee on Safety Data, Analysis and Evaluation (ANB20)
Session Number	523
Session Title	The Search for a Better Way, Part 1: Exploring New Data and New Applications of Data in Highway Safety (Part 2, Session 834)
Paper Number	18-06666
Paper Title	Evaluation of Driving Performance in Relation to Crashes on an Expressway Using Naturalistic Driving Data
Abstract	Innovative crash prediction methods aimed at minimizing the dependence on crash data is being researched upon by many across the world. The major component of any such research involves the identification of parameters that are crucial in estimating safety. The majority of the studies consider geometrical parameters or proximity measures to assess the safety of a road. Though these parameters bear relation with the crashes and represent the safety to a certain extent, it overlooks the driver behavior which is a major crash causal factor. The present study aims at evaluating the driving performance measures, namely lateral and longitudinal accelerations corresponding to g-force, a measure of acceleration force. The study uses naturalistic driving data to estimate the driver performance parameters and analyses it with respect to the geometry of the section. The results are compared with the historical crash data to evaluate its reliability in estimating safety. The results show that lateral acceleration is able to represent the safety better than the other parameters considered.

8 Transportation Safety Management

Frank Gross, VHB

Forty papers describing different aspects of transportation safety management will be presented at the 2018 TRB Annual Meeting, which are briefly discussed below.

Three papers discuss **roadway safety policy and leadership**. Hill et al. (18-03549) explore physician reporting requirements in the United States. Burdett (18-03988) discusses the disconnect between road safety policy philosophy and practice, indicating the need for policy that accounts for everyday driving (including driver distraction and inattentiveness). Yannis et al. (18-05057) develop a global road safety model that could be used for testing road safety policies.

A single paper by Beale et al. (18-01284) discusses the development, implementation, and evaluation of **data-driven safety plans and programs**. Specifically, they present the successful results of Ohio's township safety signage grant program, highlighting the benefit-cost analysis for the first twenty-four townships with twelve months of post grant completion crash data.

Three papers discuss the development of **safety management tools**. Alluri et al. (18-00369) develop a decision support system for selecting Highway Safety Manual (HSM) methods. Wang et al. (18-00738) develop a crash risk scoring tool for pedestrian and bicycle projects in Oregon. Abou-Senna et al. (18-05479) develop a safety prioritization tool for sidewalk and bike-lane gaps in Florida.

Nine papers discuss **system planning and network screening**. Kononov et al. (18-01707) discuss the importance of and how to integrate safety with other project goals in planning and project selection. Cai et al. (18-00144) apply a bayesian approach, incorporating spatial interaction, to integrate macro- and micro-level safety analyses. Lee et al. (18-01759) apply an integrated modeling approach for nonmotorized trips and crashes in the framework of transportation safety planning. Mohammadianamiri et al. (18-01655) compare four different techniques for hotspot identification in an urban network. Ambros et al. (18-02011) present the results of a safety screening of the Czech core road network. Wang et al. (18-02533) discuss hotspot identification for freeways, considering differences in single- and multiple-vehicle crashes. Lee et al. (18-05114) develop a method to identify hotspots based on an optimization technique. Wang et al. (18-05210) perform an evaluation of hot-spot identification methods for municipal roads. Braley et al. (18-06494) explore a process to improve long-range planning prioritization by using forecasted safety metrics in place of the existing Utah Department of Transportation Safety Index.

Eight papers discuss the results of various levels of **evaluation**, and will be presented in a session titled, *Lessons Learned in Safety Management: A Time to Reflect*. Marshall (18-00018) seek to understand what is behind the road safety disparities between the United States and Australia. Weijermars et al. (18-00898) analyze serious road traffic injuries in Europe, and describe lessons learned from the EU research project Safetycube. Farid et al. (18-01241) perform a cost–benefit analysis of Highway Safety Improvement Program projects in Wisconsin using the Empirical Bayes method. Dong et al. (18-01455) assess the effectiveness of highway safety laws in reducing crashes by use of multivariate dynamic tobit models. Geedipally et al. (18-01775) conducted an in-depth investigation of factors that contributed to the decline in fatalities from 2008 to 2012 in the United States. Matthews et al. (18-03391) discuss a decision support toolkit to inform road safety investment decisions. Schmit and

Munnich (18-05835) identify factors influencing policy and political leadership in improving roadway safety. Ogle et al. (18-06569) report the impacts of state-specific policy and legislation on safety.

A single paper by Parvinashtiani and Smadi (18-05919) addresses **data collection and management issues** related to effective safety management and data-driven decision-making. They compare objective and subjective roadway data collection methods using the U.S. Road Assessment Program (usRAP).

Five papers explored the **safety effects of factors such as operations, environment, economics, vehicles, and demographics**. Rouholamin and Zhou (18-00509) analyze the severity of single-vehicle crashes on rural, two-lane highways to determine if age matters. Lynn et al. (18-02062) describe the characteristics and results of a factor analysis of crashes in Mississippi. Jung et al. (18-02293) develop stratified crash fatality prediction models to understand the impact of factors such as demographics, socio-economic features, roadway conditions, traffic violations, and road user behavior, which supports the development of targeted safety strategies in South Korea. Das et al. (18-03567) employ data mining, including the use of large contingency tables, to explore vehicle consumer complaint reports involving severe incidents. Chang et al. (18-05601) propose a generalized framework for the identification of crash contributing factors on freeways.

Two papers discussed specific **driver behavior issues**. Alagbe et al. (18-02720) investigate factors influencing the individual behavior of drivers, particularly phone use at red traffic signals. Azam et al. (18-03598) identify targeted programs for distracted driving in Montana using analytics and data visualization.

One paper discussed the broader area of **traffic safety culture**. Islam et al. (18-05881) conducted a survey, employing both telephone and online methods, to collect original data on the attitudes, perceptions, and behaviours of road users to understand traffic safety culture in the Edmonton region of Alberta, Canada.

Connected and automated vehicles (C/AV) and other technologies hold promise in improving traffic safety, including mitigating crash severity and decreasing the possibility of crashes by offering warnings to drivers and/or assuming vehicle control in dangerous situations. A paper Yue et al. (18-03482) assesses the safety benefits of connected and autonomous vehicle technologies. Lawson (18-04123) discusses the roads that cars will need in anticipation of the transition to autonomous vehicles.

One paper by Chang (18-00688) focuses on **school transportation safety**. These papers deal with issues related to: student pedestrian walking speeds at crosswalks,

Four papers focus on **Emergency Medical Service (EMS)**. These papers deal with issues related to access to trauma centers as well as trends in EMS response time, treatment, and transport. The papers will be presented in a session titled, *New Research on Improving Emergency Response Time*. Amorim et al. (18-00049) focus on EMS response time, analyzing vehicle dispatching rules and proposing an intelligent dispatching algorithm. Lee et al. (18-01821) describe their analysis of fatal traffic crash reporting and reporting arrival time intervals of EMS. He et al. (18-05425) evaluate the spatial pattern between EMS stations and incidents, and then recommend a method to optimize the location of EMS stations for improving rural EMS. Tufuor et al. (18-05729) assess the suitability of land for EMS posts along state highways based on a case study in California.

Authors	Wesley Marshall
Sponsoring Committee	ANB10
Session Number	359
Session Title	Lessons Learned in Safety Management: A Time to Reflect
Paper Number	18-00018
Paper Title	The Road Safety Lessons of Australia
Abstract	Despite similarities to the US in terms of transportation, land use, and culture, Australia kills 5.3 people per 100,000 population on the roads each year, as compared to the US rate of 12.4. Similar trends hold when accounting for distance driven and the number of registered cars. This paper seeks to understand what is behind the road safety disparities between these two countries. The results suggest that a number of inter-related factors have a role in the better road safety outcomes of Australia as compared to the US. This includes Australia doing a better job with issues such as seat belt usage and impaired driving as well as their efforts to help curb vehicle speeds and reduce exposure. Design-related differences include a much greater reliance on roundabouts and narrower street cross-sections as well as guidelines that encourage self-enforcing roads. Policy-related differences include stronger and more extensive enforcement programs, restrictive licensing programs, and higher driving costs. Combined with a more urban population and multimodal infrastructure, Australia tends to discourage driving mileage and exposure while encouraging safer modes of transportation such as transit, at least more so than in most of the US. While it is difficult to attribute recent road safety successes to individual policies, Australia continues to expand their lead on the US in terms of safety outcomes and is a country with road safety lessons worthy of consideration.

Authors	Wendy Weijermars; Niels Bos; Annelies Schoeters; Klaus Machata; Ashleigh Filtness; Jean-Christophe Meunier; Robert Bauer; Nina Nuyttens; Katherine Perez; Jean-Louis Martin; Emmanuelle Dupont; Laurie Brown; Heiko Johannsen; Pete Thomas
Sponsoring Committee	ANB10
Session Number	359
Session Title	Lessons Learned in Safety Management: A Time to Reflect
Paper Number	18-00898
Paper Title	Serious Road Traffic Injuries in Europe, Lessons from the EU Research Project Safetycube
Abstract	The EU research project SafetyCube pays specific attention to serious road injuries, defined as non-fatal road traffic casualties with a MAIS3+ injury severity rating. By means of surveys, information was collected on current practices concerning the estimation of the number of MAIS3+ casualties and on costs related to serious road injuries in different European countries. Moreover, the effect of differences in practices on the estimated number of MAIS3+ casualties was investigated by applying different methods to the same data. Finally, by means of a literature review, analysis of additional case studies and burden of injury calculations, health impacts of serious road injuries were investigated. This paper presents six main lessons learnt from the SafetyCube research. Practices concerning the estimation of the number of MAIS3+ casualties differ between countries; some countries apply correction factors to police data, other countries use hospital data and a third group of countries uses linked police and hospital data. Practices also differ concerning the selection of MAIS3+ road traffic injuries within hospital data. Differences in methodology appear to affect the MAIS3+ estimate. Therefore, one should be careful when comparing figures from different countries. The SafetyCube guidelines can support further harmonization. It is important to reduce the number of serious road injuries because injuries can have major impacts on a casualty's life and pose a burden to society. About 75% of the MAIS3+ road traffic casualties indicate not to be fully recovered three years post-crash. Moreover, serious road injuries cost countries up to 2.7% of their GDP.

Authors	Yashar Zeinali Farid Yu Song Andrea Bill David Noyce
Sponsoring Committee	ANB10
Session Number	359
Session Title	Lessons Learned in Safety Management: A Time to Reflect
Paper Number	18-01241
Paper Title	Cost–Benefit Analysis of the Highway Safety Improvement Program Projects in Wisconsin Using Empirical Bayes Method
Abstract	The Highway Safety Improvement Program (HSIP) is a core Federal-aid program which aims to reduce traffic fatalities and serious injuries on all public roads in the United States. HSIP projects implemented in Wisconsin cross a wide spectrum of highway safety improvements and enhancements. The objective of this paper is to present aggregated Benefit-Cost analysis of the HSIP projects implemented between 2007 and 2012 in Wisconsin in order to help determine the best future HSIP projects. The Benefit-Cost ratios are computed based on Before-After and Empirical Bayes methods and the cost of each project is compared with actual benefits observed in terms of reduction in the number of target crashes in the after period. Results indicate that in general, the HSIP projects implemented in Wisconsin yielded an average Benefit-Cost ratio of greater than one. Rumble strips, convert-to-signalized intersection, and guardrail-end-update projects yielded the highest Benefit-Cost ratios while convert-to-interchange and visibility improvement projects resulted in low ratios.

Authors	Chunjiao Dong Shashi Nambisan Chunfu Shao Jin Zeng
Sponsoring Committee	ANB10
Session Number	359
Session Title	Lessons Learned in Safety Management: A Time to Reflect
Paper Number	18-01455
Paper Title	An Assessment of the Effectiveness of Highway Safety Laws to Reduce Crashes: Use of Multivariate Dynamic Tobit Models
Abstract	Highway safety laws aim to influence driver behavior so as to reduce the frequency and severity of crashes, and their outcomes. There are 11 types of highway safety laws in the United States. For one specific highway safety law, it would have different effects on the crashes across severities. Understanding such effects can help policy makers upgrade current laws and hence improve traffic safety. To investigate the effects of highway safety laws on crashes across severities, multivariate models are needed to account for the interdependency issues in crash counts across severities. Based on the characteristics of the dependent variables, multivariate dynamic Tobit (MVDT) models are proposed to analyze crash counts that are aggregated at the state level. Lagged observed dependent variables are incorporated into the MVDT model to account for potential temporal correlation issues in crash data. The state highway safety law related factors are used as explanatory variables and socio-demographic and traffic factors are used as control variables. Three models, a MVDT model with lagged observed dependent variables, a MVDT model with unobserved random variables, and a multivariate static Tobit (MVST) model are developed and compared. The results show that among the investigated models, the MVDT models with lagged observed dependent variables have the best goodness-of-fit. The findings indicate that, compared to the MVST, the MVDT models have better explanatory power and prediction accuracy. The MVDT model with lagged observed variables can better handle the stochasticity and dependency in the temporal evolution of the crash counts and the estimated values from the model are closer to the observed values. The results show that more lives could be saved if law enforcement agencies can make a sustained effort to educate the public about the importance of motorcyclists wearing helmets. Motor vehicle crash-related deaths, injuries, and property damages could be reduced if states enact laws for stricter text messaging rules, higher speeding fines, older licensing age, and stronger graduated licensing provisions. Injury and PDO crashes would be significantly reduced with stricter laws prohibiting the use of hand-held communication devices and higher fines for drunk driving.

Authors	Srinivas Geedipally Daniel Blower Carol Flannagan Robert Wunderlich Dominique Lord
Sponsoring Committee	ANB10
Session Number	359
Session Title	Lessons Learned in Safety Management: A Time to Reflect
Paper Number	18-01775
Paper Title	In-Depth Investigation of Factors That Contributed to the Decline in Fatalities from 2008 to 2012 in the United States
Abstract	Between 2005 and 2011, peak to trough, the number of traffic fatalities in the United States declined by 11,031, from 43,510 in 2005 to 32,479 in 2011. Most of the dramatic decline occurred from 2008 to 2012 which also coincided with the great economic recession and aftermath. The objective of this study is to provide a multidisciplinary analysis of the relative influence of the types of factors that contributed to this decline in the number of highway fatalities and fatality rates from 2008 to 2012. Two basic approaches were used to analyze the factors that were associated with the drop in traffic fatalities. The first approach developed a set of count models, using negative binomial models to examine the associations between predictors and raw fatality counts. The second approach, which is used to validate the first approach, used a log-change regression model, to examine the association between the change in predictor variables in one year with the change in the outcome variable (traffic fatalities) in the following year. The most significant contributors to the drop in traffic fatalities were the substantial increase in teen and young adult unemployment, decreased in beer consumption, and reduction in GDP/capita income. Vehicle design improvements also contributed to the decline significantly, as did the decline in rural vehicle-miles traveled (VMT) and increased strictness of DUI laws. State highway spending was not a significant contributor to the drop; the effect of changes in infrastructure was likely more cumulative and longer term. Changes in safety belt use rates and fuel prices were not significant contributors to the decline because they did not change much over the period.

Authors	Joe Matthews Keith Newman Amy Green Lee Fawcett Neil Thorpe Karsten Kremer
Sponsoring Committee	ANB10
Session Number	359
Session Title	Lessons Learned in Safety Management: A Time to Reflect
Paper Number	18-03391
Paper Title	A Decision Support Toolkit to Inform Road Safety Investment Decisions
Abstract	Road safety practitioners are tasked with maintaining safety on their network, primarily by identifying hotspots to which resources should be allocated, and ensuring existing road safety schemes are operating effectively. Both of these tasks often require road safety counts (e.g. collisions or casualties) to be analysed, however these data are frequently bedevilled by confounding statistical factors such as Regression To the Mean (RTM) and trend. Failing to account for the presence of these factors can lead to the misallocation of resources as well as sites at risk of high counts not receiving treatment. To overcome this, methods have been proposed which clean data for RTM and trend to allow for more accurate scheme evaluation, and a proactive approach towards hotspot prediction. Unfortunately, these techniques require the use of complex statistical algorithms and so can be inaccessible to some practitioners. To overcome this, user-friendly software applications have been developed which implement the aforementioned methods with minimal technical input from the user.

Authors	Matt Schmit Lee Munnich
Sponsoring Committee	ANB10
Session Number	359
Session Title	Lessons Learned in Safety Management: A Time to Reflect
Paper Number	18-05835
Paper Title	Factors Influencing Policy and Political Leadership in Improving Roadway Safety
Abstract	This study built upon recent work to examine further the factors influencing policy and political leadership in adopting evidence-based policy countermeasures and integrated performance-based approaches such as Towards Zero Death (TZD) to reduce road fatalities and serious injuries. Specifically, the study sought to increase understanding of the policy context for safety and how special interest group influence at the state and local level plays a part in roadway safety policy promotion and adoption. The study focused on six states in the Midwest region – Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin – and engaged legislators, state agency officials, and special interest stakeholders to better understand the challenges and opportunities for improving roadway safety through public policy. The study expanded upon an assessment tool applied to quantifying policy countermeasure adoption in each of the six study states and created a similar tool for gauging special interest group activity.

Authors	Jennifer Ogle Sababa Islam Kweku Brown William Davis Wayne Sarasua
Sponsoring Committee	ANB10
Session Number	359
Session Title	Lessons Learned in Safety Management: A Time to Reflect
Paper Number	18-06569
Paper Title	Impacts of State Specific Policy and Legislation on Safety Advancement by Departments of Transportation
Abstract	The overall goal of this research was to identify proven successful safety programs used in other states and assess the potential for safety improvement if similar programs were implemented in South Carolina. The research team not only sought out engineering solutions, but also expanded the search to include programs for enforcement, education, licensing, legal proceedings, and emergency services – therefore incorporating a wide range stakeholder groups. South Carolina has, for many years, had one of the highest mileage death rates of any state in the nation – far exceeding the national fatality rate. While SCDOT has a federal requirement to develop and maintain the Strategic Highway Safety Plan, which identifies the state's key safety needs and guides investment decisions toward strategies and countermeasures with the most potential to save lives and prevent injuries, South Carolina legislation and state policies have effectively blocked many paths to safety improvements. Tree protection ordinances, limited policies for graduated drivers licensing, bans on camera enforcement, and lack of universal helmet laws continue to undermine efforts to improve motor vehicle safety in the state. Using a data driven approach to safety program selection will yield support for changes in programs, policies, and standards, and have positive impacts on safety, operational, and economic aspects of the South Carolina roadway system. Further, the implementation of a data-driven safety management program will help to assure that the most appropriate strategies are implemented. The successful implementation of this research would likely result in a substantial reduction in loss of life and injuries associated with motor vehicle crashes in the state of South Carolina.

Authors	Qing Cai Mohamed Abdel-Aty Jaeyoung Lee Helai Huang
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00144
Paper Title	Integrating Macro- and Microlevel Safety Analyses: A Bayesian Approach Incorporating Spatial Interaction
Abstract	Crash frequency analysis is a crucial tool to investigate transportation safety problems. Traditionally, crash frequency analyses have been undertaken at the macro- and micro-levels, independently. If conducted in the same study area, the macro- and micro-level crash analyses should investigate the same crashes but by aggregating the crashes at different levels. Hence, the crash counts at the two levels should be correlated and integrating macro- and micro-level crash frequency analyses in one modeling structure might have the ability to better explain crash occurrence by realizing the effects of both macro- and micro-level factors. This study proposes a Bayesian integrated spatial crash frequency model, which links the crash counts of macro- and micro-levels based on the spatial interaction. In addition, the proposed model considers the spatial autocorrelation of different types of road entities (i.e., segments and intersections) at the micro-level with a joint structure. Two independent non-integrated models for macro- and micro-levels were also estimated separately and compared with the integrated model. The results indicated that the integrated model can provide better model performance for estimating macro- and micro-level crash counts, which validates the concept of integrating the models for the two levels. Also, the integrated model provides more valuable insights about the crash occurrence at the two levels by revealing both macro- and micro-level factors. It is expected that the proposed integrated model can help practitioners implement more reasonable transportation safety plans and more effective engineering treatments to proactively enhance safety.

Authors	Priyanka Alluri Dibakar Saha Albert Gan Haifeng Wang
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00369
Paper Title	Decision Support System for Selecting Highway Safety Manual (HSM) Methods
Abstract	The Highway Safety Manual (HSM) provides analytical tools to conduct quantitative safety analyses. Part B of the HSM discusses all six steps in the roadway safety management process (i.e., network screening, diagnosis, countermeasure selection, economic appraisal, project prioritization, and safety effectiveness evaluation). However, for each step, the manual simply discusses different available methods but provides no specific guidance on which methods an agency should use. As agencies have different needs and limitations, a one-size-fits-all approach toward selecting appropriate methods is not often suitable. This paper describes a decision support system that aims to assist agencies tailor the HSM to their local conditions and needs by helping them select the most suitable method(s) among those discussed in the manual. The most appropriate methods are suggested based on several factors that influence an agency's selection of the suitable methods, including available data, available statistical expertise, reliability of results, robustness of methods, etc. The process is implemented as a web-based application. For each step in the safety management process, the web-based application includes questions that focus on data requirements, data availability, and each method's robustness and reliability. Depending on the responses to the questions, the most suitable method(s) are recommended.

Authors	Mahdi Pour Rouholamin Huaguo Zhou
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00509
Paper Title	Single-Vehicle Crashes on Rural Two-Lane Highways and Injury Severity: Does the Age Matter?
Abstract	Single-vehicle crashes on rural two-lane highways impose a considerable risk to road users due to their higher severity outcome compared to other crashes on these facilities. Furthermore, considerable variation in the severity among various age groups (young, middle-aged, and older drivers) has been noticed, corroborating the need for analyzing age-classified data. Crash data from Alabama was compiled and classified based on the age group. For each age class, a generalized ordered logit model was developed to identify the effect of various variables on injury severity. This model can consider ordered nature of severity as well as provide flexibility in calculating the parameter estimates. Driver gender, seatbelt use, damage to the vehicle, driving on county roads, hitting a fixed object and animal, and speeding were found to be significant in all developed models. Intoxication is a significant factor that affects injury severity for young drivers. Time of day also significantly affects the injury severity for older drivers. Vehicle age and driving with invalid license were not found to affect injury severity for older drivers, while they affected the other age groups. It was shown that some factors have significant effect on the injury severity for all age groups while others have varying effect across different age groups. The results of this study highlight the importance of considering separate injury severity models for different age groups, specifically separating older drivers from others, as the difference among older drivers and others are substantial.

Authors	Kevin Chang Peter Foss Meagan Larrea Edinson Bautista
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00688
Paper Title	Student Pedestrian Walking Speeds at Crosswalks Near Schools
Abstract	The percentage of young people walking to elementary, middle, or high school has decreased significantly over the course of the last five decades. The reasons for this decline have been attributed to busier schedules by working parents which prevent them from accompanying their son or daughter on a daily walk to school, parental concerns about the safety of their children in the form of “stranger danger”, and concerns about the risks associated with walking routes that must cross at least one higher speed or higher volume roadway. In fact, school crossings at arterial facilities are often necessitated by the fact that newer schools are sited in peripheral locations where land costs are less expensive but are not located within the heart of a residential community where sidewalks and slower traffic are expected. The objective of this study was to measure and assess the walking speeds of today’s young people who attend either an elementary, middle, or high school and to determine how their walking behavior compare with existing guidelines. The walking speed parameter is a critical component that is used to determine the duration of flashing beacons, HAWK signals, and other pedestrian-activated devices; these devices facilitate school walking routes and provide an extra layer of assurance for children and parents alike. This study concluded that the walking speeds of school-aged children, even at the fifteenth percentile, are generally higher than those of current guidelines, suggesting that agency practitioners have an opportunity to fine tune timing parameters to reduce delay for the motoring public while still ensuring an appropriate and necessary level of safety for school-aged children.

Authors	Yi Wang Christopher Monsere Chen Chen Haizhong Wang
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-00738
Paper Title	Development of a Crash Risk Scoring Tool for Pedestrian and Bicycle Projects in Oregon
Abstract	Methods for identifying and prioritizing high-crash locations for safety improvements are generally crash-based. There are fewer reported crashes involving non-motorized users and in most states, reported crashes must involve a motor vehicle. This means that minor, non-injury events are not reported and those crashes that are reported, tend to be more severe. Selecting projects based only on crash performance is sometimes limiting for these crash types and predicting where these crashes will occur next is also a challenging task. An alternative to crash-based selection is to develop risk-based criteria and methods. This paper presents the results of a research effort to develop a risk-scoring method with weights derived from data for use in project screening and selection in Oregon. To develop the risk model, data were collected from 188 segments and 184 intersections randomly selected on both state and non-state roadways. Geometric, land use, volume, and crash data were collected from Google Earth, EPA's Smart Location Database and the ODOT crash database from 2009-2013. The sample included 213 bicycle and pedestrian crashes on the segments and 238 at intersections. Logistic regression models were developed and the outputs used to create pedestrian and bicycle risk-scoring tools for segments and intersections. The risk-scoring tool was applied to safety projects identified in the 2015 All Roads Transportation Safety (ARTS) project lists from Oregon. The risk scores for the case study applications aligned reasonably well with the project's benefit-costs estimates.

Authors	Amir Mohammadianamiri Reza Imani Nasab navid nadimi
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-01655
Paper Title	Hotspot Identification in an Urban Network: A Comparison Among Four Different Techniques
Abstract	Knowing where clusters of accidents occur would provide us great occasion to figure out the real causes of them and the processes occurring in these areas. However, it can be really difficult to realize and evaluate the real patterns latent in the crash database and identify the locations that require further consideration. Since now, several studies have been conducted on this issue; however, all principles and techniques used in this process are still not fully realized. In this regard and within this study, different types of hotspot identification methods consisted of Point Density Estimation (PDE), Kriging, Inverse Distance Weighted (IDW), and Spline have been developed and evaluated and subsequently compared using a particular index called Prediction Accuracy Index (PAI). Also, four categories of accident risk were defined to label different locations of the map as high, medium, low and no accident risk. The accident data for this research were collected from the database of police information technology center of Mashhad, Iran that includes 40,096 accidents recorded within 3 years (from March 21, 2012 to March 21, 2015). Results indicated that, based on the amount of PAI, IDW is the most accurate method followed by Spline, PDE, and Kriging. The present paper showed that although PAI is a useful index to find the accuracy of each method for hotspot detection, more considerations are required to be taken into account for the assessment of the efficiency of a method.

Authors	Jake Kononov Catherine Durso Richard Sarchet
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-01707
Paper Title	How to Bring Safety to a Common Denominator with Other Project Goals in Planning and Project Selection
Abstract	Over the last several years most states in the US adopted Moving Toward Zero Death initiative, yet it remains generally true that only a very small percentage of projects and budgets is exclusively safety motivated and funded (in Colorado, 4 percent or less). Most projects are aimed at some combination of mobility, pavement preservation, maintenance, improved air quality, operations as well as safety. Yet safety consideration is present, explicitly or implicitly, in most transportation infrastructure projects, and the challenge is to bring safety to a common denominator with the other goals of the transportation planning process such as mobility, air quality, system preservations as well as others. By contrast, the traditional approach by Metropolitan Planning Organizations (MPOs) has been to assign safety points within a predetermined range, to quantify their potential safety impacts. These safety points are often based on observed injury or fatal crash rates without considering how susceptible a location is to safety improvements. This paper will first revisit problems inherent with using crash rates and then suggest a process to aid in quantifying safety aspects of projects in concert with its other attributes (mobility, air quality, etc.). The concept of a Life Preservation Effectiveness Score, introduced in this paper, reflects how much safety benefit, expressed in dollars, can be derived per unit of expenditure. If the same approach is adapted to other important project goals, then each project within a planning region can be effectively compared with others.

Authors	Jaeyoung Lee Mohamed Abdel-Aty Qing Cai Ling Wang Helai Huang
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-01759
Paper Title	Integrated Modeling Approach for Nonmotorized Mode Trips and Crashes in the Framework of Transportation Safety Planning
Abstract	In the recent decade, considerable efforts have been made to incorporate traffic safety into long-term transportation plans (LTTPs), which is often termed transportation safety planning (TSP). Although some researchers have attempted integrate transportation plans and safety by adopting transportation planning data (e.g., trip generation) for estimating traffic crash frequency at the macroscopic level, no studies have attempted to develop trip and safety models in one structure simultaneously. We suggest a Bayesian integrated multivariate modeling approach for estimating trips and crashes of non-motorized modes (i.e., walking and cycling). The American Housing Survey (AHS) data were collected from the U.S. Census Bureau and were used for the proposed approach. In the first part of proposed model, the probabilities of choosing walking and cycling modes were estimated, and the estimated probabilities were converted to trips by multiplying the number of sampled households. In the second part, the estimated trips are fed into crash prediction models (or safety performance functions) as an exposure variable. The modeling result revealed many contributing factors for pedestrian/bicycle trips and crashes. Also, we accounted for possible shared unobserved features between pedestrian and bicycle trips, and between pedestrian and bicycle crashes by adopting a multivariate structure. In addition, it was found that the crash models with the estimated exposures outperform those with the observed exposures. It is expected that integrated modeling approach for trips and crashes in this study will provide great insights into the future directions of TSP.

Authors	Jiri Ambros Richard Turek Milan Brich Dominika Miksova
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02011
Paper Title	Safety Screening of Czech Core Road Network
Abstract	Czech motorways and national roads present the core road network, which is critical in terms of ensuring operation and maintenance, as well as safety. In this context, there was an interest in safety screening of Czech core road network. Consistently with state-of-the-art literature, this necessitated developing safety performance functions for all types of network elements (road segments, intersections, interchanges, etc.), and using them to identify and rank hotspots. Unlike a number of similar international studies, which usually dealt only with a selected road category, the study focused on the whole network, including intersections and interchanges. The authors conducted own traffic survey, collected and processed all necessary data, and used them to develop 7 safety performance functions. These not only enabled identification of hotspots, but also interpretation of effect of statistically significant risk factors. Obtained results were mostly consistent with literature, for example as to the effects of exposure variables; on the other hand, several variables did not have sufficiently significant effect or yielded unexpected results, for example regarding the effects of traffic control devices.

Authors	Ayanna Lynn Haitao Gong Lei Bu Zhao Ma Feng Wang
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02062
Paper Title	Characteristics and Factor Analysis of Vehicle Crashes in Mississippi
Abstract	Traffic crash data from 2010 to 2014 were collected by Mississippi Department of Transportation (MDOT) and extracted for the study. Three tasks were conducted in this study: (1) geographic distribution of crashes; (2) descriptive statistics of crash data; and (3) probability analysis of crash factors. Geographic Information System (GIS) was applied to show the historical crash data statewide distribution, crash distributions on primary and secondary road segments in the public road system, and crash distribution in MDOT maintenance districts. The results show a similar distribution pattern in the three crash severities in Mississippi as in other states, i.e., property damage only counts the highest, injury the second, and fatality the lowest. It also shows that large numbers of the crashes happened on specific locations and there are high crash frequencies on highway segments in Jackson metropolitan area, Hattiesburg urban area, and Gulf coastal metropolitan area. Based on the historical data and geographic distribution results, three comparison scenarios were investigated in Scenario I between US 49 and MS 25, Scenario II for statewide urban and rural areas, and Scenario III for coastal urban and hinterland urban areas. Crash data descriptive statistics for the three scenarios were initially achieved in SAS and the characteristics of differing crash frequencies and severities with the three scenarios were calculated. In order to estimate the probability of each possible causing factor to the crash severity level, the Type III analysis of variance (ANOVA) approach was adopted to assess the significance level of each crash factor, and the multinomial logit model approach with maximum likelihood estimate was applied to conduct the probability analysis and evaluate the significance of each crash factor. The strategies that may potentially decrease the crash frequencies at crash severity levels were discussed based on the probability analysis results.

Authors	Soyoung Jung Xiao Qin Cheol Oh
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02293
Paper Title	Stratified Crash Fatality Prediction Models for Developing Targeted Safety Strategies
Abstract	In South Korea, the Korea Transportation Safety Authority (KTSA) conducts the Special Traffic Safety Culture Investigation (STSCI) every year to assist local governments in promoting road safety. To address the issue of diversity, the local agencies were grouped into four regions by administrative district unit and offered region-specific safety promotion strategies. However, it is unclear if such a classification truly reflects the underlying differences that contribute to safety. The goal of this study is to identify the most relevant attributes that affect the safety performance of local agencies so that targeted safety promotion strategies can be recommended. To accomplish the goal, latent class cluster-based negative binomial regressions were applied for a comprehensive list of factors such as demographics, socio-economic features, roadway conditions, traffic violations and road user driver behavior; resulting in seven latent class clusters of local governments. The following indexes were found to significantly and strongly affect crash fatalities in the clusters: rate of wearing helmet, rate of pedestrian's signal compliance, the number of unlicensed driving violations, total paved road length, province, ratio of male to female, and population density. Further, stratified NB regression models were developed to identify statistically significant factors for predicting fatal crashes within each cluster. These cluster-specific features allow the KTSA to design targeted strategies for effective safety promotion.

Authors	Xuesong Wang Mingjie Feng Qi Shi Xiaokun Wang Yan Li
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02533
Paper Title	Hotspot Identification for Freeways Considering Difference in Single- and Multiple-Vehicle Crashes
Abstract	Previous studies found that the spatial distributions of Single-vehicle (SV) and Multi-vehicle (MV) crashes are quite different, but there has not been much research on hotspots identification considering differences in SV and MV crashes. This study identified hotspots of SV, MV and total crashes separately, using road design data, traffic operational data and crash data collected from a 45-km freeway segment in Shanghai. Full Bayes Poisson Lognormal regression models were developed for SV, MV and total crashes and the potential for safety improvement (PSI) was used to rank hotspots. Model estimation results showed that the significant influencing factors vary in different crash types. Hotspots identification results demonstrated that hotspots of SV crashes are quite different from MV crashes. For example, only three of the top ten hotspots were shared by both SV and MV crashes. Additionally, hotspots of total crashes have a higher consistency with MV crashes than with SV crashes, indicating that a majority of SV crash hotspots may be ignored if total crashes are used to identify hotspots. These conclusions prove the necessity to differentiate SV and MV crashes for hotspot identification and conducting road safety management.

Authors	JEREMIE ALAGBE Meiqi Liu Sheng Jin
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-02720
Paper Title	Drivers' Phone Use at Red Traffic Signals: A Comparison of Two Studies to Investigate Factors Influencing the Individual Behavior
Abstract	Driver distraction is a main cause of traffic accidents, where mobile phones are a key source of distraction. In two studies, we examined drivers' phone use behavior at red traffic signalized intersection. The first was a signalized intersection video recording observation based study. Data were collected at five different sites, each, during different traffic time, that was: weekday morning (WDM) for morning peak hour traffic and weekday afternoon (WDA) for light traffic period, and different days of the week, which were: weekday and weekend (WE), in Hangzhou, China, with the aim to investigate the existence of phone use among drivers at red traffic signals at different time, and to find out its potential influencing factors. Mixed logistic models were proposed for statistical analysis of phone use. The results revealed that, the phone use did not vary in terms of time of the day or the traffic volume, but there was an overall slight variation between weekday and weekend. Red signal duration, whether the red signal has count-down or not, vehicle place in the queue, driver's waiting time, whether driver was accompanied or not, vehicle type, driver's gender and age are all influencing factors for drivers' phone use. The second study, anonymously, had 151 driver participants answer online questionnaire with 27 questions which ask them about their personal intention phone use and driving, after entering their personal information and their personality, which answers provided us the certitude to confirm the results found in the first study.

Authors	Lishengsa Yue Mohamed Abdel-Aty Ling Wang
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-03482
Paper Title	Assessment of the Safety Benefits of Connected and Autonomous Vehicle Technologies
Abstract	The Connected and Autonomous Vehicle (CAV) technologies are believed to have a great effect on traffic operation and safety and expected to impact the future of our cities. However, few research have determined the exact safety benefit when all vehicles are equipped with major CAV technologies. This paper seeks to fill that gap, by using a general crash avoidance effectiveness framework for major CAV technologies to make a comprehensive crash reduction estimation. Fifteen major CAV technologies that were tested in the recent twenty-year research studies are summarized and sensitivity analysis is used for estimating their crash avoidance effectiveness. Results show that crash avoidance effectiveness of a CAV technology is significantly affected by the vehicle type and the safety estimation methodology. A 70% related crash avoidance rate seems to be the highest effectiveness for one CAV technology (or integrated CAV technologies) operating in practical environment (real driving conditions). Based on the 2005-2008 U.S. GES Crash Records, the paper estimates that the CAV technologies could lead to the reduction of light vehicles' crashes by at least 28.56% per year and for heavy trucks by at least 37.06%. The Rear-End crash type for light vehicles and the Lane Change crash type for heavy trucks have the most expected crash benefits.

Authors	Linda Hill Ganesh Rajasekar Sandra Parsons
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-03549
Paper Title	Physician Reporting Requirements in the United States
Abstract	Background: Physicians come in contact with medically impaired older drivers and can assess a person's physical and mental health on a more detailed level than motor vehicle offices, family members, and law enforcement. However, physician reporting laws vary from state to state with three types: Mandatory, Permissive, and None. The purpose of this study was to characterize current reporting requirements across states and to quantify physician reporting for states with reporting laws in place. Methods: The 50 states and the District of Columbia's departments of motor vehicles were queried by email and phone, requesting their reporting law status and data on numbers of physician reports and types of diseases. Results: The majority of states (34) are permission reporting states, followed by none (10), and mandated (7). The trend over the last decade has been from none to permissive. Of the 15 states who submitted their data (all mandated or permissive), reporting numbers per year varied from 161 (New Hampshire) to 64,257 (California). Only four states submitted data by condition. The most frequent conditions were loss of consciousness, diabetes, vision problems, and dementia. There was little change in reporting across the three years. Conclusions: Despite the aging driving population, with associated driving-impairing medical conditions, there remains wide variation across states in quantity and quality of physician reporting. Further studies are needed to confirm the need to strengthen reporting requirements across the country, and should focus on the value of universal physician reporting requirements, such as mandated reporting, with standardized data collection.

Authors	Subasish Das Abhisek Mudgal Anandi Dutta Srinivas Geedipally
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-03567
Paper Title	Vehicle Consumer Complaint Reports Involving Severe Incidents: Mining Large Contingency Tables
Abstract	In the era of connected and automated vehicle technology, it is important to assess vehicle-related disruptions that involve traffic crashes. According to 2010-2014 Fatality Analysis Reporting System (FARS) data, nearly 6.35% of fatal crashes happened due to vehicle's pre-existing defects. An in-depth analysis of the vehicle defects would be helpful in understanding the association between vehicle defects and automotive safety. The National Highway Traffic Safety Administration's (NHTSA) vehicle complaint database incorporates more than 1.37 million complaint reports (as of June 1, 2017). Around 5% of these reports involve some level of injury or fatalities. These reports contain detailed documentation on vehicle related disruptions. This study examined 67,201 detailed reports associated with injury or fatality from NHTSA vehicle complaint database. The current research has two principal objectives: 1) perform knowledge discovery to understand the latent trends in consumer complaints, and 2) identify clusters with high relative reporting ratios from large contingency table of vehicle models and associated complaints. To accomplish the research goals, this study performed exploratory text mining and empirical Bayes (EB) data mining methods. Five years (2010-2014) of Fatality Analysis Reporting System (FARS) data were analyzed to examine the research findings. The findings show that major vehicular defects are associated with issues related to air bags, brake systems, seat belts, and speed controls. The EB metrics identified several key 'vehicle model with major defect' groups that require more attention. This study demonstrates the applicability of consumer complaints in identifying major vehicular defects as well as key groups of 'vehicle model with major defect'. The findings of this study will provide a significant contribution to the reduction of crashes from vehicle-related disruptions.

Authors	Md Azam Patricia Burke Uday Raghavender Rao Manepalli
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-03598
Paper Title	Identifying Targeted Programs for Distracted Driving in Montana Using Analytics and Data Visualization
Abstract	Driver distraction is a specific type of driver inattention that can happen due to a driver being engaged in activities like cell phone calls, texting, and other activities such as adjusting radio channels/DVD player, using navigation devices, distraction by passengers or external stimuli, etc. This has been a growing concern in recent years for traffic safety especially due to the advent of technologies like the smartphone and other handheld entertainment devices. Approximately 6.7% of all fatal crashes in the US were reported to be distraction-related crashes in 2015. This study shows an analytical framework implemented by the Montana Department of Transportation that can be used to identify the problem areas and associated risk factors associated with distracted driving. Secondly, it shows some aspects of data visualization techniques that can help identify the targeted areas that can be shared with law enforcement and utilized in corresponding media campaigns to mitigate the behavior. Thirdly, the study discusses how the analytical framework can aid in distributing funding or safety grants to participating agencies. The framework can be followed by other states that have the similar education or enforcement activities.

Authors	Bridget Burdett
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-03988
Paper Title	Road Safety Policy That Accounts for Real Everyday Driving
Abstract	Despite decades of research into driver behaviour, road safety policy is not always evidence-based. The purpose of this paper is to promote policy that aligns with recent research into mind wandering during everyday driving. In contrast to traditional approaches to road safety which assume that drivers are alert and compliant, evidence from research suggests that drivers are often inattentive, and most injury crashes are the result of unintentional lapses of attention. Analysis of New Zealand's road safety policy and strategy revealed a disconnect between its philosophies and investment areas. Like many international policies, New Zealand's espouses a human-centric lens for road safety, where mistakes are inevitable and trauma ought to consider that drivers are imperfect. However, a high proportion of interventions continue to assume alert and intentional driving. The most obvious disconnect between policy philosophy and practice is the decoupling of infrastructure interventions and speed management. Rather than responding to crash clusters with isolated infrastructure changes, and responding to speed-related risk by changing posted speed limits, a more effective response might be to deliver self-explaining environments that afford safe speeds by design. It is recommended that policy interventions are made more effective by truly responding to human fallibility and inattentive driving through stronger alignment between policy philosophy and interventions.

Authors	Steve Lawson
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-04123
Paper Title	Roads That Cars Will Need: Anticipating Road Infrastructure Safety in the Transition to Autonomous Vehicles
Abstract	Much is known about the patterns of severe injuries in urban and rural areas for crashes involving conventional cars. The knowledge-base of crash-generating factors involving other road-users is not as strong. The transition to autonomous vehicles will introduce new collision partners as they collide with other road users, with infrastructure, and potentially with each other. Little is known now about the types of crash that autonomous vehicles will be involved in. Implementation of current recommendations for crash countermeasures should continue during the transition. They will be required both during the transition and probably after that. Illustrations are provided of current crash patterns and questions asked about the gaps in current knowledge and whether investment plans for safer roads will change.

Authors	George Yannis Eleonora Papadimitriou Katerina Folla Nenad Nikolic Eva Molnar
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05057
Paper Title	Developing a Global Road Safety Model
Abstract	Road accidents constitute a major social problem in modern societies, with road traffic injuries being estimated to be the eighth leading cause of death globally. The need for action based on evidence based policy making becomes more and more pronounced. In this context, this paper presents SafeFITS, a global road safety model, developed for the United Nations Economic Committee for Europe, which is based on global historical road safety data (72 indicators for 130 countries) and may serve as a road safety decision making tool for three types of policy analysis, i.e. intervention, benchmarking and forecasting analysis. A hierarchical conceptual framework of five layers of the road safety system is suggested (namely, economy and management, transport demand and exposure, road safety measures, road safety performance indicators, and road safety outcomes), and a dedicated database was developed with various road safety indicators for each layer. A two-step approach was opted for the purposes of the research, including the calculation of composite variables and then their introduction in a regression model, and the development of a model on the basis of short-term differences, accumulated to obtain medium- and long-term forecasts. The model developed has overall satisfactory performance and acceptable prediction errors, and preliminary validation provided encouraging results. Its usage might be proved highly useful for testing road safety policies, taking however into account the model limitations, mostly related to data availability and accuracy, and the recommendations for its optimal use.

Authors	Jinwoo Lee ILIA PAPAKONSTANTINOU Koohong Chung Dong-Kyu Kim
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05114
Paper Title	High Collision Concentration Location Identification Method Based on Optimization Technique
Abstract	High Collision Concentration Location (HCCL) identification approach based on the highest number of excessive collisions included within the limited covered length of hotspots has been proposed in this paper. A bi-criteria optimization model is created to maximize Potential for Safety Improvement (PSI) and to minimize the covered length by detected sites after considering the bias that can be introduced in the model due to the regression-to-the-mean phenomenon. The model is solved using Dynamic Programming-based Screening (DPS) techniques. The algorithm is computationally feasible to the size of historic collision data and applied to two freeways sites in San Francisco, California. The performance of the proposed model has also been compared with Sliding Moving Window (SMW) and Continuous Risk Profile (CRP) methods are compared to the DPS. Findings indicate that DPS can outperform both SMW and CRP in selecting sites with maximum PSI per unit distance.

Authors	Kai Wang Shanshan Zhao John Ivan ISHRAQ RAYEED AHMED Eric Jackson
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05210
Paper Title	Evaluation of Hot-Spot Identification Methods for Municipal Roads
Abstract	Estimating crash prediction models and applying the Empirical Bayesian approach in identifying hot spots for roads under municipal jurisdiction is often challenging due to the lack of traffic count data. This study presents five hot spot identification (HSID) methods in which AADT information is not required (i.e. crash frequency (CF), equivalent property damage only (EPDO), relative severity index (RSI), excess predicted average crash frequency using method of moments (MOM) and cross sectional analysis (CSA)), to identify hot spots for road segments under municipal jurisdiction in Connecticut. The segments were categorized into eleven homogenous groups based on the roadway geometric characteristics. The five HSID methods were applied to all segments in each roadway group separately and across the entire State for a systemic analysis. Four quantitative tests (i.e. site consistency test (SCT), method consistency test (MCT), total rank difference test (TRDT) and total score test (TST)) were used to compare the performance of the five HSID methods. The results indicate that the MOM outperforms others in identifying hot spots for urban one-way arterials, urban one-way local roads, urban two-lane two-way local roads, urban multilane two-way arterials, and urban multilane two-way collectors; the CF outperforms others for rural arterials and collectors, rural local roads, urban one-way collectors, urban two-lane two-way arterials, urban two-lane two-way collectors and urban multilane two-way local roads, and the CSA performs best in all of the five HSID methods in identifying and ranking the roadway hot spots for all roadway groups together.

Authors	Hatem Abou-Senna Essam Radwan Ayman Mohamed
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05479
Paper Title	Safety Prioritization Tool for Sidewalk and Bike-Lane Gaps
Abstract	Pedestrian sidewalks and bicycle lanes in Florida are not continuous, and there is a concern among planners and engineers in the FDOT that these gaps constitute discontinuity of flow and are potentially posing threats to pedestrian and bicycle safety. Before these agencies attempt to develop a prioritization program to decide on which gaps need to be addressed, it was logical to carry out an analysis that investigates the correlation between safety and sidewalk/bicycle-lane gaps. The previous research concluded that absence of sidewalk along roadway segments is one of the main factors that have a significant impact on the expected number of pedestrian crashes at a specific location. This paper builds on the previous task's results to develop a safety prioritization tool to address the gaps. The developed tool takes into account the above-mentioned parameters as well as other pedestrian-related activity variables and proximity to generators using land use, income, and auto ownership data. The prioritization method was based on a multi-criterion ordinal ranking of the parameters of five main modules, using a scoring system that combines all criteria weights then aggregates them into a single indicator. The five main modules comprise roadway and traffic data, socioeconomic data, land use data, transit, and crash data. The need for roadway segment safety improvement was ranked according to its roadway pedestrian safety indicator (RPSI) threshold and categorized into five categories. The Sidewalk/Bike-Lane Gaps Safety Prioritization Tool (SBLPT) has the capability to generate sidewalk/bike-lane gap maps that can be viewed in Google Earth ®.

Authors	hyoseuk chang Ali Haghani Farzad Daneshgar
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05601
Paper Title	A Proposed Generalized Framework for the Identification of Contributing Factors That Affect Hazardous Traffic Conditions on Freeways
Abstract	The identification of hazardous traffic conditions with high crash risk has the potential to enhance traffic safety. Crash risk is affected by multiple factors such as traffic parameters, geometric characteristics and weather conditions. This study proposes a generalized framework that can be applied universally for the identification of significant contributing factors which increase crash risk under five types of freeway segments and for the evaluation of the distinct impact each of the said types has on crash risk. 34 traffic parameters and three weather data for five segment types were collected as candidate contributing factors. The data collection site was a 13.14-mile segment of the northbound direction of the I-110 freeway in California. Random Forest and three statistical analysis tests were conducted to identify the best contributing factors for the five segment types. The results showed that each segment type has its own particular contributing factors. Then, Bayesian logistic regression was used to build crash risk prediction models to explore the constant effects of each of the contributing factors on the change in crash risk with an odds ratio. The results indicate that the intensity and direction of each factor on crash risk were distinct across segment types. The outcomes can be used for monitoring crash risk for a certain consecutive portion of a freeway with a real-time change in crash risk updates. By monitoring the change in the contributing factors, traffic managers can predict which segments are in hazardous traffic conditions and how fast those conditions change in real-time.

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Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05881
Paper Title	A Comparison of Telephone and Online Surveys for Traffic Safety Culture
Abstract	A traffic safety culture survey employing both telephone and online methods was conducted to collect original data on the attitudes, perceptions and behaviours of road users to acquire an empirically based understanding of traffic safety culture in the Edmonton region, located in Alberta, Canada. The completed survey included a total of 1,012 and 1,185 respondents for the telephone and online surveys, respectively. The objective of the current study was to conduct a comprehensive comparison of telephone and online survey results for a broad range of socio-demographic characteristics of respondents, their perceptions and self-reports about a range of driving behaviours, self-assessments of their driving skills, and support for a number of enforcement techniques. A number of statistical tests were conducted to accomplish this objective. A comparison of the respondents' characteristics shows statistically significant and strong differences only for city of residence, age distribution and driving experience. After adjustment for respondents' characteristics, no statistically significant differences were found for: acceptability of hand-held cell phone use, type text message, drinking and driving, speeding on residential streets, and self-assessment of driving skills, or for self-reported talking on hand-held or hands-free cell, tailgating, drinking and driving, driving one hour after using marijuana, and speeding on residential roads. Differences in responses between the two survey methods were found for: acceptability of hands-free cell phone use, driving one hour after using marijuana, speeding on freeways, self-assessment of aggressive driving, self-reported typing or sending of texts while driving and speeding on freeways, support for impaired driving, speed and red light running enforcement. Where differences exist even after controlling for respondents' characteristics, telephone respondents demonstrated a more positive and protective traffic safety culture than online survey, which could be due in part to a level of social desirability bias associated with telephone survey.

Authors	Niloo Parvinashtiani Omar Smadi
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-05919
Paper Title	Comparing Objective and Subjective Roadway Data Collection Methods Using the U.S. Road Assessment Program
Abstract	The United States Road Assessment Program (usRAP) is a powerful tool for conducting Systemic Safety evaluations. The level of safety of the roads can be assessed through the usRAP Star Rating method, giving one star to least safe and five stars to safest roads. As part of the Star Rating data collection process, a comprehensive list of 40 road attributes are recorded for each 100-meter segment using Google StreetView and Aerial imagery. Several challenges are associated with usRAP data collection protocols and extensive quality assurance processes are required to ensure data quality. The sources of error are human error, inaccurate measurements/estimations, and the coder's subjectivity in the data collection. To examine the effects of these errors on Star Rating results, this study has leveraged the Second Strategic Highway Research Program (SHRP 2) Roadway Information Database (RID) to complement the existing dataset. The RID includes a variety of safety-related roadway attributes collected by a mobile data collection vendor and meets high accuracy requirements by implementing a quality assurance plan. Using benefit-cost analysis, this study aims to compare the objective data collection approach of utilizing a mobile data collection vendor with high quality assurance processes versus the subjective approach of coding data manually. Star Ratings are calculated for a sample of two lane rural roads in North Carolina using the RID and the manually coded dataset. The study results showed that the dataset with more accurate input data resulted in more valid Star Rating results and more detailed safety countermeasure suggestions from the Road Assessment Program tool.

Authors	Kordel Braley Chad Worthen Walt Steinvorth
Sponsoring Committee	ANB10
Session Number	454
Session Title	Transportation Safety Management: Start to Finish
Paper Number	18-06494
Paper Title	Using a Safety Forecast Model to Calculate Future Safety Metrics
Abstract	This research sought to identify a process to improve long-range planning prioritization by using forecasted safety metrics in place of the existing Utah Department of Transportation Safety Index—a metric based on historical crash data. The research team developed a Safety Forecast Model using Highway Safety Manual Safety Performance Functions and Crash Modification Factors. The research team obtained existing roadway characteristics that served as inputs for the Safety Forecast Model from uPlan. The research team also collected future condition data—such as forecast volumes and lanes—from the Utah Statewide Travel Model, a travel demand forecasting model. The Safety Forecast Model compared crashes predicted based on the current 2015–2040 UDOT Long-Range Plan (LRP) Build scenario to crashes predicted based on the No-Build scenario. The research team determined, through a case study of 15 LRP widening projects, that the project prioritization ranking changes if the ranking considers future safety impacts rather than relying solely on historical crash data. The research team also determined that the Safety Forecast Model could be used to recommend safety projects and perform systemic safety analyses.

Authors	Marco Amorim Sara Ferreira Antonio Couto
Sponsoring Committee	ANB10
Session Number	551
Session Title	New Research on Improving Emergency Response Time
Paper Number	18-00049
Paper Title	Emergency Medical Service Response: Analyzing Vehicle Dispatching Rules
Abstract	In an era of information and advanced computing power, emergency medical services (EMS), still rely on rudimentary vehicles dispatching and reallocation rules. In many countries, road conditions such as traffic or road blocks, vehicles exact position, and demand prediction are valuable information which is not considered when locating and dispatching emergency vehicles. Within this context, this paper presents an investigation of different EMS vehicle dispatching rules by comparing them using different metrics and frameworks. An intelligent dispatching algorithm is proposed and survival metrics introduced to compare the new concepts with the classical ones. This work shows that the closest idle vehicle rule (classic dispatching rule) is far from optimal and even a random dispatching of vehicles can outperform it. The proposed intelligent algorithm has the best performance in all the tested situations where resources are adequate. If resources are scarce, especially during peaks in demand, dispatching delays will occur degrading the system's performance. In this case, no conclusion could be made to which rule might be the best option. Yet, it draws attention to the need for research focused in managing dispatch delays, by prioritizing the waiting calls that inflict the higher penalty to the system performance. Finally, the authors conclude that the use of real traffic information introduces huge gain to the EMS response performance.

Authors	Jaeyoung Lee Mohamed Abdel-Aty Qing Cai Ling Wang
Sponsoring Committee	ANB10
Session Number	551
Session Title	New Research on Improving Emergency Response Time
Paper Number	18-01821
Paper Title	Analysis of Fatal Traffic Crash Reporting and Reporting Arrival Time Intervals of Emergency Medical Services
Abstract	Emergency Medical Services (EMS) play a vital role in the post-crash effort to reduce fatalities by providing first-aid and transportation to medical facilities. This study aims to analyze the time required for crash reporting and EMS arrival in fatal traffic crashes and to identify relevant crash, roadway, environmental and zonal socio-economic factors. The time required for EMS reporting and arrivals were calculated by location type (urban or rural) and roadway functional classification using Florida data. Subsequently, a variety of duration models were estimated to reveal contributing factors for the crash-reporting and reporting-arrival intervals. Although about 90% of fatal crashes are reported to EMS within ten minutes in both urban and rural settings, EMS average reporting time in rural areas (4.5 min) is greater than in urban areas (3 min). Moreover, freeways require longer time for EMS arrival (8.3 min) compared to conventional roadways (6.8 min). It was shown that the log-logistic and gamma models perform the best for the crash-reporting and reporting-arrival intervals, respectively. The modeling results reveal that both EMS reporting and arrival times are related to the crash, roadway, environmental, and socio-economic factors. The key findings indicate that EMS reporting and arrival times differ significantly according to the urban/rural designation and road functional classification, and that they have statistically significant relationship with various factors. It is expected that the findings from this study can be used to develop effective and practical strategic plans to minimize EMS reporting and arrival time and, therefore, decrease the likelihood of fatalities.

Authors	Zhaoxiang He Xiao Qin Yuanchang Xie Jianhua Guo
Sponsoring Committee	ANB10
Session Number	551
Session Title	New Research on Improving Emergency Response Time
Paper Number	18-05425
Paper Title	A Service Location Optimization for Improving Rural Emergency Medical Services
Abstract	Approximately 40,000 fatalities transpire on U.S. highways each year with more than half occurring in rural areas. With such a high percentage of total fatalities, efficient Emergency Medical Services (EMS) becomes even more crucial in these rural areas. After an accident occurs, the time necessary for victims to receive care from EMS is critical to their survival. EMS provides pre-hospital health care for patients from the time of the 911 call to the arrival of the ambulance where the care is then transferred to a hospital. When comparing urban EMS to rural EMS, there are obvious challenges the latter must navigate to provide efficient medical care. Consequently, it's necessary to identify approaches to improve the EMS performance in rural areas. The goal of this paper is to evaluate and optimize rural EMS stations from a spatial perspective, while evaluating the spatial pattern between EMS stations and incidents and recommending the optimal locations of EMS stations. The data that was analyzed to accomplish these goals was from South Dakota, a rural state. This data was used to perform the spatial analysis and to build the location optimization model. A location optimization model, using a genetic algorithm in R software, was developed for rural EMS to increase the coverage ratio and service equity. This method serves as a tool for rural EMS officials to develop new stations or even relocate existing stations to improve service performance, which is essential given their limited resources.

Authors	Ernest Tufuor Laurence Rilett Yunwoo Nam
Sponsoring Committee	ANB10
Session Number	551
Session Title	New Research on Improving Emergency Response Time
Paper Number	18-05729
Paper Title	Land Suitability Analysis for EMS Posts Along State Highways: A Case Study of California
Abstract	The response time of Emergency Medical Services (EMS) to road accidents can be the difference between life and death. The California strategic highway safety plan highlight the need to improve the response time and recognizes that: 37% and 8% of the fatal crashes are 30 or more miles away from a trauma center in rural and urban areas respectively. The paper seeks to: (1) demonstrate the viability of using spatial multi-criteria analysis in road safety management, and (2) provide a good scientific justification in selecting optimal counties for EMS posts. The goal is to propose areas that are close to probable fatality points in order to achieve a maximum response time of 10 minutes (i.e., 3 minutes below the national average). This paper adopted a multi-criteria analysis using the weighted linear combination method on raster data of various impact factors. The land selection criteria were: (1) close to probable road fatality locations, (2) far from existing trauma centers, (3) close to existing rest stop areas, and (4) not on protected lands or bodies of water. The method proved viable and the analysis resulted in 37,387 square miles of suitable land areas. About 7% moderately suitable and 69% were unsuitable. The highway corridors linking the counties between Los Angeles and San Francisco were the most suitable locations. Other identified high suitable areas were predominantly rural counties such as Amador and Calaveras. A benefit-cost analysis is recommended in future studies to determine the suitability of specific sites within the identified counties.

Authors	Victoria Beale Derek Troyer Alejandro Chock Cory Hopwood Michael McNeill
Sponsoring Committee	ANB10
Session Number	ANB10
Session Title	Transportation Safety Management Committee
Paper Number	18-01284
Paper Title	Getting to Zero Deaths on Ohio's Low-Volume Roads
Abstract	Ohio faces the challenge, as do many other states, of how utilize Highway Safety Improvement Program (HSIP) funding to improve safety on its low-volume roadways while meeting the data-driven safety funding requirements of the Fixing America's Surface Transportation (FAST) Act. Low-volume roads present unique challenges because data is rarely available and other factors, such as roadway ownership, impact the implementation of safety countermeasures on this system. Beginning in 2014, the Ohio Department of Transportation (ODOT) created a township safety signage grant program designed to address the issues with utilizing HSIP funding on low-volume roadways. The grant program's goal was to drive down the number of fatalities, serious injuries and overall crashes occurring on Ohio's low-volume roads. ODOT took into consideration overriding issues regarding low-volume roads in how it structured the grant program. ODOT also utilized the direction from its Strategic Highway Safety Plan (SHSP) in choosing a safety countermeasure which met the needs of its roadway departure and intersection crash trends. The program has been actively engaged in by Ohio townships and now has a large enough amount of post safety countermeasure installation data available to quantify its initial success. This paper presents the successful results by highlighting the human capital and comprehensive societal benefit/cost analyses for the first twenty-four townships with twelve months of post grant completion crash data.

9 Interacting Committees

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

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.

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

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.

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

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

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.

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.