Committee ANB20 Safety Data, Analysis and Evaluation

Synthesis Report

On safety-related papers presented at the 90th TRB Annual Meeting
January 23-27, 2011, Washington, D.C.
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1 Introduction

This report is mainly aimed at facilitating access to Committee ANB20-related presentations and events at the 90th 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-nine papers sponsored by ANB20 are identified. These papers are presented on three poster sessions and three podium sessions. The papers address the following topics (some papers were classified in more categories):

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

[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.

4 Papers on safety performance functions,

d) 5 Papers on crash severity prediction,
e) 6 Papers on network screening,
f) 7 Papers on surrogate measures for crash data, and
g) 8 Papers on bicycle and pedestrian crash relationships.

Table 1 ANB20 events

Event type	Time	Title	Location
Workshop	January 23, 9:00 AM–5:00 PM	International Workshop on Transferability of Crash Modification Factors (CMFs). Sponsors: ABJ80, AFB10, AHB65, ANB10, ANB20, and ANB25	Marriott, Washington B2
Meeting	January 24, 8:00 – 9:45 AM	Bicycle and Pedestrian Crash Relationships Joint Subcommittee of ANB20, ANF10, and ANF20	Marriott, Washington B2
Meeting	January 24, 10:15 – 12:00 AM	Surrogate Measures for Crash Data Subcommittee, ANB20(3)	Marriott, Washington B1
Poster session (331)	January 24, 2:30 – 5:00 PM	Safety: Analysis, Modeling, and Data	Marriott, Salon 2
Poster session (395)	January 24, 7:30 – 9:30 PM	Walking and Biking: Exploring Injury and Risk	Marriott, Salon 2
Podium session (396)	January 24, 7:30 – 9:30 PM	What's Hiding in the Data? Issues for Safety Analysis	Marriott, Delaware A
Meeting	January 25, 8:00AM- 12:00PM	Safety Data, Analysis and Evaluation Committee	Marriott, Washington B5
Poster session (472)	January 25, 9:30 – 12:00 AM	Surrogate Measures in Safety Analysis	Marriott, Salon 2
Meeting	January 26, 10:15 – 12:00 AM	Animal-Vehicle Collisions Subcommittee, ANB20(2)	Hilton, Columbia Hall 3 & 4
Podium session (707)	January 26, 2:30 – 4:00 PM	Bicycle and Pedestrian Safety Relationships	Marriott, Delaware A
Podium session	January 26, 2:30 – 4:00 PM	Surrogate Measures of Road Safety for Modeling and	Marriott, Maryland C

(712) Management

2 Papers on crash data and safety analysis tools

Real-world crash data play a vital part in the development of safer road 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 road design criteria currently being used.

From a methodological perspective, different methodologies were used, such as a meta-analysis of previous studies (11-0134), a fuzzy logic-based data mapping algorithm to identify matching data from two datasets so that data are not over-counted when combining the two data sets (11-0551), classification trees to identify intersection crash casual factors (11-0699), Random Forests (a relatively recent data mining technique) to indentify significant traffic flow variables affecting visibility related crash occurrence (11-0920), matched case-control logistic regression to explore the effects of traffic flow variables on visibility related crashes (11-0920), proportionality tests to compare the crash distributions (11-0955), logistic regression models to identify the circumstances associated with different crash types (11-2428), ordered probit models to predict the lane group in the freeway diverge areas (11-0955), autoregressive models to link motorization level with the decreasing fatality rates (11-1060), Generalized Negative Binomial models to allow dispersion to vary across each observation (11-1397), use of high-resolution detector and signal data to support crash identification and reconstruction (11-1852), latent class models to analyze crash data (11-2098).

From an applications perspective, the papers addressed several issues, such as animal-vehicle crash data (11-0551), crash risk of using mobile phones while driving (11-0134), intersections (11-0699), visibility related crashes on freeways (11-0920), crashes at freeway diverge areas (11-0955), mid-block crashes in urban arterial roads (11-2428), exploration of the impact of self-selection bias caused by self-reporting driver distraction on the likelihood estimates of being involved in crashes (11-3409), and the exploration of the role of segmentation to prepare datasets for use with new advanced safety analysis tools, Highway Safety Manual and SafetyAnalyst (11-4156). Further, relationship between safety and congestion (11-0292) and validity of quasi-induced exposure in estimating exposure in the safety analysis (11-0619) were addressed.

ANB20, Effects on Accident Risk of Using Mobile Phones: Problems of Meta-analysis When Studies Are Few and Bad (11-0134)
This paper reports a meta-analysis of studies that have evaluated the effects on accident risk of using mobile phones while driving. The paper illustrates the difficulties of doing meta-analysis when studies are few and bad. Two main groups of studies were formed, one consisting of five studies, the other of seven studies, but studies were quite heterogeneous even within these small groups. Publication bias was detected, but its effects on summary estimates of risk varied depending on whether a fixed-effects or random-effects model of meta-analysis was used. Evidence from the epidemiological studies was not consistent with the findings of effects on driver behavior, obtained in driving simulator studies.
Authors
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ANB20, Safety Implications of Violations in Concurrent-Flow Lane Operations (11-0292)
This paper investigates and quantifies the safety impact of access-type violations in the context of concurrent flow lane operations given a nonbarrier separated managed lane facility. A safety index that accounts for increased speed variation is developed and a three-step simulation-based methodology is proposed for its quantification. The methodology is applied to a case study constructed on a calibrated simulation network of an existing roadway segment of I-270 in Maryland. Results of simulation experiments provide evidence in favor of the hypothesis that illegal traffic maneuvers between managed and general purpose lanes operating concurrently can greatly affect safety. Moreover, results of this study corroborate a parabolic relationship between safety and congestion that was only previously hypothesized in the literature.
Authors
Chou, Chih-Sheng , University of Maryland, College Park
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ANB20, Fuzzy Logic-Based Mapping Algorithm for Improving Animal-Vehicle Collision Data (11-0551)
Animal-Vehicle Collisions (AVCs) cause hundreds of human and wildlife animal fatalities, and tens of thousands of human and wildlife animal injuries in North America. It is estimated that more than $1 billion in property damage each year in the U.S.. Further research efforts are needed to identify effective countermeasures against AVCs. Two types of data have been widely used in AVC-related research: reported AVC (CRpt) data and carcass removal (CR) data. However, previous studies showed that these two datasets are significantly different, implying the incompleteness in either set of the data. Hence, this study aims at developing an algorithm to combine these two types of data to improve the completeness of data for AVC

studies. A fuzzy logic-based data mapping algorithm is proposed to identify matching data from the two datasets so that data are not over-counted when combining the two data sets. The membership functions of the fuzzy logic algorithm are determined by a survey of Washington State Department of Transportation carcass removal staff. As verified by expert judgment collected through another survey, the accuracy of this algorithm was approximately 90%. Applying this algorithm to Washington State data sets identified that about 25%~35% of the CRpt data records have matching pairs in the CR data. Compared to the original CR dataset, the combined dataset has 15%~22% more records. The proposed algorithm provides an effective means for merging the CRpt data and the CR data. Such a combined dataset is more complete for wildlife safety studies and countermeasure identifications.

Authors

Lao, Yunteng , University of Washington
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ANB20, Using U.S. National Household Travel Survey to Validate Exposure Estimates by Quasi-Induced Exposure Technique (11-0619)

As opposed to exogenous estimates of exposure to risk such as vehicle miles of travel, number of registered vehicles, or number of licensed drivers, quasi-induced exposure has not received adequate vetting. A criticism of quasi-induced exposure is that its underlying assumptions are not convincingly validated or verified, partially because the risk estimates of quasi-induced exposure have not been sufficiently compared to the more conventional techniques. In this paper, the 2009 national household travel survey data are utilized to derive annual vehicle miles traveled, disaggregated by characteristics of interest (namely age and gender). Comparisons are developed at different disaggregation levels between the vehicle miles traveled and the relative exposure calculated by quasi-induced exposure. The main findings of the exercises include: (1) statistical results suggest that the exposure estimates for 15 age groups and driver gender are in good agreement with the corresponding annual vehicle miles traveled and thus the induced exposure estimates are deemed to be reasonably representative of the driving population and (2) the validation study reveals that data disaggregation improves the homogeneity of age and gender distributions. Based on the comparisons here, quasi-induced exposure is confirmed as a promising and powerful tool in estimating exposure in the safety analysis.

Authors

Jiang, Xinguo , Southwest Jiaotong University, China
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ANB20, Understanding Intersection Crash Causality: A Virginia Case Study (11-0699)

Intersection crashes cost $40 billion annually, accounting for one fifth of highway fatalities. Although VDOT maintains several databases containing detailed crash, driver, and roadway attributes, it was not clear to database users how these data elements could help identify intersection crash causal factors because of the random variation inherent in crashes. To address such variation, classification trees and crash estimation models (CEMs) were developed. The trees showed that specific causal factors, such as the approach alignment or surface condition, successfully indicate whether a given crash was rear-end or angle. By extension, the trees suggested that intersection crashes were not purely random. Accordingly, it was feasible to develop CEMs that for 17 intersection classes predicted the number of crashes for four crash types: rear-end, angle, injury, and total. The 68 CEMs showed deviance-based pseudo-R-square values between 0.07 and 0.74, suggesting that the causal factors explained some, but not all, of the variation in intersection crashes. The CEMs, including dispersion parameters, varied by intersection class, suggesting multiple CEMs were required. Two lessons appear applicable elsewhere. First, the small proportion of variables that successfully classified most rear-end and angle crashes may be given increased attention such that every effort is made to ensure these data elements are recorded accurately at the crash scene. Second, facility-specific intersection CEMs should be developed because a given geometric variable may be a surrogate for other phenomena. For example for multilane intersections, the number of lanes may be a greater indicator of complexity than capacity.

Authors

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ANB20, Exploring Visibility-Related Crashes on Freeways Based on Real-Time Traffic Flow Data (11-0920)

There is a lack of prior studies that investigated the relationship between traffic flow variables and traffic crashes that occur due to reduced visibility. This paper aims at exploring the occurrence of visibility related (VR) crashes on freeways using real-time traffic surveillance data (speed, volume and occupancy) collected from underground loop detectors (LD) and radar sensors potentially associated with VR crash occurrence. The research hypothesis here is to compare traffic flow characteristics leading to VR crashes with non-crash cases at reduced visibility conditions. Historical crash and LD data were collected from Interstates 4 and 95 in Florida between December 2007 and March 2009. To achieve the objectives of this study, Random Forests (RF), a relatively recent data mining technique, was used to indentify significant traffic flow variables affecting VR crash occurrence. Using significant variables selected by RF, matched case-control logistic regression model was estimated. The purpose of using this statistical approach is to explore the effects of traffic flow variables on VR crashes while controlling for the effect of other confounding variables such as the geometric design elements of freeway sections (i.e. horizontal and vertical alignments). The results revealed that the 5-minutes average occupancy observed at the nearest downstream station during 10-15 minutes before the crash along with the average speed measured at the downstream and upstream stations during 5-10 minutes before the crash increase the likelihood of VR crash occurrence in between. In addition, by using a threshold value of 1.0 for the corresponding odds ratio, over 67% VR crash identification was achieved.

Authors

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ANB20, Identifying Crash Distributions and Prone Locations by Lane Groups at Freeway Diverge Areas (11-0955)

In this study, the overall and severe crashes for four exit ramp types at freeway diverge areas were compared by crash distributions and locations. Crash contributing factors were identified, including exit ramp types, geometric design features, traffic conditions, and crash related attributes. Exit ramp types are defined by the number of lanes exiting freeways and the lane-balance theory which is determined by AASHTO. Four typical exit ramp types were considered: 1) one-lane exit with lane-balanced design (Type 1); 2) one-lane exit with lane-unbalanced design (Type 2); 3) two-lane exit with lane-balanced design (Type 3); and 4) two-lane exit with lane-unbalanced design (Type 4). Lanes are further classified as Exit/Drop Lane-Group, Impact Lane-Group, and Interior Lane-Group. Proportionality tests were employed to compare the crash distributions on different lanes. The results indicate that lane-balanced designs (Type 1 and Type 3) have a statistically significant higher percentage of severe crashes on the impact lane-group than that of lane-unbalanced designs (Type 2 and Type 4). As for the interior lane-group, Type 4 ramps have a statistically significant higher percentage of severe crashes than the other types. In addition, ordered probit models were developed for overall crashes and severe crashes

by one-lane exits and two-lane exits, respectively. Model results suggest that more crashes occurred on the exit/drop lane-group for the lane-unbalanced designs (Type 2, Type 4) and more severe crashes occurred on the interior lane-group for the lane-unbalanced designs. The study would expectedly help engineers have a better understanding of crash locations for different exit types, thus to select appropriate countermeasures.

Authors

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ANB20, Modeling Traffic Fatalities in Europe (11-1060)

The objective of this paper is to provide a parsimonious model for linking motorization level with the decreasing fatality rates observed across EU countries during the last three decades. Earlier models used to describe the - at the time - increasing relationship between motorization and traffic fatalities were adjusted in order to describe the decreasing relationship observed in the last three decades. A macroscopic analysis of road-safety in Europe at the country level (16 EU countries) is proposed through the application of non-linear models correlating fatalities and vehicles for the period between 1970 and 2002. Given the time series nature of road safety data, these models result in autocorrelated residuals, thus violating at least one of the assumptions of non-linear regression. Autoregressive forms of the considered models that overcome these limitations and provide superior predictive capabilities are also considered. An autoregressive log-transformed model seems to outperform the base autoregressive non-linear model in this respect. The use of these models allowed for the identification of the best and worst performing countries in terms of traffic fatalities. The proposed models may be proved useful for assessing the road safety performance of the examined countries, as well as for obtaining some insight on the current and future trends of less developed countries.

Authors

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ANB20, Effects of Adverse Winter Weather on Drivers in High-Risk Age Groups: Statewide Analysis (11-1397)

Using new state-level data our research shows that young (<19) and older (65+) drivers are significantly overrepresented in crashes during winter road conditions. Drivers in Maine are, on average, involved in 93 crashes per day, about one crash per 10,000 drivers. The daily number of crashes varies with many factors, including two that are the focus of this study: temperature and snowfall. Winter-maintenance activities also influence safety and mobility and are costly. Maine spent $98 million in 2008-2009 on winter road maintenance efforts to improve safety and mobility. In order to efficiently allocate winter road maintenance resources, managers and policy makers need to understand the relationship between road safety and varying levels of adverse winter weather. Our analysis improves on past studies by exploring the relationship between winter weather and vehicle crashes for different age groups on a state level rather than a national level where it is more difficult to control for confounding variables. The methodology advances past efforts by employing a model allowing for greater heterogeneity and using more detailed weather, traffic volume and crash data. Results indicate that young drivers have the highest crash risk with below freezing temperature and mid-levels of daily snowfall amongst all age groups. Crash risk is also shown to increase for young drivers by 13% on Fridays with trace amounts of snowfall.

Authors

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ANB20, Using High-Resolution Detector and Signal Data to Support Crash Identification and Reconstruction (11-1852)

Traffic accidents may not always result in severe or fatal injuries, but can still have nontrivial impact on system performance, particularly during heavy traffic conditions. One way to reduce the frequency of such incidents is to identify the necessary circumstances that resulted in the collision. However, road accidents, particularly intersection related crashes, are complex phenomenon and may result from different combination of causal factors such as excessive speed, successive braking of vehicles, signal violation, inadequate gap acceptance during merging, lane changing or taking a right turn on red. Recent traffic studies have witnessed increased use of high-resolution arterial traffic data to evaluate various traffic performance measures. It is also important for traffic safety engineers to explore such high-resolution data to analyze crashes, and identify the necessary causes of the crashes. In this study we illustrate, for one particular intersection crash resulting from signal violation, how high-resolution event-based data obtained from loop detectors can be used to identify the incident and the vehicles involved in the crash. We also illustrate how high-resolution data could support a traditional reconstruction of this crash. A Monte Carlo simulation technique was used to estimate the most probable combination of the driver behaviors that resulted in the collision. It was found that the excessive speed of the vehicle violating the red light was the most critical factor contributing to the crash.

Authors

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ANB20, Applying Latent Class Growth Model in Longitudinal Analysis of Traffic Crashes (11-2098)

One of the most important and meaningful tasks in traffic safety is to describe how traffic crash risk changes over time. Over the last 20 years, a lot of work has been done on this topic. However, with the recent introduction of latent class models for analyzing crash data, there is a need to examine how this new type of models could be used for longitudinal data analysis. Latent class models dictate that part of the heterogeneity can be attributed by grouping distinct subpopulations into a common dataset. Investigating the commonalities among the different subgroups can be useful for targeting specific safety interventions. This paper consequently describes the application of the latent class growth models (LCGM) that is specifically tailored for longitudinal data. The analysis was accomplished using data collected between 1997 and 2007 on rural two-lane highways in Texas. Trends for all crash severities and injury crashes were examined and it was determined that the crash data could be drawn from three population subgroups: low crash risk, medium crash risk and high crash risk. The results of this study show that average shoulder width and speed limit has a stronger effect for the sites that were classified as high crash risk, whereas traffic flow had a stronger influence for sites classified as low risk. As expected, higher speed limits increased crash risk, while wider shoulder width reduced the risk. In conclusion, the LCGM offers good potential for analyzing longitudinal data, but further work is needed on this topic.

Authors

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ANB20, Non-Intersection-Related Crashes at Midblock in Urban Divided Arterial Road with High Truck Volume (11-2428)
This study analyzes the crashes that occur at mid-block called "mid-block crashes" in an urban arterial road. The association of mid-block crashes with various factors was examined using the 7-year (2000-2006) crash data on a section of a divided arterial road in Windsor, Ontario, Canada. To account for difference in traffic volume and road geometric factors between two directions of travel in a divided road, the data were collected for two directions separately. The results of log-linear models using these bidirectional data show that mid-block crashes are more likely to occur on the road sections with access point and high percentage of truck (> 20%). It was also found that the effects of access point and truck percentage were not statistically significant when the unidirectional data were used. A sensitivity analysis was also performed to identify the bidirectional variables affecting crash frequency by direction. It was found that the difference in truck percentage between two directions can most effectively reflect the difference in crash patterns by direction. The results of logistic regression models show that median opening, driver age/gender, lighting, time of day and day of week are associated with different types of crashes classified by the vehicles involved in crashes. The study shows the importance of analyzing mid-block crashes using the bidirectional data by vehicle type in urban divided arterial roads with high truck volume.
Authors

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ANB20, Identification of Self-Selection Bias in National Crash Database and Its Impact on Crash Estimates (11-3409)
Over the last decade, driver distractions, such as cell phone use and texting, have become a significant contributor to roadway crashes. Some states now have legislation that severely restricts or bans driver activities deemed distracting. However, many policies and engineered countermeasures are based on self-reported crash data. This raises the issue of potential bias than when not controlled for in analysis supporting policy decisions can lead to poor commitment of public resources. This study explores the impact of self-selection bias caused by self-reporting driver distraction on the likelihood estimates of being involved in crashes. Using a two step correction technique, the study tests and controls for the bias when present, and interpret its impact on the effects of distraction drawn in other studies. The findings show that selection bias is present in the National Automotive Sampling System General Estimates System, a national database often used to help evaluate policy and engineering safety countermeasures. Additionally, our findings show that self-selection bias understates the true effect of driver distraction on injury severity and as a result, the forecast of potential savings of countermeasure policies or in-vehicle devices will be underestimated.
Authors

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ANB20, Model Minimum Uniform Crash Criteria and Minimum Inventory Roadway Elements: Role of Segmentation in Safety Analysis (11-4156)
Several states have already begun to prepare datasets for use with new advanced safety analysis tool, Highway Safety Manual and SafetyAnalyst, and one of the overarching concepts in these safety processes is the identification of homogeneous segments and intersections. Homogeneous, with respect to a roadway segment, implies that all of the characteristics of that segment are the same. The characteristics used to specify homogeneity could include number of lanes, shoulder width and type, traffic volume, median presence and type, and a host of others. The idea of homogeneous segments may or may not easily mesh with existing state GIS databases depending on what type of segmentation process is used by individual states. Additionally, segmentation has very real impacts with respect to biasing the outcomes of safety analysis, especially when considering traditional site selection methods such as rates and frequencies. However, segmentation also plays an important role in advanced methods and potentially impact the validity of the results. The overarching goal of this research is focused toward aiding the new user of advanced safety analysis methods with database development and maintenance activities. In particular, the results of this research depict various issues related to choice of segmentation method and approaches for generating homogeneous segments. First, the results of a simple length based segmentation approach will be used to show how segment length can skew the results of a safety analysis. Second, the results of multiple segmentation approaches using varying levels of sensitivity for roadway data element data sensitivity and varying number of included elements will be compared. Finally, recommended strategies are presented for data management and segmentation for use by early adopters of advanced methods.
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 before-and-after studies that incorporate the current best study design and statistical analysis methods provide vital support for the roadway safety management process.

In the majority of cases, the success of road safety initiatives are not "self-evident", even to road safety professionals that have considerable practical experience. There is rarely a simple cause and effect relationship associated with road safety initiatives. Usually, several factors that influence safety in different ways operate simultaneously on a transportation system. Therefore, the importance of conducting rigorous evaluations of road safety improvement programs cannot be overstated. The most common method to estimate the effectiveness of safety initiatives is a time series analysis, which is often referred to as "before and after" analysis. This approach attempts to measure the change in safety over time due to the implementation of a safety initiative. A before-and-after study is perceived by many to be the best way to estimate the safety effect of changes in roadway characteristics. The current popular state-of-the-art road safety evaluation is based on the Empirical Bayes Odds Ratio (EB-OR) methodology. Recently, the application of the Full Bayes (FB) approach in before-after studies has been proposed in the literature and were shown to provide accurate results and to have several advantages over the Empirical Bayes Approach.

Four papers sponsored by ANB20 and one paper sponsored by other Committees (ANB25) are identified.

ANB20, Treatment of Zero Counts in Before-and-After Road Safety Evaluation Studies: Exploratory Study of Continuity Corrections (11-0133)
Before-and-after studies of safety measures introduced at locations that have a low mean number of accidents often encounter the problem of zero accident counts. This is a problem for three reasons. First, it is highly implausible that the true long-term mean number of accidents at any site is zero. Second, if results from several sites are combined by means of the inverse-variance (i.e. logodds) technique of meta-analysis, zero counts must be adjusted when estimating the statistical weight to be assigned to each result. Third, if a zero count is taken at face value, it suggests that the effects of a safety treatment could be either a hundred percent accident reduction (if there was a positive count before and a zero count after) or an infinite increase in the number of accidents (if there was a zero count before and a positive count after), both of which are highly implausible. This paper explores the use of techniques for continuity correction to adjust zero counts. A technique proposed in epidemiology is applied to a fictitious data set. A simple method derived from the empirical Bayes (EB) method is proposed for implementing continuity corrections to the count of accidents after treatment in EB-studies.
Authors
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ANB20, Safety Benefits of Converting HOV Lanes to HOT Lanes: Case Study of I-394 MnPass (11-0361)
Recently the conversion of high-occupancy-vehicle (HOV) lanes to high-occupancy-toll (HOT) lanes has been increasingly popular in the U.S. Several empirical studies have explored the benefits and costs associated with the conversion. However, few quantitative studies have been performed to examine the impact of HOV-to-HOT conversion on traffic safety. Applying the Empirical Bayes method, this paper investigated the crashes on the I-394 MnPass lane before and after its conversion, controlling for the length of highway segments and AADT. We found that total crashes were reduced by 5.3% after the conversion. The benefits were practically important when compared to the tolls collected. We also compared Empirical Bayes approaches with other simple before-after approaches, and we found that other approaches tend to overstate the safety benefits of the HOV-to-HOT conversion.
Authors
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ANB20, Empirical Bayes Model to Assess Deer-Vehicle Crash Safety in Urban Areas in Iowa (11-1199)
Deer-vehicle crashes are a growing problem in Iowa. In 2008, deer-vehicle crashes represented 12% of all crashes reported and included 9 fatalities and 442 injuries. These crashes are especially problematic in urban areas of Iowa, where the prevalence of deer-vehicle crashes is becoming a more visible issue. Quite a bit of research has been conducted on countermeasure action that could help mitigate deer-vehicle crashes. However, little previous work has attempted to model deer-vehicle crashes in urban areas using the two data sources available: deer carcass salvage reports and deer-vehicle crash reports. The objective of this paper is to assess the safety of roadway segments in three cities with long-running deer management programs using both deer-vehicle crash and deer carcass salvage data. The authors reconciled records to help eliminate double counting and estimated count data models to examine deer-vehicle crash frequency as a function of roadway and environmental factors. The count model estimates were used in an empirical Bayes model to predict deer-vehicle crashes in the select urban areas of Iowa. This model can be used to help allocate safety funds to implement appropriate deer-vehicle crash countermeasures in high-risk locations.
Authors

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ANB25, Use Of Empirical Bayesian Methods To Estimate Temporal-based Crash Modification Factors For Construction Zones (11-2678)

Many studies have been conducted to estimate the traffic safety impacts of roadway construction. Overall, the results of the analyses have varied widely, traditionally attributed to site-to-site and project-to-project differences. In this paper, researchers describe an effort to use empirical Bayesian (EB) techniques to develop temporal-based construction zone crash modification factors (CMFs). Specifically, separate CMFs were estimated for various time-of-day (daytime, nighttime), work status (work activity occurring at the site, work area inactive), and temporary traffic control (temporary lane closure present, no lane closure present) conditions. Daily project inspector diaries from 64 freeway construction projects in four states were analyzed to determine hours of work, hours and locations of temporary lane closures, and the number of travel lanes closed during each work period. Researchers used EB methods in a before-during study design to investigate the safety impacts of the different work zone conditions.

Work activities requiring the temporary closure of one or more travel lanes resulted in the largest CMFs (i.e., the largest increases in crashes), followed by periods of work activity that did not require a lane closure (i.e., work was occurring in the median or beyond the edge of the travel lanes). The lowest increase in crashes occurred during periods when work was not occurring at the project. Interestingly, the CMFs during work activity did not vary significantly between daytime and nighttime conditions when there was a lane closure. The results suggest that EB methods can be useful in assessing temporal factors influencing road safety.

Authors

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ANB20, Separating Safety Effects of Multiple Improvements by Alternate Empirical Bayes Methods (11-3863)

Empirical Bayes before-after evaluations provide the average safety effectiveness estimate for safety improvement treatments that have been implemented on a group of sites. When multiple improvements have been installed at each site, a single effectiveness estimate is provided for the combination of improvements. To obtain individual safety effectiveness estimates for the improvements by the current EB method, separate studies of each improvement must be conducted. However, alternative EB methods may be formally accomplished when sites having the combined improvements installed and sites having all but the desired improvement to be estimated are both available. This paper examines the safety evaluation methodology, safety effect estimators, and statistical test of significance for these alternative EB methods. The recent study of the Safety Edge treatment is used to illustrate these methods. Recommendations include conducting individual EB analyses for study sites with and without the desired treatment and estimating the effect directly from the results. A statistical test of significance can be conducted by estimating the precision and generating a confidence interval from the estimated precision of the estimates.

Authors

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4 Papers on safety performance functions

For these papers, predictive methods 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.

Sixteen papers were identified by the Subcommittee to address safety performance functions (SPFs). From a methodological perspective, these papers used a wide range of techniques from the traditional Negative Binomial (NB) Models to other more recent applications.

The traditional NB approach was used by 6 papers (11-0418, 11-0512, 11-0910, 11-0998, 11-1016, and 11-2610). Other traditional approaches were used such at the Multinomial Logit Model (11-1423), Quantile Regression (11-3276) and Random Parameter NB (11-3740).

Other approaches used by researchers were the Diagonal Inflated Bivariate Poisson Regression (11-0552) to model paired correlated data, and Data Mining techniques (11-0104) to identify significant factors. Others attempted different functional forms of SPFs, e.g. sigmoid and exponential, using the Neural Networks methodology (11-2070).

From an applications perspective, several papers addressed Freeway sections' safety (11-2070 and 11-3740). Others addressed specific type of crashes or locations on freeways, e.g. Freeway Diverge areas (11-0512), Cross Median Crashes (11-1016), and Diamond Interchanges (11-1019). Intersections were investigated by 3 studies (11-0418, 11-0910, and 11-1019). Other applications included: Animal-Vehicle crashes (11-0552 and 11-2199), Arterial Signal Coordination (11-1423), Aggregate level analysis (11-0104, 11-2610, and 11-4116).

ANB20, Zonal-Level Safety Evaluation Incorporating Trip Generation Effects (11-0104)

Exploring the significant variables related to specific types of crashes is vitally important in the planning stage of a transportation network. This paper aims to identify and examine important variables associated with total crashes and severe crashes per traffic analysis zone (TAZ) in four counties of the state of Florida by applying nonparametric statistical techniques such as data mining and random forest. The intention of investigating these factors in such aggregate level analysis will be helpful in incorporating proactive safety measures for long range transportation planning. Total and severe crashes per TAZ were modeled to provide predictive decision trees. The variables which carried higher weight of importance for total crashes per TAZ were - total number of intersections per TAZ, airport trip productions, light truck productions, and total roadway segment length with 35 mph posted speed limit. The other significant variables identified for total crashes were roadway segment length with 15 mph posted speed limit, and 65 mph posted speed limit, and non-home based work productions. For severe crashes, total number of intersections per TAZ, light truck productions, total roadway segment length with 35 mph posted speed limit and 65 mph posted speed limit were among the significant variables. These variables were further verified and supported by the random forest results.

Authors

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ANB25, Safety Performance Functions for Intersections in Virginia (11-0418)

In recent years, significant effort and money have been invested through both research and implemented projects to enhance highway safety in Virginia; however, there is still substantial room for improvement in both crash frequency and severity. As available funds are limited it is crucial to carefully allocate resources for safety improvement projects to be able to achieve the maximum safety benefits and the best possible return on investment. In this study, safety performance functions (SPFs) for intersections in Virginia were developed for use in conjunction with SafetyAnalyst, which contains a set of computerized analytical tools developed by the Federal Highway Administration. Some of these tools can be used to identify and prioritize highway locations that have the highest potential for crash reduction and safety improvement (ITT Corporation SafetyAnalyst User's Manual, 2008). A SPF is a mathematical relationship between frequency of crashes by severity and the most significant causal factors on a specific type of road. The SafetyAnalyst User's Manual presents several SPFs for intersections, but they were developed using data from Minnesota. It has been suggested that each state should develop its own SPFs based on crash and traffic data from the state (Harwood et al, 2004), because the suggested Minnesota SPFs may not adequately represent the crash characteristics in all states. In this study, the SPFs were developed using the average annual daily traffic (AADT) as the most significant causal factor, imitating the SPFs currently suggested by SafetyAnalyst. The SPFs were developed for both total crashes and combined fatal plus injury crashes through generalized linear modeling (GLM), using negative binomial (NB) distribution. SPFs were also developed for urban and rural intersections separately. In order to account for the different topographies in Virginia, statewide SPFs as well as specific regional SPFs were developed for the Northern, Western and Eastern regions (Read 2009). Because of the data available, the types of intersections included in this study were, 4-leg signalized, 4-leg with stop control at the minor approaches, 3-leg signalized, and 3-leg s with stop control at the minor approaches. The scope of the study was limited to Virginia Department of Transportation (VDOT) maintained roads due to the data that could be obtained from the databases used. Statistical comparisons of the SPFs based on Minnesota data

with those based on the Virginia data showed that the specific SPFs developed for Virginia fit the Virginia crash data better. The report recommends that the Virginia Department of Transportation (VDOT) uses the SPFs developed for Virginia as this will facilitate the identification of sites with a high potential for safety improvement, which, in turn, with the implementation of appropriate safety improvements, will result in a considerable reduction in crashes and their severity.

Authors

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ANB20, Safety Evaluation of Truck-Related Crashes at Freeway Diverge Areas (11-0512)

The study evaluated the impacts of geometric design factors and traffic factors on the truck-related crashes at freeway diverge areas. For this purpose, 391 freeway segments with different geometric designs were selected in various locations throughout the State of Florida. Crash data and inventory data were collected from the selected freeway segments and organized into two sets: site-based and crash-based for developing two prediction models (truck-related crash frequency model and truck-related injury severity model) respectively. The truck-related crash frequency model, fitted by the Negative Binominal regression, is used to identify the significant factors contributing to truck-related crash frequency at freeway diverge areas, and quantify the impacts of the factors. And the injury severity model, developed by the Ordered Probit regression, is utilized to address the factors that contribute to the injury severity of truck-related crashes at freeway diverge areas and the factor impacts. The analysis of the two models show that exit configurations (Type I, II, III and IV) have no significant influence on the injury severity of truck-related crashes at diverge areas. Type III exit configuration has the best safety performance in terms of the lowest truck-related crash frequency at freeway diverge areas. For one-lane freeway exit ramp, replacing a Type I exit configuration with a Type II exit configuration will increase truck-related crash counts at freeway diverge area by 21%. For two-lane exit ramps, replacing a Type III configuration with a Type IV configuration will increase crash counts at freeway diverge area by 26%. Other significant factors on truck-related crashes at freeway diverge areas include deceleration lane length, number of through lanes/surface width, median/shoulder width, curvature and grade design, speed limit, AADT on mainline/ramp, and truck percentage.

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ANB20, Modeling Animal-Vehicle Collisions Using Diagonal Inflated Bivariate Poisson Regression (11-0552)

Two types of Animal-Vehicle Collision (AVC) data are commonly adopted for AVC-related risk analysis research: reported AVC data and carcass removal (CR) data. One issue with these two data sets is that they were found to have significant discrepancies by previous studies. In order to model these two types of data together and provide a better understanding of highway AVCs, this study adopts a Diagonal Inflated Bivariate Poisson (DIBP) regression method, an inflated version of Bivariate Poisson (BP) regression model, to fit the reported AVC and CR data sets collected in Washington State during 2002-2006. The DIBP model not only can model paired data with correlation, but also handle under- or over- dispersed data sets as well. Compared with three other types of models, Double Poisson (DP), BP, and Zero-inflated DP (ZIDP), the DIBP model demonstrates its capability of fitting two data sets with remarkable overlapping portions resulting from the same stochastic process. Therefore, the DIBP model provides researchers a new approach to investigating AVCs from a different perspective involving three distribution parameters. The modeling results show the impacts of traffic elements, geometric design and geographic characteristics on the occurrences of both reported AVC and CR data. It is found that the increase of some associated factors, such as speed limit, annual average daily traffic, and shoulder width, will increase the numbers of reported AVCs and CRs. Conversely, the presence of some geometric factors, such as rolling and mountainous terrain, will decrease the number of reported AVCs.

Authors

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ANB10, Disaggregate Safety Evaluation for Signalized Intersections and an Evaluation Tool (11-0910)

The purpose of this study was to evaluate traffic safety at four-legged signalized intersections and to develop a spreadsheet tool for identifying high-risk intersections that considered vehicle movements, left-turn signal phase types, and times of day. The study used data from Virginia and employed count data models and the empirical Bayes (EB) method to conduct the safety evaluation. Crash pattern defined by vehicle movements involved in a crash and time of day were found to be important factors for intersection crash analysis. Especially for a safety performance function (SPF), a model specification (Poisson or negative binomial), inclusion of left-turn signal types, type of traffic flow variables, variable functional forms, and/or magnitudes of coefficients turned out to be different across times of day and crash patterns. The spreadsheet application tool incorporated the developed SPFs and the EB method. As long as Synchro files for signal plans and crash database are maintained, no additional field data collection efforts are required. The developed SPFs and the spreadsheet can be adapted for recent traffic and safety conditions by applying the calibration methods employed in SafetyAnalyst and the Highway Safety Manual.

Authors

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ANB20, Effects of Congestion Charging on Road Traffic Casualties: Causal Analysis Using Difference-in-Difference Estimation (11-0998)

This paper aims to identify the impacts of the London congestion charge on road casualties within the central London charging zone. It develops a full Difference-In-Difference (DID) model that is integrated with generalized linear models, such as Poisson and Negative Binomial regression models. Covariates are included in the model to adjust for factors that could violate the parallel trend assumption, which is critical in the DID model. The lower Bayesian Information Criterion value suggests that the full Difference-In-Difference model performs well in evaluating the relationship between road accidents and London congestion charge as well as other socio-economic factors. After adjusting for a time trend and regional effects, the results show that the introduction of the London congestion charge has a significant influence on incidence of road casualties. The congestion charge reduces the total number of car accidents, but is associated with an increase in two wheeled vehicle accidents.

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ANB20, Factors Contributing to Cross-Median Crashes (11-1016)

The objective of this study was to explore the relationship between various geometric and traffic characteristics and cross-median crash (CMC) frequency on highway segments. Negative binomial (NB) regression was used to identify the factors that affect CMC frequency. Information on roadway segments, extracted from all divided highways (without median barrier)in Wisconsin was used to estimate NB regression models for CMC frequency. Each segment contains information on geometric characteristics such as median width, influence of bridge, left and right horizontal curves, entrance and exit interchange ramps, and average annual daily traffic as well as the number of single- and multi-vehicle CMC in those segments from 2001 through 2007. Frequency models were developed for total number of CMC (sum of single and multi-vehicle CMC) as well as only multi-vehicle CMC. NB models predict that total CMC frequency increases with the presence of influence of bridge, as well as entrance and exit interchange ramps, but decreases in the presence of left curve. In general, the models predict that the narrower the median, the greater the CMC frequency. A sensitivity analysis was performed with respect to segment length and the results were consistent, indicating that the NB model is robust. The results from the frequency model for only multi-vehicle CMC are significantly different from those of total CMC. The only significant factors for the multi-vehicle model were interchange ramp and right curve. This could be due to the fact that limiting the dataset to only multi-vehicle CMC biases the dataset because both single and multi-vehicle CMC have the same crash causation and contributory factors. The results of this research will be used to develop predictive and retrofit median barrier warrants.

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ANB25, Safety Performance Functions for Diamond Interchange Ramp Terminals (11-1019)

The objectives of this research were to identify factors contributing to ramp terminal crashes and develop safety performance functions for four-leg diamond interchange ramp terminals. Four-leg diamond interchange ramp terminals in Wisconsin were sampled to construct two datasets. The first dataset was comprised of 60 pairs of interchange ramp terminals and was used to do general analysis and identify the effects of geometric factors. The other dataset was comprised of only signalized diamond interchange ramp terminals and was used to study the effect of signal timing. The major factors considered included traffic volume, traffic control, and geometric design. For signalized interchange ramp terminals, yellow and all-red clearance intervals were also considered as factors. The presence of cross road median is negatively correlated with average crash frequency. For signalized interchange ramp terminals, the crash frequency increases with deficient yellow or all-red intervals and decreases if there is an exclusive right turn phase. Decreasing the deficient yellow clearance interval by one sec was found to reduce the crashes by 84 percent. While decreasing the deficient all-red clearance interval by 0.5 sec was found to reduce crashes by 39 percent. These findings indicate that providing adequate clearance times at signalized ramp terminals can significantly improve their safety performance. Validation of these SPFs for signalized ramp terminals with an expanded dataset is recommended.

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ANB20, Safety Effect of Arterial Signal Coordination (11-1423)

Traffic signals are coordinated mainly with traffic mobility in mind while the impact on safety is not well known. It is not clear how strong this impact is under specific conditions and which coordination solutions increase or reduce this impact. Engineers who set coordinated signals have at their disposal a number of tools to improve traffic mobility along urban streets but no tool to account for safety. In this paper, we study the impact of arterial signal coordination on the frequency and severity of rear-end and right-angle collisions – the two types of crashes that are prevalent at signalized intersections - the frequency and severity of which are likely to be affected by signal coordination. Multinomial logit models were developed to estimate crash likelihood in 15-minute intervals as well as the severity of crash outcome on arterial intersection approaches. The obtained models were used to investigate the safety impact of signal coordination and other road and traffic variables. We determined the following. (1) Signal coordination can significantly affect crash likelihood and severity. The concentration of vehicle arrivals in the second half of a green phase is associated with significantly lower crash likelihood and severity. (2) Certain components of the traffic flow are most susceptible to crashes. (3) Short distances between intersections and short cycle lengths are associated with a lower risk of crash. (4) The presence of a right-turn bay is associated with a considerable improvement in safety manifested by a lower risk of rear-end and right-angle collisions. The developed models can be used as a tool for evaluating alternative signal coordination plans from the standpoint of safety.

Authors

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ANB20, Relating Flow, Speed, and Density of Urban Freeways to Functional Form of a Safety Performance Function (11-2070)

Constructive discussion of the appropriate choice for the functional form of Safety Performance Functions (SPFs) is largely absent from research literature on road safety. There appears to be a consensus among researchers developing SPFs that the underlying randomness in accident counts is well described by the Negative Binomial distribution. The underlying phenomenon itself, however, is not well understood and rarely discussed. The art of choosing the regression equation is seldom transparent, reasoned or documented (1). Researchers most commonly use the power function, possibly because most Generalized Linear Modeling (GLM) statistical packages can accommodate it with little effort. The modeling process, however statistically rigorous, at times seems disconnected from the physical phenomenon it is trying to describe. This disconnect, however, has attracted only limited interest from researchers to date. Accidents on an urban freeway are a byproduct of a traffic flow; therefore, it is reasonable to expect that observing changes in the flow parameters may give clues about the probability of accident occurrence and changes in accident frequency. This paper relates traffic flow parameters such as speed and density with the choice of the functional form of the SPF. Additionally it compares SPF models for urban freeways developed with sigmoid and exponential functional forms using data from Colorado and California by contrasting their Cumulative Residual (CURE) plots. SPFs developed around a sigmoid functional form using the Neural Networks (NN) methodology suggest possible underlying relationships between safety and traffic flow characteristics. Cumulative Residual (CURE) plots for Neural Networks generated SPFs generally show a better quality model fit when compared with power function SPFs developed in the GLM framework with a Negative Binomial error structure.

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ANB20, Modeling Animal-Vehicle Collisions Considering Animal-Vehicle Interactions (11-2199)

Animal-Vehicle Collisions (AVCs) have been a major safety problem in the United States over the past decades. Countermeasures against AVCs are urgently needed for traffic safety and wildlife conservation. To better understand the AVCs, a variety of data analysis and statistical modeling techniques have been developed. However, these existing models seldom take human factors and animal attributes into account. This paper presents a new probability model which explicitly formulates the interactions between animals and drivers to better capture the relationship among drivers' and animals' attributes, roadway and environmental factors, and AVCs. Findings of this study show that speed limit, rural versus urban, and presence of white-tailed deer habitat have an increasing effect on AVC risk, whereas male animals, high truck percentage, and large number of lanes put a decreasing effect on AVC probability.

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ANB20, Accident Prediction Models for Winter Road Safety: Does Temporal Aggregation of Data Matter? (11-2610)

Accident prediction models are mostly developed using single-level count data models such as the traditional negative binomial models with fixed or varying dispersion parameter, assuming independency of data. For many accident data sets in road safety analysis, especially those of some highly disaggregated nature (hourly data), there often exists a hierarchical structure in the data which manifests itself in some form of correlation. Crash prediction models developed with aggregate data could produce biased results due to the assumption of data independence and inflation of the adequacy of the model's explanation due to the use of aggregate data. This paper investigates the potential effects of data aggregation and correlation on accident prediction models. The analysis uses an accident database including hour-level and storm-level accident counts over individual winter snow storms at four highway sections in Ontario. Models of two different levels of aggregation: aggregated event-based models and disaggregated hourly-based models were developed. It was found that the effect of data aggregation has a significant effect on model results while the difference between the conventional regression and multilevel regression is inconsequential.

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ANB20, Analysis of Crash Data Using Quantile Regression for Counts (11-3276)

Statistical models that describe the relation between accident frequency and its influencing factors have been widely studied for the last few decades. Most of the existing methodologies use these models with count data and their variants to study the mean effects of covariates on crash frequency. This study seeks to explore the use of quantile regression (QR) for counts as a methodological alternative in analyzing accident frequency. Compared with existing models, the proposed model provides a fuller and more robust analysis of crash data for at least two reasons. First, crash data usually follow typical count distributions with a large proportion of zeros and the remaining values highly skew toward the right. Quantile regression becomes appealing to provide a more complete picture of effects of covariates on accident frequency rather than just the mean because it estimates various quantiles of a population. Second, as a semiparametric technology, quantile regression for counts allows researchers to relax restrictions in the form of the distribution function of the response variable, resulting in more robust estimation. Crash data collected on interstate highways in Washington State in 2002 were abstracted from the Highway Safety Information System (HSIS), and studied using the proposed model. The results were compared with those from the negative binomial regression model. The empirical study shows that while the significance and signs of the effects derived from both models are consistent, the proposed model reveals more detailed information such as how the marginal effects of covariates change across the conditional distribution of the response variable.

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ANB20, Identification of Self-Selection Bias in National Crash Database and Its Impact on Crash Estimates (11-3409)

Over the last decade, driver distractions, such as cell phone use and texting, have become a significant contributor to roadway crashes. Some states now have legislation that severely restricts or bans driver activities deemed distracting. However, many policies and engineered countermeasures are based on self-reported crash data. This raises the issue of potential bias than when not controlled for in analysis supporting policy decisions can lead to poor commitment of public resources. This study explores the impact of self-selection bias caused by self-reporting driver distraction on the likelihood estimates of being involved in crashes. Using a two step correction technique, the study tests and controls for the bias when present, and interpret its impact on the effects of distraction drawn in other studies. The findings show that selection bias is present in the National Automotive Sampling System General Estimates System, a national database often used to help evaluate policy and engineering safety countermeasures. Additionally, our findings show that self-selection bias understates the true effect of driver distraction on injury severity and as a result, the forecast of potential savings of countermeasure policies or in-vehicle devices will be underestimated.

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ANB20, Modeling Relationship Between Interstate Crash Occurrence and Geometrics: Exploratory Insights from Random Parameter Negative Binomial Approach (11-3740)

This paper proposes the use of a random parameter negative binomial model for the analysis of crash counts. Using a nine year continuous panel of crash histories of total crash frequencies on interstates in Washington State for the period (1999-2007), a random parameter negative binomial model is estimated accounting for parameter correlations, panel effects contributing to intra-segment temporal variations as well as between-site effects. Interstate geometric variables such as lighting type proportions by length, shoulder width proportions, lane cross section proportions, and curvature variables are used in the model specification. Curvature variables include number of horizontal curves in segment, number of vertical curves in segment, shortest horizontal curve in segment length, largest degree of curvature in segment, smallest vertical curve gradient and largest vertical curve gradient in segment. Segments were analyzed at the interchange/non-interchange level. A total of 1,168 directional segments comprising of the seven Washington State interstates were analyzed, yielding a statistical model of crash frequency based on 10,512 observations. It was found that several curvature effects were random, meaning they varied from segment to segment. For example, while number of horizontal and vertical curves in a segment were fixed parameters, the largest degree of curvature, as well as the smallest and largest vertical curve gradient

variables were random parameters. The logarithm of ADT, median and point lighting proportions were also found to be random parameters. These results suggest that segment specific insights into crash frequency occurrence can be improved for appropriate design policy and prioritization insights.

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ANB20, Modeling Highway Safety and Simulation in Rainy Weather (11-4116)

The objectives of this research were to comprehensively examine the safety impacts of rainy weather conditions on multi-vehicle crash frequency and severity and to validate the impact on traffic operations through micro-simulation modeling. To meet these objectives, three primary tasks were performed as follows. For weather data processing, the following factors were estimated by using currently available data: rainfall intensity, water film depth, and deficiency of car-following distance. For statistical modeling, negative binomial regression was used for crash frequency while sequential logistic regression was tested with forward and backward formats for crash severity. Particularly, a better format for the crash severity estimation was determined by combining all model performance measures. Using VISSIM, traffic simulation models were additionally designed to reflect weather impacts on traffic operation with five scenarios of the following weather-sensitive parameter adjustments: desired deceleration rate function, desired speed distribution and headway time. As weather-related determinants, daily rainfall and wind speed were found to be statistically significant to crash frequency and severity estimations, respectively. Additionally, VISSIM provided the most similar traffic data to the observed data when both desired speed distribution and deceleration rate function were adjusted. Statistical modeling in this research can be used to examine highway safety especially in rainy weather and provide quantitative support on implementing road weather safety management strategies. Correspondingly, the adjustments of weather-sensitive traffic parameters will be the preliminary step to measure the strategy efficiencies through safety surrogate indexes in traffic simulation.

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5 Papers on crash severity prediction

Seven papers were identified by the Subcommittee to address injury severity. Some papers outlined above addressed both SPFs and injury severity (11-0512 and 11-3409).
Most of these papers were less focused on the modeling contribution and more on the specific applications. Apart from using the Mixed Logit Model (11-2299) and Structural Equations (11-2663), the other papers used NB or simple risk estimation. Applications ranged from risk factors at Work Zones (11-3785), Cross Median and Median Barrier Crash severity (11-1024), Severe crash frequency within TAZs (11-0065), the effect of age on injury severity (11-2299) to the Influence of Accessibility on Accident Severity with Structural Equation Modeling (11-2663).

ANB10, Integrating Trip and Roadway Characteristics in Managing Safety at Traffic Analysis Zones (11-0065)
A transportation network is a conglomeration of various sets of road-traffic-environment modules and is featured by multi-categories of inter-dependent factors. This makes the management of safety in Traffic Analysis Zones (TAZs) explicitly challenging. This study aims at investigating the association between crash frequencies and various types of trip productions and attractions in combination with the road characteristics of 1349 TAZs of four counties in the state of Florida. Crash safety management of these TAZs is emphasized through prioritizing them by examining the effects of various trip and roadway factors on the aggregated crash frequencies. Models were developed separately for total crashes, severe crashes (fatal and severe injury crashes), total crashes during peak hours and pedestrian and bicycle related crashes taking various groups of estimators into considerations. It was found that total crash model and peak hour crash model were best estimated by the total trip productions and total trip attractions. Severe crash model was best fit by the trip related variables only and pedestrian and bicycle related crash model was best fit by the road related variables only. The results from this study pave the way for better safety management and incorporating safety measures in travel and network planning.
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ANB25, Injury outcomes and costs for cross-median and median barrier crashes (11-1024)
The objective of this research was to quantify the injury outcomes and develop reliable and comprehensive injury costs for cross-median crashes (CMC) and median barrier crashes (MBC). A three-step methodology was developed to quantify the crash costs for each crash severity and type. All CMC and MBC between 2001 and 2007 in Wisconsin were identified and used in this analysis. The Wisconsin 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 both more total injuries and more severe injuries than single-vehicle CMC. Injury costs for the same injury level on KABCO scale are different for different crash types. Injury costs for concrete MBC are 33to 50% less than those of multi-vehicle CMC while the injury costs of concrete MBC for lower severities (B and C) are similar to those of single-vehicle CMC for the same severities; but for incapacitating injuries the costs are 30% less. As expected, concrete MBC result in lower severities than CMC. The costs by crash severity, vary significantly between different crash types. Concrete median barrier injury crashes are roughly 20% of multi-vehicle CMC costs and 50% of single-vehicle CMC costs. Results indicate that using one set of crash costs for all crash types biases any evaluation. Therefore, it is recommended that crash-type-specific costs be used in applications such as development of median barrier warrant where specific types of crashes are considered (CMC and MBC).
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ANB20, Mixed Logit Model Approach to Investigate Effects of Age on Driver Injury Severity in Single-Vehicle Accidents (11-2299)
This research develops a mixed logit model of driver-injury severity in single-vehicle accidents to investigate in particular the effect of driver age. Using data for single-vehicle crashes in 2003–2004 from the Statewide Integrated Traffic Records System of the California Highway Patrol, several factors were found to significantly increase the probability of fatal injury for drivers in single-vehicle crashes: older driver 65+, male driver, drunk driving, unsafe speed, older driver driving an older vehicle, and darkness without streetlights. It was also shown that older drivers (aged 65 and over) lead to a uniform distributed random parameter for fatal injury and gender accounts for heterogeneity for new to 5 year old vehicles, with males linked to an increase in the probability of fatal injury in a newer vehicle but with females linked to a decrease.
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ANB20, Measuring Influence of Accessibility on Accident Severity with Structural Equation Modeling (11-2663)
SEM (Structural Equation Model) is a confirmatory, multivariate technique used to examine causal relationships between variables. Related to path analysis, where the goal is to select a model which best explains underlying relationships between variables, SEM is a useful tool for traffic safety research. This study examines the severity of crashes in terms of factors commonly attributed to accidents. These include human, vehicle and roadway factors along with accessibility measures determined to be relevant in the previous studies. SEM is used to test an a priori model of crash severity. The analysis was carried out in a two-step process. The measurement model was first tested with a Confirmatory Factor Analysis (CFA). After establishing the validity of the measurement model, a four latent factor structural model was run. With an acceptable model fit, the magnitude of standardized path coefficients from the exogenous latent variables provides a means of assessing the relative importance of the latent factors on crash severity. The results show that the human latent factor was most influential. While roadway factors also positively influenced

crash severity, accessibility factors had the opposite effect on crash severity, that is, increased accessibility is shown to reduce crash severity.

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ANB20, Risk Factors Associated with Injury Severity of Work Zone Crashes (11-3785)

As most of the nations highway infrastructure is aging, the current highway works are shifted from the construction of new highways to the maintenance and rehabilitation of existing roadways during which work zones are created. The safe and efficient flow of traffic through these work zones is a major concern to many highway agencies. The crash severity in these work zones is increasing day by day. Thus, identification of various risk factors associated with work zone crashes is very important to improve work zone safety. In this analysis, an ordered probit statistical modeling technique was used by considering all possible explanatory variables under various characteristics. Based on the analysis, it was found that work zone crashes involving trucks, light duty vehicles such as vans, pick-up and SUVs had a tendency for higher injury severity. Middle age drivers were more prone to severe injuries than old age and young age drivers involved in work zone crashes. Following too close, non deployment of airbags, sideswipe collision of the same direction vehicles had a tendency to cause more severe injuries to occupants in work zone crashes. On roadway work zone crashes and crashes occurred while vehicles were taking left/right turns in work zone area are some of the other factors that contribute towards higher injury severity in work zone crashes. Several other factors were analyzed based on which crucial results were obtained which when rectified would help attenuate the severity of crashes in work zone areas.

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6 Papers on network screening

Usually, the first stage in a typical road safety improvement program consists in network screening to identify black spots or crash-prone locations (also called hot spots, hazardous locations and sites with promise). A crash-prone location may be defined as any location (section or intersection) that exhibits a crash potential that is significantly high when compared with some norm or average crash potential which is established from other locations with similar characteristics. Several techniques have been used to identify these locations using Empirical Bayes and Full Bayes techniques. It is vital that a sound procedure be used to identify crash-prone locations; otherwise, resources will be wasted on locations that are incorrectly identified as unsafe while those that are unsafe will remain untreated.

ANB20, Development of Proactive Hot-Spot Identification Method for Urban Arterials Using a Stochastic Catastrophe Model (11-0519)

During the last few decades, the two-fluid model and its two parameters have been widely used in transportation engineering to represent the quality of operational traffic service on urban arterials. A catastrophe model has also often been used to describe traffic flow on freeway sections. This paper investigates the analogy in logic behind the two-fluid model and the catastrophe model using straightforward graphical illustrations. The paper then demonstrates the application of two-fluid model parameters to a stochastic catastrophe model designed to estimate the level of safety on urban arterials. The current road safety management process, including network safety screening, is a post-active rather than pro-active approach in the sense that an existing hotspot must be identified before a safety improvement program can be implemented. This paper suggests that we need a scientific tool such as the stochastic catastrophe model in order to identify a vulnerable urban arterial that may currently show an acceptable level of safety, but that may easily turn into a crash hotspot. Such a tool would lead to a paradigm shift in the way we approach the overall road safety management process: we would be able to implement remedial actions pro-actively before a hotspot develops.

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ANB20, Safety-Indicator Performance in the identification of Black Spots on 2-Lane Rural Roads - Performance Evaluation of Black Spot Identification Methods (11-1008)

Defining a black spot is not so perceptual as it might seem. Simply observing unusually high crash counts does not necessarily indicate a real safety problem. When identifying black spots on two-lane rural roads with low and medium traffic volumes, a reduced number of observed crashes is a critical issue that can emphasize weak results obtained from using different safety indicators and checks. It is generally assumed that an Empirical Bayesian estimate represents the best approach for the identification of black spots, but it is difficult to quantitatively define the precision of estimates that are arrived at using different procedures. Considering that traffic volume, segment length and crash observation period are critical issues in the identification of black spots and can emphasize the quality of the results obtained using different safety indicators and checks, the aim of this paper is to define the limits and errors that can be expected when using inadequate indicators and procedures to identify black spots on two-lane rural roads. Using a Monte Carlo simulation it was possible to produce theoretical crash data similar to empirical data and use them to define a priori hazardous sites and, therefore, assess whether a method can correctly identify such sites. The paper defines and compares the accuracy and efficiency of procedures based on the observed frequency (OB) of crashes, Crash Rate (CR), Empirical Bayes estimation (EB) and the Potential for Safety Improvement (PSI). As a general rule, even if some arrangements can mitigate the lower performance of some indicators, the best practice is to use the indicators based on the Empirical Bayes approach (EB, PSI) to identify True Positives.

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ANB20, Prediction of Accident Frequency at Their Severity Levels and Its Application in Site Ranking Using Two-Stage Mixed Multivariate Model (11-2510)

Accident prediction models (APMs) have been extensively used in site ranking with the objective of identifying accident hotspots. Previously this has been achieved by using a univariate count data or a multivariate count data model (e.g. multivariate Poisson) for modelling the number of accidents at different severity levels simultaneously. This paper proposes an alternative method to estimate accident frequency at different severity levels, namely the two-stage mixed multivariate model which combines both accident frequency and severity models. The accident, traffic and road characteristics data from the M25 motorway and surrounding major roads in England have been collected to demonstrate the use of the two-stage model. A Bayesian spatial model and a mixed logit model have been employed at each stage for accident frequency and severity analysis respectively, and the results combined to produce estimation of the number of accidents at different severity levels. Based on the results from the two-stage model, the accident hotspots on the M25 and surround have been identified. Compared to the traditional frequency based analysis, the two-stage model has the advantage in that it utilises more detailed individual accident level data and it is able to predict low frequency accidents (such as fatal accidents). Therefore, the two-stage mixed multivariate model is a promising tool in predicting accident frequency according to their severity levels and site ranking.

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ANB20, Investigation and Evaluation of Ranking Criteria for Hot-Spot Identification (11-3933)

The Fully Bayesian (FB) approach to hazardous site identification has been available for some time. However, there is no evaluation study with regards to the ranking criteria and little research has been conducted on the performance of the FB method. The objective of this study was to fill this gap by conducting a thorough evaluation of the FB method for black spot identification. First, an evaluation is conducted on the FB versus the empirical Bayesian (EB) method. It is confirmed that the FB method is superior to the EB with respect to key ranking criteria: the posterior Poisson mean (PM) of crash frequency and potential for safety improvement (PSI) based on evaluation criteria that included sensitivity and specificity, and the sum of the PM. Then, a total of 8 ranking criteria, which include PM, posterior expected, mode and median ranks, and probability of being the worst, have been examined for the best selected FB model. Specifically, the mode rank of the posterior distribution of the Poisson mean was

proposed as a ranking criterion as it provided the best results for top ranked sites. Similarly, the sum of the Poisson mean in the evaluation period was proposed as an evaluation criterion especially when a limited number of top ranked sites are selected.

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ANB20, Evaluation of Influence of Crash Underreporting on Hot-Spot Identification (11-4119)

Hot spot identification (HSID) plays a significant role in improving the safety of a road network. Numerous hot spot identification methods have been developed and proposed in the past. Most of them rely heavily on official crash statistics to conduct HSID. Crash underreporting, along with many other issues, has long been recognized as a threat to the accuracy and completeness of historical traffic crash records. As a natural continuation of a previous study, the paper intends to evaluate the exact influence underreported crashes might have on HSID. To conduct the evaluation, five groups of data gathered from Arizona Department of Transportation (ADOT) over the course of three years are adjusted to account for fifteen different levels of underreporting. Three identification methods are utilized: simple ranking (SR), empirical Bayes (EB) and full Bayes (FB). Various cutoff levels to establish hotspots are explored. Finally, two evaluation criteria are compared across HSID methods. The results illustrate that the identification bias due to crash underreporting may be significant. Comparatively speaking, the crash underreporting has the largest influence on the FB method, and has the least influence on the SR method. Additionally, the impact appears to be positively related with the percentage of the underreported PDO crashes, but inversely related with the percentage of the underreported injury crashes. This is significant because it establishes that although PDO crashes are seen as the least severe, they have the most significant influence on hot spot identification.

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7 Papers on surrogate measures for crash data

The ANB20(3) Surrogate Measures of Safety Subcommittee is aimed at stimulating research on surrogate measures of safety and their validation through field measurements, computer simulation, and driving simulators (https://wiki.umn.edu/TRB_ANB203/WebHome). A strong emphasis is put on a scientific rigor of the research and validity of the results.

Twenty papers submitted to the 90th Annual TRB Meeting deal with surrogate measures of safety. Most of the papers are presented in two sessions:

(1) January 25, 9:30 – 12:00 AM, poster session 472: "Surrogate Measures in Safety Analysis", in Marriott, Salon 2, and
(2) January 26, 2:30 - 4:00 PM, podium session 712: "Surrogate Measures of Road Safety for Modeling and Management", in Marriott, Maryland C.

Surrogate events have been applied in nine papers (11-0117, 11-1118, 11-1226, 11-1339, 11-1417, 11-1991, 11-1991, 11-1991, and 11-2119) while speed and its variation in four papers (11-1156, 11-2505, 11-2846, and 11-4199). Other papers used more complex measures such as vehicle trajectories with probabilistic representation of crash potential (11-1852) or routine road evaluation by experts (11-1139). Majority of papers (14) used field observations of the surrogate measures data. It is worth to note that the data used in three papers were collected through naturalistic driving (11-1226, 11-1506, and 11-1991). Another new trend is a growing number of safety analyses with micro-simulation (11-1453, 11-2119, and 11-3607). Only one paper discussed the difficult issue of estimating the potential severity of crash outcome corresponding to the observed surrogate event (11-4199). Surrogate measures were applied to investigate specific safety effects: roundabouts improvements (11-2119), separation of trucks from cars (11-1991), use of cell phones (11-1226), and drivers' and pedestrians' distractions (11-1991). Two papers used surrogate measures of safety to identify temporal high-risk conditions (11-2343 and 11-2713) and one used surrogate measures of safety to optimize programming of road improvements (11-1139). A growing need for validation of surrogate measures resulted in five papers that examined the relationship between the frequency of surrogate events and the frequency of crashes (11-0117, 11-1118, 11-1417, 11-1991, and 11-2119).

ANB20, Investigating Collision Factors by Mining Microscopic Data on Vehicle Conflicts and Collisions (11-0117)
Road collisions represent not only deplorable human costs to society but also considerable financial and environmental consequences. Although some progress has been made, a renewed effort is necessary to tackle this growing worldwide issue. This paper advocates the development of proactive methods for road safety analysis that do not depend on the occurrence of collisions. In particular, a better understanding of collision processes, i.e. the chains of events that lead to collisions, would yield many benefits: beyond improvements to the road system, this would help to identify traffic events without a collision with stronger links to collisions that can be used to develop more reliable surrogate safety measures. To achieve this goal, historical collision data obtained from police and insurance reports is unsuitable: better data on collision processes is needed, i.e. microscopic data (road users' trajectories) about traffic events with and without a collision. This paper reports on the first phase of a project relying on microscopic data extracted from video sensors and data mining techniques to identify patterns in the traffic event database. This approach is demonstrated on a dataset collected in Kentucky of 295 traffic events, constituted of 213 conflicts and 82 collisions. Its analysis illustrates the approach: in particular, three clusters are found by the k-means partitioning algorithm based on speed indicators extracted from the road users' trajectories. These clusters hint at the existence of conflicts that are dissimilar from most collisions and may therefore not be suitable for surrogate safety analysis.
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ANB20, Conflicts-Based Safety Performance Functions (11-1118)
Recent research has shown that traffic conflicts provide useful insight into the failure mechanism that leads to road collisions while being more frequent and of marginal social cost. However, the relationship between collisions and conflicts must first be bridged to use traffic conflicts as surrogates to collisions for safety analysis. This paper proposes the development of Safety Performance Functions (SPFs) using traffic conflicts as a potential predictor while correcting for measurement errors (ME). The objectives are to (i) establish the relationship between collisions and conflicts, and (ii) compare the predictive safety performance capabilities of volume-based SPFs with conflict-based SPFs using a data set from British Columbia. The proposed conflicts-based model was applied to a dataset corresponding to 51 signalized intersections in British Columbia. The model

was employed to predict the number of accidents at signalized intersections using conflicts' counts and area type (urban/suburban) as covariates. A significant relationship was found between collisions and conflicts upon adjusting for measurement errors. Compared with the volume-based NB model, the proposed model fitted the accidents data equally well. The comparison demonstrated that conflict-based SPFs have capabilities to predict safety performance on equal terms with what can be obtained through traffic volume-based exposure measures. The significance of this research stems from the establishing a relationship between collisions and conflicts, which calls for further research on the countermeasures needed to reduce conflicts as effective means for decreasing the number of collisions. Apart from the traffic- and geometric-based traditional countermeasures, new driving-behavior-based measures can be devised that would hopefully have a downward influence on collisions.

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ANB20, Surrogate Safety Measures for Optimizing Local Rural Road Network Investments (11-1139)

Safety management of local rural road network is often constrained by low budgets and a variety of external local requirements. Moreover, for the safety management of these roads, where a screening of the network based on observed crashes can be affected by a lack of quality and an insufficient quantity of collision data, alternative analyses have to be carried out to establish those circumstances that make a particular road intervention cost-effective, examining cost versus safety trade-offs for a series of alternative projects. As result of research project funded by the European Commission, a Safety Index (SI) was formulated as surrogate measure of safety. SI is related to the safety features of the road segment, which are assessed by two methodologies: RSIs (Road Safety Inspections) and Design Consistency Evaluations and Standards Checks. Given the significant correlation found between SI values and expected number of crashes, this paper presents a methodological approach using the SI to evaluate the safety effectiveness of the alternative proposed investments. Moreover, as there are often situations when the available budget will not be sufficient to undertake all the alternative projects evaluated as being effective, a formal method for selecting projects to be included in the budget was applied to maximize the safety benefits of the investments. The procedure implemented in the SAFOPT software (SAFety OPTminization), makes it possible to identify the intervention strategies that produce the greatest safety benefits, in terms of variations in the SI, while at the same time being compatible with the available annual budget. In other words the optimum budget to obtain the maximum benefit.

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ANB25, Evaluation of Level of Safety for Freeway Exits Based on Individual Speed Difference (11-1156)

Speed consistency has a strong correlation with safety. Conventional measure ΔV85, which is the subtraction of operating speed on two successive elements, may fall into ecological fallacy and overestimate the safety level of roadway elements. Aiming at overcoming these pitfalls, the 85th percentile individual speed difference 85ΔV and the speed reduction rate 85ΔVR are developed as alternatives to evaluate the level of safety for freeway exits. Speeds of 7617 individual traceable vehicles on freeway mainline, deceleration lane, upper ramp and lower ramp are collected at 42 exits with radar guns. A three-level criterion is given as guideline for the evaluation of level of safety. Safety level of the 42 exits are evaluated using three different speed consistency measures, namely the conventional ΔV85, newly proposed 85ΔV and 85ΔVR. The results show that ΔV85 has the most "Good" and the least "Poor" safety level linkages, and that 85ΔV produces the least "Good" and the most "Poor" safety level linkages. 85ΔVR gives an in-between outcome. Another finding is that the ratio of 85ΔV/ΔV85 is 1.42 for freeway mainline-deceleration lane linkage, 1.68 for deceleration lane-upper ramp linkage, and 1.98 for upper ramp-lower ramp linkage. Historical crash data on 31 exits are available for validation. The validation results approve the reasonability of measure 85ΔVR, which considers not only the individual speed reduction but also the base operating speed on approaching element.

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ANB70, Distraction in Commercial Trucks and Buses Using Naturalistic Data (11-1226)

The purpose of this Federal Motor Carrier Safety Administration-funded research was to conduct an analysis of naturalistic data collected by DriveCam® over a consecutive 1-year period. Commercial trucks (3-axle and tractor trailer/tanker) and buses (transit and motor coaches) were the target vehicles in the analyses. All safety-critical events (including crashes, near-crashes, and crash-relevant conflicts) and baselines in the last 90 days data set that were coded with cell phone use were re-reviewed to determine the frequency of the following cell phone sub-tasks: dial cell phone, reach for cell phone, reach for wireless headset/earpiece, talk/listen on hands-free cell phone, talk/listen on hand-held cell phone, and text/email/surf web on cell phone. Two large and diverse data sets were used in the current study. The data in DriveCam's first 275 days data set (data set A) came from 207 different truck and bus fleets comprising a total of 13,431 vehicles. A total of 1,336 crashes, 15,864 near-crashes, and 173,591 crash-relevant conflicts were captured from these 13,431 vehicles in data set A. The data in DriveCam's last 90 days data set (data set B) came from 183 different commercial truck and bus fleets comprising 13,306 vehicles. A total of 1,085 crashes, 8,375 near-crashes, 30,661 crash-relevant conflicts, and 211,171 baselines were captured from these 13,306 vehicles in data set BAs in previous naturalistic studies, the current study found that the odds of involvement in a safety-critical event differed as a function of performing different cell phone sub-tasks while driving.

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ANB20, Methodologies for Aggregating Traffic Conflict Indicators (11-1339)

Various quantitative conflict indicators have been proposed in the literature in order to measure the severity of traffic events. An important subset of these conflict indicators are based on the observation of sequences of road user positions. Objective conflict indicators measure various spatial and temporal aspects of proximity. Nevertheless, these aspects of severity may be partially overlapping and in some cases independent. Two sets of conflict indicators are used in this study. The first requires the presence of a collision course and the second measures severity in terms of mere temporal proximity. The integration of severity cues provided by each conflict indicator is performed on the hope that the resulting severity index will better reflect the true, but unobservable, severity of traffic events. This study proposes a methodology to aggregate conflict indicators into a safety index. First, individual conflict indicator measurements are mapped into severity intervals [0,1]. Second, these severity indices are aggregated to a safety index that includes both individual severities and exposure.

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ANB25, Surrogate Events in Modeling Traffic Safety – A Road Departure Case (11-1417)
The limited ability of existing safety models to properly reflect crash causality is a concern to researchers. The deficiency of the current safety models, most of them cross-sectional, has its source in the combination of the intrinsic complexity of the safety factors and the high aggregation and poor quality of data. It is possible to elevate the adequacy of data thanks to the unprecedented rapid progress in sensing technologies and the invention of the naturalistic driving method of data collection. The mainstream safety models are not capable of handling the new type of data. A new modeling paradigm therefore is proposed in this paper which integrates several types of safety and traffic flow models. The primary improvement would be a more adequate representation of the crash occurrence process by incorporating crash precursor events in to the modeling framework. A Pareto-based estimating of the likelihood of collision, given a precursor event, is described and illustrated with a simple example of road departures.
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ANB20, Simulating Traffic Conflicts on Truck-Only Infrastructure Using an Improved Time-to-Collision Definition (11-1453)
Transportation agencies have traditionally relied on historical crash records as the primary measure to evaluate the safety of roadways. The infrequent and sporadic occurrence of accidents, and the long period of time required to collect accident data have led to the use of surrogate safety measures. Conflict analysis using microsimulation modelling has been popularized for evaluating experimental changes to existing road networks. Previous freeway studies have used a simplified time to collision (TTC) definition, which in this study was found to produce unrealistic conflict situations. More specifically, the definition included situations where no collision path was occurring, such as when two vehicles were travelling at the same speed or when the leading vehicle was speeding away from the following vehicle. A revised conflict definition is developed to address these issues and is then contrasted with the simplified definition used in earlier studies. An investigation of acceleration rates demonstrates that the revised approach retains the meaningful conflicts produced by the previous definition, but eliminates the situations which are unlikely to be actual conflicts. Using this revised conflict definition, the evaluation of a truck-only highway in the Greater Toronto Area (GTA) is investigated to observe the effects on traffic conflicts. In general, it was found that while providing a separate highway for trucks does reduce truck-related conflicts, car lane change conflicts increase due to their increased manoeuvrability and presence on the truck-free highway.
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ANF10, Effect of Road User Distractions on Pedestrian Safety at Mid-block Crosswalks on a College Campus (11-1498)
Safety at mid-block crosswalks depends on the ability of drivers and pedestrians to recognize potential conflicts. As past literature has shown, when road users are distracted they have trouble processing information and their wherewithal to quickly identify conflicts is diminished. Consequently, vehicle-pedestrian interactions tend to be problematic when distractions are involved. Seven mid-block crosswalks on the campus of the University of North Carolina at Charlotte (UNC Charlotte) were observed and through data processing and analysis, the safety effects of pedestrian and driver distractions were determined. Findings show that drivers who were noticeably distracted (n=59) yielded about 5% of the time while attentive drivers (n=266) yielded about 77% of the time. Due to their poor yielding behavior, distracted drivers were approximately 4 times more likely to be involved in a conflict with a pedestrian. Interestingly, results show no significant difference between chance of conflict for distracted pedestrians (n=95) and attentive pedestrians (n=230). However, the research did find that drivers were nearly 40% more likely to yield to distracted pedestrians than to those who were attentive, perhaps due to increased aggressiveness and decreased cautiousness on the part of distracted pedestrians. Overall, this study provides evidence that pedestrian safety at crosswalks is dependent upon the willingness of road users to pay attention when they interact with one another.
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ANB20, Naturalistic Driving Event Data Analysis: Omitted Variable Bias and Multilevel Modeling Approaches (11-1506)
Naturalistic driving studies have been conducted over the last 5 or more years; one frequent technique applied to naturalistic data is the identification of crash, near crash and critical incident events which are subjected to subsequent analysis. There is a need to develop statistical methods that are applicable to these event data and to test their efficacy. This paper addresses two issues in model development for naturalistic driving event data: testing for omitted variable bias and exploring the advantages of hierarchical model structures in data analysis. Using data from the Virginia Tech 100-car study focusing on roadway departure events, a series of logit models are used to estimate the probability of a crash/near crash occurring compared to a critical incident. The models indicate a substantial omitted variable bias for estimation of the effect of context variables, but little difference for driver variables. Variables characterizing the effect of event variable such as driver distraction and precipitating event were particular significant and of substantial magnitude in the models. These tests indicate that modeling of naturalistic event data should include variables describing the attributes of the event, the driver and context in order to reduce the likelihood of bias. Hierarchical model structures offer the advantage of using driver-level predictors (e.g. years of driving) to parameterize the effects of event attributes and contexts. The models thus reflect how driver decisions are executed: drivers with particular characteristics (one level) find themselves in particular contexts executing specific driving maneuvers (second level) leading to certain outcomes. The paper concludes with suggestions for future research including the need for testing with additional data sets and potential applications to analysis of crash surrogates.
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ANB20, Real-Time Crash Risk Estimation: Are All Freeways Created Equal? (11-1645)
Underground loop detectors have been recently used by many researchers to investigate the links with real-time crash risk and the traffic data. An issue that has been raised but not explicitly addressed in these studies is how the results from one freeway might transfer to another. This study attempts to look at the relationship between crash risk and real-time traffic variables from a freeway corridor (I4 eastbound in Orlando, FL) and attempts to apply the models to three other freeway corridors (I-4 westbound, and I-95 north and southbound). Traffic data used in the study were collected using loop as well as radar detectors already installed on these freeways. The traffic information was collected for crash as well as random non-crash cases so that a binary classification approach may be adopted. The Random Forest based models provide a list of significant variables based on the mean average reduction in the Gini indices to the overall forest classification. The period between 5-10 minutes before and 10-15 minutes before the crash were taken into consideration to allow for the model to be developed so as to facilitate the issuance of warning in

advance. Average occupancy of upstream station and average speed and coefficient of variation of volume for downstream stations were observed to better the classification trees. Application of multilayer perceptron neural network models showed that while the model developed for I-4 corridor works reasonably well for the I-4 westbound data the performance is not as good for the I-95 sections. It indicates that the same model for crash risk identification may only work for corridors with very similar travel patterns. Keywords: Real-time crash risk, transferability, freeway safety, random forest, neural network.

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ANB20, Using High-Resolution Detector and Signal Data to Support Crash Identification and Reconstruction (11-1852)

Traffic accidents may not always result in severe or fatal injuries, but can still have nontrivial impact on system performance, particularly during heavy traffic conditions. One way to reduce the frequency of such incidents is to identify the necessary circumstances that resulted in the collision. However, road accidents, particularly intersection related crashes, are complex phenomenon and may result from different combination of causal factors such as excessive speed, successive braking of vehicles, signal violation, inadequate gap acceptance during merging, lane changing or taking a right turn on red. Recent traffic studies have witnessed increased use of high-resolution arterial traffic data to evaluate various traffic performance measures. It is also important for traffic safety engineers to explore such high-resolution data to analyze crashes, and identify the necessary causes of the crashes. In this study we illustrate, for one particular intersection crash resulting from signal violation, how high-resolution event-based data obtained from loop detectors can be used to identify the incident and the vehicles involved in the crash. We also illustrate how high-resolution data could support a traditional reconstruction of this crash. A Monte Carlo simulation technique was used to estimate the most probable combination of the driver behaviors that resulted in the collision. It was found that the excessive speed of the vehicle violating the red light was the most critical factor contributing to the crash.

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ANB20, Analysis of Crash Rates and Surrogate Events: Unified Approach (11-1991)

This paper summarizes a preliminary study into the use and validation of crash surrogates, to be obtained from naturalistic driving studies for the detailed analysis of risk factors. The approach is based on a unified statistical analysis of crash data and surrogate events using a spatial referencing system and a common measure of exposure. Statistical methods based on a bivariate response and Bayesian update models were adapted to the joint analysis of crashes and surrogates. The specific crash type addressed in this study is single vehicle road departure crashes. It is proposed that suitable surrogates should be based on underlying continuous measures of disturbance in the driver's lateral control of the vehicle. Naturalistic driving data from a field operational test conducted in Southeastern Michigan were spatially joined with highway data and crash data from the same area, and a set of candidate crash surrogates was tested. Analysis results indicate that simple lateral lane position did not provide a satisfactory surrogate, while estimated time to road departure was found to show the correct statistical dependencies, consistent with the crash data. The approach developed in this study provides a way to assess crash risk in a common framework and also to validate or invalidate candidate surrogates. When applied to data from the future SHRP2 naturalistic driving study, the increased statistical power resulting from the much larger dataset will provide more definitive conclusions about surrogate validity and factors influencing overall crash risk.

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ANB20, Development and Validation of Conflict Models for Single-Lane Roundabout Slip Lanes from Microsimulation (11-2119)

Conflict patterns at single-lane roundabouts with and without having slip lanes are evaluated and compared through VISSIM simulation and Surrogate Safety Assessment Model (SSAM) analysis. From a sensitivity analysis of several traffic percentage turning volume distributions (scenarios), five zone-based conflict prediction models are developed using Poisson regression. The models capture simulated conflict differences that result from the addition of a right turn slip lane, evaluated under three different exit control scenarios (yield, stop, and free-flow merge). Using SSAM analysis, the models predict the occurrence of conflicts for different roundabout zones with different R-squared values ranging from 0.69 to 0.97. The models are compared to national and international crash prediction models for single-lane roundabouts and are further validated using actual crash data from ten single-lane roundabouts in the City of Carmel, Indiana. The number of conflicts of a single-lane roundabout was predicted as a function of approach entry, circulating, and slip lane traffic flows and was determined to be sensitive to the slip lane exit type. Results confirm that conflicts in the merge area are more frequent than in the roundabout approach area, and that the installation of a free-flow slip lane exit type reduces overall conflict occurrence. The results demonstrate the usefulness of SSAM analysis for evaluating roundabout safety and developing an empirical relationship between simulated conflicts and field-observed crashes.

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ANB20, Investigation of Attributes of Kinematic Waves Preceding Traffic Collisions (11-2343)

The present study examines attributes of backward-moving kinematic waves that preceded traffic collisions in the vicinity of a recurrent bottleneck and compares with the ones from collision free days. The speed of backward moving waves accompanying traffic collisions were faster than the ones observed from collision free days. Traffic states observed prior to collisions were closer to the semi-congested state. Duration and frequency of kinematic waves, and the speed difference in traffic states before and after the passage of waves are also examined. Attributes of kinematic waves accompanying the secondary traffic collisions are briefly discussed in the paper. The findings indicate different attributes of kinematic waves can be used as a safety surrogate measure.

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ANB20, Speed Profile Variation as a Road Network Screening Tool (11-2505)

Roadway sections with a higher than expected number of crashes are usually identified by long term crash frequency data. In situations where historical crash data are either limited or unavailable, surrogate safety measures based on roadway characteristics (e.g. road geometry, traffic volume, and speed) are often substituted. This study developed and evaluated several candidate measures to estimate crash frequency on urban streets based on speed consistency along the roadway. These speed consistency measures were based on speed profiles along road segments collected from GPS-equipped vehicles. The relationships between these surrogate measures and historical crash frequency are quantified using a combination of regression tree and generalized linear modeling (GLM) approaches. These findings support the potential use of the profile-based measures to evaluate the safety of road networks as the deployment of GPS-equipped vehicles become more prevalent.

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ANB20, Methodology for Developing Real-Time Motorway Traffic Risk Identification Models Using Individual-Vehicle Data (11-2713)

Most of existing motorway traffic safety studies using disaggregate traffic flow data aim at developing models for identifying real-time traffic risks by comparing pre-crash and non-crash conditions. One of serious shortcomings in those studies is that non-crash conditions are arbitrarily selected and hence, not representative, i.e. selected non-crash data might not be the right data comparable with pre-crash data; the non-crash/pre-crash ratio is arbitrarily decided and neglects the abundance of non-crash over pre-crash conditions; etc. Here, we present a methodology for developing a real-time MotorwaY Traffic Risk Identification Model (MyTRIM) using individual vehicle data, meteorological data, and crash data. Non-crash data are clustered into groups called traffic regimes. Thereafter, pre-crash data are classified into regimes to match with relevant non-crash data. Among totally eight traffic regimes obtained, four highly risky regimes were identified; three regime-based Risk Identification Models (RIM) with sufficient pre-crash data were developed. MyTRIM memorizes the latest risk evolution identified by RIM to predict near future risks. Traffic practitioners can decide MyTRIM's memory size based on the trade-off between detection and false alarm rates. Decreasing the memory size from 5 to 1 precipitates the increase of detection rate from 65.0% to 100.0% and of false alarm rate from 0.21% to 3.68%. Moreover, critical factors in differentiating pre-crash and non-crash conditions are recognized and usable for developing preventive measures. MyTRIM can be used by practitioners in real-time as an independent tool to make online decision or integrated with existing traffic management systems.

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ANB20, Effect of Speed on Roundabout Safety Performance: Implications for Use of Speed as Surrogate Measure (11-2846)

Safety Performance Functions (SPFs) for modern roundabouts typically do not include geometric variables to allow a designer to assess the safety implications of decisions in designing a roundabout. The paper explores an approach for addressing this void. The premise is that if safety performance can be related to speed, and speed can be better estimated from traffic and geometric variables than crash experience, then speed can be used indirectly as a surrogate in evaluating the safety implications of decisions in designing or re-designing a roundabout. Four models, including approach level speed-based, approach level non speed-based, roundabout level speed-based, roundabout level non speed-based models, were developed based on the same sample of U.S. sites. Then, these models were compared using statistical methods. The speed-based model developed by appropriate speed measure - inside average speed (average speed of entry speed, circulating speed and exiting speed, also used as IAS) in this study – was seen to be better than the non speed-based model. Given the strong relationship between speed and crash experience, the paper further explores models for predicting roundabout speed as a function of design features, with a view to using speed estimated from these models, along speed-based crash prediction models, to assess roundabout safety performance. With this approach, speed is in effect used as a surrogate safety measure.

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ANB20, Estimating Traffic Conflict Risk Associated with Merging Vehicles on a Highway Merge Section (11-3607)

This study proposes a methodology for estimating rear-end conflict risk of merging vehicles on freeway merge sections as a probabilistic measure. The methodology consists of two major components. The first part estimates the merging probability of a vehicle given its position on a merge lane. Detailed vehicle trajectory data from Next Generation Simulation (NGSIM) program are used to find the underlying probability density function of merging decision. The second part derives the probabilistic risk of a merging vehicle conflicting with vehicles around it as a function of a surrogate safety measure, namely modified time-to-collision (MTTC). Combining these two parts together, an index is proposed to describe the conflict risk of each merging vehicle at each time step. By aggregating the conflict risk over time and space, a risk map for describing the level of conflict risk can be created. A case study demonstrates the implementation of the proposed method for traffic conflict analysis in detail. The result of this study can be used to evaluate the safety level of merge sections and develop real-time traffic control strategies to reduce conflicts associated with merging traffic.

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ANB20, Delta-V as a Measure of Traffic Conflict Severity (11-4199)

Delta-V (Δv) is a measure of the severity of a traffic collision, defined as the change in velocity between pre-collision and post-collision trajectories of a vehicle. Delta-V emerged in the 1970s in the context of crash reconstruction analysis, and is considered by some researchers to be the best single predictor of crash severity. However, this indicator has not been applied to the analysis of traffic conflicts, until recently when it was incorporated into the automated conflict analysis algorithms of the Surrogate Safety Assessment Model (SSAM). This paper introduces Delta-V and

demonstrates how it overcomes shortcomings present in several traditional measures of traffic conflict severity. We discuss the ambiguity present in the literature on the topic of traffic conflict severity, and suggest the adoption of alternative terminology and definitions. We demonstrate a new approach, incorporating Delta-V, to estimate the collision propensity and potential collision severity of a traffic conflict.

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8 Papers on bicycle and pedestrian crash relationships

This year the ANB20, ANF10 (Pedestrians), and ANF20 (Bicycle Transportation) Committees formed the joint Subcommittee "Bicycle and Pedestrian Crash Relationships". The Subcommittee is aimed at (a) stimulating research on all topics related to bicycle and pedestrian crash relationships, (b) encouraging (crash modeling) researchers to give more attention to walking and biking, and (c) to promote a greater use of statistical modeling methods in the safety papers related to walking and biking.

Most of the papers related to bicycle and pedestrian crash relationships are presented in two sessions:

(1) January 24, 7:30 – 9:30 PM, poster session 395: "Walking and Biking: Exploring Injury and Risk", in Marriott, Salon 2, and
(2) January 26, 2:30 – 4:00 PM, podium session 707: "Bicycle and Pedestrian Safety Relationships", in Marriott, Delaware A.

Only one paper studied simultaneously pedestrians and bicyclists (11-1247), whilst the other studies addressed separately pedestrians (11-0283, 11-1419, 11-1819, and 11-1967) and bicyclists (11-1319, 11-2286, 11-2363, 11-3156, and 11-4212).

From a methodological perspective, injury severity models were developed using ordered logit models (11-1247), an ordered probit model (11-2363), and a bivariate ordered probit model with sample selection to deal with the sample selection issue (11-1419). A safety performance function for motor-vehicle crashes involving pedestrians was developed using a random-parameter negative binomial model for predicting pedestrian crash frequencies at the census tract level, allowing the incorporation of unobserved heterogeneity across the spatial zones in the modeling process (11-1967). Cyclist safety performance functions were developed using negative binomial models (11-2286 and 11-3156). Data mining techniques, such as classification trees and association rules, were used to detect interdependence as well as dissimilarities among crash patterns (11-0283**Errore. L'origine riferimento non è stata trovata.**). To overcome problems associated with measuring exposure and accounting for potential confounders the case-crossover design has been applied (11-1319). A before-and-after study of pedestrian improvements was carried out using a pedestrian risk index as a surrogate measure of safety (11-1819). One study, sponsored by ANF20, calculated crash rate for bicyclists in relation to traffic volumes (11-4212).

ANB20, Data Mining Techniques for Exploratory Analysis of Pedestrian Crashes (11-0283)
Aim of the study was the exploratory analysis of pedestrian crashes to detect interdependence as well as dissimilarities among crash patterns, and provide insights for the development of safety improvement strategies focused on pedestrians. At this aim, explorative analysis of the data relative to the 56,014 pedestrian crashes occurred in Italy in the period 2006-2008 was carried out by data mining techniques, such as classification trees and association rules. The response variable more sensitive to crash patterns was the crash severity. The most influential crash patterns were the road type, the pedestrian age, the lighting conditions, the vehicle type, and several interactions between these patterns. Some of the more remarkable results were the associations with fatal crashes of rural area, urban provincial and national roads, pedestrians older than 75, nighttime, pedestrians older than 65 in nighttime crashes, drivers' young age and male gender in nighttime crashes, and truck involvement. To mitigate the fatal crash patterns identified by the classification trees and association rules, several measures are suggested for implementation. Results of this study are consistent with the results of previous studies which used different analytical techniques, such as probabilistic models of crash injury severity. An interesting aspect of the data mining techniques used in this study is their ability to detect interdependencies among crash characteristics. The use of classification trees and association rules must not, however, be seen as an attempt to supplant other techniques, but as a complementary method which can be integrated into other safety analyses.

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Estimating Potential Effect of Speed Limits, Built Environment, and Other Factors on Pedestrian and Cyclist Injury Severity Levels in Traffic Crashes (11-1247)

In spite of the benefits of non-motorized transportation modes, road facilities in urban areas are still a major source of harm to non-motorized road users. In particular, large Canadian cities like Montreal still face serious pedestrian and cyclist safety problems. To address this problem, investments are continually allocated through different safety improvement programs such as speed limit reduction, improvement of intersections and increased traffic enforcement. However, there is a lack of analytical tools that help to identify and quantify the benefits of countermeasures such as roadway design, speed management strategies, or land use policies, for instance, in reducing accident frequency and severity. Subsequently, the objectives of this research are to develop injury severity models for determining the effects that road design, built environment, speed limits and other factors (e.g. vehicle characteristics and movement type) have on the injury severity levels of both pedestrians and cyclists involved in motor vehicle collisions. To do so, this research integrates different sources of data including police reports describing vehicle-pedestrian and vehicle-cyclist collisions, as well as information on land use, transit network, and road design attributes from the City of Montreal. After data preparation, various ordered-response modeling settings have been attempted. Accordingly, the impacts of road design, land use, built environment and other potential strategies on the injury severity levels of vulnerable users have been investigated. Among other results, it was found that factors such as darkness, vehicle movement, whether an accident occurred at an intersection, vehicle type and the degree of landuse mixity affect pedestrian collision severity. However, for cyclists, only vehicle movement and whether the accident occurred at a signalized intersection seem to have tangible effects on the severity of injury.

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Tackling Methodological Issues in Studying Bicycling Safety: Illustration Using Bicyclists' Injuries and Cycling Environment Study (11-1319)

Bicycling is a less attractive transportation mode than driving in much of the world because it is often less safe. Differences in injury rates between jurisdictions with different cycling infrastructure indicate that studying route design should be a fruitful avenue of investigation to improve safety and increase ridership. However, such research has been limited by problems associated with measuring exposure to route infrastructure (the denominator necessary for risk calculations) and accounting for potential confounders (e.g., risk-taking behaviour, weather conditions). This paper discusses these methodological issues and how researchers can address them using the case-crossover design. We illustrate the design by describing the Bicyclists' Injuries and the Cycling Environment Study, and present data on its feasibility. Injured cyclists were recruited from the emergency departments of five hospitals in Vancouver and Toronto, Canada. In 18 months, 690 participants were successfully recruited and interviewed. Each participant was interviewed to map the route of their injury trip, identify the injury site, and to select two control sites at random from the same route, thus adjusting for exposure to risk. The case-crossover analysis will compare infrastructure at the injury site to control sites within the same trip, thus preventing confounding. A concern about within-trip comparisons is insufficient variance in the transportation infrastructure, but preliminary data demonstrate that almost all trips included multiple infrastructure types. Future studies could replicate this design in other locations to expand the range of cycling infrastructure compared and facilitate evidence-based cycling infrastructure design to make cycling safer and more appealing.

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Pedestrian Injury Analysis with Consideration of the Sample Selection Bias in Linked Police-Hospital Data (11-1419)

This paper investigates pedestrian injury severity factors using linked Indiana police-hospital data. Pedestrian safety has recently received increased attention as pedestrians have come to be seen as a vulnerable group of road users who are exposed to particularly severe injuries when hit by vehicles. A bivariate probit model including both the sample selection and the pedestrian MAIS components is used to detect the presence of the selection bias and to account for it in the MAIS estimates. The sample selection issue has been confirmed for the linked police-hospital data. This issue, if not properly addressed, can lead to a considerable bias in both the model coefficient estimates and the model predictions. The selection bias is particularly high when predicting low injury levels. This study utilized the bivariate ordered probit model with sample selection to deal with the sample selection issue. The differences between the results obtained with this model and the traditional univariate ordered probit model are considerable and they indicate that the applied model is capable of mitigating or removing the selection bias. The pedestrian injury analysis conducted with the bivariate probit model identified and estimated several severity factors, including pedestrian, road, and vehicle characteristics. Male and older pedestrians were found to be particularly exposed to severe injuries. Rural roads and high-speed urban roads appear to be more dangerous for pedestrians, particularly when crossing such roads. Crossing a road between intersections was found to be particularly dangerous behavior. The size and weight of the vehicle involved in a pedestrian crash were also found to have an effect on the pedestrian injury level. The relevant safety countermeasures that may improve pedestrian safety include police enforcement of legal road crossing by pedestrians (mostly at intersections), adding pedestrian bridges and underpasses, and setting and enforcing lower speed limits on roads with considerable pedestrian traffic, high-speed vehicle traffic, and a large percentage of medium and heavy vehicles.

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Before-and-After Study of Crosswalks Using Pedestrian Risk Index (11-1819)

More than 14% of the about 25,000 people killed each year in road crashes in European Countries are pedestrians. The relevance of the problem led transportation researchers to consider the improvement of pedestrian safety like a priority. For crashes involving pedestrian, the lack of performance models based on crash data is due to the spread distribution of the data that make difficult to identify statistical correlations. In spite of traditional reactive strategies based on crash history analysis, overly depending from the quality and availability of the crash data, surrogate safety measures were developed as an efficient preventive approach. Traffic Conflict Technique (TCT) was developed as "surrogate measure of road safety" by using near-accident indicators based on measures of spatial and temporal proximity of road users. In the paper, a new indicator of conflict, named Pedestrian Risk Index (PRI), has been proposed, linking both probability of collision between vehicle and pedestrian and severity of the consequences (2). As case study and in order to evaluate the safety performance of new traffic calming devices installed replacing zebra marked

crosswalks, a before-after study was carried out in Spain using PRI as surrogate measure of safety. The application of the Pedestrian Risk Index showed that PRI is effective to highlight modifications in drivers' behavior due to installation of different safety countermeasures at a crosswalk, highlighting for a reduction in severity of conflicts with an expected propensity to improvement in pedestrian safety.

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Random-Parameter Model to Explain Effects of Built Environment Characteristics on Pedestrian Accident Frequency (11-1967)

Pedestrian safety has been a major concern for a megacity like New York City. Although pedestrian fatalities show a downward trend, these fatalities constitute a high percentage of overall traffic fatalities in New York City. This paper studies the factors influencing the frequency of pedestrian accidents using data from New York City. Specifically, a random-parameter negative binomial model is developed for predicting pedestrian accident frequencies at the census tract level. The advantage of this approach is that it allows the incorporation of unobserved heterogeneity across the spatial zones in the modeling process. This study reports the influences of a comprehensive set of variables describing the socio-demographic and built environment characteristics on pedestrian accidents. The model has found several parameters as random indicating their heterogeneous influences on the numbers of pedestrian accidents. Overall these findings can help towards framing better policies for improving pedestrian safety.

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Exposure Measures and Injury Frequency Models for Analysis of Cyclist Safety at Signalized Intersections (11-2286)

To address the rising issue of cyclist safety at signalized intersections, establishing the relationship between motor-vehicle and cyclist flows, geometric design and built environment characteristics is fundamental. To date, there is very little empirical evidence of the impact of these factors on cyclist injury occurrence and on the most effective countermeasures in North America. In this regard, this research (i) proposes a new approach to measure risk exposure and (ii) develops cyclist injury frequency models. Three separate definitions of risk exposure are used: completely aggregated flows, motor-vehicle flows aggregated by movement type and potential conflicts between motor vehicles and cyclists. As an application environment, a sample of signalized intersections on the island of Montreal was used, as well as data comprising of disaggregate motor-vehicle and cyclist flows. Several negative binomial models were fitted to the data. Among the results, this study shows that cyclist collisions are sensitive to changes in cyclist flows: a 10% increase in bicycle flow is associated with a 5.3% increase in the frequency of cyclist injuries. Surprisingly, motor-vehicle volumes at the intersection level do not have a significant effect on cyclist collision frequency. However, when motor-vehicle flows are considered based on movement type, it becomes apparent that right turn movements have a great effect on accident occurrence. Similar results, indentifying right turns as having the greatest effect on cyclist injuries, are achieved when potential conflicts are considered. It was also found that the number of bus stops in the proximity of intersections increases cyclist injury occurrence. Some geometric design factors such as presence of median and three-leg intersections were tested; however, their effect was found to be statistically non-significant.

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Bicyclist Injury Severity in Bicycle-Motor Vehicle Crashes at Unsignalized Intersections in Kentucky (11-2363)

This research investigated the contributing factors of injury severity of bicyclists in bicycle-motor vehicle crashes at unsignalized intersections. The crash data were extracted from Kentucky Collision Database maintained by Kentucky State Police between 2000 and 2009 and an ordered probit model was introduced to explore significant factors of bicycle safety. Injury Severity was classified into four categories: none and slight injured, non-incapacitating, incapacitating and fatal. Fifteen factors were incorporated in the model, describing bicyclist characteristics, driver characteristics, roadway characteristics and crash characteristics. The model estimates and marginal effects revealed that several factors were strongly associated with injury severity of bicyclists, including traffic control, number of lanes, driver age, bicyclist age, weather condition, light condition, roadway condition, and speed limit. Stop control, one-way traffic, young bicyclists, and low speed limits were found to make bicyclists safer, while no traffic control, two-lane approaches, old drivers, fogy and rainy weather, no lights, and icy roads were more likely to aggravate injury severity of bicyclists. Explanations of the results and some possible countermeasures were also discussed.

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Safety Performance Functions for Bicycle Crashes in New Zealand and Australia (11-3156)

After decades of decline, recreational and commuter cycling is becoming more popular in many Australasian cities. While this is encouraging from a sustainable transport and public health perspective, a major concern to national, state and local governments is the higher crash risk faced by cyclists compared with drivers or passengers in motor-vehicles, particularly when cycling on roads. It is important that transport professionals understand the level of risk faced by cyclists within various parts of the road network and the measures they can employ to mitigate that risk. This paper presents research findings from three main safety studies undertaken in New Zealand using data from New Zealand cities and Adelaide in Australia. Research has been undertaken using both generalized linear modelling and before-after control-impact methods. Over the various studies, crash, traffic and cycle volumes and layout data has been collected for urban road links, traffic signals and roundabouts. Flow-only models have demonstrated a 'safety in numbers' effect; with crash risk per cyclist shown to be lower as cycle volumes increase. By adding other variables to the models, it is been possible to gain a level of understanding of the impact that road section length, motor-vehicle speed, visibility, presence and type of cycle facilities and lane and road width have on various crash types. Before and after analysis has been employed to help understand whether there is any bias in the sites that have received cycle facilities The research findings concerning the effect of cycle facilities in improving safety are mixed. Well designed facilities, including those of adequate width and painted with colour appear to perform the best.

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ANF20, Effect of Increased Bicyclist Volumes on Individualized Bicyclist Risk (11-4212)

Little is known about the relationship between the number of bicyclists on a roadway and the number of crashes involving bicyclists. However, studies from Europe have found that with increased ridership comes increased safety in the form of a reduction in the number of crashes per cyclist. Our study examines whether these trends can also be found in the U.S., to what extent does this hypothesis hold, and what other factors might be playing a role in the results. We conducted this research in Boulder, Colorado using average cyclists per peak hour based on turning movement counts on corridors with both high and low bicycle traffic and related that to five years of bicyclist crash data. The data suggests that while bicycle crashes do typically increase with motor-vehicle volumes and bicycle volumes, the crashes per bicyclist decrease with bicycle volume. In other words, more bicyclists on the road can help reduce the crash risk of each bicyclist.

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