Committee ANB20 Safety Data, Analysis and Evaluation

Synthesis Report

On safety-related papers presented at the 91st TRB Annual Meeting
January 22-26, 2012, Washington, D.C.
Prepared by
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1 Introduction

This report is mainly aimed at facilitating access to Committee ANB20-related presentations and events at the 91st Annual TRB meeting (see

Table 1). With this aim, papers sponsored by the Committee 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 Committees which are within the scope of ANB20[1] have been identified and classified in order to promote better interaction between ANB20 and these other Committees.

Fifty papers sponsored by ANB20 are identified. These papers are presented on two poster sessions (536 and 537) and one podium session (432). The papers address the following topics (some papers were classified in more categories):

a)

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

c) 2 Papers on crash data and safety analysis tools,
d) 3 Papers on before-and-after safety evaluations,
e)

4 Papers on safety performance functions,

f) 5 Papers on crash severity prediction,
g) 6 Papers on network screening, and
h) 7 Papers on surrogate measures for crash data.

Table 1 ANB20 events

Event type	Time	Title	Location
Workshop (144C)	January 22, 9:00AM – 5:00PM	Working in the Data Mines: SHRP 2 Naturalistic Driving Study Data Set Sponsors: ABJ60, ABJ80, ANB20, AND10, AND30, and FA000	Marriott
Meeting	January 23, 8:00AM – 9:45AM	Traffic Speed and Safety - Cross-cutting Issues Joint Subcommittee of ANB20, AHB65, ANB10	Marriott, Taft
Meeting	January 23, 1:30PM – 5:30PM	Safety Data, Analysis and Evaluation Committee	Marriott, Washington B3
Meeting	January 23, 3:45PM – 5:30PM	Animal-Vehicle Collisions Subcommittee, ANB20(2)	Marriott, Taft
Podium session (432)	January 23, 7:30PM – 9:30PM	Research for the Sake of Safety	Marriott, Virginia A
Poster session (536)	January 24, 10:45AM – 12:30PM	Safety Performance of High-Speed Facilities	Marriott, Salon 2
Poster session (537)	January 24, 10:45AM – 12:30PM	Safety: Performance, Screening, and Contributing Factors	Marriott, Salon 2
Podium session (547)	January 24, 1:30PM – 3:15PM	International Benchmarking on Road Safety: Network for International Road Traffic and Accident Database Sponsors: ABE80, ANB20, AND20, and ANB10(8)	Marriott, Delaware A
Meeting	January 24, 7:30PM – 9:30PM	Surrogate Measures for Crash Data Subcommittee, ANB20(3)	Marriott, Taylor
Podium session (644)	January 24, 7:30PM – 9:30PM	Access Management Implementation, Safety, and Analysis Sponsors: ANB20 and AHB70	Marriott, Thurgood Marshall Noth
Meeting	January 25, 10:15AM – 12:00PM	Bicycle and Pedestrian Crash Relationships Joint Subcommittee of ANB20, ANF10, ANF20	Marriott, Tyler
Podium	January 25, 10:15AM – 12:00PM	Beginning Analysis of SHRP 2	Marriott,

session (716)	Naturalistic Driving Study Sponsors: ANB20, AND10, and FA000	Thurgood Marshall West

2 Papers on crash data and safety analysis tools

Real-world crash data play a vital part in the development of safer transport since information on crash data is essential as a means of understanding why crashes occurred in the past, how the occurrence of similar events may be prevented in the future, and in refining design criteria currently being used.

The Subcommittee identified ninehteen papers dealing with crash data and safety analysis tools. Six papers were sponsored by the ANB20 Committee while thirteen papers were sponsored by other Committees.

From a methodological perspective, different methodologies were used, such as a novel method called “crash clustering contour” (12-4238), mixed logit models (12-1095), bivariate probit models (12-0419), binary logit models (12-0419 and 12-3826), principal component analysis (12-3826), partial proportional odds models (12-1435), Kolmogorov-Smirnov and Cramér–von Mises tests of goodness of fit (12-4576), spatially-based crash analyses (12-4214), linear models (12-3475), review of DOTs safety tools (12-0994), and literature review (12-1583).

From an applications perspective, the papers addressed several issues, such as propensity of drivers to engage in crash avoidance maneuvers (12-1095) and link between crash severity and crash avoidance maneuvers (12-1435), identification and analyisis of secondary crashes (12-1740), analysis of the evolution of road safety as a function of motorization (12-3475), spatiotemporal clustering in crash occurrence on urban freeways (12-4238), median-related crashes near unsignalised intersections (12-0419), tools for road safety management (12-0067 and 12-0994), relationship between urbanization and crashes (12-3603), factors affecting road safety (12-1583), enhanced penalty zones (12-4384), influence of cannabis on traffic crashes (12-1179), safety investigations focused on older drivers (12-4214), crashes involving trucks on freeways (12-4576), relationship between crash probability and hours worked by truck drivers (12-0607), evaluation of truck onboard safety systems (12-1006 and 12-3831), truck driver behaviors during crashes (12-3826), and contributing factors of motorcycle crashes (12-4249).

ANB20, Associating Crash Avoidance Maneuvers with Driver Attributes and Accident Characteristics: Mixed Logit Model Approach (12-1095)

This study focuses on the propensity of drivers to engage in crash avoidance maneuvers in relation to driver attributes, critical events, crash characteristics, vehicles involved, road characteristics and environmental attributes. Five alternative actions involving emergency lateral and speed control maneuvers are considered: “no avoidance maneuvers”, “braking”, “steering”, “braking & steering”, and “other maneuvers”. The importance of avoidance maneuvers derives from the key role of responsible, proactive and state-aware road users within the concept of sustainable safety systems, as well as from the key role of the ability of drivers to perform effective corrective maneuvers for the success of automated in-vehicle warning and driver assistance systems. The analysis is conducted by means of a mixed logit model that accommodates correlations across alternatives and heteroscedasticity. Data for the analysis are retrieved from the General Estimates System (GES) crash database for the year 2009. Results show that (i) the nature of the critical event that made the crash imminent influences the choice of crash avoidance maneuvers, (ii) women and elderly have a lower propensity to conduct crash avoidance maneuvers, (iii) fatigue and distractions have a greater negative impact on the tendency to engage in crash avoidance maneuvers than alcohol consumption, (iv) difficult road conditions increase the propensity to perform crash avoidance maneuvers, (v) visual obstruction and artificial illumination have an adverse effect on the probability to carry on crash avoidance maneuvers, and (vi) the combination “braking & steering” is more closely related to “steering” than “braking”.

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ANB20, Braking News: Link Between Crash Severity and Crash Avoidance Maneuvers (12-1435)

Research on crash severity focuses on a variety of determinants, but the link between crash severity and crash avoidance maneuvers remains unraveled. This study focuses on this link by examining single-vehicle crashes extracted from the General Estimates System (GES) crash database for the period 2005-2009. Various emergency lateral and speed control maneuvers are considered in response to different critical events that made the crash imminent. Partial proportional odds models are estimated to accommodate the ordered-response nature of severity while allowing for changes in effects across severity levels. Results show the correlation between crash avoidance maneuvers and crash severity, with differences emerging when analyzing different critical events. Moreover, results show two trends: (i) most drivers do not perform any action when facing critical events, de facto waiving the opportunity to mitigate crash severity, and (ii) drivers rarely perform crash avoidance maneuvers that are

correlated with higher probability of lower crash severity. These trends suggest that effort should be posed toward understanding the reaction mechanisms to different critical events, improving in-vehicle warning systems, promoting responsible driving behavior, and designing forgiving infrastructure.

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ANB20, Identification of Secondary Crashes and Recommended Countermeasures (12-1740)

The objective of this study was to identify and analyze the occurrence of secondary crashes on roadways in Kentucky and recommend countermeasures to reduce their frequency and severity. Results show a small percentage of crashes coded as a “Secondary Collision” were confirmed to be a secondary crash based on the definition and requirement of “a crash occurring as a result of a previous crash.” It appeared that many of those miscoded as a “Secondary Collision” were the result of misinterpretation of what constituted a secondary crash versus a secondary event. Adoption of the definition used in this analysis, along with more training and data input quality control was recommended. A review of 9,330 crashes coded as a “Secondary Collision” confirmed 362 or 3.88 percent as secondary crashes, and matching collision reports for the previous crash were located for only 236 crashes. An alternative analysis involved a query of the CRASH database to determine the time and distance relationships between the primary and subsequent-related crashes. The algorithm was able to identify 87 percent of the secondary crashes that were previously identified with the extensive manual search and review of crash reports. Based on analysis of the severity associated with secondary collisions (362) identified in the 18-month period of 2009-2010, the overall costs were estimated to be $11,228,100 when considering “Economic Cost” and $33,636,100 when considering “Comprehensive Cost.”

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ANB20, Long-Term Safety Trends Related to Vehicle Ownership in 26 Countries (12-3475)

The objective of this paper is to model the evolution of road safety as a function of motorization level. The authors completed a country-level as well as a time-dependent analysis focusing on countries where data are available for a longer period of time (1965-2009). For the statistical analysis a function is proposed describing road safety trends (decline, turning, improvement). Two coefficients in the model are estimated for each country and for each year as well as their change over time is discussed. The results show that the shape of the curve changes over time. In some countries the decrease in the mortality rate gets slower over time, however, in others there is still a greater potential in road safety. Possible reasons for the general positive trends in road safety are the continuous improvement in engineering solutions (better infrastructure, safer cars) as well as road users being better trained and skilled due to education and experience. It is concluded that besides the factors mentioned above, the increased speed of the spreading of safety related information and knowledge are contributing to the decrease of the differences among countries in their safety levels.

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ANB20, Spatiotemporal Clustering of Freeway Crashes (12-4238)

Spatiotemporal clustering in crash occurrence is one of well known features on urban freeways. However, some important aspects of the crash’s spatiotemporal clustering have been neglected largely due to unsuitable data representation. In light of this, the objective we set for this study is: i) to unveil detailed features of the crash’s spatiotemporal clustering and ii) to identify traffic conditions that affect the intensity of the crash clustering. To these ends, we developed a novel method called “crash clustering contour” to concisely depict spatiotemporal clustering patterns in freeway crash. In this study, the crash clustering contour is applied to explore actual crashes that occurred on a 10-mile freeway stretch. For this stretch, three years’ data concerning both traffic conditions and crash occurrence were analyzed. Combined inspections of the crash clustering contour along with its corresponding speed contour unveil the relationship between crash clustering and traffic congestion. A key finding of this study is that, as the traffic congestion becomes aggravated, crash rates tend to more drastically increase at crash-concentrated sections than at relatively safe sections. This finding confirms that for all else being equal, the crash’s spatial clustering would be prominent under severe traffic congestion. Keywords: crash occurrence, crash clustering contour map, freeway crash, traffic congestion

Authors
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ANB20, Analysis of Timing of Truck and Car Accidents in a Busy Freight Corridor (12-4576)

The objective of this study is to understand the timing of truck and car accidents on a busy freight corridor (I-110 and I-710 freeways) connecting the Ports of Los Angeles and Long Beach to nearby intermodal rail and trans-loading facilities, and various warehouses. We analyze 16,417 accidents that occurred between 2005 and 2007 on these two freeways in Los Angeles County, California; approximately 14.5 percent of these accidents involved trucks. Vehicle Miles Traveled (VMT) data were collected from the Freeway Performance Measurement System (PeMS) to compute hourly and monthly car and truck accident rates for both freeways in both traffic directions. Kolmogorov-Smirnov and Cramér–von Mises tests of goodness of fit were then used to test whether directional accident probabilities are similar or not and whether the risk of an accident is time dependent. We found that the probability of an accident involving only cars is highest after midnight (the peak probability occurs between 1 AM and 3 AM for both freeways) while the probability of an accident involving a truck is highest during mid-day (the peak probability occurs between 8 AM and 4 PM for both freeways). These results have implications for programs that attempt to move truck deliveries during off-peak hours such as the PierPass program implemented by the Ports of Los Angeles and Long Beach.

Authors
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AHB70, Examining Median Types Near Unsignalized Intersections to Identify Interplay Between Safety and Access Management (12-0419)

This study is concerned with access management analysis related to unsignalized intersections and access points. All possible median types that could exist across from unsignalized intersections were identified, which included closed, directional (allowing access from both major road directions), open, undivided, two-way left turn lane, and mixed (allowing access from a single major road direction only). The study made use of data collected from 2500 unsignalized intersections in the State of Florida. The analysis included differentiating between crashes that are related to medians and intersection-related to convey a better understanding of safety deficiencies to facilitate the countermeasures recommendation. Identifying different median-related crash patterns at each median was also investigated. The binary logit approach was implemented in this study as a new promising application for understanding those factors affecting median-related crashes at different median types. The bivariate probit model was also used to examine the interrelation between median type and median-related crash patterns. Both approaches succeeded in identifying those factors affecting median-related crash occurrence. Some of the significant factors were median width, speed limit on major roads, the annual average daily traffic volume on the major road, the spatial covariates represented by the upstream and downstream distances to the nearest signalized intersection, and crash pattern. The study also recommended safety countermeasures for improving access management across from unsignalized intersections.

Authors
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ANB10, Does Use of Formal Tools for Road Safety Management Improve Safety Performance? (12-0067)

The use of ten formal tools for road safety management in eighteen European countries was surveyed by means of a questionnaire sent to national highway agencies. Use of the management tools was found to vary. An attempt was made to determine if there was a relationship between use of the tools and safety performance. The basic hypothesis was that the more extensive use a country made of the safety management tools, the better would be its safety performance. Four statistical analyses were made to test this hypothesis. Results were ambiguous, but there is no clear support for the hypothesis. However, the study has serious limitations and is essentially inconclusive. It nevertheless identifies an approach that might give clearer results if the study is replicated in larger sample of countries.

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ANB10, Road Safety Analysis: States' Current Practices and Their Future Direction (12-0994)

SAFETEA-LU required each of the states to develop a Strategic Highway Safety Plan (SHSP) and establish Highway Safety Improvement Program (HSIP) as a core program. HSIP requires states to submit annual five percent reports describing at least 5% of their most hazardous locations, approaches being used to improve safety at these locations, and their effectiveness in improving safety. A review of FHWAï¿½s 2009 five-percent reports indicated that most state DOTs are still using basic safety analysis procedures such as frequency, rate, or crash index. Understanding that the traditional methods are fraught with issues, biases, and false assumptions, recent research has opened doors to more advanced methodologies in the form of SafetyAnalyst and the Highway Safety Manual. Unlike basic traditional methods, the EB approach used in these tools involves rigorous calculations and requires safety performance functions, in addition to roadway characteristics, traffic volume, and crash information. The data requirements and statistical complexity of these new safety tools are considered by many as a hindrance to their adoption; but there are levels of increasing complexity with additional requirements that allow states to adopt at their own speed. The intent of this paper is to document the current safety analysis practices and statesï¿½ perspective toward adopting/ implementing SafetyAnalyst and the Highway Safety Manual. Several statesï¿½ perspective on SafetyAnalyst implementation was obtained through a survey and discussed in this paper. This survey mainly helps the practitioners, administrators, and researchers to understand the various safety analysis methods used across states, and the statesï¿½ perception on shifting to newer tools.

Authors
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ANB10, Factors Affecting Road Safety: A Review and Future Research Direction (12-1583)

Understanding the risk factors affecting road accidents is an important area in road safety research. This paper provides a summary and overview of those factors, as well as road safety theories that explain how and why these factors affect road traffic accidents. This provides the road safety community with a better understanding of road accidents and aids in developing suitable methods and policies for road safety improvement. Road

safety analysts could use the findings from this research as a marker as to the important risk factors that need to be controlled for while developing accident prediction models so as to reduce the impact of omitted variable bias. Several factors most notably: speed, traffic density, flow, congestion, demographics (namely age gender and deprivation), driving behaviour (involving alcohol consumption, helmet or seat belt usage) and land use, such as residential or economic zones, were found to have mixed effects on road safety and need further examination. In addition, factors relating to the environment, in particular lighting, road surface and weather conditions need to be explored. Future research directions on the effect of risk factors are also developed such as improving the quality of data and developing causal relationships. There is also a need to further investigate issues such as the effect of speed on road accidents, whether curvature improves road safety, the use of more sophisticated statistical models so as to better understand the effects of risk factors on road accidents and the utilisation of naturalistic driving data in accident analysis.

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ANB10, Spatiotemporal Analysis of Macroscopic Patterns of Urbanization and Traffic Safety: Case Study in Sacramento County, California (12-3603)

This study provides a preliminary investigation into the relationship between urbanization and traffic collisions by analyzing the spatial patterns in Sacramento County, California from 1998 to 2008 using urban land classifications from the California Department of Conservationâ€™s Farmland Mapping and Monitoring Program and traffic collision data from the Statewide Integrated Traffic Records System. The analysis uses the directional distribution tools of ArcGIS to investigate the distributional trend of urban land and traffic collisions over time and then compares the statistical outputs representing changes of geographical centroids, elliptical areas, and standard distances (long and short axes). Collisions were also subset by severity level to account for inherent differences in the spatial distribution of different types of collisions. The approach in this study would be useful for other metropolitan areas with similarly changing development patterns and can be helpful in guiding future research comparing these two phenomena.

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ANB40, Analysis of Crashes, Injuries, and Speeds on Freeway Enhanced-Penalty Zones (12-4384)

This study examines the Enhanced Penalty Zones (EPZs) established on Interstate 95 in three counties in Florida to assess the effects of increased penalties on improving the safety (reducing crashes and injuries) of freeway segments. Further, data about enforcement activities were collected by troopers working along EPZ and non-EPZ segments of the I-95 corridor to study the differential effects of enforcement on speeding between the EPZ and non-EPZ segments. A systematic analysis of crash and injury data before and after the establishment of EPZs indicate that the crashes and injuries were reduced in the EPZ segments, although the magnitude of the reduction varied by analysis methodology. On examining the impact on speeds, we find that 15-minute average speeds in EPZs are lesser than the speeds in non-EPZ segments after controlling for traffic volumes. However, no reductions in speeds were estimated during periods of police enforcement either in the EPZ or in the comparison segments. Overall, this analysis suggests that the EPZs did improve freeway safety by resulting in lower speeds and fewer crashes and injuries.

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ANB50, Influence of Cannabis in Fatal Traffic Crash Production: Detailed Analysis (12-1179)

The influence of cannabis on traffic crashes is a growing concern. Experimental studies provide ample evidences of cannabis influence on psychomotor and cognitive performances. Epidemiological works describe the excess crash risk that this substance causes. And yet, this psychotropic drug influence in causing crashes is still at the centre of many discussions. The present analysis consists in exploiting crash data in detail to obtain a more precise understanding of the failures that drivers are subject to when they have consumed cannabis, depending on the level of Tetrahydrocannabinol (THC) measured in blood samples. Two groups representative of fatal crashes occurring in France were studied: the Cannabis group (n=174) and a Control group (n=174) involving neither cannabis nor alcohol. The results of this analysis notably show that cannabis consumption significantly increases the rate of "generalized failures" by the driver, reflecting an alteration of all sensorial, motor and cognitive functions, specifically for high blood levels of THC (>5 ng/mL). At lower levels of intoxication, cannabis leads to a poor diagnosis of driving difficulties.

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ANB60, Application of Spatial Crash Analyses and Road Safety Investigations to Increase Older Driver Safety (12-4214)

An issue facing the transportation profession is the ability to provide social equity with regards to safety and mobility given the aging population. Given the dominance of the automobile within the transportation system, the ability to provide feasible alternatives is daunting. This fact, when coupled with the well-documented challenges of older drivers, underscores the need for improved safety features and system-wide safety approaches with a focus on the older driver. This paper describes an application of spatially-based crash analyses and road safety investigations that

were employed in Massachusetts with a focus on the older driver. Specifically, the paper outlines an approach for identifying high crash locations for older drivers and presents the results of older driver focused road safety investigations for selected locations. The research approach targets roadway segments where older drivers are overrepresented in crashes. The road safety investigations resulted in recommended countermeasures aimed at mitigating the older driver crash problem at the identified locations. Although the resulting countermeasures, which were based upon established literature such as the Older Driver Highway Design Handbook, included a full spectrum of recommendations, a specific emphasis was placed on short-term and low cost measures that could be readily employed. Techniques to identify relationships between high crash location identification methods and the recommended countermeasures for the identified locations are considered. Ultimately the application of these techniques may provide transportation professionals with a means to associate specific older driver focused countermeasures with the results of particular methods of high crash location identification.

Authors
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ANB70, Effects of Hours of Service and Driving Patterns on Motor Carrier Crashes (12-0607)

There is a need to explore the relationship, if any, between the probability of a crash and hours worked by truck drivers. The need arises from the continued adjustment of Federal Hours of Service (HOS) regulations for truck drivers. This research uses data logs from less-than-truckload carrier operations in 2004-05 and 2010, to estimate the probability of a crash after a certain amount of time driving given no crashes until that time. Driver logs for seven days prior to each crash were used and compared to a random sample (two drivers) of non-crash-involved drivers selected from the same company, terminal, and month. After the 4th hour of driving, there is a consistent increase in crash odds as driving time increases. Breaks from driving reduce crash odds by as much as 50% compared to drivers with no breaks. Crash odds are lowest when drivers return to work during the day without an immediately preceding recovery period. Drivers returning to work immediately after a recovery period had crash odds 50-150% higher than day drivers without recovery. Drivers have the highest crash odds immediately after returning from the extended time off, the effect then diminishes with time.

Authors
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ANB70, Efficacy of Roll Stability Control, Forward Collision Warning, and Lane Departure Warning Using Carrier-Collected Crash Data (12-1006)

Large truck crashes have significantly declined over the last ten years due in part to the increased use of onboard safety systems. Unfortunately, there is a paucity of data of the potential efficacy of these devices in large trucks. The purpose of this project was to conduct an effectiveness evaluation of three different onboard safety systems using data collected directly from motor carriers. These OBSS technologies included lane departure warning (LDW), roll stability control (RSC), and forward collision warning (FCW) systems. The current study assessed the safety benefits of these onboard safety systems installed on Class 7 and 8 trucks as they operated during normal revenue-producing deliveries. Although crash data was collected from 14 carriers representing small, medium, and large carriers hauling a variety of commodities (including a total of 88,112 crash records and 151,624 truck-years that traveled 13 billion miles traveled), the data set in the current study was skewed toward larger, for-hire carriers and may not represent the overall U.S. trucking population. There was no significant difference in the crash rate ratio (CRR) between the non-FCW and FCW cohorts ($p = 0.991$). The non-LDW cohort had an LDW-related crash rate that was 1.917 times higher than the LDW cohort ($p = 0.001$), and the non-RSC cohort had an RSC-related crash rate that was 1.555 times higher than the RSC cohort ($p < 0.001$). The results strongly support the use of LDW and RSC, more research is needed to assess the efficacy of FCW.

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ANB70, Predicting Truck Crash Involvement: Commercial Driver Behavior-Based Model (12-3826)

With safety as a top priority, the trucking industry has worked diligently to identify novel methods for further reducing an already record low number of truck crashes. In an attempt to realize that goal, this research has utilized an archival research design to identify truck driver behaviors that frequently accompany future crash records. Specifically, the researchers collected two years' worth of recent crash, violation and conviction data for 582,772 U.S. commercial motor vehicle drivers and found dozens of driver infractions that were significant predictors of future crash involvement. In addition to pinpointing which specific behaviors were significantly linked to commercial vehicle crashes, the researchers quantified the strength of each association, revealing future crash risk increases that ranged from 26 to 96 percent. Beyond measuring individual driver behaviors, principal components analysis was used to group the more than thirty driver infractions from this study into 11 related factors. This smaller set of negative driver behavior categories was then entered into a logistic regression model, which revealed the classes of behaviors that trucking companies and enforcement agencies should be most proactive in targeting for enhanced driver training and enforcement efforts, respectively.

Authors
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ANB70, Safety Benefits of Stability Control Systems for Motorcoach Buses (12-3831)

This paper contains an analysis of the potential safety benefits of electronic stability control systems (ESC) for motorcoach buses operating within the U.S.. Motorcoaches are defined here as flat-front, high platform buses equipped for intercity or long distance travel. The deployment of the

stability technologies for single motorcoach buses is in its infancy. National crash databases do not include information that can be used to identify buses equipped with ESC; moreover, even if they could be identified, in the current stage of deployment it is unlikely that there would be sufficient data to evaluate the safety performance of the technology particularly given the low number of motorcoach crashes. In light of these limitations, this study examined all recent fatal motorcoach crashes utilizing information from the accident reports, formal studies such as NTSB, and information contained in reconstruction reports to determine the likelihood that the crash may have been prevented or mitigated should the motorcoach have been fitted with functioning ESC technology. From this analysis it was determined that assuming ESC was fitted to all motorcoach buses, savings from LOC and rollover crashes prevented are estimated at $25 million annually. While the financial benefits for motorcoaches were found to be limited the intrinsic value of this technology will likely exceed the financial benefits given that motorcoaches transport the public and there is an expectation that effective safety technology should be used even if the exposure is low.

Authors
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ANF30, Who, What, When, and Where of Motorcycle Crashes in Alabama (12-4249)

Similar to the national trend, motorcycle crashes in the State of Alabama have more than doubled over the past decade. This study is the first of its kind in Alabama to investigate the reasons contributing to motorcycle crashes in Alabama and the relationship among specific crash characteristics. Analyses were performed using the Critical Analysis Reporting Environment (CARE) tool by filtering out necessary crash data, generating frequency distributions and cross-tabulations of different motorcycle crash characteristics. Some of the characteristics of motorcycle crashes considered include age, gender, primary contributing circumstances (alcohol, speeding, run off road, etc.), license status, citations, severity, location,manner of collision, weather, lighting, type of road etc. Further, motorcycle-related crashes were analyzed separately in terms of whether they were caused by the motorcyclist or the driver of another vehicle type. Where appropriate, overrepresentations in the data were identified and discussed. The results of the analyses were compared with relevant previous studies and with basic statistics of other southeastern states and the U.S. Finally, the results were summarized and recommendations for additional research were presented.

Authors
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3 Papers on before-and-after safety evaluations

Information regarding the effects of various implemented safety treatments is used to estimate how effective a proposed countermeasure or set of countermeasures will be in reducing crashes at a specific location. Crash modification factors developed in rigorous studies that incorporate the current best study design and statistical analysis methods provide vital support for the roadway safety management process.

The Subcommittee identified twenty-one papers dealing with before-and-after safety evaluations. Five papers were sponsored by the ANB20 Committee while sixeen papers were sponsored by other Committees.

The majority of these papers employed the Empirical Bayes approach (12-0879, 12-1360, 12-2126, 12-4067, 12-0076, 12-2521, 12-4550, 12-1658, and 12-3237) while the Full Bayes approach was employed in three studies (12-0495, 12-2093, and 12-3794). Cross-sectional regression methods were employed in two studies (12-4067 and 12-1658) and one study used the comparison group method (12-4067). Other evaluation techniques were also proposed (12-2378).

The safety impact of countermeasures was generally represented by changes in crashes and crash severity. However, one study evaluated traffic conflicts as a surrogate measure (12-0448). Two studies proposed collision modification factors that change with time (12-0495 and 12-2093) to account for the novelty effect.

The evaluated countermeasures included geometric elements (12-0448, 12-0495, 12-0879, 12-0076, 12-0853, 12-2378, 12-4550), intersection traffic control elements (12-0116, 12-2126, 12-4067, 12-2521, 12-3794), roundabouts (12-1658), speed reduction and enforcement (12-1360, 12-0226), system-wide road safety improvement programs (12-0326), and pedestrian countermeasures (12-3237).

Two studies dealt with general issues related to the use and estimation of crash modification factors, their accuracy, and how to combine the safety effect of multiple countermeasures (12-0326 and 12-1652).

ANB20, Feasibility of Computer Vision-Based Safety Evaluations: Case of Signalized Right-Turn Safety Treatment (12-0448)

Traditional road safety analysis has often been undertaken using historical collision records. However, limitations on the quality and completeness of collisions data gave rise to surrogate safety measures especially the traffic conflict technique (TCT). Traditionally, TCT's have relied on in-field observation, which has some reliability and repeatability problems. Therefore, successful automation of extracting conflicts from video sensors data can have considerable benefits for traffic safety studies. One safety application that could greatly benefit from automated traffic conflicts analysis is before-and-after (BA) evaluation of safety treatments. There are several advantages that support the adoption of traffic conflict techniques in BA safety studies. Traffic conflicts are more frequent than road collisions and are of marginal social cost. Traffic conflicts provide insight into the failure mechanism that leads to road collisions. BA studies based on traffic conflicts can be conducted over shorter periods. The main objective of this paper is to demonstrate the use of automated traffic conflicts analysis for a before-and-after safety evaluation. A right-turn safety improvement was implemented at an intersection in the City of Edmonton in 2009 to mitigate high occurrence of rear-end and merging collisions. The right-turn ramp was closed and all right-turning vehicles were brought to the right-turn lane at the intersection where a “no right turn on red” sign was installed. Video sensors are selected in this study as the primary source of conflicts data. The analysis of video data to measure traffic conflicts is undertaken using an automated traffic safety tool. The distributions of the calculated conflict indicators before-and-after the treatment show a considerable reduction in the frequency and severity of traffic conflicts which suggests a significant positive change in safety for rear-end, merging and total conflicts. It is hoped that the results of this study will show the potential for the adoption of automated conflict analysis to conduct BA safety studies.

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ANB20, Linear and Nonlinear Safety Intervention Models: Novel Methods Applied to the Evaluation of Shoulder Rumble Strips (12-0495)

The most common practice in safety evaluation utilizes a longitudinal (before-after) study design with comparison groups to estimate the effects of a safety countermeasure. These longitudinal evaluations base their results on actual changes that have occurred over a period of time extending from the before condition to the after condition. Recent research has advocated the use of linear intervention models developed within a Hierarchical full Bayes context. These models acknowledge that the safety treatment (intervention) effects do not occur instantaneously but are spread over future time periods. Despite the demonstrated advantages of such models, there is still a lack of complete understanding of how the implemented countermeasures affect safety at the treated locations in terms of novelty, direct and indirect effects. This paper proposes a novel nonlinear intervention model in an attempt to provide a better understanding of how safety countermeasures work. The model is known as the 'Koyck' intervention model. To demonstrate its capabilities, the linear and nonlinear (Koyck) models are applied to estimate the effectiveness of the installation of shoulder rumble strips in a number of highway segments in the province of British Columbia, Canada. For both models, the treatment effectiveness was measured as a function of post treatment time providing researchers and analyst with a better representation of the treatment impact in subsequent years after installation. Moreover, the treatment impact was decomposed into direct and indirect effects. The direct treatment impact enables the analysts to assess the effectiveness of the countermeasures apart from local (site-related) factors. In addition to providing the best fit, the nonlinear 'Koyck' model has provided valuable insight into the effectiveness of shoulder rumble strips showing an immediate 24.9% reduction after one year which decreased with time resulting in a permanent treatment impact of 19.2%. The results of this study can have a significant impact on the economic evaluation of safety programs and countermeasures. Given the way future benefits are discounted to present values, the results of using a collision modification factor that changes with time can significantly affect the estimation of the cost effectiveness of safety countermeasures.

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ANB20, Safety-Effectiveness of Super 2 Highways in Texas (12-0879)

The objective of this study is to evaluate the safety effectiveness of Super 2 highways in Texas. This study utilized the before-after study with the empirical Bayes (EB) method since it is superior to other methods in that it can address the regression-to-the-mean bias. Based on the identified potential study sites in seven Districts (Paris, Childress, Corpus Christi, Austin, Wichita Falls, Yoakum, and Bryan) in Texas, four reference groups were considered by imposing different restrictions. Then, negative binomial regression models were used to develop safety performance functions for each reference group. From the model selection process, the most restricted reference group was selected for the final analysis. For roadway inventory and crash history data, twelve years (1997-2001 and 2003-2009) of Texas data were examined. The analysis used fatal (K), incapacitating injury (A), non-incapacitating injury (B), and minor injury (C) crashes (i.e., property damage only crashes were not included). The EB analyses were carried out for five corridors of about 53 centerline-miles. The results showed that the installation of Super 2 highways led to a statistically significant crash reduction of 35 percent for segment-only crashes (KABC) and 42 percent for segment-and-intersection crashes (KABC) on the study corridors. This finding is consistent with findings of previous safety-related studies of Super 2 corridors, which show improvements in safety with installation of passing lanes, even at traffic volumes higher than those considered under previous guidance in Texas.

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ANB20, Safety Effects of Restricting the Speed Limit from 90 to 70 km/h (12-1360)

In 2001 the Flemish government decided to lower speed limits from 90 to 70 km/h at different regional roads. To examine the effect of this speed restriction on traffic safety, a before-after study with comparison group was performed. This study encompasses 61 road sections of which the speed limit was restricted since 2001, and has a total length of 116 km. The comparison group has a total length of 53 km across 19 road sections. The results indicate a 5% decrease in number of crashes after speed restriction. A higher effectiveness (9%) was found for more severe crashes compared to injury crashes. Separate analyses for crashes at intersection and at road sections, showed a higher effectiveness at road sections, both for injury crashes and more severe crashes.

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ANB20, Investigating Effect of Collision Aggregation on Safety Evaluations Using Multivariate Linear Intervention Models: Case Study of Signal Head Upgrade Program (12-2093)

This paper investigates the effect of collision aggregation on safety evaluations using a case study from the Insurance Corporation of British Columbia (ICBC) 2001 Signal Head Upgrade Program. Three different types of evaluations were carried out. Bivariate intervention models were used in the first two evaluations to assess the safety impacts on different collision severity levels (severe and property-damage-only) as well as collision time of occurrence (daytime and nighttime). In the third evaluation, multivariate intervention models were utilized to determine the safety impacts of the program on each combination of collision severity and collision time of occurrence (i.e. severe/daytime, severe/nighttime, PDO/daytime, PDO/nighttime). Overall, the results indicated the effectiveness of the program in improving the safety of the treated intersections. However, the results reveal that aggregate analyses can lead to misleading results. Aggregating collisions over time of day indicated the treatment had significant reductions on PDO collisions but not severe collisions. Alternatively, aggregating collisions over severity levels indicated the treatment had significant reductions on both day- and night- time collisions. These results are different from the results of the disaggregate analysis, where significant reductions were found for all collision types except for daytime severe collisions.

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AHB50, LED Traffic Signal Retrofits: Implications for Intersection Safety (12-0116)

The recent advancements in light emitting diode (LED) technology and the comparative energy savings over traditional incandescent bulbs have led to many municipalities retrofitting traffic signals with new LED bulbs. Although a significant amount of literature exists regarding benefits of LED installations in terms of energy and economic savings, less attention has been given to the potential safety impacts of these massive retrofit projects. This paper presents the results of a study to evaluate the safety implications of the change to LED technology in traffic signals in Memphis, Tennessee, where 56 full LED conversions and 712 partial conversions (red and green only) of signalized intersections have occurred since 2000. Eight intersections where LED retrofit has occurred and two comparison sites with no LED installation were evaluated. Analysis of before and after crash data for the study sample indicates a 47% decrease in safety after LED installation.

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AHB50, Safety Performance of Flashing Yellow Arrow Signal Indication (12-2126)

Currently, the 2009 Manual on Uniform Traffic Control Devices (MUTCD) recommends using a flashing yellow arrow (FYA) signal display to indicate permissive left turns for all separated left-turn signal head. However, the FYA signal display is relatively new and many traffic engineers still are hesitant to use it due to some safety concerns. Therefore, this study is to fully investigate the safety issues in the implementation of the FYA at signals with protected/permissive left-turn (PPLT) control mode. For this purpose, historical crash data were collected at 17 intersections with FYA signals installed and the Empirical Bayes method (EB) was used to analyze the crash data. The results of study indicated that, in most cases, the use of the FYA signal indication did not have adverse effect on traffic safety at intersections. However, the results also identified two specific safety issues that are related to the FYA signal indication, and the possible solutions for these issues were proposed

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AHB50, Evaluation of Two Treatments for Reducing Crashes Related to Traffic Signal Change Intervals (12-4067)

The paper presents two evaluation studies, which were conducted under NCHRP Project 17-35, The research objectives were to use the most appropriate analytical methods, and the best available data, to build on previous research in developing crash modification factors (CMFs) for two treatments for reducing crashes related to traffic signal change intervals: modifying the change interval and installing dynamic signal warning flashers (DSWF). Three evaluation methods were used as appropriate -- the empirical Bayes (EB) before-after method, the comparison group before-after method, and cross sectional multiple regression models. A secondary objective of using cross-section models for some evaluations was to examine the comparability of before-after and cross-sectional studies, a subject of topical interest in CMF development. There was a general safety benefit for installing dynamic signal warning flashers, with indications that crash reductions can be obtained overall, and for several crash types, including injury, angle, and heavy vehicle crashes. For the change interval modification, the before-after study results showed significant reductions (at the 5% level) in total, injury, and rear-end crashes under various scenarios. For both treatments, the results from cross-sectional analyses were relatively consistent with those from the before-after analyses.

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ANB10, Safety Effects of Icy Curve Warning Systems (12-0985)

The California Department of Transportation (Caltrans) deployed an Icy Curve Warning System (ICWS) on a five-mile section of State Route (SR) 36 in Lassen County over Fredonyer Pass. This section of roadway had a history as a high-crash location, with multiple fatal crashes. The vast majority

of these accidents occurred when the pavement was icy, despite static signage that Caltrans had installed to increase motorist awareness. This study presents the results of research that investigated safety effects of the ICWS. An observational before-after study method with Empirical Bayes technique was used to determine the effect the ICWS on crash frequencies. The results showed that the ICWS reduced annual crashes by 18%. Moreover, analysis of ice-related accidents during winter seasons found that the ICWS had reduced crash severities on this roadway section. Based on these results, a benefit analysis revealed that the ICWS provided an estimated monetary benefit of $1.7 million dollars per winter season to motorists through reduced crashes. The study results are anticipated to contribute to a better understanding of safety effects of ice (or icy curve) warning systems and increase the knowledge base of weather-specific treatments and their associated effects.

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ANB10, Evaluation of Effectiveness of Federal Highway Safety Improvement Program (12-4058)

The Safe, Accountable, Flexible, Efficient Transportation Equity Act - A Legacy for Users (SAFETEA - LU) established the Highway Safety Improvement Program (HSIP), which authorized about $ 1.3 billion US dollars per year from 2006 to 2009 to be spent on highway safety projects. The HSIP aims "to achieve a significant reduction in fatalities and serious injuries on all public roads," and the number of national traffic fatalities seems to have decreased at about the same time. This study seeks to evaluate the effectiveness of the HSIP on reducing fatal crashes in the United States. This study adopted fixed-effect panel models and multilevel mixed-effect models to deal with the random fluctuations before and after the introduction of the HSIP and state specific effects. The results show that national traffic fatalities, indeed, have been reduced about 7.5 percent nationwide since the introduction of the HSIP compared to the 2001-2005 average, but the magnitude of the reduction varied by states. It was found that the states' safety-related spending did not increase after the introduction of HSIP. Increased safety funding from the federal government was offset by a reduction in funding at the state level, referred to as a crowd-out effect. This study found that the magnitude of state fatal crash reduction was highly associated with the years of crash data available, prioritizing method, and utilization of roadway inventory data. Moreover, states that prioritize hazardous sites using more detailed roadway inventory data and the Empirical Bayes method have the most remarkable reduction, relying heavily on the quality of crash data system. This study found that effectiveness of the HSIP on reducing national fatal crashes is very likely due to the mandated reporting requirements, which helped states allocated safety spending more effectively and efficiently. This study also suggests that with more consistent and reliable crash data, states will be able to employ more sophisticated prioritization methods and make better highway safety investment decisions.

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ANB25, Developing Lane-Width Crash Modification Factors for Urban Multilane Roadways with Curb-and-Gutter and Asymmetric Lanes (12-0076)

This study developed lane width crash modification factors (CMFs) for urban curb-and-gutter multilane roadways with asymmetric lanes, i.e., outside lane wider than inside lane. The roadway segments used were urban four-lane with a raised median (4D) and with a two-way left-turn lane (5T). Data used included 25 centerline miles of 5T segments and 39 centerline miles of 4D segments. Three crash categories were evaluated; KABCO { Fatal (K), incapacitating-injury (A), non-incapacitating injury (B), possible injury (C) and property damage only crashes (O)}, KABC {Fatal (K), incapacitating-injury (A), non-incapacitating injury (B), and possible injury crashes (C)}, and PDO (property damage only) crashes. A cross-sectional method was used as it was the most practical and feasible for this study. Six-year (2004 to 2009) of segment crashes were examined. The analysis involved statistical modeling using the negative binomial model, whose coefficients were used to develop multiplicative CMF equations for a combined effect of variable inside and outside lane width. In summary, the results show that reducing the inside lane width from 12 ft to 11 ft does not affect estimated crash frequency of 4D segments for all three crash categories, and PDO crashes for 5T segments. However, narrowing the inside lane width appears to be associated with increased estimated KABCO and KABC crashes for 5T sections. The results also suggest that widening the outside lane from the baseline 12 ft causes a reduction in estimated crash frequency for all three crash categories (KABCO, KABC, and PDO) for both 4D and 5T segments.

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ANB25, Crash Modification Factors: Foundational Issues (12-0326)

Crash Modification Factors (CMFs) are listed in the Highway Safety Manual (HSM) and other authoritative publications. Using these one cannot distinguish predictions of safety effect that can be made confidently and are likely to lead correct decisions from those that lead to decisions that can easily be wrong. Nor can one know how transferable are past research results from some circumstances to decisions about future actions to be implemented in different circumstances. The conceptual framework described in this paper aims to be of guidance for future research about CMFs and to meta-analyses thereof. The central claim is that CMFs are random variables with a mean and a standard deviation; that they are not universal constants that apply everywhere and at all times. The smaller the standard deviation of a CMF the more confident can be the related decision-making. Therefore, the aim of research about CMFs is to reduce their standard deviations. Ways to do so efficiently are indicated. The requisite theory and equations are provided.

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ANB25, Crash Modification Factor for Inexpensive Yet Very Cost-Effective Safety Improvement: Converting Undivided Four-Lane Urban Roadways to Five-Lane Roadways (12-0853)

Undivided multilane roadways have consistently exhibited low safety performance, particularly in urban or suburban areas where roadside development is relatively intense. Changing a four-lane undivided road to a divided roadway by either building a boulevard cross-section or installing a physical barrier is a desirable option to improve the safety performance, but it requires significant resources and sometimes a strong political will. This paper introduces a crash countermeasure successfully implemented on two different segments of urban undivided four-lane roadways in Louisiana. This crash countermeasure is to change an undivided 4-lane roadway to a 5-lane roadway with a two-way left-turn lanes (TWLTL) by re-striping pavement markings without increasing pavement width. Although the five-lane roadway is no longer an acceptable roadway type for new construction in Louisiana, the impressive crash reductions on both roadway segments clearly demonstrate it as a feasible solution under constrained conditions. Based on the statistical analysis with six years of crash data (three years before and three years after excluding the project implementation year), the crash modification factors for both roadways are estimated to be less than 0.5 with a standard deviation less than 0.07. While it is not surprising to see the biggest crash reduction comes from the rear-end collisions, the other types of collisions are also reduced. The crash reduction is consistent for the time of day and by pavement surface condition (wet vs. dry). One-size-fits-all solutions do not always prevail in roadway safety. Under financial and other foreseeable or unforeseeable constraints, proactively doing something to reduce crash problems is better than just passively waiting for the probably unrealistic best solution. The tall order of the Louisiana Strategic Highway Safety Plan for Destination Zero Death on Louisiana roadways calls for all feasible crash countermeasures.

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ANB25, Issues Related to Combination of Multiple Crash Modification Factors (12-1652)

There is a need to raise awareness about the issues associated with estimating the safety effects of multiple treatments. Specifically, crash modification factors (CMFs) are one tool to support this effort, but further research and guidance is needed to help practitioners estimate the expected safety effects when multiple treatments are implemented at a given location. 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. The issue is that there is limited guidance on the application of multiple CMFs, and the existing guidance has not been rigorously tested. This paper presents existing methods for combining multiple CMFs and identifies related issues. The primary issue is whether it is valid to assume that the effects of individual treatments are independent. If multiple treatments are not independent and the CMFs are simply multiplied to estimate the combined effect, the result may be an over- or underestimation of the combined treatment effect. A framework is developed for investigating interrelationships between treatments, and a matrix is provided to help identify potential overlapping effects. Six distinct scenarios are identified based on potential interrelationships and the applicability of CMFs. Scenarios 1 through 3 are relatively straightforward (i.e., no overlapping treatment effects) and currently accepted methods for combining CMFs are presented for each of the three scenarios. Scenarios 4 through 6 are more complex (i.e., overlapping treatment effects). Several methods are proposed for estimating the combined effects of multiple treatments, but it is emphasized that there has been very little research to support these methods.

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ANB25, Crash Modification Factors for Changing Left-Turn Phasing (12-2521)

This study estimated crash modification factors (CMFs) from before-after evaluations of two treatments targeted at left turn crashes at signalized intersections: (1) changing from permissive to protected-permissive phasing, and (2) implementation of flashing yellow arrow (FYA) for permissive left turns. Results of the first evaluation, which was based on 59 intersections from Toronto and 12 from North Carolina, indicated a substantial reduction in left turn opposing through crashes, especially at intersections where more than one leg was treated, and a small percentage increase in rear end crashes. For the second evaluation (FYA), which was based on data from 51 signalized intersections from Oregon, Washington, and North Carolina, results indicated a safety benefit at locations with some kind of permissive left turn operation before, and a disbenefit where there was protected only operation before. A key aspect of the study was the estimation of the standard deviation of the distribution of the CMF in addition to the conventionally estimated standard error of the mean CMF value. For several CMFs, the standard deviation of the distribution was larger than the standard error of the mean value of the CMF, indicating substantial variation in the treatment effect across sites. This indicates the need for further research into the development of crash modification functions instead of crash modification factors, and for the use of large treatment databases to undertake more extensive disaggregate analysis of safety effects. Equally important, it emphasizes the importance of providing more explicit consideration of CMF variability in future editions of the Highway Safety Manual.

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ANB25, Developing Crash Modification Factors for Interchange Influence Areas on Urban Four-Lane Freeways Using Multivariate Adaptive Regression Splines (12-2378)

Crash modification factors (CMFs) are used to measure the safety impacts from changes in specific geometric characteristics. Their development has gained much interest following the adoption of CMFs by the recently released Highway Safety Manual (HSM) and SafetyAnalyst tool. This paper aims at developing CMFs for interchange influence areas on urban four-lane freeways in the state of Florida. The need to model freeway interchange areas apart from their basic mainlines has been recognized by SafetyAnalyst. Different methods for developing CMFs can be found in the literature. This paper introduces a promising data mining method known as multivariate adaptive regression splines (MARS) for CMF development. MARS is characterized by its capability to accommodate the nonlinearity in crash predictors, which can be a mixture of continuous and categorical variables. In addition, MARS allows the impact of more than one geometric variable to be simultaneously considered when estimating CMFs. Separate CMFs were developed for inside and outside shoulder widths within the interchange influence areas. The results showed that MARS produced CMFs with higher confidence than those using the negative binomial model. The influential variables identified included the inside shoulder width, outside shoulder width, traffic volume, shoulder type, and speed limit. It was also found that inside shoulders less than 4 ft and 4 to 6 ft experienced safety improvement in relative to the 4-ft width.

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ANB25, Crash Reduction Effects of Flashing LED Stop Signs (12-3794)

A flashing LED stop sign is a regular octagonal stop sign with flashing light-emitting diodes (LED) on its vertices. The hope is that by increasing the conspicuity of the stop sign the frequency of violations, and related intersection crashes, will be reduced. At present however there does not appear to be conclusive evidence regarding the crash reduction effects of this treatment. In this paper, we implemented a hierarchical Bayesian approach to estimate the right-angle crash reduction factor for those intersections installed flashing LED stop signs in Minnesota. The treatment and reference group data were prepared based on Minnesota District Engineer and County Engineer survey, Highway Safety Information System data, Minnesota Crash Mapping Analysis Tool data, and Google Maps observations. Three models with different predictors were fitted and five covariates were found to be significant, including the major approach average daily traffic, the minor approach average daily traffic, the major approach speed limit, the minor approach speed limit, and the number of legs in the intersection. The point estimate of right-angle crash reduction factor indicates a 40% reduction. It has a wide confidence interval due to the small sample size of after-treatment data and the probability that it is greater than 0 is 94%, suggesting that a decrease in the frequency of right-angle crashes is associated with installation of flashing LED stop signs, but that the magnitude of this reduction remains uncertain. Once more after-treatment data are available in the future, the precision of crash reduction factor estimate could be improved.

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ANB25, Estimation of Safety Effectiveness of Composite Shoulders on Rural Two-Lane Highways (12-4550)

A paved shoulder has been regarded as an effective safety improvement to reduce crashes. There is belief that there is a diminishing safety benefit for each additional increment of paved shoulder width. Thus there may be opportunities for greater system-wide safety benefits from paving longer roadway segments with a composite shoulder than paving shorter roadway segments with a full-width paved shoulder. The objective of this study was to determine the safety benefits of composite shoulders - such as a small paved shoulder combined with turf outside of that. This approach was part of the Kansas Department of Transportation's effort to find "Practical Improvements" to maximize benefits relative to the input costs required. Among the 8,300 miles (13,358 km) of rural two-lane highways in Kansas, approximately 25 percent of them are equipped with composite shoulders consisting of three ft (0.9 m) of pavement with the remainder turf. Their safety effectiveness was studied using a combined Empirical Bayes (EB) Method. Three developed Safety Performance Functions (SPFs) were used to create Kansas-specific Crash Modification Factors (CMFs) for composite shoulders compared with segments with no or unpaved shoulders. It was found that upgrading narrow unpaved shoulders to composite shoulders can reduce shoulder related crashes by up to 61 percent and fatal and injury crashes by 31 percent. Based on these results, 20-year projections were developed projecting the safety effectiveness that can be achieved through implementing these safety improvements.

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ANB40, Safety Evaluation of Automated Section Speed Enforcement System (12-0226)

Speeding is among the most significant contributing factors to fatal crashes, so most road agencies attempt to achieve the right operating speed among drivers by imposing speed limits. Unfortunately, there tends to be a high prevalence of speed limit violations, even on motorways with speed cameras. Part of the problem with speed camera enforcement is that some motorists brake before passing a camera location and then speed up to above the speed limit after they have passed it. This sudden braking can cause dangerous situations, crashes, or tailbacks. Furthermore, a safe operating speed is not achieved where there are no cameras, especially where the enforcement is overt, as is the case in Italy. A new technique to overcome these problems is the Automated Section Speed Enforcement System (ASSES). Unlike conventional speed meters, which measure the speed of a vehicle at one point, ASSESs determine the average speed over a long distance. The objective of this study was to evaluate the safety effectiveness of the ASSES installed on the Italian Motorway A1 Milan-Naples in the 2007. An empirical Bayes observational before-after study was performed. The estimate of the total crash reduction is 31.2%, with a lower 95% confidence limit of 24.3%. The greatest crash reductions were observed for severe crashes and crashes at curves. The reduction was 55.6% for severe crashes, 26.6% for non-severe crashes, 43.4% at curves, and 28.4% at tangents. However, it is worthwhile to observe that the effectiveness decreased over time. The crash reduction was 39.4% in the first semester after the system activation while it was 18.7% in the fifth semester. Overall, the study results strongly support the activation of the ASSES because of the highly significant and substantial safety effects. On the other hand, it is stressed that the system effectiveness decreases over time, a situation that may be correctible with higher levels of enforcement.

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ANB75T, Safety-Effectiveness of Converting Signalized Intersections to Roundabouts (12-1658)

Roundabouts may be new builds but often are conversions from existing intersections. When contemplating the later, there is a need to estimate the safety effects of conversions. Several studies have estimated large reductions in crashes and severity; however, these results pertain mainly to conversions from unsignalized intersections. Results for conversions from signalized intersections have been less conclusive. The objective of this study was to estimate the safety effectiveness of converting signalized intersections to roundabouts. Several States helped to identify signalized intersections that were converted to roundabouts in the recent past. In total, 28 conversions were identified in the United States. The empirical Bayes (EB) method was employed in an observational before-after study to estimate the safety effects. Data from select States were also used in a cross-sectional analysis to investigate the compatibility of results from cross-sectional and before-after studies. The EB results indicated a safety benefit for converting signalized intersections to roundabouts. There were reductions in both total and injury crashes, with a larger benefit for injury crashes. Further analysis indicated that the safety benefit of roundabouts for total crashes decreased as traffic volumes increase, a result that led to the development of a crash modification function. The safety benefit for injury crashes was sustained across all traffic volumes. Both results were supported by the cross-sectional analysis. Based on the analysis, it appears that roundabouts have the potential to significantly reduce crashes and severity at signalized intersections.

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ANF10, Relative Effectiveness of Pedestrian Safety Countermeasures at Urban Intersections: Lessons from New York City Experience (12-3237)

Walking has many benefits for pedestrians and the society. Yet, pedestrians are a vulnerable group and safety concerns are a significant barrier in one's decision to walk. Multiple countermeasures have been proposed to promote pedestrian safety, however, their relative effectiveness is unknown and those effective in reducing pedestrian crashes may be at odds with motorist safety. In this study, we seek to evaluate the relative effectiveness of five countermeasures in New York City—increasing the total cycle length, Barnes Dance, split phase timing, signal installation, and high visibility crosswalk—and examine potential trade-offs in their effectiveness in reducing pedestrian crashes and multiple vehicle crashes. We adopted a rigorous two-stage design that first identifies a comparison group, corresponding to each treatment group, and then estimates a negative binomial model with the Generalized Estimating Equation (GEE) method to further control confounding factors and within-subject correlation. Built environment characteristics are also accounted for. Set in a large urban area, this study suggests that the four signal-related countermeasures are more effective in reducing crashes than high visibility crosswalks. The findings indicate that the types of conflicts and balance the time for different groups of road users at the intersections should be considered so that the improvement of the safety of one group does not compromise that of other groups.

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4 Papers on safety performance functions

Safety performance functions (SPFs) are developed for estimating expected crash frequency (including by crash severity and collision types) of a network, facility, or individual site. The predictive methods provide a quantitative measure of expected average crash frequency under both existing conditions and conditions which have not yet occurred.

Thirty-six papers were identified by the Subcommittee to address safety performance functions. Thirteen papers were sponsored by the ANB20 Committee, one paper was sponsierd by the ANB00 Section, and twenty-two papers were sponsored by other Committees.

From a methodological perspective, these papers used a wide range of techniques, mostly the traditional Negative Binomial (NB) or variations, Bayesian models and few other non parametric techniques. The applications included macroscopic crash frequency, e.g., traffic analysis zones (TAZ), freeway segments, intersections, roundabouts, two-lane roads, work zones and pedestrian crashes.

Generalized linear models with NB error distribution were used in several papers (12-2759, 12-2880, 12-3079, 12-3208, 12-3318, 12-4332, 12-4730). Other traditional approaches were used such as the Multinomial Logit Model (12-2759), Random Effect NB (12-2416), and Quantile Regression (12-2218).

The Bayesian approaches were featured in several publications this year. Among the models were Hierarchical Bayesian (12-0242 and 12-0243), Bayesian logistic regression (12-0998), Bayesian Model Averaging (12-3544 and 12-3548) and Empirical Bayesian (12-0644). Other approaches used by researchers were Neural Networks (12-0411 and 12-1837), Simultaneous Equation Models (12-4132), Tobit to model crash rates (12-2611), and Poisson-Weibull and Poisson Gamma (12-2793 and 12-4472) compared the zero inflated regression models to the Poisson and Poisson Gamma.

From an applications perspective, several papers addressed Freeway sections' safety (12-0411, 12-0998, 12-1837, 12-0702, 12-2611, 12-3544, 12-4730, 12-3544, and 12-1965). Intersections were investigated by 5 studies (12-3208, 12-3510, 12-4132, 12-1966 and 12-2271). Macroscopic safety models were developed for traffic analysis zones (12-0243, 12-0242, 12-1991, and 12-3079), Census tracts and Block groups (12-0243) and transit and city transportation plans (12-3318). Other applications included roundabouts (12-2412), two-lane roads (12-4549 and 12-0972), work zones (12-2416), pedestrians' safety (12-0242 and 12-3208), and roadway curves and signage (12-4728, 12-4564, and 12-2759).

Microsimulation was used in investigating conflicts and surrogate safety measures (12-1966 and 12-2271). Several papers addressed the transferability of the HSM models or calibrated models and compared them to the HSM (12-0190, 12-0972, and 12-2835), another study compared the Florida and Safety Analysts SPFs for urban freeways (12-4730). Several studies investigated the relationship between traffic flow parameters and safety (12-0998, 12-0411, 12-1837, and 12-0702). Two studies addressed the urban streets layout on safety (12-2148 and 12-1991).

ANB20, Comparison of Geographical Unit-Based Macro-Level Safety Modeling (12-0243)

A wide array of spatial units has been explored in macro-level crash modeling. With the advancement of Geographic Information System (GIS) safety analysts are able to analyze crashes for various geographical units. However, a clear guideline on which geographic entity should a modeler choose is not present. This preference of spatial unit can vary with the dependent variable of the model. Or, for a specific dependent variable, models may be invariant to multiple spatial units by producing a similar goodness-of-fits. This problem is closely related to the Modifiable Areal Unit Problem (MAUP) which is a common issue in spatial data analysis. In this study three different crash models were investigated for traffic analysis zones (TAZs), block groups (BGs) and census tracts (CTs) of two counties of Florida. The models were developed for the total crashes, severe crashes and pedestrian crashes in this region. The primary objective of the study was to explore and investigate the effect of zonal variation on these specific types of crash models. These models were developed based on various roadway characteristics and census variables (e.g., land use, socio-economic, etc.). The models were compared based on three measures of goodness-of-fit: Deviance Information Criterion (DIC), Mean Absolute Deviation (MAD), and Mean Square Prediction Error (MSPE). Based on MAD/MSPE it was evident that the total, severe and pedestrian crash models for TAZs and BGs had similar fits, and better than the ones developed for CTs. This indicated that the total, severe and pedestrian crash models are being affected by the size of the spatial units rather than their zoning configurations.

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ANB20, Relationship Among Traffic Density, Speed, and Safety and Its Implication on Setting Variable Speed Limits on Freeways (12-0411)

Speed-flow relationships for a typical basic freeway segment are well understood at present and are documented by the successive editions of the Highway Capacity Manual. All recent freeway studies show that speed on freeways is insensitive to flow in the low to mid range. Increase in flow and density without reduction in speed has a significant influence on safety, however, constructive discussion of this influence is largely absent from extant literature. Empirical examination of the relationship between flow/density, speed and crash rate on selected freeways in Colorado suggests that as flow/density increases crash rate initially remains constant until a certain critical threshold combination of speed and density is reached. Once this threshold is exceeded the crash rate rapidly rises. The rise in crash rate may possibly be explained by the fact that compression of flow without notable reduction in speed produces headways so small that it becomes very difficult or impossible to compensate for driver's error to avoid a crash. In addition to calibrating corridor specific SPFs relating crash rate to hourly volume/density and speed this paper proposes a variable speed limit (VSL) algorithm intended to slow traffic down in real time in advance of a high speed-high density operational regime. Deployment of such an algorithm has the potential to improve safety and reduce travel time variability.

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ANB20, Segment Length Impact on Highway Safety Analysis (12-0644)

Highway information is usually stored in the form of links and nodes, with links as segments and nodes as intersections. The purpose of mirroring the linear nature of a highway is to create and maintain a highway inventory and a location reference system. Segmentation based on fixed length, changes in geometric attributes or location of intersections may be convenient for storage and maintenance of data, but is not necessarily the most appropriate approach for a safety analysis. Any fixed-segment length based analysis will be subject to the features and length of the segment, resulting in possible bias towards crash rates for extremely short segments or crash frequency for long segments. Sliding scale segmentation is advantageous in highway safety applications because it is more flexible and accurate than fixed segmentation. An empirical Bayesian (EB) adjusted sliding scale analysis adds robustness to the safety analysis, e.g. reducing the effect of regression-to-the-mean (RTM). However, guidance for determining the length of the sliding scale is needed, as analysis results may vary significantly by the selection of sliding window size. A sensitivity analysis was conducted to quantify the similarities and discrepancies between ½ mile, 1 mile, and 2 mile window sizes. The empirical results show that a ½ mile long scale may create more false positives than the other two scales in South Dakota, a predominantly rural state. A discussion of window size selection based on application is offered to advance knowledge of the impact of segmentation on safety analysis.

Authors

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ANB20, Assessment of Interaction Between Crash Occurrence, Mountainous Freeway Geometry, Real-Time Weather, and Automatic Vehicle Identification Traffic Data (12-0998)

This study investigates the effect of the interaction between roadway geometric features, and real-time weather and traffic data on the occurrence of crashes on a mountainous freeway. The Bayesian logistic regression technique was used to link a total of 301 crash occurrences on I-70 in Colorado with the real-time space mean speed collected from the Automatic Vehicle Identification (AVI) system, real-time weather and roadway geometry data. The results suggest that the inclusion of roadway geometrics and real-time weather with AVI data in the context of active traffic management systems is essential, in particular with roadway sections characterized by mountainous terrain and adverse weather. The modeling results showed that the geometric factors are significant in the dry and the snow seasons and the crash likelihood could double during the snow season because of the interaction between the pavement condition and steep slopes. The 6-minute average speed at the crash segment during 6-12 minutes prior to the crash time and the 1-hour visibility before the crash time were found to be significant in the dry season while the logarithms of the coefficient of variation in speed at the crash segment during 6-12 minutes prior to the time of the crash, 1-hour visibility as well as the 10-minute precipitation prior to the time of the crash were found to be significant in the snow season. The results from the two models suggest that different active traffic management strategies should be in place during these two distinctive seasons.

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ANB20, Development of a Procedure for Using Surrogate Safety Assessment Model and VISSIM for Safety Assessment at Signalized Intersections (12-1966)

The primary objective of this study is to investigate the potential of using microscopic simulation models and Surrogate Safety Assessment Model (SSAM) for evaluating the safety performance of signalized intersections. A widely used microscopic simulation package VISSIM was used in this study to develop simulation models. The validity of using VISSIM and SSAM for traffic safety analysis at signalized intersections was tested by comparing the simulated conflicts to those measured in the field using traditional traffic conflicts techniques. Of particular interest was to identify if the consistency between simulated and observed conflicts could be improved by calibrating VISSIM simulation models and adjusting threshold values used for defining simulated conflicts in SSAM. A two-stage procedure was proposed in this study to develop, calibrate and validate VISSIM simulation models. It was found that the two-stage calibration procedure greatly improved the goodness-of-fit between simulated conflicts and real-world conflicts. After model calibration, the mean absolute percent error (MAPE) for total conflicts was reduced from 44% to 24%. More specifically, the MAPE value was reduced from 26% to 15% for rear-end conflicts, from 69% to 29% for crossing conflicts, and from 83% to 81% for lane-change conflicts. Linear regression models and the spearman rank correlation coefficient were also developed to study the relationship between simulated conflicts and observed conflicts. Data analysis results showed that there was a reasonable goodness-of-fit between simulated and observed rear-end and crossing conflicts. However, it was also found that the simulated conflicts generated by VISSIM and SSAM are not good indicators for traffic conflicts which are generated by unexpected driving maneuvers such as illegal lane-changes in the real world.

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ANB20, Relationship Between Freeway Flow Parameters and Safety and Its Implications on Hard Shoulder Running (12-1837)

Decisions to run traffic on freeway shoulders during peak period are motivated by the need to relieve congestion. It is generally believed by practicing traffic engineers that decreased congestion resulting from hard shoulder running is associated with some unspecified degree of improved safety, yet the majority opinion among researchers is that accident rates increase with increase in the number of lanes even if full shoulders are provided. Despite many years of modern road building these conflicting views have not been reconciled. This paper first examines the relationship of traffic flow parameters such as volume, density, and speed to safety by calibrating corridor specific safety performance functions. On the basis of understanding this relationship a possible explanation of the effect of hard shoulder running on safety is formulated. Empirical examination of the relationship of flow, density, and speed to the crash rate on selected freeways in Colorado suggests that, as flow increases crash rate initially remains constant until a certain critical threshold combination of speed and density is reached. Once this threshold is exceeded, the crash rate rapidly rises. The rise in crash rate may possibly be explained by the fact that increase in density without notable reduction in speed produces headways so small that it becomes very difficult or impossible to compensate for driver's error. This model suggests that during hard shoulder running crash rates decline because of lower traffic volume/density per lane. It also suggests that safety benefits of reducing volume or density per lane outweigh adverse effects of not providing a full shoulder.

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ANB20, Macro-Level Model Development for Safety Assessment of Road Network Structures (12-1991)

Traffic safety is beginning to receive increasing attention at the stage of transportation planning. Although road network features are an essential aspect of transportation planning, studies of the safety effects of network patterns still remain limited. In this study, macro level safety models were developed to explore the relationship between crash occurrence and several underlying variables including demographic, land use, and road network variables. Prior efforts to model network structures have been hampered by difficulties quantifying network properties. In this study, different indices (e.g., Meshedness Coefficient, Closeness Centrality) of network structures were developed to examine the network structure effects on zonal level safety. In many cases, a large percentage of the crash locations (especially for arterial crashes) were not related to the Traffic Analysis Zones (TAZs) where drivers lived. To ensure proper linkage of crashes and zonal level features, we propose to model crashes of each TAZ for non-state maintained arterials (i.e., off-system), and state-maintained arterials (i.e., on-system), separately. We developed several Conditional Autoregressive (CAR) Bayesian models that incorporated the spatial correlation of nearby zones. Estimation results showed that crashes occurring on non-state maintained roads correlate more closely to the zonal network structure, and the demographic characteristics inside the TAZ, compared to crashes occurring on state-maintained arterials that correlate more closely with the traffic and road features of the major roads. The categorical variable generated from the Meshedness Coefficient performed well in capturing the nature of network patterns as they relate to off-system road crashes. This study shows that both the roadway type and the structure of the road network should be considered when developing TAZ level safety models.

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ANB20, Integrating Observational and Traffic Simulation Models for Priority Ranking of Unsafe Intersections (12-2271)

Observational models based on reported accident history is the most common approach used to identify unsafe sites for priority intervention. Observational models are good at predicting higher severity accidents but ignore higher risk vehicle interactions that failed to result in accidents in the historical data (e.g. near misses). Proponents of microscopic simulation models argue that ignoring these higher risk interactions can severely

understate the safety problem at a given site and lead to misallocation of scarce treatment funds. This paper takes the position that a complete understanding of safety problem at a given site can only emerge if both accident potential and traffic conflicts are taken into account. A priority ranking model is presented that integrates estimates from observational accident prediction models with an analysis of traffic conflicts. Traffic conflicts are based on simulated vehicle interactions and deceleration requirements for different traffic scenarios. The suitability of the approach for priority ranking of sites is assessed using six different ranking approaches: accident frequency, empirical Bayes, potential for safety improvement, conflict frequency, conflict rate (sum and cross product of traffic volume) and the integrated model. Priority ranking is evaluated using five different test criteria: site consistency, method consistency, rank difference, total rank score, sensitivity and specificity. These models are applied to a sample of 58-signalized intersections from Toronto for the period of 1999 to 2006. The integrated model was found to yield better results for the five evaluation criteria.

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ANB20, Analysis of Work Zone Crash Frequency with Focus on Police Enforcement (12-2416)

Highway work zone safety has been a concern nationwide and will likely draw ever increasing attention as more highway funds are being invested in the maintenance of existing highways. To improve work zone safety, the Indiana Department of Transportation (INDOT) established a special fund for work zone patrolling, and this study was commissioned to help INDOT achieve the maximum safety benefits within their budget constraint. With help of INDOT, a survey of project engineers was conducted to collect work zone information. It has been linked with other available data. A Random Effect Negative Binomial model was developed to identify the contributing factors and to estimate crash frequency in highway work zones. The results from the model provided insight to better understand work zone crashes. Various factors, including roadway information, traffic volume, work zone specific features, and police presence were identified as affecting work zone crash frequency; and these and other findings will be used to plan police enforcement activities in future INDOT work zones.

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ANB20, Assessment of Models to Estimate Crashes at Intersections: With and Without Using Traffic Volume (12-2880)

The focus of this paper is to develop and assess generalized linear models based on Negative Binomial distribution (to account for observed over-dispersion) to estimate the number of crashes at intersections for two different scenarios. While models were developed considering all variables (including traffic volume) that are not correlated to each other as independent variables in the first scenario, models were developed considering all variables (excluding traffic volume) that are not correlated to each other as independent variables in the second scenario. Data collected for 150 intersections randomly selected in the city of Charlotte, North Carolina were used to develop the models for each scenario. The numbers of crashes at each intersection was used as a dependent variable. Demographic characteristics (population and the number of households), socio-economic characteristics (average household income and employment), and land use characteristics (commercial, industrial, institutional and residential area) within the vicinity of each intersection as well as on-network characteristics (signalized or unsignalized intersection, whether the intersection is skewed or not, the number of approaches, speed limit for major and minor street, the number of left turn, through and right turn lanes along major and minor street, and traffic volume) were considered as independent variables. Results obtained indicate that models with traffic volume have better predictive capability than those without traffic volume. An assessment of models based on the effect of buffer width indicates that a 0.25-mile buffer width around an intersection would be ideal to capture spatial off-network data and yields statistically meaningful results for both the considered scenarios. The methodology and the models could be used by practitioners to estimate potential risk at “new” intersections or at existing intersections near “new” developments so as to pro-actively apply safety treatments.

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ANB20, Developing Zonal Crash Prediction Models with a Focus on Application of Different Exposure Measures (12-3079)

Assessing the safety impacts of Travel Demand Management (TDM) strategies is essential to be carried out by means of a proactive approach. Since TDM strategies are usually conducted at an aggregate level, Crash Prediction Models (CPMs) should also be developed at a more aggregated level. Therefore Zonal Crash Prediction Models (ZCPMs) are considered to construct the association between observed crashes and a set of predictor variables in each zone. This is carried out by the Generalized Linear Modeling (GLM) procedure with the assumption of Negative Binomial (NB) error distribution. Different exposure, network and socio-demographic variables of 2200 Traffic Analysis Zones (TAZs) are considered as predictors of crashes in the study area, Flanders, Belgium. To this end, an activity-based transportation model framework is applied to produce exposure variables. Crash data used in this study consist of recorded injury crashes between 2004 and 2007. Other network and socio-demographic variables are also collected from other sources. In this study, different ZCPMs are developed to predict the Number of Injury Crashes (NOICs). These models are classified into three different groups, i.e. 1) flow-based models, 2) trip-based models and 3) a combination of the two. The results show a considerable improvement of the model performance when both trip-based and flow-based exposure variables are used simultaneously in the model’s formulation. The main purpose of this study is to provide a predictive tool at the planning-level which can be applied on different TDM strategies to evaluate their traffic safety impacts.

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ANB00, Improving Transferability of Safety Performance Functions by Bayesian Model Averaging (12-3548)

A jurisdiction can import a safety performance function (SPF) from another jurisdiction or another time period through model calibration. To achieve this success, the calibrated model must sufficiently capture local road and traffic features. As proposed in the Highway Safety Manual, the model calibration factor is estimated as the ratio of the sum of observations in a local sample to the sum of predictions for the sample from the uncalibrated model. While this approach may be adequate in terms of overall goodness of fit measures, there is no guarantee that satisfactory fit will be achieved over all ranges of the covariates. This paper seeks to address this limitation by investigating a new methodology for transferring models, using four groups of sample data from Canada and Italy. First, the calibration factor approach was evaluated using goodness of fit tests. Then, local models were developed and evaluated. For these models, a wide variety of random structures for Frequentist and Bayesian approaches were explored, using generalized linear regression (GLR), nonlinear mixed fitting, or Markov chain Monte Carlo (MCMC) simulation procedures. Finally, a Bayesian model averaging approach, which integrates all considered models, was investigated as an alternative approach to traditional model selection. This methodology did improve model transferability over all ranges of covariates, suggesting that Bayesian model averaging can be a sound alternative to conventional model calibration, especially considering the flexibility and estimation ease of this technique. Moreover, by explicitly addressing model uncertainty, this approach is conceptually superior to a single “best model” one.

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ANB20, Examination of Endogeneity of Speed Limits and Accident Counts in Crash Models (12-4132)

A properly set speed limit establishes a reasonable and acceptable threshold that the majority of drivers can follow. It is fair and allows officers of the law to go after those who deviate from the rest of the pack. When a speed limit is too low, drivers are more likely to speed in order to make up for what they may believe is an unfair limit, creating a ¡°speed trap.¡± Exactly what happens when a speed limit is high is subject to much contention. Some believe that setting speed limits too high invites a higher rate of accidents and that the ensuing accidents tend to be more severe than at a site with a lower speed limit. Others argue that there are many contributing factors and that road conditions and driver behavior ¨C not speed ¨C are the main indicators of accident frequency and severity. Much literature has been devoted to this subject but the results have been widely variable. It is speculated that the variance of these conclusions can be attributed to the endogeneity of the two variables (speed limit and accident count). Traffic volumes and crash counts at a total of 298 intersections in the City of Corona were collected and analyzed using simultaneous equation models in order to eliminate the influence of the endogenous variables and obtain unbiased predictor variables. By running single equation models individually involving crash counts, speed limits and then comparing them with a simultaneous equation model (SEM) that evaluates these same variables, it was possible to determine the effect of endogeneity on the resultant estimator variables. It was found that although the difference between the estimator variables in the single and simultaneous equation models was not statistically significant in the 298 locations observed in this study, the presence of endogenous variables was confirmed. It is therefore anticipated that endogeneity might need to be accounted for in transportation models involving crash histories and speed limits in the future. Keywords: Speed limit, endogeneity, single equation models, simultaneous equation models

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ANB20, How Far Are Current Advisory Speeds from Being Optimal? Analysis Based on Safety Performance (12-4728)

Posting advisory speed signs at sharp horizontal curves to provide the driving public with a safe speed is a practice well established in the United States. The operational effectiveness of these signs has long been questioned in the current literature. The authors of this paper recently developed a function to model the expected safety effect of these signs. The function stems from a statistical analysis on crash data from 2-lane rural highways in the state of Oregon. In general, that research effort found that advisory speed signs tend to enhance safety. However, the authors also determined that advisory speed signs may not be displaying the value with the greatest potential for safety enhancement. Since the derived function proved meaningful from the engineering and human factors perspectives, these authors then extend the use this function to compute and recommend the theoretically “optimal” advisory speed. A new posting procedure resulted from this effort. The authors compared the expected performance of advisory speeds from the proposed procedure to the speeds derived from current posting guidelines. A comparable performance suggests that current guidelines are close to the hypothetically “optimal” advisory speed. In general, both the current and new computational methods performed better than speeds determined by the ball bank indicator method. This paper also presents a field validation analysis of the engine function of the new posting method. The results confirmed the meaningfulness of the function, and therefore, of the potential benefit for determining safety-based advisory speeds with the method proposed in this paper.

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ABJ80, Quantile Effects of Factors on Crash Distributions (12-2218)

Crash data are heterogeneous in nature, as they are collected from different sources, at different locations, and at different times. This data heterogeneity may cause significant bias in the estimation of standard errors for the coefficients as well as their statistical inferences. In the last decade, several promising modeling strategies have been proposed to handle over-dispersed crash data, most of which focus on estimating the conditional mean crash count. This paper introduces an alternative crash modeling approach called quantile regression (QR) in the context of a count data model. The application of QR for modeling crash frequency is illustrated and empirical results are interpreted. As a reference, Poisson-gamma, the benchmark statistical model for crash count, is employed to estimate the covariate coefficients for the mean crash count. It is demonstrated that focusing on means may miss important aspects of the data. A more detailed analysis using a QR model for crash count data confirms that crash predictors have varying impact on the different areas of the crash distribution. Moreover, the marginal effects of covariates

provide a more direct observation of changes in the quantity, rather than percentage of crash frequency, responding to a one-unit change in regressors.

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ABJ80, Study of Factors Affecting Highway Accident Rates Using Random-Parameters Tobit Model (12-2611)

A large body of previous literature has used a variety of count-data modeling techniques to study factors that affect the frequency of highway accidents over some time period on roadway segments of a specified length. An alternative approach to this problem views vehicle accident rates (accidents per mile driven) directly instead of their frequencies. Viewing the problem as continuous data instead of count data creates a problem in that roadway segments that do not have any observed accidents over the identified time period create continuous data that are left-censored at zero. Past research has appropriately applied a tobit regression model to address this censoring problem, but this research has been limited in accounting for unobserved heterogeneity because it has been assumed that the parameter estimates are fixed over roadway-segment observations. Using nine-year data from urban interstates in Indiana, this paper employs a random-parameters tobit regression to account for unobserved heterogeneity in the study of motor-vehicle accident rates. The empirical results show that the random-parameters tobit model outperforms its fixed-parameters counterpart and has the potential to provide a fuller understanding of the factors determining accident rates on specific roadway segments.

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ABJ80, Examining Poisson-Weibull Generalized Linear Model for Analyzing Crash Data (12-2793)

Over the last 20 to 30 years, there has been a significant amount of tools and statistical methods that have been proposed for analyzing crash data. Yet, the Poisson-gamma (PG) is still the most commonly used and widely acceptable model. The Poisson-Weibull (PW) distribution has only been applied once in highway safety and has not been used so far in the context of generalized linear model (GLM). This paper documents the application of the PW GLM for modeling motor vehicle crashes. The objectives of this study were to evaluate the application of the PW GLM for analyzing motor vehicle crashes and compare the results with the traditional PG model. To accomplish the objectives of the study, several PG and PW GLMs were developed and compared using two crash datasets. The results of this study show that the PW GLM performs as well as the PG GLM in terms of goodness-of-fit (GOF) statistics.

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ABJ80, Latent Variable Representation of Count Data Models to Accommodate Spatial and Temporal Dependence: Application to Predicting Crash Frequency at Intersections (12-3510)

This paper proposes a reformulation of count models as a special case of generalized ordered-response models, which then allows the introduction of temporal and spatial dependencies across multiple counts in an efficient manner. The modeling framework is applied to predict crash frequency at urban intersections in Arlington, Texas.

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ABJ80, Application of Bayesian Model Averaging in Predicting Motor Vehicle Crashes (12-3544)

Developing reliable statistical models is critical for predicting motor vehicle crashes in highway safety studies. However, the conventional statistical approach ignores model uncertainty. Transportation safety analysts typically select a single “best” model from a series of candidate models (called model space) and proceed as if the selected model is the true model. This paper proposes a new approach for deriving more reliable and robust crash prediction models than the conventional statistical modeling approach. This approach uses the Bayesian model averaging (BMA) to account for model uncertainty. The derived BMA crash model is an average of the candidate models included in the model space weighted by their posterior model probabilities. To examine the applicability of BMA to Poisson regression model and negative binomial (NB) regression model, the approach is applied to the crash data collected on 338 rural interstate road sections in Indiana over a five-year period (1995 to 1999). The results show that BMA was successfully applied to Poisson and NB regression models. More importantly, in the presence of model uncertainty, the proposed approach can provide better prediction performance than single models selected by conventional statistical techniques. Thus, this paper provides transportation safety analysts with an alternative approach to predict motor vehicle crashes when model uncertainty is suspected to exist.

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ABJ80, Comparing Statistical Methods for Analyzing Crash Frequencies (12-4472)

The paper investigates several statistical methodologies to develop prediction model for motor vehicle crash frequencies and aims to provide a framework for reasonable choice of modeling. Commonly considered statistical models for analyzing crash frequencies are extensions of Poisson regression that has proper distributional property. Recent researches in the area are particularly interested in zero-inflated Poisson (ZIP) and zero-inflated negative binomial (ZINB) regression models to take account of the excess zeroes that are prevalent in crash frequency data. The purpose of the research is to examine extensions of Poisson regression for modeling motor vehicle crash frequency and evaluate the performance of each through empirical data analysis. Cross validation method is mainly used as the evaluation criteria. This paper is particularly concerned with the suitability of using zero-inflated regression in modeling crash frequency and thus attention is given to comparing Poisson and Poisson-gamma models versus ZIP and ZINB.

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AFB10, Investigating Effect of Roadside Features on Single-Vehicle Roadway Departure Crashes on Rural Two-Lane Roads (12-2759)

One of the most important tasks in traffic safety is to investigate the relationship between motor vehicle crashes and the geometric characteristics of roadways. There is a large amount of previous work that has provided meaningful results in knowing the impacts of geometric design on crash frequency. However, little attention has been paid in finding the relationship between road departure crashes and relevant roadside features such as lateral clearance, side slope condition and driveway density. The lack of roadside data for estimating rigorous statistical models has been a major obstacle of roadside safety research for many years. The objective of this paper is to investigate the relationship between single vehicle roadway departure crashes and roadside features. Two types of models were developed: Crash frequency models using a negative binomial model and crash severity model using a multinomial logit model. The objective was accomplished by using field data collected in four districts in Texas. The results of this study show that shoulder width, lateral clearance and side slope condition has a significant effect on the roadway departure crashes. The crash frequency and severity will increase when there is a decrease in lateral clearance or shoulder width and when the side slope condition becomes worse. Driveway density is not found to be significant in influencing the crash frequency or their severity.

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ANB10, Exploring Traffic Safety and Urban Form in Portland, Oregon (12-2148)

Street layout and design, once established, are not easily changed. Urban form affects community development, livability, sustainability, and traffic safety. There has been an assumed relationship between urban form and traffic safety that favors designs with less through streets to improve safety. An empirical study to test this assumed relationship was carried out using crash data and an extensive resource of data to define the urban form. Total reported crashes in the Portland, Oregon city limits from 2005-2007 (21,492) were aggregated utilizing a uniform 0.1 mile grid for the spatial unit (n=792 cells) and modeled using negative binomial regression to study the effect of urban form – defined by variables to capture street layout, exposure, connectivity, transit accessibility, demographics, and trip making (origins and destinations). These relationships were modeled separately by mode (vehicle, pedestrian, and bicycle crashes), by crash type, and by crash injury severity. The models found that urban form variables of street connectivity and intersection density were not significant at 95% confidence for vehicle and pedestrian crashes, nor for different crash severity levels, indicating that a high connectivity grid street layout may have comparable safety to other street layout designs such as loops and lollipops, in contrast to results in earlier studies. Elasticity estimates for all models were dominated by VMT increases. Business density, population, and transit stops were significant variables in many models, underlining the importance of street layout design and planning to direct where businesses, employment, and housing development will grow to handle traffic volumes safely.

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ANB10, Evaluating Safety Estimates of Transit Operations and City Transportation Plans (12-3318)

Modern transportation planning considers issues such as traffic mobility and pollution proactively. Road safety on the other hand is usually evaluated in a reactive manner, and only when safety problems arise. Therefore, several researchers developed macro-level collision prediction models (CPMs) that could assess road safety in a proactive manner, and provide a safety planning decision support tool to community planners and engineers. However, these models could not target the safety evaluation of different goals of a typical city transportation plan. The motivation for this research arose from the necessity of developing tools that could predict the safety effect of a typical city transportation plan such as changes in the transportation and transit network configurations, and ultimately evaluate the safety level associated with alternatives of different transportation plans and policies. A set of macro-level CPMs was developed to investigate the relationship between various transportation and sociodemographic characteristics, and the overall roadway safety. The developed models considered the Poisson variations and the heterogeneity (extra-variation) on the occurrence of collisions. Data from Metro Vancouver, British Columbia were used to develop models using a generalized linear modelling approach with a negative binomial error structure. Several transit-related variables were found to be statistically significant, namely bus stop density, percentage of transit-km traveled with regard to total vehicle-km traveled, and percentage of commuters walking, biking, and using transit. The developed CPMs were shown to relate total, severe, and property damage only collisions to the implemental aspects related to the goals of long-term transportation plans.

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ANB25, Assessing International Transferability of Highway Safety Manual Crash Prediction Algorithm and Its Components (12-0190)

The Highway Safety Manual (HSM) provides an algorithm, and associated knowledge, for predicting crashes for different facility types. This algorithm requires calibration to current local conditions to enhance transferability, using a procedure that is prescribed in the HSM. However, there is no procedure for assessing transferability. To fill this void, this paper is focused on the methodology for assessing the transferability of the key HSM algorithm components, the baseline Safety Performance Function (SPF) and the Crash Modification Factors (CMFs), using the Italian road network for an illustrative case study. The calibration of the HSM crash prediction model is investigated with a dataset for two-lane two-way rural highways, to demonstrate tools that could be used by jurisdictions around the world for assessing the validity and compatibility of the CMFs and base models, as well as the performance of the complete algorithm. A comparison with the results from a similar study carried out in Canada is provided in supplementing the conclusions on the transferability of the HSM algorithm outside the United States.

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ANB25, Relationship Between Freeway Flow Parameters and Safety and Its Implication for Adding Lanes (12-0702)

Decisions to add lanes on a freeway are motivated by the need to relieve congestion. It is generally believed by the practicing engineers and planners that decreased congestion resulting from adding lanes is associated with some degree of improved safety, yet the majority opinion among researchers is that the accident rates increase with increase in the number of lanes. Despite of over 70 years of modern road building these conflicting views have not been reconciled. This paper first examines the relationship of traffic flow parameters such as volume, density, and speed to safety by calibrating corridor specific safety performance functions. On the basis of understanding this relationship, a possible explanation of the effect of adding lanes on safety is formulated. Empirical examination of the relationship of flow, density, and speed to the crash rate on selected freeways in Colorado suggests that, as flow increases, crash rate initially remains constant until a certain critical threshold combination of speed and density is reached. Once this threshold is exceeded, the crash rate rapidly rises. The rise in crash rate may possibly be explained by the fact that increase in density without notable reduction in speed produces headways so small that it becomes very difficult or impossible to compensate for driver's error. This model suggests that, following construction of additional lanes, crash rates initially decline because of lower traffic volume/density per lane. However, as development and rerouting occurs, freeways with more lanes are expected to have higher crash rates due to more opportunities for lane change related conflicts.

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ANB25, Calibration of Highway Safety Manual Safety Performance Function and Development of New Models for Rural Two-Lane Two-Way Highways (12-0972)

This paper documents the calibration of the Highway Safety Manual (HSM) safety performance function (SPF) for rural two-lane two-way roadway segments in Utah and the development of new SPFs using negative binomial regression. Crash data from 2005-2007 on 157 selected study segments in Utah provided a 3-year frequency of observed crashes for calibrating the HSM SPF and developing new models. The calibration factor for the HSM SPF for rural two-lane two-way roads in Utah is 1.16, indicating that the original HSM model underpredicts crashes in Utah. The HSM suggests that jurisdiction-specific SPFs may predict crashes with greater reliability than calibrated SPFs. Negative binomial regression was used to develop four new models for predicting crashes on rural two-lane two-way highways in Utah. The following variables were significant in each of the four models developed by this research: average annual daily traffic (AADT), segment length, speed limit, and the percentage of AADT comprised of combo-unit trucks. AADT and segment length are used in the HSM SPF; speed limit and the percentage of AADT comprised of combo-unit trucks are two additional variables that were found to be significantly correlated with observed crash frequencies. It was found that the fourth negative binomial model developed in the study would be the best SPF for predicting crashes on rural highways in Utah. As encouraged by the HSM and contemporary research, the empirical Bayes (EB) method can be applied with each jurisdiction-specific SPF because the analysis provided an overdispersion parameter for each model.

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ANB25, Crash Frequency Analysis for Urban Expressways by Considering Segment Type (12-1965)

Incidents occurring on congested urban expressways can have enormous impacts in terms of capacity reduction and commuter time loss. Minor crashes are usually neglected in the field of traffic safety, but should be considered from the perspective of congestion alleviation. This paper investigated crash frequency extracted from incident data obtained by video monitoring system, which is implemented on three expressways in Shanghai. Features of urban expressways are quite different from that of freeways, especially in length of segments between two consecutive ramps. In general, only ramp density was considered when analyzing the effect of ramps on crash occurrence and all segments were modeled together, but the differences among different types of segments in terms of varied ramp junction areas were ignored. In this analysis, disaggregate data was used by considering variation by day of week and peak/off-peak hours. Biased structure in annual aggregate data was avoided and the effect of temporal aggregation was then discussed. Segments are classified into four categories, namely merge segment, diverge segment, weaving segment and basic segment, and prediction models were established for each type of segment respectively. Results showed that temporal aggregation of data led to loss of impact factors and change in effect size. It was also found that relationship between crash frequency and its

impact factors varied remarkably among different segment types. The relationship between crash frequency and segment length is not constantly linear and segment length has a significant two-side effect on crash occurrence on expressways.

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ANB25, Calibration of Highway Safety Manual Prediction Method for Rural Kansas Highways (12-2835)

A great deal of research and resources were focused on the development of the predictive methods provided in Part C of the Highway Safety Manual (HSM). Despite these efforts, some states were still hesitant to begin implementing crash prediction due a lack of research validating the accuracy of these methods in practical application. To address this gap, the Kansas Department of Transportation (KDOT) commissioned this study to analyze both the accuracy and the practicality of using the HSM rural two-lane predictive methods on Kansas highways. This study was focused on analyzing the predictive methods in a manner that was most consistent with how they would be utilized in the KDOT project delivery process. As part of that research multiple methods for calibrating the rural two-lane segment safety performance function (SPF) were analyzed. First, all of the methods published in the HSM were analyzed to determine their accuracy. The calibrated predictions showed significant improvements versus the uncalibrated predictions and were extremely accurate when analyzed at the aggregate level. In an effort to improve the crash prediction accuracy, alternative calibration methods were considered and analyzed. These alternatives included several linear calibration methods that addressed variables that have shown a positive correlation to highway crashes in Kansas in previous research, but are not considered in the HSM. While the linear calibration methods did not perform as well on the aggregate level, they did show improvement on the project level. Ultimately, the analysis of the HSM rural two-lane segment predictions showed a favorable accuracy and has been recommended for inclusion in KDOT's safety evaluation toolbox at the project level.

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ANB25, Effects of State-Specific Safety Performance Functions, AADT Estimations, and Overdispersion Parameters on Crash Predictions Using SafetyAnalyst (12-4332)

SafetyAnalyst performs network screening using empirical Bayes approach which requires safety performance functions (SPFs) in addition to roadway characteristics, traffic, and crash data. Simple SPFs (i.e. crashes are predicted as a function of traffic alone) are used by SafetyAnalyst. These simple SPFs were generated using CA, MN, NC, OH, and WA data. Within the software, these national default SPFs are calibrated to represent the agency's data. How well these calibrated default SPFs fit another state's data is a question yet to be answered. This research aims at comparing the fit of Georgia specific SPFs and the national default SPFs calibrated to Georgia data. As hypothesized, it was found that state specific SPFs fit the data well, however, the accuracy of traffic data significantly affected the fit of SPFs. SPFs developed using longer segments and with actual traffic data have lower overdispersion parameter with minimal amount of unaccountable dispersion than the SPFs developed using segments with both actual and estimated traffic data.

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ANB25, Developing a Regional Safety Performance Function for Rural Two-Lane Highways (12-4549)

For over 30 years, crash prediction models (CPMs) have been created and analyzed, trying to find the best way to predict where crashes will occur and how to prevent them in the future. This has recently become a popular discussion and reality since the release of the Highway Safety Manual (HSM) and its CPM in 2010. However, many are still hesitant to begin implementing these methods as the accuracy can vary. This is a study testing the original HSM's CPM to a state calibrated CPM, and new, independent CPMs to find the best model for rural, two-lane highways in Kansas. Almost 300 miles of highway geometric data were collected to create these new models using negative binomial regression. The most significant variables in each model were found to consistently be lane width and roadside hazard rating. These models were compared against CPMs calibrated to be used on the HSM using nine validation segments. A difficulty to overcome was the large amount of animal-related crashes, as they account for 58.9 percent of crashes on Kansas highways. Removing those from the equation showed a large improvement in accuracy against other models created.

Authors
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ANB25, Horizontal Curves, Signs, and Safety (12-4564)

Although there has been considerable research in the past on safety at horizontal curves, data availability and quality has been the Achilles' heel of many studies. Furthermore, there is added significance to the subject of safety at horizontal curves in view of the changes in the current Manual on Uniform Traffic Control Devices (MUTCD) with respect to traffic control devices at horizontal curves. The objective of this research was to evaluate safety of horizontal curves with respect to curve geometric characteristics and sign data. The focus was on collecting a good quality large dataset to develop models and explore the relationship between safety on horizontal curves and sign types, specifically curve and turn signs. The dataset included curves on different road types to determine the difference in safety characteristics that had not been examined in the literature. The crash prediction models displayed highly significant variables showing a positive relationship with AADT, posted speed, and curve length, and negative relationship with curve radius. The results show that sharper curves (Curve Class B-F) on two-lane roads are less safe as compared to curves on freeways, multilane, and urban roads. However, further investigation is required into safety characteristics of Class A curves on freeway and multilane roads as compared to two-lane roads. Moreover, for sharper curves (Dataset 2b, Class B-F), sign usage did not appear as a significant variable meaning that on sharper curves regardless of the presence of the sign turn or curve, other influencing factors take over. The results identified variables with large significance and describe curve characteristics in greater detail. The crash prediction models will be used in safety

performance functions for horizontal curves.

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ANB25, Comparing Locally Calibrated and SafetyAnalyst-Default Safety Performance Functions for Florida's Urban Freeways (12-4730)

Freeways carry a large proportion of vehicle miles in the national roadway system. Therefore, assessing their safety performance is of special importance. Although freeway interchanges have significantly different crash and traffic flow characteristics compared to basic freeway segments, they are seldom assessed separately in highway safety analysis. This can be attributed to minimal guidance on the definition of interchange areas and lack of network databases that could allow for easy separation of such areas. Although interchange influence areas are defined in the SafetyAnalyst User Manual, specific method for separating a freeway network into interchange areas and basic freeway segments is not provided. This paper proposes a method using GIS and spatial manipulation techniques to identify and separate segments within interchange influence area from the freeway network. Once separated, safety could be evaluated on basic freeway segments and freeway segments within interchange influence areas individually. With the recent releases of advanced safety analysis tools including SafetyAnalyst and the Highway Safety Manual (HSM), states are trying to assess the need for developing agency specific safety performance functions (SPFs). Even though SafetyAnalyst provides national default SPFs calibrated to local agency data, it is believed that the use of state specific SPFs might better identify problematic sites. Using four years of crash data from Florida, state specific SPFs for both basic freeway segments and freeway segments within interchange influence areas were developed using the negative binomial (NB) model. These state specific SPFs were compared to the default national SPFs calibrated to Florida data using Freeman-Tukey R square statistic. The results show that Florida specific SPFs produce a better-fitted model than the default calibrated SPFs.

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ANB75T, Evaluation of Sight Distance and Crash Frequency at Roundabouts in the United States (12-2412)

The objective of this paper is to investigate the safety effect of different sight distance parameters at single lane roundabouts in the United Sates. Crash, traffic and geometric data were collected on 98 approaches to 26 single lane suburban roundabouts in 6 states. These sites were used to develop crash prediction models as a function of AADT and sight distance attributes. Five (5) crash prediction models were developed that predict total and rear end entry crashes per year for a roundabout approaches. Additionally, 39 of the approaches were for sites with 25 mph speed limits. For these sites observational associations were made between different sight distance parameters and crash parameters to identify possible trends Observational associations were made between the total and entry rear end crash rates and different sight distance attributes. The results of this analysis showed that as you increase the intersection sight distance, upstream approach sight distance, circulating approach sight distance and circulating sight distance the total and entry rear end crash frequencies also increase. Crash prediction models were also developed that predict total and entry rear end crash frequencies on approaches to roundabouts as a function of the sight distance parameters. The results of these models also revealed that the sight distance parameters do add value in explaining the variability of crash frequencies when compared to base models that use AADT as the only predictor variable. This work was an observational study and there are other parameters not included in this study that contribute to the variability in crashes and crash frequencies. However, moving to apply performance based standards into the state of practice requires this type of research to identify the safety implications of design decisions. These results are consistent with other studies that state exceeding sight distance standards may increase the risk of crashes which is likely a result of an expected increase in travel speeds for vehicles approaching the roundabout.

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ANB75T, A statistical analysis and development of a crash prediction model for roundabouts on high-speed rural roadways (12-4191)

Roundabouts have proven to be effective in urban and suburban environments in the United States, but little has been reported on their effectiveness in rural environments with high-speed roadways. There is no question that roundabouts reduce speeds of all vehicles at intersections and reduce the frequency of fatal and injury related crashes. This research is the first comprehensive look at roundabouts in a rural environment with high speed approaches. Nineteen intersections had ample comprehensive crash data to be evaluated and analyzed for safety performance. The findings validated the hypothesis that roundabouts in a rural environment out perform other intersection safety improvements as well as roundabouts in urban and suburban environments . A before and after crash analysis was conducted for the nineteen intersections using a negative binomial regression model . Results showed statistically significant reductions for both the total number of crashes (63%) and injury crashes (88%) when roundabouts were implemented. A before and after empirical Bayes estimation was also conducted and the results were consistent, indicating a 67% reduction in total crashes and a 87% reduction in injury crashes at these rural intersections. Furthermore, results showed that injury producing crash types, such as the angle crash, were reduced by 91%, and were statistically significant. Finally, this research produced planning level crash prediction models for both total and injury crashes at rural roundabouts on high-speed roadways which supplement the models produced in NCHRP Report 572 Roundabouts in the United States and will be considered for inclusion in the next edition of the AASHTO Highway Safety Manual.

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ANF10, On the nature of modeling boundary pedestrian crashes at zones (12-0242)

Traffic analysis zones are often delineated by the existing street network. This may result in considerable number of crashes on or near zonal boundaries. While traditional macro-level crash modeling approach assigns zonal attributes to all crashes that occur within the zonal boundary, this paper acknowledges the inaccuracy resulting from relating crashes on or near the boundary of the zone to merely the attributes of that zone. We propose a novel approach to account for the spatial influence of the neighboring zones on crashes which specifically occur on or near the zonal boundaries. Predictive models for pedestrian crashes per zone were developed using a hierarchical Bayesian framework and utilizing separate predictor sets for boundary and interior (non-boundary) crashes. It was found that the hierarchical Bayesian model accounting for spatial autocorrelation had better goodness-of-fit measures compared to the models which had no specific consideration for crashes located on/near the boundaries. Additionally, the models were able to capture some unique predictors associated explicitly with interior and boundary-related crashes. For example, the variables- 'total roadway length with 35mph posted speed limit' and 'long term parking cost' were statistically not significant from zero in the interior crash model but they were significantly different from zero at the 95% level in the boundary crash model.

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ANF10, Exposure-Based Model of Pedestrian Safety in Areas and Its Application to Identification of Townships with Pedestrian Safety Problems (12-2408)

The shortage of direct measures of pedestrian risk exposure hampers efforts to identify safety needs and to improve pedestrian safety. This paper presents an exposure-based model of pedestrian safety and its application to identifying Indiana urban and rural townships with a high risk of pedestrian crashes during. A negative binomial model was selected as suitable for this purpose. The presence of spatial autocorrelation was tested over the residuals of the developed models, and no significant autocorrelation was found. Estimation of the safety effect of the exposure variables in this study indicated a considerable difference between rural and urban areas as far as the strength of the same variables. The following variables were found to significantly affect pedestrian safety: jobs, population, intersections, road mileage, K-12 schools, and shopping centers. In addition, the number of vehicles per household and the number of days with precipitation were found to be significant as well. The developed safety performance function was used to identify Indiana townships with pedestrian safety needs. Many urban townships in Indiana experience a high number of pedestrian crashes. In most cases, the number of pedestrian crashes was explained by the large risk exposure. However, a number of rural townships exhibiting a small number of pedestrian crashes were identified as experiencing too many crashes for the risk exposure. A balanced approach to planning pedestrian safety improvements and budget allocations for them should consider both types of townships.

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ANF10, Pedestrian Injury Risk at Signalized Intersections: Exposure Measures and Geometric Designs (12-3208)

Pedestrian safety is a topic of growing concern. To better understand the environmental factors (traffic controls, geometric and land use factors) associated with pedestrian-vehicular accidents, this paper presents a methodology for quantifying pedestrian accidents at signalized intersections. For this purpose, a rich and unique intersection inventory with geometry and accident data was built and analyzed comprising a very large sample of 1 871 signalized intersections across the island of Montreal, Canada. To investigate the impact of vehicle movements, three separate definitions of risk exposure were used: completely aggregated flows, motor-vehicle flows aggregated by movement type (left, right and through movements) and disaggregated flows analyzing potential conflicts between motor vehicles and pedestrians. Various negative binomial (NB) models were fitted to the data with and without geometric design characteristics. Among other findings, vehicular traffic is found to be the main contributing factor in accordance with previous works. It was a bit surprising to see that through vehicular movements at intersections had a greater effect on accident rates than left and right turns. A separate analysis was conducted to incorporate geometric variables into the risk exposure models. Significant geometric properties included pedestrian phasing, exclusive left turn lanes, commercial entrances and exits, total crossing distance, curb extension and number of lanes. Exclusive left turn lanes, pedestrian phasing and curb extensions were found to decrease pedestrian accidents, whereas longer crossing distances, number of lanes and more commercial entrances and exits were found to significantly increase pedestrian-vehicular accidents after controlling for vehicular and pedestrian flows.

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5 Papers on crash severity prediction

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 nineteen papers dealing with crash severity prediction. Eleven papers were sponsored by the ANB20 Committee while eight papers were sponsored by other Committees.

From a methodological perspective, different methodologies were used, such as multivariate poisson lognormal models (12-0494), full Bayes estimates (12-0494), multilevel models (12-1907), ordered probit models (12-1805), bayesian ordered probit models (12-3764), random parameter ordered probit models (12-1962), ordered logit models (12-1534, 12-2626, 12-3582, 12-3607), multinomial logit models (12-0057, 12-1722, 12-2759, 12-4528), logistic regressions (12-1264, 12-1278, 12-1915), heterogeneous choice models (12-0080), data mining (12-3285).

From an applications perspective, the papers addressed departure crashes (12-1278, 12-1264, 12-1915, 12-2753, 12-2759, 12-4485), environmental factors (12-0080, 12-0494, 12-1000, 12-1907, 12-3285, 12-3582, 12-3607, 12-3764), vehicle characteristics (12-0080, 12-1000, 12-1805, 12-1907, 12-2626, 12-3285, 12-3582, 12-3607, 12-3764, 12-4528), driver characteristics (12-0080, 12-1000, 12-2626, 12-3285, 12-3582, 12-3607, 12-3764), traffic characteristics (12-0080 and 12-3607), highway characteristics (12-0080, 12-3285, 12-3764), roadside features (12-2753 and 12-2759),

The papers investigated also specific road users and vehicle types, such as pedestrians (12-1534 and 12-3285), byciclists (12-0057), older drivers (12-3582), commercial vehicle drivers 12-1264, motorcycles (12-1278 and 12-2753), trucks (12-1962 and 12-4528).

ANB20, Assessing Time and Weather Effects on Collision Frequency by Severity in Edmonton Using Multivariate Safety Performance Functions (12-0494)

Weather factors have been identified by many as one of the major environmental risks that are known to have a significant effect on collision occurrence. To investigate the impact of weather-related factors on collision risk, collision data by frequency and severity were combined with weather-related information from Environment Canada Weather Office in this study for statistical analysis. Considering the multivariate nature of the data, a multivariate model with a multiple regression link is proposed to use the number and severity of collisions as a representative outcome variable with weather-related data and a proxy of exposure added as independent variables. The multivariate model was found to predict collisions with high precision. Also, the results indicated a high correlation between severe and property-damage-only collisions which demonstrates that higher property-damage-only collisions are associated with higher severe collisions, as the collision likelihood for both levels is likely to rise due to same weather conditions, similar deficiencies in roadway design and/or other unobserved factors. For severe collisions, there was a significant declining annual trend, significant decrease during weekends and holidays, significant inverse relationship with mean temperature and a significant positive relationship with total snow fall and total precipitation. On the other hand, for property-damage-only collisions, there was a significant growing annual trend, significant decrease during weekends and holidays, significant inverse relationship with mean temperature and a significant positive relationship with total and previous snow fall and total precipitation. It is worth mentioning that the above results reflect the analysis of daily collision and weather data for the entire City of Edmonton (Alberta, Canada) over a course of 11 years.

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ANB20, The Roles of Vehicle Footprint, Height, and Weight in Crash Outcomes: Application of Heteroscedastic Ordered Probit Model (12-1805)

This paper uses a heteroscedastic ordered probit model to distinguish the effects of vehicle weight, footprint and height on the severity of injuries sustained by vehicle occupants while controlling for many occupant, roadway and other characteristics. Model results suggest that the impacts of physical vehicle attributes on crash outcomes depend on the number of involved vehicles, and typically are more significant in one-car crashes than in two-car crashes. While larger-footprint vehicles and shorter vehicles are estimated to reduce the risk of serious injury for their occupants in single-vehicle crashes, they appear to be less crashworthy in two-vehicle collisions. Heavier vehicles are anticipated to be more crashworthy regardless of crash type. Under evolving U.S. fuel economy standards, moderate changes in light-duty-vehicle weights, footprints, and heights are estimated to have relatively small impacts on crash severities, while other factors, such as seat belt use, driver intoxication, and the presence of roadway curvature and grade influence crash outcomes much more noticeably.

Authors

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ANB20, Analysis of Injury Severity Outcomes of Highway Winter Crashes: Multilevel Modeling Approach (12-1907)

This paper presents a multilevel modeling framework for relating the injury severity of winter road collisions to various influencing factors such as weather and surface conditions, traffic conditions, road design and vehicle and driver characteristics. Thirty one road sections from across the province of Ontario, Canada were selected for this analysis, each representing an actual patrol route covered by a specific maintenance yard. Collisions over a period of six years (2000-2006) were analyzed using multilevel logistic regression for the conditional probability of a collision resulting in one of the pre-defined severity levels. Three levels of aggregation were considered for the data, namely: occupant based, vehicle based and collision based. It was found that a multilevel multinomial unordered logit model has a better fit to the data than multilevel sequential binary logistic models and multilevel multinomial ordered logit models. Furthermore it was found that results obtained from occupant based data are more reliable than vehicle and collision based data. It was found that factors related to drivers (age, sex, action, condition), collision impact location, road characteristics (condition, alignment, number of lanes), vehicle data (age, type, condition, maneuver, number), personal choices (position in vehicle, safety equipment used), weather conditions (precipitation type & intensity, temperature, wind speed, visibility), day of the week, lighting, speed limit, traffic volume and road surface conditions have statistically significant effects on collision severity outcome. In general, results indicate that poor weather, road surface conditions, high traffic volume, young and male drivers, new vehicles and good lighting conditions are associated with injury severity levels.

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ANB20, Rural Road Departure Crashes: Why is Injury Severity Correlated with Lane Markings? (12-1915)

This study aimed to determine if injury outcome is related to the presence of lane lines in road departure crashes on rural 2-lane roads. Cases were extracted from a nationally representative sample of crashes, where supplemental crash reconstructions were performed as part of NCHRP Project 17-22. The data set consisted of 851 road departure collisions that corresponded to 271,603 weighted collisions. The majority of cases (55%) occurred on 2-lane roads with undivided, 2-way traffic. Of all paved 2-lane, undivided roads with 2-way traffic, only 19% of collisions did not have lane markings yet these collisions accounted for a disproportionate 48% of seriously to fatally injured drivers. A logistic regression found that the presence of lane marking at the side of the first lane departure decreased the odds of serious injury for the driver, adjusted for belt use and departure velocity. The finding that the presence of lane markings was correlated with injury severity in road departure crashes was unexpected. Roadside factors, such as maximum sideslope and speed reduction from departure to impact, did not appear to explain the difference in injury outcome. Only 42% of drivers, however, were wearing their seat belt in crashes on unmarked roads compared to 67% of drivers on marked roads. In this sample lane marking presence was correlated to seat belt use. This result suggests that the primary explanation for higher injury levels on unmarked roads was lower seat belt use, not the absence of lane markings.

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ANB20, Severity of Single-Vehicle Crashes During Holidays (12-2626)

This research examined the effects of different contributing factors on the severity of single-vehicle crashes occurring during holidays in the years 1999-2008 in Alberta, Canada. Urban and rural crashes were analyzed separately to isolate the location effects. Partially constrained generalized ordered logit models were estimated for each of the specified location types with three possible severity outcomes: property damage only, minor injury and serious injury. Our results indicated that various temporal, crash, environmental, roadway, demographic and vehicular attributes significantly affected holiday crash severity and the location specific models outperformed the joint model. Moreover, the substantial differences in marginal effects demonstrated that different variables affected urban and rural holiday crashes differently.

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ANB20, Exploring Factors Contributing to Injury Severity at Freeway Merging and Diverging Locations in Ohio (12-3607)

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. Factors such as driver-related, traffic-related, environment-related and geometric design-related were considered when developing statistical models to predict the effects of these factors on the severity of injuries sustained from motor vehicle crashes at merging and diverging locations. Police-reported crash data at selected freeway merging and diverging areas in the state of Ohio was used for the development of the models. A generalized ordinal logit model also known as partial proportional odds model was applied to identify significant factors increasing the likelihood of one of the five KABCO scale of injury severity: no injuries, possible/invisible injuries, non-incapacitating injuries, incapacitating injuries, or fatal injuries. The results of this study show that semi-truck related crashes, higher number of lanes on mainlines, higher number of lanes on ramps, speed related crashes, angle collisions, and alcohol related crashes tend to increase the likelihood of sustaining severe injuries at both freeway junction locations. In addition, female and seniors are more likely to sustain severe injuries at freeway merge/diverge locations. Lane-ramp configuration type D and poor lighting condition significantly increase the likelihood of severe injury crashes at diverging areas only.

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AFB10, Investigating Effect of Roadside Features on Single-Vehicle Roadway Departure Crashes on Rural Two-Lane Roads (12-2759)

One of the most important tasks in traffic safety is to investigate the relationship between motor vehicle crashes and the geometric characteristics of roadways. There is a large amount of previous work that has provided meaningful results in knowing the impacts of geometric design on crash frequency. However, little attention has been paid in finding the relationship between road departure crashes and relevant roadside features such as lateral clearance, side slope condition and driveway density. The lack of roadside data for estimating rigorous statistical models has been a major obstacle of roadside safety research for many years. The objective of this paper is to investigate the relationship between single vehicle roadway departure crashes and roadside features. Two types of models were developed: Crash frequency models using a negative binomial model and crash severity model using a multinomial logit model. The objective was accomplished by using field data collected in four districts in Texas. The results of this study show that shoulder width, lateral clearance and side slope condition has a significant effect on the roadway departure crashes. The crash frequency and severity will increase when there is a decrease in lateral clearance or shoulder width and when the side slope condition becomes worse. Driveway density is not found to be significant in influencing the crash frequency or their severity.

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AFB10, Analysis of Injury Severity on State Routes Incorporating Pavement Quality Using Bayesian Ordered Probit Model (12-3764)

The injury severity of traffic-related accidents has been studied by many researchers in the last few decades. A growing body of literature has focused on the impacts of various factors on the outcome of accidents using statistical analyses based on Maximization Likelihood (ML) estimation methods. However, the evaluation of some factors is still in dispute and until this point, no studies have taken into account pavement quality as a factor of interest. This study attempts to estimate the influences of some key factors including pavement quality on injury severity. Four types of accidents including single-vehicle accident, two-vehicle rear-end crash, two-vehicle sideswipe crash, and two-vehicle angle crash occurring on Tennessee State Route highways from 2004 to 2008 were analyzed. The Ordered Probit (OP) models were fitted on each accident type to identify the variables that contribute most significantly to the outcome. The Bayesian Ordered Probit (BOP) models were simulated afterwards with the selected variables from the OP models. The results indicate that pavement quality is significant in all four collision types. In addition, AADT, median width, lane width, vertical alignment, number of lanes, speed limit, rural or urban, type of terrain, peak hour, light condition, weather condition, driver age, driver sex and vehicle type, as well as the interaction between Pavement Serviceability Index (PSI) and light condition were found to be significant in all or some of these collision types. Differential effects of light condition, driver sex, driver age and vehicle type were found between single-vehicle accident and two-vehicle accident, and the influence of some factors varied among the three types of two-vehicle accident as well.

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AHB70, Modeling Impacts of Access Designs on Injury Severity at Midblock Segments of Urban Multilane Highways Using Heterogeneous Choice Regression (12-0080)

This paper presents results of a study that developed a statistical model to evaluate impacts of 6 types of access design on crash injury severity at midblock segments on urban multilane highways. A heterogeneous choice model was developed in this study to identify the significant factors contributing to crash injury severity and to quantify the impacts of access design on crash injury severity at midblock segments on urban multilane highways. For model development, a total of 153 access points with different access design were selected from Florida state roads and 1830 crashes occurred in these access points for 3 years (2008-2010) were collected for modeling. Results of this study shows at four-leg access points, changing full median opening to directional median opening will decrease the probability of severe injury or fatality by 2.44% and that of no-capacitating injury by 8.5%. And at three-leg access points, replacing full median opening with direction median opening will not influence crash injury severity significantly. Closing median opening will decrease injury severity compared to other access designs. Other significant factors contributing to injury severity at access points were also identified as crash type, left-turn storage space on major roads, pavement surface width, outside shoulder width, median width, speed limit, AADT, high density residential area, day light condition, age of driver at-fault, and truck involvement. The results are expected to assist transportation agencies in implementing proper countermeasures to improve safety performance at midblock segments of urban multilane highways.

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ANB10, Effects of Drivers' Action on Severity of Emergency Vehicle Collisions (12-1000)

Emergency vehicles (EV) are used to provide essential services to the society in the event of an emergency. Hence, crashes involving these vehicles are a concern and investigating the crash characteristics of EV is the first step towards improving the safety of these vehicles. In particular, the identification of the contribution of any improper behaviour/actions of the drivers involved is important for recommending any programme to the proper authorities involved to bring the behavioural modification and for providing countermeasures to improve the road safety. This study attempts to identify the drivers' actions that contribute significantly to the severity of a crash involving at least one EV using data from the Province of Alberta for the years 1999-2008. In addition, the impact of different control variables formed from crash environment, demographic, vehicle, environmental and other behavioural factors will also be explored. Our results indicate that drivers' violation of the road rules significantly contributed in increasing the severity of crashes. Non-EV drivers' errors, non-repairable damage of the vehicle, collision of EV with two-wheeler and sun glare were some of the other variables that had significant influence on crash severity.

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ANB25, Injury Outcomes and Costs for Cross-Median, Median Barrier, Median Entry, and Run-off-the-Road Crashes (12-4485)

Lane departure crashes (LDC) have the capability of causing very serious injuries or even death. The costs associated with LDC can be difficult to compute, which might impede future benefit-cost analysis or decision-making. The objective of this research was to quantify the injury outcomes and develop reliable and comprehensive injury costs for median-entry crashes (MEC) and run-off-the-road crashes (ROTR) and compare with costs of cross-median crashes (CMC) and median-barrier crashes (MBC). A three-step methodology was used to quantify the crash costs for each crash severity and type. MEC and ROTR crashes in 2006 and 2007, in addition to CMC and MBC crashes between 2001 and 2007 in Wisconsin, were identified and used in this analysis. The Wisconsin Crash Outcome Data Evaluation System (CODES) database provided comprehensive injury costs based on the injury types and severities suffered by participants in study crashes. As expected, multi-vehicle CMC result in more total injuries and more severe injuries than single-vehicle CMC, MEC, ROTR and MBC. Costs by crash severity vary significantly between different crash types. On average, injury crashes could cost between $115,516 for MBC and $586,933 for multi-vehicle CMC. Results indicate that using one set of crash costs for all crash types may bias any evaluation. Using crash specific costs can lead to a more realistic benefit-cost analysis and enable better decision-making.

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ANB60, Temporal Modeling of Highway Crash Severity for Seniors and Other Involved Persons (12-3582)

This paper describes analysis using ordinal logistic regression to uncover temporal patterns in the severity level (fatal, serious injury, minor injury, slight injury or no injury) for persons involved in highway crashes in Connecticut. Existing state sources provide data describing the time and weather conditions for each crash and the vehicles and persons involved over the time period from 1995 to 2008 as well as the traffic volumes and the characteristics of the roads on which these crashes occurred. Controlling for characteristics known to be related to severity, e.g., age, crash type, and road characteristics, statistical modeling enables us to predict the probability of an individual to have a specific severity outcome if he/she is involved in a crash. Specifically, this paper investigates overall, long-term, time dependant and seasonal trends in senior drivers and travelers (65 years and over). This study also accounts for special conditions in data distribution and modeling in order to point to significant impacts on public health and safety as seniors become a larger portion of the population. Findings indicate an overall increase in increased crash severity probability for seniors, as well as a distinct seasonal trend. Other time-dependant trends in the data were visible, but not significant.

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ANB70, Run-Off-Road Crashes of Commercial Vehicle Drivers (12-1264)

The number of commercial vehicles on US roads has grown dramatically over the past few decades. Although the number of large trucks involved in fatal and injury crashes has decreased over the past 20 years, large trucks still have a higher fatal crash involvement rate than passenger cars. This study seeks to gain insights on the impact of commercial driver characteristics on crash severity with respect to single-vehicle, run-off-road (ROR) crashes. A logistic model was conducted using large truck crash data from the Washington State Department of Transportation (from year 2006 to 2009). The model predicted the effects of truck driver distraction, inattention, speeding, seatbelt usage, and drowsiness/fatigue on the likelihood of a ROR crash involving injury or fatality. Other factors such as environmental conditions, roadway types and truck-related factors were controlled in the model. The results indicated that speeding, drowsiness/fatigue, distraction and inattention had strong effects on increasing crash severity. As expected, using seatbelts significantly decrease the severity of a ROR crash. The study confirms that several driver factors observed in other studies on crash likelihood are also significant for ROR crashes involving large trucks.

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ANB70, Crashes Involving Large Trucks: Exploratory Injury Severity Analysis (12-1962)

In recent years, a growing concern related to large-truck accidents has increased due to potential economic impacts and level of injury severity that can be sustained. Yet, studies related to large-truck involved crashes are scarce and lack human behavior factors that can greatly influence crash outcomes. In this study, we present an analysis of data from the fusion of several national data sets addressing large-truck involved injury severity. This is done by considering human, road-environment, and vehicular factors in large-truck involved crashes on U.S. interstates. A random parameter ordered probit model was estimated to predict the likelihood of five injury severity outcomes—fatal, incapacitating, non-incapacitating, possible injury, and no injury. The modeling approach accounts for possible unobserved effects relating to human, vehicular, and road environment factors not present in the data. Estimation findings indicate that the level of injury severity is highly influenced by a number of complex interactions of factors and that the effect of the some of the factors can vary across the observations.

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ANB70, Evaluation of Factors Influencing Large-Truck Crash Severity (12-4528)

This paper presents an evaluation of large truck safety issues described in historical crash data. The understanding of factors associated to the severity of large truck crashes serves to define potential countermeasures and to maximize the allocation of resources destined to large truck safety. Moreover, overturn crashes involving large trucks are analyzed considering factors such as body type, vehicle configuration, gross weight and number of axles in order to identify if some of these characteristics increase the likelihood of large trucks to overturn. In addition, a statistical analysis is conducted to determine a combination of explanatory variables that can better predict the severity of large truck crashes. The results associated to this paper serve as guidelines for the allocation of large truck safety funds in locations, vehicles or users that experiment higher incidence of crashes involving heavier vehicles. Also, the findings can be used to generate safety strategies as countermeasures to elements that may be increasing the fatal and incapacitating large truck crashes.

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ANF10, Effects of Distracted and Impaired Drivers on Severity of Pedestrian Injuries (12-1534)

Crashes that involve pedestrians are of substantial interest due to their vulnerable status in the transportation system. Most studies on the severity of pedestrian injuries examine the influence of factors associated with the crash and pedestrian, but rarely, on the driver. This study extends the previous research by examining drivers' characteristics on the injury severity of pedestrians, and more specifically the potential impact of distracted and impaired drivers. This was achieved using an ordered logit model and crash data for the State of Washington during the period 2006 to 2009. The findings suggest that pedestrians were more likely to be severely injured if a driver was distracted by non-technology distractions, speeding, had consumed alcohol, or was fatigued. The factors related to this association with non-technology-related driver distractions will need to be examined in a more controlled environment. This study does demonstrate that the behavior of the driver substantially increased the likelihood of pedestrians experiencing more severe injuries. Future work should extend these findings to examine the severity of injuries among other vulnerable roadway users (e.g., bicyclists and motorcyclists).

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ANF10, Clustering Regression Approach: Comprehensive Injury Severity Analysis of Pedestrian-Vehicle Crashes in New York, United States, and Montreal, Canada (12-3285)

Understanding the underlying relationship between pedestrian injury severity outcomes and factors leading to more severe injuries is very important in dealing with the problem of pedestrian safety. To investigate injury severity outcomes, many previous works relied on statistical regression models. There has also been some interest for data mining techniques, in particular for clustering techniques which segment the data into more homogeneous subsets. This research combines these two approaches (data mining and statistical regression methods) to identify the main contributing factors associated with the levels of pedestrian injury severity outcomes. This work relies on the analysis of two unique pedestrian injury severity datasets from the City of New York, US (2002-2006) and the City of Montreal, Canada (2003-2006). General injury severity models were estimated for the whole datasets and for sub-populations obtained through clustering analysis. This paper shows how the segmentation of the accident datasets help to better understand the complex relationship between the injury severity outcomes and the contributing geometric, built environment and socio-demographic factors. While using the same methodology for the two datasets, different techniques were tested. For instance, for New York, latent class with ordered probit method provides the best results. However, for Montreal, the K-means with multinomial logit model is identified as the most appropriate technique. The results show the power of using clustering with regression to provide a complementary and more detailed analysis. Among other results, it was found that pedestrian age, location at intersection, actions prior to accident, driver age, vehicle type, vehicle movement, driver alcohol involvement and lighting conditions have an influence on the likelihood of a fatal crash. Moreover, several features within the built environment are shown to have an effect. Finally, the research provides recommendations for policy makers, traffic engineers, and law enforcement to reduce the severity of pedestrian-vehicle collisions.

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ANF20, Modeling Bicyclist Injury Severity: Focus on Impact of Alcohol and Drug Use (12-0057)

This study examined the impact of alcohol and drug use on bicyclist injuries caused by bicycle-motor vehicle crashes. We used six-year data from the city of Jacksonville, Florida. Descriptive statistics results showed that with data involving alcohol/drugs there was 22.12% incapacitating injury outcomes and 16.81% fatal outcomes while with the data not involving alcohol/drugs there was 11.11% incapacitating injury outcomes and only 1.25% fatal outcomes. Due to this discrepancy, crashes involving alcohol and/or drug use and those not involving alcohol and/or drug use were analyzed separately to identify whether there exist specific factors explaining the discrepancy in injury severity among the two groups. In addition to estimating separate multinomial logit (MNL) models for each data set, a model was estimated using combined data. Both MNL models estimated with separate data indicated that the following factors which were identified as significant with combined data were not significant: night time, fault motor vehicle turning right and fault motor vehicle changing lanes. However, whether the crash occurred at the intersection and whether the roadway surface was dry were significant variables in the models estimated with separate sub-data but not in the combined-data analysis. To compare the effect of the variables on injury severity for crashes involving alcohol/drugs and those not involving alcohol/drugs, we computed elasticities. The results indicated that variables that are significantly affecting the injury outcome when considering crashes involving alcohol and/or drug use are not necessarily significant when considering crashes not involving alcohol and/or drug use. Even when a variable was found to be influential on both data sets, there was a difference in what bicyclist injury severity is impacted. The only factors found to have effect on severity for both sub-data sets (although inconsistent on the direction of the effect on some injury levels) were bicyclist age and whether or not the crash occurred on dry surface.

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ANF30, Fatality Risk Mitigation for Rural Motorcycle Collisions with Trees and Utility Poles (12-1278)

Around 200 motorcycle fatalities result from rural roadway departures into trees or utility poles in the United States annually. A logistic regression model for calculating the fatality risk for motorcyclists colliding with fixed objects was previously developed by the authors. In this paper, the model is used to estimate the fatality risk of motorcyclists colliding with trees and utility poles following a departure from a rural roadway. Real-world data of fatal cases from 2000 to 2009 in the United Sates is collected, and a fatality risk analysis is performed to investigate the benefits that various road safety measures may have had in the reduction of the fatality risk in these cases. Safety measures include reducing speed, helmet use and the installation of barriers to protect the motorcyclists from impacting the trees or poles. The benefits are expressed in terms of the resulting reductions in fatality risk, calculated using the logistic regression model. The road safety measures are discussed in terms of their relative benefit to

reducing the fatality risk of motorcyclists, in rural roadway departure collisions with trees and utility poles.

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ANF30, Characteristics of Injuries in Motorcycle-Barrier Collisions in Maryland (12-2753)

Motorcycle to barrier collisions are more serious than many other motorcycle crash modes, such as collisions with only the ground or passenger cars. In order to identify the potential need for design improvements to traffic barriers to reduce the severity of these crashes, the injuries incurred during these collisions must first be better understood. The objective of this study is to determine the type, relative frequency, and severity of injuries incurred in motorcycle to barrier crashes in Maryland. The Crash Outcome Data Evaluation System (CODES) was used to analyze motorcycle crashes in Maryland from 2006-2008. CODES links police-reported crashes to hospital data, providing detailed information about the injuries incurred during the collision. This study focused on four different crash modes for motorcyclists: single-vehicle barrier collisions, single-vehicle fixed object collisions, multi-vehicle collisions, and single-vehicle overturn collisions. The most commonly injured regions for all motorcycle crashes were the upper and lower extremities – over 70% of motorcyclists involved in the crashes analyzed suffered an injury to the upper and/or lower extremities. Motorcyclists involved in barrier collisions were more likely to suffer a serious injury to the thorax than motorcyclists involved in overturn-only collisions. Additionally, severe lacerations were more common in motorcycle collisions with barrier than overturn only collisions.

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6 Papers on network screening

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, is the first step of the highway safety management process. It is vital that a sound procedure be used in network screening; otherwise, resources will be wasted on locations that are incorrectly identified as unsafe while those that are unsafe will remain untreated.

The Subcommittee identified thirteen papers dealing with network screening. Six papers were sponsored by the ANB20 Committee, two papers were sponsored by the ANB00 Section, and five papers were sponsored by other Committees.

From a methodological perspective, different methodologies were used, such as hierarchical Bayesian logistic regression models (12-1802), the empirical Bayes method (12-4070), integration of simulated traffic conflicts with procedures based on observed crashes (12-2271), composite ranking methods (12-3349), spatial analysis methods (12-3162, 12-4516, 12-3788), crash injury severity models (12-4733), proportion methods (12-1424), and segmentation methods (12-2293),

One papers investigated network discretization methods and the intersections safety impact zone (12-2271).

To test the effectiveness of the different network screening method, simulation based performance measures were defined (12-2271).

From an applications perspective, the papers addressed several issues, such as freeways (12-2293), signalized intersections (12-2271 and 12-2779), unsignalized intersections (12-2271 and (12-2293), and deer-vehicle crashes (12-4516).

ANB20, Comparative Analysis of Bayesian Methods for Identifying Highway Locations with High Proportions of Hot Spots (12-1802)

The identification of highway system locations having safety problems, or “hot spots,” is an important first step in safety management. Most techniques for identifying such locations have utilized greater than expected crash frequencies for making this determination. However, statistical techniques utilizing higher-than-expected proportions of target crashes can also be used to identify such sites. The recently released Highway Safety Manual (HSM) includes such a technique. This method identifies crash prone locations by making inferences from a Bayesian posterior beta-binomial probability distribution of the crash rate at each location. For this research, another Bayesian method is developed and compared to the current HSM methodology. Specifically, a hierarchical Bayesian logistic regression model is used to directly model individual site effects, including traffic volume. Site specific inferences can then be made from a Bayesian posterior model. For this method, a mixture of three normal distributions was used to estimate site effects, rather than a typical single normal distribution. Direct comparison of these methodologies demonstrated that the hierarchical Bayesian model to be better suited for all distributions, but particularly for multimodal or sparsely distributed data. Future areas of research are also identified.

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ANB00, Integrating Observational and Traffic Simulation Models for Priority Ranking of Unsafe Intersections (12-2271)

Observational models based on reported accident history is the most common approach used to identify unsafe sites for priority intervention. Observational models are good at predicting higher severity accidents but ignore higher risk vehicle interactions that failed to result in accidents in the historical data (e.g. near misses). Proponents of microscopic simulation models argue that ignoring these higher risk interactions can severely understate the safety problem at a given site and lead to misallocation of scarce treatment funds. This paper takes the position that a complete understanding of safety problem at a given site can only emerge if both accident potential and traffic conflicts are taken into account. A priority ranking model is presented that integrates estimates from observational accident prediction models with an analysis of traffic conflicts. Traffic conflicts are based on simulated vehicle interactions and deceleration requirements for different traffic scenarios. The suitability of the approach for priority ranking of sites is assessed using six different ranking approaches: accident frequency, empirical Bayes, potential for safety improvement, conflict frequency, conflict rate (sum and cross product of traffic volume) and the integrated model. Priority ranking is evaluated using five different test criteria: site consistency, method consistency, rank difference, total rank score, sensitivity and specificity. These models are applied to a sample of 58-signalized intersections from Toronto for the period of 1999 to 2006. The integrated model was found to yield better results for the five evaluation criteria.

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ANB20, Discretization of Road Networks for Safety Evaluation with Consideration of Intersection Impact Zones (12-2779)

The goal of safety management is to reduce the number and severity of crashes in transportation networks. One of the methods of safety management is identifying roads that experience an excessive number of crashes by comparing the actual number of crashes to the exposure-based predictions. The identification task typically includes dividing the road network into intersections and segments in such a way that independent prediction of safety at these components can be defended. There is an evidence, however, provided by recent research that the assumption of independence can be violated leading to biased safety predictions. This paper proposes a refined road network discretization and accounting for the safety impact of intersections on nearby short segments. This was accomplished by including the “distance-to-intersection” variables to the safety performance functions for segments. Three network discretization methods including the proposed one are presented and discussed based on their application to the Indiana state road network. Considerable differences between the average safety impact zones of signalized and unsignalized intersections have been detected. Rural signalized intersections tend to have very short impact zones while rural unsignalized intersections are influential over greater distances. For urban areas, unsignalized intersections have a short impact zone while signalized intersections are influential over greater distances. Potential sources of these differences were discussed and future work was detailed.

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ANB20, Spatial Analysis Methods for Identifying Hazardous Locations on Expressways in Korea (12-3162)

Identifying hazardous locations on highways is an essential step for safety improvement programs and projects since it provides decision makers with a logical and scientific basis for the allocation of budgets and other resources in a cost-effective manner. There have been numerous studies into methodologies for identifying hazardous locations; however, most have not considered spatial interactions between traffic accidents. In this paper, we suggest two spatial analysis methods using geographic information systems for identifying hazardous locations on expressways: the geographically weighted regression method and the kernel density estimation method. Geographically weighted regression can verify the effect of spatial dependency and heterogeneity on the outbreak of traffic accidents. Kernel density estimation is used to identify crash-clustered areas with appropriate bandwidths and kernel functions. The suggested methods have been applied to a case study at Gyeongbu Expressway in Korea with 3-year crash data. The results imply the necessity of 1) examining spatial dependency and spatial heterogeneity in accident analyses and 2) exploring hazardous locations based on the crash severity as well as the frequency.

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ANB20, An Evaluation of Crash Frequency, Crash Severity, and Composite Rank Methods for Hotspot Identification (12-3349)

An important step in highway safety analysis is the identification of hotspots. Various methods are currently used for hotspot identification (HSID). This paper proposes two methods, first, crash factor method (CFM) that incorporates crash severity in addition to annual average daily traffic (AADT), period of analysis and length of segment. Second, this paper introduces a composite rank method, F1, based on principal component analysis used to overcome existing approaches that utilize the sum or average of rankings based on procedures that may or may not be reliable. The HSID methods, CFM, F1, the empirical Bayes (EB), the crash rate (CR), the equivalent property damage only (EPDO), the empirical Bayes supplemented with crash severity (EBCS), and the sum-of-ranks (SOR) (a composite rank method) methods are evaluated using three tests based on empirical data and five simulation based performance measures. To ensure detailed assessment, the evaluation was carried out for the entire length of the highway i.e., beyond the top 1 to 10% of hotspots commonly tested. The results from the evaluation demonstrate that the EB, CFM, and F1 methods performed consistently and are recommended for use. The CR method is not recommended for HSID based on inconsistent results obtained.

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ANB20, Comparison of Methods to Identify Deer-Vehicle Crash Hot Spots (12-4516)

This project evaluated the advantages and disadvantages of two methods to examine the underlying distribution of point data and six methods to identify and prioritize DVC hotspots. The methods tested included those currently used by state DOTs, as well as other methods identified in a literature review, and consisted of average nearest neighbor distances and Moran's I to identify the underlying distribution of the data, and expert analysis, visual analysis, density-based measures, models, and two types of spatial statistics to identify hotspots locations. Each approach was applied to four different DVC data sets provided by the Iowa and New York State DOTs, the results produced by each method were compared, and each method was also evaluated based on the level of expertise and resources needed for implementation. The results of the comparison do not indicate a single "best" method to identify DVC hotspots, but model-based approaches and spatial statistics appear to offer advantages because meeting assumptions required for their implementation reduces the subjectivity of results interpretation. Applying multiple approaches and looking for the locations that are repeatedly identified as a hotspot may yield the best results. The project was funded by the Deer-Vehicle Crash Information and Research (DVCIR) Center.

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ANB20, Development and Application of Crash Injury Severity Model in Hot-Spot Detection (12-4733)

Road traffic fatalities and injuries pose significant social and economic impact all over the world. In developing countries like India, nearly 2% of GDP is lost every year, which is enormous in terms of loss of productivity and property damage. However, systematic data collection and scientific research on road traffic crashes are rare in India. This study makes an attempt to present statistical evidence showing how different characteristics such as seasonal variation, vehicle type, road user's attributes and collision type will influence probabilities of sustaining different levels of injury severity in motor vehicle accidents. To perform this different injury severity levels such as crashes involving property damages, minor injuries, major injury and fatalities are analyzed using ordered probit model. A total of 1100 accident records from National Highway 6 in Howrah district for years 2007, 2008 & 2009 are considered for this study. Results indicate that factors such as location of the crash, time of occurrence of the accident, the vehicles involved in the accidents as well as the maneuver of collisions are the four most important attributes that are very significant in explaining crash severity It has also been observed that accidents occurring near intersections are relatively less severe than accident occurring on roadway segments. Pedestrians, motorcycles, bicycle and auto-rickshaws are observed to sustain higher levels of injury severity than other users. Potential use of the results from this crash severity model is explored in detecting crash hotspots, especially in the absence of quality data.

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ABJ80, Comparing the Performance of Sliding Moving Window, Peak Searching, and Continuous Risk Profile Methods for Identifying High Collision Concentration Locations (12-2293)

This paper documents findings from evaluating performances of three different methods for segmenting freeway sites for the purpose of identifying high collision concentration locations: Sliding Moving Window (SMW), Peak Searching (PS) and Continuous Risk Profile (CRP). The traffic collision data from sites segmented in each method were used to estimate excess expected average crash frequency with empirical bayes adjustment with respect to two different sets of Safety Performance Functions (SPFs): one set of SPFs currently being used by California Department of Transportation (Caltrans) and the other set developed in present study. The estimates from each of the methods were then used to rank the detected sites to be compared with known true hot spots (THS). The input requirements for each of the three methods were identical, yet their performance varied. The findings from comparing the performance of each method are documented in the paper.

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ABJ80, Guidelines for Choosing Hot-Spot Analysis Tools Based on Data Characteristics, Network Restrictions, and Time Distributions (12-3788)

A number of studies have shown different results in identifying crash hot-spots using different methods such as repeatability analysis, Moran I, Getis-Ord (Gi*), and Kernel Density Estimation (KDE). However, few researchers have addressed the reasons that cause the above differences; nor have they provided appropriate guidelines to select appropriate method based on their results. Also, a limited number of studies have analyzed crash data combined with other types of data, such as crime data. In this study, we present a strategy for choosing the appropriate hotspot analysis tool according to this study's limitations, data characteristics, and the study's objectives. This study used crash and crime data provided by the College Station Police Department. Two important issues were addressed: (1) how to apply data characteristics to the problem of hot-spot identification (e.g., network restrictions for crashes, different hot-spot definitions for crimes and crashes), and (2) how to incorporate spatial-time distributions in order to identify hot-spots. For the first issue, our solution was to apply network distance instead of straight-line distance as the point distance for any calculations, set a spatial limit of KDE, and to combine KDE and Gi* maps to capture the problem area within the high risk and cluster patterns. For the second issue, a spider graph was used to identify the temporal patterns of events occurring at different time scales: daily and weekly. Then a co-map, a graph which combines serial KDE maps according to the times of occurrence of certain events, was used to demonstrate the spatial-temporal interactions of the various events. The framework of this study can be used to identify problem locations for crashes, as well as other related data.

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ANB25, Identifying High-Collision Locations Without Traffic Volume Data (12-1424)

Safety network screening is used to identify road locations (particularly intersections and roadway segments) which exhibit an abnormally high number of expected collisions or an unusually high proportion of a certain configuration of collisions. The current state-of-the-art network screening methods rely on safety performance functions (SPFs) that require traffic volume as an input, but many cities in Canada, including the City of Saskatoon, do not collect traffic volume for every single segment within the city limits. Lack of traffic volume data for a study network severely restricts the applicability of a SPF-based network screening method. The binomial and the beta-binomial tests, however, are formal collision diagnosis tests that can be used to screen roadway networks that include roadway segments for which traffic volume data are not available. Unfortunately, previous studies have applied these two collision diagnosis tests without explicitly defining the circumstances that indicate which test is preferable. This study uses a formal statistical test known as the "overdispersion test" to determine when there is a need to apply the beta-binomial test instead of the binomial test to screen a roadway network. The study targeted uncontrolled major arterial segments in Saskatoon using five years (2005-2009) of collision data for the two most frequent collision configurations: rear end collision and side swipe same direction collision. We used ArcGIS to develop collision maps that visually display the screening results. The collision map will facilitate the governing agencies' decision-making processes when selecting appropriate safety countermeasures to reduce target collision configurations at screened locations.

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ANB25, Comparing Highway Safety Manual Predictive Method to Traditional Ranking Methods: Case Study of Intersections in Corvallis, Oregon (12-4070)

An intersection, due to its vehicle and pedestrian conflict movements, experiences complex traffic situations that might contribute to crashes. It is important to develop a transportation safety planning process that correctly identifies hazardous locations so that an agency can implement improvements that provide the roadway users a safe transportation system. The predictive method in the Highway Safety Manual (HSM) provides quantitatively reliable, science-based estimates for urban and suburban intersection and segment locations (AASHTO, 2010). This method incorporates traffic volume, site geometric characteristics, and traffic control features to approximate predicted crashes. The procedure then applies the Empirical Bayes (EB) method to combine the predicted crash frequency with historic crash data. The primary objective of this study is to use the predictive method in the HSM to identify high crash locations that have potential for reducing the number and severity of crashes and to contrast three traditional network screening safety procedures (the crash frequency method, the crash rate method, and the crash severity method) to results obtained using the HSM predictive method. The authors used 24 intersections in the Corvallis, Oregon urban area as a case study. The results demonstrated that developing a ranked list of candidate intersection using these four methods identified different locations since each method specifically evaluates a particular safety metric. The authors further present how the use of the HSM predictive procedure, in combination with other ranking methods, can help an agency confidently establish funding initiative objectives and identify target sites that will directly meet these goals.

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7 Papers on surrogate measures for crash data

Emerging research methods relate to surrogate measures of safety and their validation through field measurements, computer simulation, and driving simulators.

The Subcommittee identified eighteen papers dealing with surrogate measures of safety. Unlike the last year, there is no special session focused on surrogate measures. These papers are scattered across various sessions and they supplement more traditional approaches to safety analysis.

Traffic conflicts have been applied in seven papers (12-0448, 12-1966, 12-2011, 12-2263, 12-2825, 12-2955, and 12-3403) while speed and its variation in four papers (12-0113, 12-0368, 12-2001, and 12-1321). There are considerable more papers than last year that use safety indices (12-0472, 12-1448, 12-2310, 12-2607, 12-2955, 12-3037, and 12-4267). These safety indices aggregate various traffic characteristics and are focused on certain types of roads (for example interchanges or unsignalized intersections) or traffic interactions (for example rear-end collisions). Majority of papers (at least 11) used field observations of the surrogate measures data by utilizing loop detector data (12-0113, 12-2310, 12-2607, and 12-3037), image processing (12-0448 and 12-2955), tags readers (12-0113 and 12-0368), and GPS receivers (12-2001). Micro-simulation remains one of the methods of filling gaps in available data. Three papers used VISSIM together with SSAM (12-1966, 12-2011, and 12-2825); the authors calibrated VISSIM before its use to improve the VISSIM's ability to predict traffic conflicts. Five papers dealt with real-time estimation of the risk of crash (12-0113, 12-0368, 12-2310, 12-2607, and 12-3037). This line of research must be considered important for two reasons: (1) its potential for preventing crashes if a real-time countermeasure is implemented and (2) because the results indicate the existence of the relationship between the surrogates and the risk of crash.

Surrogate measures were applied to investigate specific safety effects such as complexity of freeway interchanges (12-0472), aggressive driving (12-2011,), improvement of right-turning at signalized intersections (12-0448), various configurations of driveways (12-4267), flashing yellow signal (12-2263), treatment of pedestrians at signalized intersections (12-3403), merging zone on congested freeways (12-2825), and to prioritize unsignalized intersections for safety improvements (12-1448).

ANB20, Real-Time Analysis of Visibility-Related Crashes: Can Loop Detector and Automatic Vehicle Identification Data Predict Them Equally? (12-0113)

More researchers started using real-time traffic surveillance data, collected from loop/radar detectors (LDs), for proactive crash risk assessment. However, there is a lack of prior studies that investigated the links between real-time traffic data and crash risk of reduced visibility related (VR) crashes. Two issues that have not explicitly been addressed in prior studies are; (1) the possibility of predicting VR crashes using traffic data collected from the Automatic Vehicle Identification (AVI) sensors installed on Expressways and (2) which traffic data is advantageous for predicting VR crashes; LDs or AVIs. Thus, this study attempts to examine the relationships between VR crash risk and real-time traffic data collected from LDs installed on two Freeways in Central Florida (I-4 and I-95) and from AVI sensors installed on two Expressways (SR 408 and SR 417). Also, it investigates which data is better for predicting VR crashes. The approach adopted here involves developing Bayesian matched case-control logistic regression using the historical crashes, LDs and AVI data. Regarding models estimated based on LDs data, the average speed observed at the nearest downstream station along with the coefficient of variation in speed observed at the nearest upstream station, all at 5-10 minute prior to the crash time, were found to have significant effect on VR crash risk. However, for the model developed based on AVI data, the coefficient of variation in speed observed at the crash segment, at 5-10 minute prior to the crash time, affected the likelihood of VR crash occurrence. Argument concerning which traffic data (LDs or AVI) is better for predicting VR crashes is also provided and discussed.

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ANB20, Bayesian Updating Approach for Real-Time Safety Evaluation Using Automatic Vehicle Identification Data (12-0368)

Although numerous studies have attempted the use of data from inductive-loop and radar detectors in real-time crash prediction, there is a lack of safety analyses that have investigated the use of traffic data from an increasingly prevalent non-intrusive surveillance system; the tag readers on

toll roads known as Automatic Vehicle Identification (AVI) Systems. In particular in this paper, we tackle three main issues 1) explicitly comparing between the prediction performance of a single generic model for all crashes and a specific model for rear-end crashes using AVI data, 2) applying Bayesian updating approach to generate full probability distributions for the coefficients and 3) examining the estimation efficiency of the Semi-parametric Bayesian modeling over the frequentist matched-case control logistic regression. By contrasting AVI data preceding all crashes and rear-end crashes with matched non-crash data, it was found that rear-end crashes can be identified with a 72% accuracy while the generic all crash model achieved accuracy of only 69% using different validation datasets, moreover, using the Bayesian updating approach increased the accuracy of both models by 3.5%.

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ANB20, Feasibility of Computer Vision-Based Safety Evaluations: Case of Signalized Right-Turn Safety Treatment (12-0448)

Traditional road safety analysis has often been undertaken using historical collision records. However, limitations on the quality and completeness of collisions data gave rise to surrogate safety measures especially the traffic conflict technique (TCT). Traditionally, TCT's have relied on in-field observation, which has some reliability and repeatability problems. Therefore, successful automation of extracting conflicts from video sensors data can have considerable benefits for traffic safety studies. One safety application that could greatly benefit from automated traffic conflicts analysis is before-and-after (BA) evaluation of safety treatments. There are several advantages that support the adoption of traffic conflict techniques in BA safety studies. Traffic conflicts are more frequent than road collisions and are of marginal social cost. Traffic conflicts provide insight into the failure mechanism that leads to road collisions. BA studies based on traffic conflicts can be conducted over shorter periods. The main objective of this paper is to demonstrate the use of automated traffic conflicts analysis for a before-and-after safety evaluation. A right-turn safety improvement was implemented at an intersection in the City of Edmonton in 2009 to mitigate high occurrence of rear-end and merging collisions. The right-turn ramp was closed and all right-turning vehicles were brought to the right-turn lane at the intersection where a “no right turn on red” sign was installed. Video sensors are selected in this study as the primary source of conflicts data. The analysis of video data to measure traffic conflicts is undertaken using an automated traffic safety tool. The distributions of the calculated conflict indicators before-and-after the treatment show a considerable reduction in the frequency and severity of traffic conflicts which suggests a significant positive change in safety for rear-end, merging and total conflicts. It is hoped that the results of this study will show the potential for the adoption of automated conflict analysis to conduct BA safety studies.

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ANB20, Modeling Interchange Complexity and Its Effect on Safety (12-0472)

Complex interchanges are typically designed to accommodate large traffic volumes within a constrained area. If their structure is unexpected, it may surprise drivers and lead to driver errors, compromising road safety. This experimental study provides a model for assessing the complexity of different interchange configurations using a drivers’ point of view and driving workload. 25 interchanges from the New Jersey Interstate road system were rated and analyzed by the Interchange Complexity Index model (ICI). Based on these ratings, the safety of these interchanges was then examined in relation to their corresponding ICI ratings. The results suggest that interchanges that received high ICI ratings often encompass more crashes in their vicinities. These interchanges usually include high AADTs estimations. It is suggested that highway designers use the ICI model to assess the complexity of interchange design alternatives in order to lower driver workload and provide for a safer drive.

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ANB20, Development of a Procedure for Using Surrogate Safety Assessment Model and VISSIM for Safety Assessment at Signalized Intersections (12-1966)

The primary objective of this study is to investigate the potential of using microscopic simulation models and Surrogate Safety Assessment Model (SSAM) for evaluating the safety performance of signalized intersections. A widely used microscopic simulation package VISSIM was used in this study to develop simulation models. The validity of using VISSIM and SSAM for traffic safety analysis at signalized intersections was tested by comparing the simulated conflicts to those measured in the field using traditional traffic conflicts techniques. Of particular interest was to identify if the consistency between simulated and observed conflicts could be improved by calibrating VISSIM simulation models and adjusting threshold values used for defining simulated conflicts in SSAM. A two-stage procedure was proposed in this study to develop, calibrate and validate VISSIM simulation models. It was found that the two-stage calibration procedure greatly improved the goodness-of-fit between simulated conflicts and real-world conflicts. After model calibration, the mean absolute percent error (MAPE) for total conflicts was reduced from 44% to 24%. More specifically, the MAPE value was reduced from 26% to 15% for rear-end conflicts, from 69% to 29% for crossing conflicts, and from 83% to 81% for lane-change conflicts. Linear regression models and the spearman rank correlation coefficient were also developed to study the relationship between simulated conflicts and observed conflicts. Data analysis results showed that there was a reasonable goodness-of-fit between simulated and observed rear-end and crossing conflicts. However, it was also found that the simulated conflicts generated by VISSIM and SSAM are not good indicators for traffic conflicts which are generated by unexpected driving maneuvers such as illegal lane-changes in the real world.

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ANB20, Urban Expressway Speed Spatial Inconsistency and Its Effect on Safety (12-2001)

Accidents on urban expressways lead to large external costs due to its process effects of congestion and to reduce its influence is the main objective for traffic management. The speed difference between the adjacent positions along the road, called speed spatial inconsistency, is a potential risk factor which is less studied due to data limitation. It may be one of the substantial reasons of crash on urban expressway. Thanks to the floating car data (FCD) generated by the globe positioning system (GPS), which are installed in taxies, we can acquire detailed speed data along a road by viewing taxies as probe vehicles instead of isolated loop-detectors. The objective of this study is to explore the relationship between crash frequency and speed spatial inconsistency on urban expressway while controlling for other relevant factors. To accomplish this objective, we chose 174 segments belonged to the four main urban expressways of Shanghai where tracks are prohibited in the analysis time. Meanwhile, more than 45,000 taxies¡¯ FCD with 10 seconds fixed time interval were obtained, and a series of indicators to speed spatial inconsistency were developed. Also, the relevant crash data, traffic data and road characteristics data were collected. After that, Bayesian Poisson-gamma models were established for the frequencies of total crash, rear-end, and sideswipe. The results suggest that larger speed spatial inconsistency for a road segment lead to more crashes and each factor has the same positive or negative effects on the three kinds of frequencies.

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ANB20, Safety Evaluations of Aggressive Driving on Motorways Through Microscopic Traffic Simulation and Surrogate Measures (12-2011)

The majority of road accidents, 75-90%, are related to driver errors of one form or another. Aggressive driving is the most common driver error which results into unnecessary fatalities, injuries and frustrations. This paper addresses the safety evaluations of aggressive driving through use of microscopic traffic simulation and safety surrogate measures. A motorway was simulated and calibrated in VISSIM with vehicle classes of normal. The proportion of aggressive drivers was made to increase from a base model of all normal vehicles to a maximum of 15% with an increment of 3% at a time. Four different scenarios of driving aggression were investigated, namely: (1) Close following or tailgating, (2) Weaving in and out through traffic, (3) Speeding or driving too fast for condition, and (4) Combined aggression of close following, weaving through traffic and speeding practiced all at the same time. Surrogate Safety Assessment Model (SSAM) was used to evaluate the safety of each scenario by comparing them against a base model of all normal drivers. Quantitative results on the measures of safety performance of the scenarios were presented in terms of percentage increase in simulated vehicle conflicts of probable crashes or near crashes. The severity of the resulting crashes and also crash risk involvement of aggressive drivers was also discussed separately for each form. Drivers who speed, follow closely, weave through traffic and their combination were found to be involved in vehicle conflicts by much as 2.36, 6.16, 7.02 and 10.36 times more than normal drivers respectively. Key words: Aggressive driving, driver errors, crash risk, Surrogate Safety Measures, SSAM, VISSIM

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ANB20, Development of Crash Risk Index to Identify Real-Time Crash Risk on Freeways (12-2310)

The primary objective of this study is to develop a quantitative indicator that can be directly used to identify hazardous traffic states on freeway mainlines. Using data obtained from a 22-mile freeway segment on the I-880N freeway in San Francisco Bay Area in the United States, Fisher discriminant analysis was conducted to derive a linear combination of traffic flow parameters which can be used to distinguish traffic states which may lead to crashes from normal traffic conditions which were potentially safe. A new variable termed ¡°crash risk index¡± was defined based on the discriminant function. A crash risk index which is smaller than 0 represents a hazardous traffic condition potentially leading to a crash. Accordingly, a crash risk index which is greater than 0 represents normal traffic conditions which, theoretically, will not lead to crash occurrences. The research team tested the prediction performance of using the crash risk index to identify hazardous traffic conditions on freeway mainlines. An overall prediction accuracy of about 65.7% was achieved. Conditional logistic regression analysis was then conducted to evaluate the impacts of crash risk indexes on the likelihood of crash occurrences. It was found that the likelihood of freeway crashes increased with the decreases in crash risk index. One unit decrease in crash risk index increased the risk of crash occurrence by 180.3 %. The research team also looked extensively at the impacts of crash risk indexes at different time slices. It was found that the impacts of crash risk index decrease with time and the crash risk index at the time slice most immediately before crashes had the greatest impact on crash occurrences.

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ANB20, Real-Time Prediction of Freeway Rear-End Crash Potential by Support Vector Machine (12-2607)

This paper aims at developing new real-time freeway rear-end crash potential predictors using support vector machine (SVM) technique. To explore the relationship between rear-end crash occurrences and traffic conditions, historical loop detector data were collected on Interstate-894 in Milwaukee, Wisconsin. The extracted loop data were then aggregated over different stations and time levels to produce explanatory features. Afterwards, a feature selection process, which addresses the interaction between SVM classifiers and explanatory features, was conducted to identify the features that significantly associated with rear-end crashes. Then the selected significant explanatory features over three separate time levels were used to train three SVM models. Another three SVM models using unselected feature inputs were also established to examine the impact of the feature selection procedure on SVM performances. The results showed that the proposed feature selection procedure greatly enhanced the accuracy and generalization capability of SVM models. Moreover, the multi-layer perceptron (MLP) artificial neural network models were developed to evaluate the performance of SVM models against other commonly applied real-time crash potential predictors. In comparison with MLP artificial neural networks, SVM models provided better results in terms of crash prediction accuracy and false positive rate, which affirmed the superior performance of SVM technique in rear-end crash potential prediction analysis.

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ANB20, Surrogate Safety Analysis at Protected Freeway Ramps Using Cross-sectional and Before-After Video Data (12-2955)

This study presents a surrogate approach for safety analysis of freeway facilities using automated trajectory collection and behavioural analysis from surrogate measures of safety (in particular time to collision). This methodology is proposed as a potential alternative or complement to the classical approach based on historical accident data, particularly suited for evaluating the microscopic safety effects of road treatments for which there is a lack of traffic and accident data. A short theoretical discussion of traffic conflicts is followed by a proposed methodology illustrated using as a small sample of freeway ramps as an application environment. From this sample, video data is obtained as part of a safety study to investigate the effectiveness of the “one-way lane-change ban” treatment near urban freeway ramps in Montreal, Canada. To illustrate the applicability of our methodology, two comparative examples are presented: (1) a cross-sectional study and (2) a before-after study involving two sites, one of which had video data available before and after the implementation of the treatment. Various methods of aggregating the data, spatially and temporally, are explored in the applications.

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ANB20, Surrogate Safety Measure for Evaluating Rear-end Collision Risk near Recurrent Bottlenecks (12-3037)

This study presents a surrogate safety measure for evaluating the rear-end collision risk near recurrent bottleneck area using aggregated traffic data from loop detectors. The attributes of kinematic waves that accompanied rear-end collisions and the traffic conditions at detectors stations spanning the collision location were examined to develop the rear-end collision risk index (RCRI). The logistic regression model was developed using RCRI and standard deviation in occupancy observed at an upstream location. Findings indicated that a unit increase in RCRI results in increasing the odds of rear-end collisions by 32.3%, and an additional unit increase in standard deviation of upstream occupancy increases the odds by 19.8%. The likelihood of rear-end collisions were highest when traffic approaching from upstream location is near capacity while the downstream condition is congested. The proposed model was used to predict rear-end collision risk at the 6-mile study site and compared with the observed traffic collision data from year 2008. Predicted rear-end collision risks were consistent with the observation.

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AFB10, Risk Rating Procedure for Assessing Driveway Configurations (12-4267)

The placement and design of driveway and median configurations and their relative orientation can intuitively be expected to have a direct influence on vehicle operations and safety; however, currently there is not an analytical method available that permits the direct consideration of traffic movements, vehicle paths, stopping sight distance, and their associated impact on safety. This paper presents a quantitative procedure that can numerically evaluate the various driveway and median configurations by establishing an index that is adjusts all crashes to an equivalent 55 mph head-on collision. This procedure considers the individual level of conflicts based on relative speed, vehicle orientation, and vehicle or driveway proximity. The authors further associated the traffic volume and expected conflicts for vehicle diverge, crossing, and merge maneuvers to ultimately develop a risk assessment index. Throughout the paper, a simple example application is presented. The paper concludes with a second, more detailed example of how this risk assessment index can be used to compare expected exposure to risk for different intersection configurations.

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AHB50, Safety of Flashing Yellow Arrow Indication with Protected-Permissive Left-Turn Operation (12-2263)

This paper was to investigate the safety performance of flashing yellow arrow (FYA) indication with protected/permissive left-turn (PPLT) operation by conducting two studies: 1) surveys of traffic engineers and general motorists, and 2) field traffic conflict study. The results of this study demonstrated that the majority of drivers showed very good understanding of FYA indication, and FYA did not present safety issues at most of the field study intersections. However, FYA signals may result in more traffic conflicts between left-turn and opposing vehicles at the intersections with high left-turn and opposing volumes. The results of this study will help traffic engineers to deploy the FYA signal display more correctly and safely.

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AHB50, Pedestrians and Left-Turning Vehicles: Evaluation of Safety Treatments (12-3403)

Pedestrian safety is a growing concern at signalized intersections. Pedestrian-vehicle crashes tend to be less frequent but more severe than crashes involving only vehicles. A pedestrian-vehicle crash has been estimated to cost four times a vehicle-vehicle crash cost on a willingness-to-pay basis. To address pedestrian safety concerns at signalized intersections, treatments can be used to separate pedestrians and vehicles in time and space, improve pedestrian compliance with signal control, or remind drivers and pedestrians to be aware of each other's presence. The effectiveness of pedestrian safety treatments is often assessed by monitoring trends in pedestrian-vehicle conflicts (as indicated by evasive movements by drivers or pedestrians) and pedestrian compliance (as indicated by pedestrians' response to the Walk interval). Crash data can be used, but the relative rarity of pedestrian-vehicle crashes must be overcome by observing a long time period or a large number of sites. Conflicts are also more frequent and thus can provide more timely safety evaluation than crash-based analysis. Four pedestrian safety treatments were evaluated through the conduct of before-after studies. These treatments included adding a leading protected left-turn phase, implementing split phasing, implementing pedestrian recalls, and increasing the Walk interval duration. The first three treatments were found to reduce pedestrian-vehicle conflict rates. The treatments had mixed effects on pedestrian compliance.

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AHB65, Evaluation of Operations and Safety in a Congested Freeway Merging Area with Auxiliary Through Lane (12-2825)

Highway and traffic engineers in the United States have recognized the importance of effective application of auxiliary lanes at high volume interchanges. Previous research has shown that congested merge areas with longer acceleration lanes appeared to increase the potential for collisions and operational problems due to the frequency of merging maneuvers over the total acceleration length, and implementing a no merging zone along the speed-change lane created safer and more efficient traffic operations. This study examines the I-40 and US 70 Bypass interchange near Garner, North Carolina, which consists of closely spaced ramps with an unbalanced number of lanes and poor application of auxiliary lanes, including an auxiliary through lane that begins and ends just beyond the subject interchange. The purpose of this study is to evaluate the balance in the number of lanes on closely spaced ramps and to evaluate if a congested merging area with poor application of auxiliary lanes is likely to worsen operations due to creating a greater potential for collisions. This study evaluates multiple low-cost alternative designs which should improve operational and safety problems identified in this congested merging area. The VISSIM Model is used to simulate the operations of the designs, and the FHWA Surrogate Safety Assessment Model is used to evaluate safety. This study amplifies the importance of appropriate auxiliary lanes and a need to implement a no-merging zone in a congested merging area.

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ANB10, A Method for Highway Collision Rate Estimation Considering Traffic Flow State (12-1321)

Among traffic-related variables, vehicle speed is thought to be one of the major variables closely related to collision occurrence. This study aims to develop a methodology to estimate collision rate considering the traffic state in a freeway section focusing on the speed variables. To define the traffic condition of a section, four section-based traffic states were used according to the speed of upstream and downstream locations. The collisions were classified into three types (Rear-end, Sideswipe, and Others), and two variables (speed difference between upstream and downstream and average speed of upstream and downstream) were considered as independent variables for standard linear regression analysis. The findings showed that both speed difference and average speed had an influencing explanation to state the collision rate by each type of collision and traffic state. Rear-end and sideswipe collisions showed different collision rate pattern with the others, and the influence of the speed difference between upstream and downstream changed according to the traffic state. Through regression analysis, rear-end and sideswipe collision rates were expressed by the speed difference, while other types of collision were described by the average speed. The research can provide a methodology to understand the collision potential for the highway according to the traffic state, and can be widely used for roadway traffic safety improvement.

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ANB10, A Ranking Procedure of Unsignalised Rural Intersections for Safety Improvement (12-1448)

The paper presents a ranking procedure for rural unsignalised intersections which uses quantitative safety evaluations performed as part of the safety inspection process. It might be effective for the selection of cost effective treatments at intersections and might be very helpful for administrations which do not have quality crash data and for administrations which manage low volume roads where crash data cannot give enough information on crashes to be prevented. The procedure evaluates a safety index (SI) that can be used to rank intersections for further investigations. SI can be assessed whether crash data are available or not. If crash data are available and their quality is good, SI can be effectively used in conjunction with the EB estimate of frequency as ranking criteria. If crash data are not available or poor, SI can be used as a proxy of crash data and becomes the only ranking criteria. Validation of the safety index procedure was carried out by comparing the results with the EB safety estimates. The SI was assessed in twenty-two three leg intersections in Italy. In the same intersection, a safety performance function was calibrated and the EB refinement technique was used to obtain a better estimate of the existing safety performance. Correlation between SI values and EB safety estimates is highly significant, with 84% of the variation in the estimated number of crashes explained by the SI value. The results from the Spearman's rank-correlation show that ranking from the SI and the EB estimate do agree at the 99.9% significance level.

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ANB40, Actual and Perceived Risk of Apprehension for Speeding in Norway (12-0066)

This paper presents a study of the actual and perceived risk of apprehension for speeding in Norway. The actual risk of apprehension was estimated by combining data on the speed of traffic and data on the number of citations for speeding. The risk of apprehension for minor violations was zero, which shows that both police officers and speed cameras allow a safety margin before citing a driver for speeding. There was a dose-response relationship between the level of speeding and the risk of apprehension: the more severe the violation, the higher the risk of apprehension. In general, however, the risk of apprehension for speeding is very low and tends to be overestimated by drivers.

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ANB40, Spatial Effectiveness of Speed Feedback Signs (12-0743)

Speed Feedback Signs (SFS), also known as Dynamic Speed Displays (DSD), provide drivers with feedback about their speed in relationship to the posted speed limit. When appropriately complemented with police enforcement, SFS can be an effective method for reducing speeds at a desired location. However, as reported in the literature, the effectiveness of SFS is limited not only in terms of time after the deployment but also in terms of distance. Therefore, there is a need to understand how far upstream and downstream of the SFS are speed reductions maintained. Through a unique data collection methodology researchers obtained trajectories of free flowing vehicles that approached a SFS as well as trajectories of vehicles receding from the SFS. Trajectory data was used by researchers to determine the location at which drivers willing to reduce their speed when approaching the SFS actually started the reduction. Downstream of the SFS the distance at which drivers started increasing their speed after complying with the sign was also determined. Results show the feasibility of determining the spatial effectiveness of SFS. Using the methods in this paper, speed enforcement personnel can understand how drivers in an area of interest react to SFS and therefore determine the best location as well as the number of SFS that need to be deployed to achieve a speed reduction over a segment of road.

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ANF10, Analysis of Pedestrian Risk Exposure in Relation to Crossing Behavior (12-1353)

The objective of this research is the analysis of pedestrians risk exposure along urban trips in relation to pedestrians crossing behavior. First, an appropriate microscopic indicator is selected for the estimation of pedestrians risk exposure while road crossing at isolated locations. This indicator expresses exposure as the number of vehicles encountered by pedestrians during the crossing of a single uncontrolled road lane, and can be further adapted and applied for various road design and traffic control features. Moreover, the number and type of crossings along a pedestrian trip can be identified on the basis of the trip length and topology, whereas the choice set of alternative crossing locations for each crossing decision can also be defined. The crossing probability associated with each alternative location along the trip can be then estimated by means of a sequential logit model. Finally, a method is presented for the estimation of pedestrians exposure along a trip in relation to their crossing behavior. The proposed approach is demonstrated on the basis of a pilot implementation, for a typical pedestrian trip in the centre of Athens, Greece, for four scenarios combining different traffic conditions and pedestrians' walking speed. The results show that pedestrians' exposure along a trip is significantly affected by their crossing choices, as well as by road and traffic characteristics. It is also revealed that pedestrians with increased walking speed may partly compensate for their risk exposure, so that it is not significantly affected by traffic volume. Moreover, specific locations with increased pedestrian risk exposure can be identified for each trip. The proposed microscopic analysis of pedestrian exposure is proved to be advantageous compared to existing macroscopic ones, revealing the different possible definitions and aspects of pedestrians exposure, with useful implications for road safety analysis.

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8 Interacting Committees

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.

AHB50, Traffic Control Devices
This committee is concerned with the development, design, application, and evaluation of traffic control devices, and their effect on traffic operation and safety.

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

AHB70, Access Management
The committee will share the latest knowledge, expertise, and experience to facilitate leadership and partnerships to advance the state-of-the-practice in access management and its integration into established planning, policy, and design processes.

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.

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.

ANB40, Traffic Law Enforcement
This committee is concerned with research relating to safety effects of enforcement activity and other traffic supervision measures, including those involving the driver and vehicle.

ANB50, Alcohol, Other Drugs, and Transportation
This committee is concerned with alcohol and other drugs as they relate to all significant modes of transportation with particular emphasis on those relationships that are common to more than one mode.

ANB60, Safe Mobility of Older Persons
Stimulate quality research and evaluation, provide a forum for interested researchers and practitioners to disseminate research and related information to those involved and interested in improving the safety and mobility of older drivers.

ANB70, Truck and Bus Safety
This committee will focus on motor carrier safety in all its aspects. This will include research and evaluation in human, roadway, vehicle, operational, organizational, and regulatory arenas as they relate to motor carrier safety.

ANB75T, Roundabouts Task Force
The TRB Roundabouts Task Force is concerned with all factors encompassing modern roundabouts. The Task Force provides focus within TRB on current issues and future research needs pertaining to modern roundabouts. It serves as a forum for discussions about roundabout research, projects, and policy for all interested stakeholders; identifies research needs and develops research problem statements to meet the needs; and facilitates the exchange of knowledge by various media, meetings, and conferences.

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.