2017 Transportation Research Board Papers, Posters and Presiders
Mountain-Plains Consortium

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COLORADO STATE UNIVERSITY

Increased Inspection Intervals of Two-Girder Steel Bridges Using Probabilistic Fracture Mechanics

Hussam Mahmoud, Colorado State University

Presented in a workshop presenting the latest research and technical developments in the design of steel bridges and steel components for long-term service life and durability.

Thermal Effects on Deck Joint Movement in Colorado

Aura Lee Harper-Smith
Karly Rager, Raker Rhodes Engineering
Rebecca Atadero, Colorado State University
Hussam Mahmoud, Colorado State University
Jessica Martinez, Colorado Department of Transportation
Trever Wang, Colorado Department of Transportation
Aziz Khan, Colorado Department of Transportation

Deck joints are causing significant bridge deterioration and maintenance problems for Departments of Transportation (DOTs). Due to the lack of resources for deck joint maintenance, Colorado State University researchers partnered with the Colorado DOT (CDOT) to analyze the effects of temperature change and thermal gradients on deck joint movement and provide recommendations regarding deck joint elimination in Colorado. A typical steel bridge was

instrumented with strain, displacement, and temperature sensors along the expansion joint and continuous data was collected for four months. The data indicates that temperature shifts and thermal gradients through the depth of the girders along the joint are impacting the bridge's movements and causing changes in stress. A strong parallel is shown between the temperature changes and the study joint's movement and changes in girder stress. Despite being clogged, the joint showed a half inch of movement and maximum stress changes of 5-10 ksi (34450 - 68900 kPa) in the adjacent girder during greater temperature changes and temperature gradients. Preliminary implications include increased changes in stress and deterioration of the abutments due to the clogged joint limiting movement. Joint elimination could relieve and potentially minimize these concentrated stresses; however, further analysis would be needed to account for thermal expansion movement throughout a continuous bridge. Nonetheless, the preliminary data indicates that eliminating deck joints could decrease maintenance costs.

Decision Support Framework for Transit-Oriented Development Projects

Kelly Strong, Colorado State University
Mehmet Ozbek, Colorado State University
Avi Sharma, Colorado State University
Duygu Akalp, Colorado State University

Even though the use of personal automobiles in the U.S. continues to grow, there are increasing concerns about the possible effects of automobile dependent transportation, including environmental concerns, the reduction in quality of life caused by long commutes, and a decline of community and societal interactions. These concerns have led to discussions on the revitalization of public transportation systems (*1*); and to counter the problem of congestion resulting from modern urbanization, urban planners have developed the idea of Transit-Oriented Development (TOD). TOD is a type of development designed to encourage the use of public transit and the creation of pedestrian-friendly environments (*2*). The plethora of literature on this subject is no surprise considering the issues of revitalization of community living and affordable housing and related factors directly influencing and getting influenced by TOD. Notwithstanding the abundance of literature on TOD, the literature review uncovered very few studies which somewhat address the important question of: "How can a transit agency choose among alternative TOD sites to develop/build?" Given this, the purpose of this research is to develop a decision support framework which can be used by different transit agencies when choosing a TOD site to develop/build by incorporating and assessing unique success factors and their weights. This research uses a multiple-criteria decision-making tool called Analytic Hierarchy Process in developing that framework. The paper presents two implementation examples which demonstrate the feasibility of the developed decision support framework for both a large, urban transit district and a smaller, more rural transit agency.

NORTH DAKOTA STATE UNIVERSITY

Motor Carrier Alternative Compliance

Brenda Lantz, North Dakota State University

Lantz presided over this subcommittee meeting which explored potential ideas aimed at assisting federal truck and bus regulators in establishing a congressional mandated "alternative" compliance program that would reward carriers for exceeding regulatory requirements.

Truck and Bus Safety Research

Brenda Lantz, North Dakota State University

Lantz presided over this research session featuring 14 posters/practice ready papers on various topics focusing on commercial carrier safety research.

Truck and Bus Safety Committee

Brenda Lantz, North Dakota State University

Lantz presided over a meeting of TRB's Truck and Bus Safety Committee. The committee identifies and articulates research needs related to commercial vehicle safety.

Graphite-Enabled Phase Change Material Composites for Enhanced Thermal Management of Concrete Pavement

Mingli Li, North Dakota State University
Zhibin Lin, North Dakota State University
Fei Yan, North Dakota State University

Concrete pavement in cold regions requires effective ice and snow melting systems in winter, as well as high strength, to ensure its long-term durability. Embedded heating systems has currently been implemented in some pavement designs, such as airport runways and pavement, to enable rapid ice and snow melting solution. The major challenges in heated concrete pavement, however, are associated with the low thermal conductivity and low energy storage capacity of concrete. Both limitations reduce the efficiency of the heated concrete pavements and their long-term reliability. Thus, this study investigated the feasibility of using graphite-enabled phase change material (PCM) based concrete composite to address both thermal conductivity and energy storage capacity for more efficient thermal management in concrete pavement. Two different kinds of PCMs- Micro-encapsulated PCM (MEPCM) and paraffin with the same melting point but different latent heats were used in concrete mixture. A series of laboratory test: SEM, heat transfer test, and compressive strength test were performed to characterize the morphology, thermal, and mechanical behavior of different materials. The results show that graphite products dramatically improve the thermal

conductivity, while the PCMs increases the thermal storage capacity. In addition, incorporating graphite products and PCMs has a certain decrease in the compressive strength, mainly due to weak interfaces between graphite and cement matrix.

Connected-Vehicle Method of Estimating International Roughness Index

Raj Bridgelall, North Dakota State University
Md Tahmidur Rahman, Fugro Roadware, Inc.
Denver Tolliver, North Dakota State University
Jerry Daleiden, Fugro Roadware, Inc.

The high cost of deploying inertial profiler vehicles to evaluate pavement roughness limits data collection to relatively small portions of the network. Previous research demonstrated a connected vehicle method that enables continuous roughness evaluations for all roadways, including local and unpaved roads. This research estimates the international roughness index from the connected vehicle method that produces a roughness index called the road impact factor. The authors establish a theory that the ratio between the road impact factor and the international roughness index changes with the dominant profile wavelengths. Case studies validated the theory by evaluating the ratio of the two roughness indices across five different pavement types, using the same vehicle at a fixed speed. The ratios distributed normally. The spread of the distribution reflected expected differences in the dominant spatial wavelength among the different surfaces. The normal distribution anticipates that the precision of estimating previously unknown international roughness indices from the measured road impact factors will continuously increase with traversal volume.

Revamping Tribal Road Networks from Various Sources and Improving Quality

EunSu Lee, New Jersey City University

The objectives of this study are to integrate road networks to provide comprehensive road network using multiple public sources and provide guides to perform a quality control (QC) assessment before delivering data and using it for geospatial analysis. This study focuses on the Forth Berthold Reservation located in North Dakota. This study proposes a method to integrate multiple public road networks to support a tribal transportation agency. The workflows and techniques proposed are transferrable to other tribal transportation agencies. Depending on current data being used for transportation planning and operations, the workflow and processes are subject to change from agency to agency, but the study will provide general guidance for the agency. The authors recommend that the agency develop linear referencing systems (LRS) on the proposed road network to adopt efficient asset management and version control. The LRS should comply with state or federal guidelines for improved communication. To develop an application in an appropriate manner, the road network should include additional attributes based on needs of the reservation.

Three Affiliated Tribes Seat Belt Primary Seat Belt Intervention Assessment

Kimberly Vachal, North Dakota State University
Andrew Kubas, North Dakota State University

Tribal populations experience a greater risk for traffic injuries than other populations. The Three Affiliated Tribes on the Fort Berthold Reservation recently enacted a primary seat belt law to try to improve public safety on its roads. An assessment in the initial months shows early gains in increased seat belt use may have been eroded in towns. On highways, however, the intervention appears to have produced sustained gains in seat belt use by male car and sport utility vehicles drivers. Previous studies have shown the longer-term success of the primary law intervention requires ongoing reinforcement in terms of education and enforcement activities.

Accessibility Analysis of Emergency Services to K-12 Schools in North Dakota – Using Virtual Sensor Data

Diomo Motuba, North Dakota State University
Muhammad Khan, North Dakota State University

The main objective of this study was to analyze the accessibility of emergency care services to K-12 schools in North Dakota using a gravity model. The main dependent variables used where real time travel data obtained from virtual sensor data and the trauma center level. Accessibility of emergency services to K-12 schools were estimated for several travel time thresholds for two scenarios; overall accessibility (from ambulance services to K-12 schools and then to trauma center) and quick response services (QRS) to K-12 schools. A spatial autocorrelation analysis was performed to analyze the spatial inequalities of accessibility of K-12 schools to Emergency care services. The results indicated that, the urban areas had high overall accessibilities in comparison to rural areas. For QRS to K-12 school scenario urban areas also had high comparatively higher accessibility indices. The spatial autocorrelation results for both scenarios showed spatial clustering of accessibility measures indicating spatial inequalities for different locations. The results suggest the spatial distribution of emergency services relative to K-12 schools in North Dakota are not well balanced and need further location optimization. The study is important to policymakers to highlight low accessibility areas and to provide new and/or relocate emergency health services. In addition, K-12 schools could incorporate the results of this study in their emergency plans.

Integrated Multimodal Transportation Model for Switchgrass-Based Bioethanol Supply Chain with Case Study Based on North Dakota

Yong Shin Park, North Dakota State University
Joseph Szmerekovsky, North Dakota State University
Atif Osmani, Minnesota State University
N. Muhammad Aslaam, North Dakota State University

This study formulates a mixed integer linear programming (MILP) model that integrates multimodal transport into the switchgrass-based bioethanol supply chain (MTSBSC). The two transport modes are truck and rail. The objective of this study is to minimize the total cost for

cultivation/harvesting, infrastructure, storage process, bioethanol production, and transportation. Strategic decisions, including the number and location of intermodal facilities and biorefineries, and tactical decisions, such as amount of biomass shipped, processed, and converted into bioethanol are validated using the state of North Dakota as a case study. It was found that multimodal transport scenario is more cost effective than single mode of transport (truck), which results in cheaper bioethanol cost. A sensitivity analysis was conducted to demonstrate the impact of key factors on MTSBSC decision and bioethanol cost.

Case Studies and Surveys of Transit Needs in Rural Communities

Jill Hough, North Dakota State University

Hough presided at this session where participants learned about estimating the demand for services within and between rural and small communities. Case studies and surveys were conducted at the local, regional, and national scales to identify needs and trends in rural public transportation.

Estimating Demand for Intercity Bus Services in a Rural Environment

Jeremy Mattson, North Dakota State University

A significant need exists for creating a model to estimate demand for intercity bus services, especially in rural areas, as existing models have their limitations. The general objective of this research is to develop an intercity mode choice model that can be incorporated into a statewide travel demand model to estimate demand for rural intercity bus services. Four intercity transportation modes are considered in the study: automobile, bus, rail, and air. A stated preference survey was conducted of individuals across the state of North Dakota, and a mixed logit model was developed to estimate a mode choice model. Results from the mode choice model show the significant impacts of individual, trip, and mode characteristics on choice of mode. Gender, age, income, disability, trip purpose, party size, travel time, travel cost, and access distance were all found to have significant impacts on mode choice. This study was conducted in the largely rural state of North Dakota, but results could be transferable to other areas with similar geographic characteristics.

Exploring Transit's Contribution to Livability in Rural Communities: Case Study of Valley City and Dickinson, North Dakota

Ranjit Prasad Godavarthy, North Dakota State University
Jeremy Mattson, North Dakota State University

This study investigates the nexus of transit and rural livability by conducting case studies in the North Dakota communities of Valley City and Dickinson. While there are many factors that influence the livability of a rural community, transit is an important contributor. For each of the two North Dakota communities considered, public/resident surveys, local transit rider surveys, and stakeholder interviews were conducted to understand differing opinions on livability and how transit contributes to livability.

In both Valley City and Dickinson, surveys of residents showed that they believe that affordable housing, low crime, quality healthcare, overall cost of living, quality public schools, and available jobs are the most important factors contributing the livability of a community. While transit was not among the top factors, survey respondents expressed considerable support for providing transit services and funding it through various sources. Residents in both cities expressed the opinion that transit should be provided in their community as a transportation option for seniors and people with disabilities, those who choose not to drive, and those who cannot afford to drive. Transit riders in both cities indicated that transit is very important to their quality of life, and stakeholders from both communities expressed the sentiment that transit is a critical lifeline for people who are elderly and/or have a disability, individuals with no vehicle, and those who cannot drive.

Estimating Ridership of Rural Demand-Response Transit Services for the General Public

Jeremy Mattson, North Dakota State University

The general objective of this study is to develop a model for estimating demand for rural demand-response transit services for the general public. Lack of data for demand-response service characteristics and geographic coverage has limited the estimation of such models. This study developed and estimated two models. The first was estimated using data from the 2013 rural National Transit Database, and the second was estimated with more detailed service data collected from surveys of transit agencies. Results showed that in addition to total population, demographic characteristics are important. Ridership was found to significantly increase when the percentage of the population comprised of older adults or people without access to a vehicle increased. Both models showed a negative effect of fares on ridership. The second model analyzed the impacts of service span and reservation requirements on ridership. Results showed that providing more days of service had an expected positive impact on ridership, while allowing users to reserve rides on shorter notice also had a significant positive effect. Compared to previous research, the inclusion of a greater number of variables and more specific service information improved the performance of the models.

SOUTH DAKOTA STATE UNIVERSITY

Investigating the Driver Behavior at Minor-street Stop Sign Intersections in Qatar

Khaled Shaaban, Qatar University
Jonathan Wood, South Dakota State University
Vikash Gayah, Pennsylvania State University

Stop-controlled intersections are dangerous locations in which drivers must negotiate conflicts between traffic streams. This study examines driver stopping compliance at minor-street stop-controlled intersections in Qatar. Variables are considered that may influence driver behavior when approaching a stop sign, including age, gender, heritage-related differences in drivers, the type of vehicle, presence of an approaching vehicle or a pedestrian, peak and non-peak hours,

weekday versus weekend, and residential versus commercial land use. Binary and ordinal logistic regression models were developed to describe driver stopping behavior as functions of these characteristics. The results indicate an alarmingly low compliance rate with minor-street stop signs in Qatar. More generally, the results indicate that male drivers, young drivers, and SUV drivers are less likely to come to a complete stop at these locations. The results also reveal that drivers are more likely to ignore the stop sign when they notice a vehicle or pedestrian approaching, most likely to "beat" the approaching vehicle or pedestrian through the intersection and reduce delay encountered at the stop sign. These findings raise a major safety concern and indicate aggressive driving tendencies. Potential countermeasures include increasing police enforcement, initiating traffic safety campaigns (perhaps targeting the higher-risk drivers identified in the results), and improving the visibility of stop signs using different measures such as larger and additional stop signs, "Stop Ahead" advance traffic control signs, and enhanced pavement markings.

Stopping Sight Distance and Available Sight Distance: A New Model and Comparison Using Reliability Theory

Jonathan Wood, South Dakota State University
Eric Donnell, Pennsylvania State University

Stopping sight distance (SSD) is an important design criterion used in the geometric of highways and streets. Design guidance implies that SSD is used to ensure safety along the roadway. This paper reviews SSD design criteria, and develops an updated model to improve consistency between available sight distance (ASD) and SSD criteria found in geometric design policy. A new variable, the distance from the front of the car to the drivers' eye ($L_{front\text{-}eye}$), is used in the updated model. Distributional values for $L_{front\text{-}eye}$ are determined. A method accounting for lighted (daytime and lighted nighttime) versus unlighted nighttime conditions is also discussed. A probabilistic analysis of vertical curve SSD is then provided using Monte Carlo simulation. The results of this analysis are compared with the SSD model found in current geometric design policy. Possible values for $L_{front\text{-}eye}$ that can be used in design guidance are proposed. Potential issues that should be investigated in future work are also discussed.

UNIVERSITY OF COLORADO DENVER

Initial Findings for the Impacts of Ridesourcing on VMT, Parking Demand, Transportation Equity, and Travel Behavior

Alejandro Henao, University of Colorado, Denver

The transportation sector is currently experiencing a monumental disruption with the introduction and evolution of technology and transportation services such as bikesharing, carsharing, on-demand ridesourcing (e.g. Lyft, Uber), and microtransit. As these new layers of technology-based transportation options begin to flourish, it is important to understand how they compete and interact with more traditional modes. For example, ridesourcing

theoretically takes an underutilized existing resource – empty seats in single-occupancy vehicles – and fills them with passengers. In reality, it is difficult to disentangle the interrelated short- and long-term outcomes and self-selection issues that arise from simply asking whether ridesourcing takes cars off the road or if we are siphoning from walking, bicycling, and transit modes. Beyond travel behavior, these evolving transportation services can also significantly impact our transportation systems, society, and the environment. Due to such complications, these outcomes have yet to be adequately studied. Accordingly, this study first provides a framework to do this research and then, investigates the impacts of ridesourcing on transportation. This research implements an innovative approach by collecting and using driver data from Lyft and Uber trips, as well as interviewing passengers. Initial findings show that the overall efficiency mileage rate of ridesourcing drivers is around 59-percent. This result along with parking, equity, and travel behavior impacts gives us insights to better understand the impacts on VMT and transportation in general. This, in turn, will help cities and transportation organizations better account for the impacts of technology and evolving transportation services in their policies, planning, and engineering processes.

Impacts of Ridesourcing on VMT, Parking Demand, Mode Choice, and Travel Behavior

Alejandro Henao, University of Colorado, Denver, presented in a workshop on doctoral research in transport modeling. The goal of the work shop was to provide a platform for younger TRB attendees to present their research in transportation modeling and travel behavior analysis that may not be at a stage where it would be accepted for a traditional TRB session.

Motorist-Cyclist Crash Data Needs in U.S. Communities

Geoff Gibson, TREC at Portland State University
Krista Nordback, UNC Highway Safety Research Center
Sirisha Kothuri, Portland State University
Nick Ferenchak, University of Colorado, Denver
Wesley Marshall, University of Colorado, Denver

Over the past decade, understanding traffic data using a data driven approach has become standard practice. While cycling has become popular in the US, safety remains a top concern, especially for engaging new riders. Although fatal cyclist crashes are recorded using standardized methods, there is a considerable variation in non-fatal crash data collection within and across communities. Non-fatal crash data is critically important for analyzing safety trends over time, prioritizing infrastructure improvements, and planning efforts. The lack of robust and standardized cyclist crash data precludes the analysis of trends across communities and limits the improvements and countermeasures that can be applied to increase cyclist safety. This paper summarizes the issues encountered with non-fatal crash data across eight communities with respect to data availability, standardization, and quality. Findings reveal that while time variables such as hour, month, and day of crash were consistently coded across locations, vast differences existed with critical variables such as crash type and crash severity. These differences were observed both between communities as well as within communities from

year-to-year. The non-standard data formats and differences within and between communities diminishes our ability to create safety performance functions and crash modification factors, which are critical metrics for safety analyses. This paper also provides suggestions to standardize non-fatal cyclist crash data in order to spotlight the data needs and bring much needed attention towards improving bicycle safety related data collection in the US.

The Reach of Bicycling in Rural, Small, and Low-Density Places

Carolyn McAndrews, University of Colorado, Denver
Kenta Okuyama, Colorado School of Public Health
Jill Litt, University of Colorado, Boulder

Lessons derived from the urban experience of bicycling may not be broadly supportive of bicycling in what we call rural, small, and low-density (RSLD) places because of differences in built environment, social, and political contexts. In this study we investigated the hypothesis that bicycling is primarily an urban activity. We used binary logistic regression to compare the frequency of bicycling and the population characteristics of bicyclists across urban and RSLD places. We use multiple operational definitions of urban-rural continua to examine whether the results are sensitive to how RSLD places are defined. The data for bicycling are from the 2009 National Household Travel Survey (NHTS), which was designed to represent the general population of the U.S. We found that bicycling is primarily—but not exclusively—an urban activity. Moreover, women and youth were more likely to bicycle in RSLD places compared to urban places. These findings suggest that an urban perspective on bicycling could limit the success of initiatives aiming to increase the diversity of populations that bicycle. Developing a base of empirical knowledge of bicycling in RSLD places is a necessary step toward developing more inclusive and effective multimodal transportation strategies.

Remotely Sensed Data in Road Safety Research

Yaneev Golombek, University of Colorado, Denver
Wesley Marshall, University of Colorado, Denver

This paper tests the usefulness of GIS and LiDAR data for transportation research purposes. One research strand where such data could exert influence comes with better measuring street trees and understanding their relationship with road safety outcomes. Traditional engineering practices focus on crude tree counts and mitigating street side tree quantities to improve road safety. Some more modern isolated case studies indicate that increase street side tree coverage may be affiliated with reduced car crashes. This study utilizes GIS to compare two different models of trees and crashes, investigating the topic over a 21 square mile area in Denver, CO. In the first model, tree point counts are modeled against crashes and in the second, tree canopies are derived from LiDAR data and the canopy polygons are modeled against the crash data. GIS processes and applications are used to group street segments along with the canopy polygon and tree point data. Statistical processes are run on each model. The results show that holistically, the relationship between tree points and crashes are random while greater areas of tree canopy polygon clusters are directly affiliated with lower crash rates. Since LiDAR is a costly technology and not yet available in all urban areas, the same statistical process is run against

QuickBird2 tree canopy data for the same area. The QuickBird2 data also shows strong affiliation with tree clusters and crash rates however the coefficient is not as strong as when compared with results from the LiDAR test

Arterials, Population Health, and Community

Carolyn McAndrews, University of Colorado Denver, presiding

Why Does TRB Have a Task Force on Arterial Health and Transportation?

Carolyn McAndrews, University of Colorado, Denver, presented the keynote address describing the task force's efforts to inform the planning, design, and operation of arterials while considering public and population health.

Understanding Livable Streets in the Context of Arterials That Surround Them

Wesley Marshall, University of Colorado, Denver
Carolyn McAndrews, University of Colorado, Denver

Not long after the advent of cars arose a conflict between traffic and residential livability. The typical response pushed traffic off residential streets onto nearby major roads. This line of thinking evolved into a hierarchical approach to street networks and arterial roads designed to carry the vast majority of vehicle traffic. With many researchers – notably Donald Appleyard with his influential Livable Streets research strand – identifying traffic on residential streets as an underlying issue behind poor livability, this solution makes perfect sense. However, is the relationship between residential livability and traffic moderated by the character of the nearby arterial road?

Via a residential study in Denver, CO, we partitioned ten arterials along two dimensions: high/low traffic; and high/low design quality. Within each of the surrounding neighborhoods, we selected comparable residential roads to fit Appleyard's heavy, moderate, and light traffic descriptions and surveyed 721 residents. Our results suggest that the surrounding street network – and in particular, the character of the nearby arterial road – influences residential livability across a number of livability measures. When controlling for income, high levels of traffic as well as low levels of urban design on the arterial both detract from livability in the surrounding neighborhoods. This should not be taken as a call to increase traffic on residential streets; rather, planners and engineers looking to promote residential livability need to begin taking a broader, network perspective to understanding livability. Livable residential streets can only be part of the solution; we also need more livable arterial roads.

The All-Consuming Nature of Parking at Purported Transit-Oriented Developments

Wesley Marshall, University of Colorado, Denver

This paper investigates parking and the provision of parking as it relates five existing station areas in the Denver region. The research included attempting to catalog *all* parking spaces –

and the occupancy of these spaces – within a half-mile of each station. We then characterized the parking provided and assessed the levels of parking provided and utilized in terms of issues such as requirements, efficiency, and land consumption.

While the park-and-ride lots were often approaching capacity, the TOD districts as a whole generally provided far more parking than was either used or required. Looking at the area within a half-mile of these stations as a district suggests that some were providing more than twice as much parking as utilization rates suggest are needed. One station area even boasts more than 12,000 potentially unnecessary parking spaces within a half-mile zone, which equates to more than 70 acres of land being consumed by empty parking.
Parking has long been a cause of frustrations along transit lines, especially for second-generation transit systems in formerly auto-dependent regions. The cases studied in this paper suggest that agencies and municipalities continue to err on the side of providing more parking than necessary. While inadequate parking supply is almost always considered the problem, the real issue are more likely to be inefficient management, poor organization, bad design, and little walkability. The opportunity is there to develop TODs in a different way. Parking is one piece of this puzzle that should not be overlooked.

Bicycle Backlash: Qualitative Examination of Aggressive Driver-Bicyclist Interactions

Daniel Piatkowski, University of Nebraska
Wesley Marshall, University of Colorado, Denver
Aaron Johnson, University of Colorado, Boulder

This exploratory study investigates aggressive driver-bicyclist interactions. In this study, individuals that self-identify as both a driver and bicyclist are asked about their stated behavior when encountering a bicyclist on the road while driving a car. We examine descriptive statistics from individuals who report a high likelihood of driving too close to a bicyclist and then explore open-ended survey responses. There is little guidance in the research as to why individuals – whether they bicycle or not – would choose to intimidate or possibly strike a bicyclist while driving. We draw on applicable theory from sociology and behavioral economics to aid in our understanding of why individuals might act aggressively toward bicyclists. Specifically, the literature on deviant behavior, crime as social control, and altruistic punishment. This research is a first-step at identifying testable hypotheses via qualitative methods to explain such behaviors and eventually mitigate them. Movements such as “Vision Zero” place a great deal of emphasis on infrastructure, but there is a need for more research into how specific infrastructure investments impact multi-modal interactions actual and safety outcomes. This research provides an important early step in the process of providing actionable directions for addressing dangerous on-street interactions that have potentially deadly consequences and act as barriers to fostering a safe transportation system in the US that accommodates all users.

Estimating Lives Saved and Injuries Reduced by Motorcycle Helmet Use in Colorado, 2006 - 2014

Bruce Janson, University of Colorado, Denver

Many rigorous studies have shown the effectiveness of helmet use in reducing severe injuries and fatalities to motorcyclists. The National Highway Traffic Safety Administration (NHTSA) reports estimates of lives saved by motorcyclists wearing or potentially wearing helmets in the U.S. This calculation uses a statistically derived estimate of helmet effectiveness in preventing deaths to motorcyclists involved in crashes. Two parts of the lives saved estimate are (i) deaths prevented assuming crashes occurred not killing helmeted motorcyclists in proportion to those that did kill helmeted motorcyclists, and (ii) deaths that may have been prevented if unhelmeted motorcyclists killed in crashes had been helmeted. Similar estimates can be made for injuries, and more readily available crash data enables analysts to investigate whether crashes in their jurisdictions support the inherent assumptions of these estimates. Moreover, the estimates can be stratified to include other crash characteristics such as crash type, gender, and age. This paper compares estimates of potential fatality and injury reductions based on NHTSA averages to estimates using all reported crashes in Colorado in the years 2006 to 2014.

Lyft and Uber Driver Perspective: Travel Distances, Times, and Earnings

Alejandro Henao, University of Colorado, Denver
Wesley Marshall, University of Colorado, Denver

The transportation sector is currently experiencing a monumental disruption with the introduction and evolution of technology and transportation services such as bikesharing, carsharing, on-demand ridesourcing, and microtransit. As these new layers of technology-based transportation options begin to flourish, it is important to understand how they impact our transportation systems. This is the first independent research study that focus on the driver perspective implementing an innovative approach by collecting and using driver data from Lyft and Uber trips. More specifically, this paper investigates three very important aspects of Lyft and Uber ridesourcing services from the driver perspective: travel distances, breakdown of time spent by drivers, and driver earnings. We calculate efficiency rates for times and travel distances by comparing with-passenger travel and total travel time and distance, estimating the total mileage a Lyft/Uber driver has to travel - vehicle miles traveled (VMT) - per 100-with-passenger miles traveled (WPMT). Finally, we calculate drivers' net earnings, expenses, and gross earnings per hour of work and per mile traveled. The results for this study show that ridesourcing overall efficiency rates based on time and mileage are 41.5% and 59.2%, respectively; and the gross earning after expenses are about $7.73 per hour of work. These results gives us insights to better understand the impacts on ridesourcing in VMT and transportation in general, including an important labor force as the drivers-partners. This, in turn, will help cities and transportation organization better account for the impacts of ridesourcing on travel times and distances, as well as inform the ridesourcing labor market on the complicated issue of earnings and expenses.

UNIVERSITY OF UTAH

Overview of Functions, Applications, Design Considerations, and Guidelines

Steven Bartlett, University of Utah

Presented in a workshop on "Applications of Expanded Polystyrene Geofoam for Transportation Infrastructure." The objective was to provide participants with an overview of expanded polystyrene-block geofoam applications such as embankments over soft ground, slop stabilization, bridge abutments and approaches, temporary and permanent bridge support, retaining wall systems, culverts and utilities, rail systems and airport applications.

Rapid Seismic Repair of Severely Damaged Cast-in-Place Reinforced Concrete Bridge Piers

Ruoyang Wu, University of Utah
Chris Pantelides, University of Utah

A repair technique for severely damaged reinforced concrete Cast-in-Place (CIP) bridge columns has been developed that utilizes a carbon fiber-reinforced polymer (CFRP) shell and epoxy anchored headed steel bars to relocate the column plastic hinge. The CFRP shell which encloses the headed steel bars is filled with non-shrink concrete to a certain height to form a repair "donut". Two original CIP specimens were built and were damaged to failure under quasi-static cyclic loads: the first specimen is a cap beam-to-column connection and the second is a footing-to-column connection. Failure of the original specimens occurred at drift ratios of 9.3% and 8.8%, with severe concrete crushing and spalling, longitudinal bar fracture or bar buckling. Preliminary design using nonlinear finite element analysis was performed to obtain the geometry and thickness of the CFRP shell. The two repaired specimens were re-tested to failure under cyclic quasi-static loading. The repair method successfully relocated the plastic hinge at a section adjacent to the CFRP repaired section and was capable of restoring the load and displacement capacity. Failure of the two repaired CIP specimens occurred at drift ratios of 8.1% and 8.4%, with concrete crushing and spalling but without bar fracture. The repair method is found to be practical and efficient for seismic repair of severely damaged bridges. The repair is relatively fast to construct and implement compared to traditional techniques and thus could be classified as a rapid seismic bridge repair technique.

Dynamic Transit Accessibility and Transit Gap Causality Analysis

Seyed Kiavash Fayyaz Shahandashti, University of Utah
Xiaoyue Cathy Liu, University of Utah
Richard Porter, VHB

Public Transit Accessibility (PTA) analysis helps transit agencies and planners identify areas in need of transit service improvements and prioritize transit investments. To evaluate the accessibility of existing transit services and identify access gaps, it is critical to accurately estimate travel times between transit stops, which change throughout the day due to transit schedule variations. Commonly used methods in PTA ignore such temporal fluctuation.

Moreover, these methods are unable to elucidate the causes of poor PTA. To address these issues, we first implemented an algorithm to effectively compute travel times at multiple departure times throughout the day in order to enable spatiotemporal PTA analysis. A series of indicators that are intuitive to interpret were developed to determine the varying causes of poor PTA and identify areas with immediate needs for improvements. We showcase the analytical framework using a transit network in the State of Utah operated by the Utah Transit Authority. The analysis is based solely on publicly-available open datasets, which makes it generally adaptable to other transit networks. Results can assist transit agencies with identifying areas in need of service improvement and prioritizing future investments.

Low-Temperature Performance of Aged Hot Asphalt Mixtures Containing Reclaimed Asphalt Pavement

Abu Sufian Mohammad Asib, University of Utah
Pedro Romero, University of Utah
Yang Li, University of Utah
Daniel Sudbury, University of Utah
Faramarz Safazadeh, University of Utah

At low temperatures, stiff asphalt concrete roads can crack if it cannot relax thermal tensile stress. Long-term oxidative aging during the service period and current practice of adding Reclaimed Asphalt Pavement (RAP) make Hot Mix Asphalt (HMA) pavement more brittle which is susceptible to thermal cracking during freezing weather. Thus, research on the combined effect of long-term aging and RAP at low temperature is necessary. In this study, by binder substitution, RAP was added to virgin binder and aggregates at variable proportions to prepare Superpave® HMA mixes. The mixes were then aged for 1, 3 and 5 days in a forced-draft oven at 80 °C and their performance were evaluated using the Bending Beam Rheometer (BBR) at -18 °C. The long-term aging effect was also investigated after conditioning the BBR specimens containing 0% and 20% RAP on the roof in natural exposure and their performances were evaluated in BBR at different intervals. It was found that long-term aging would not affect low-temperature performance for samples with RAP contents less than 10%. However, aging effect is significant on RAP contents higher than 10%. Lab aging facilitates rapid stiffness growth in a short period under a constant temperature while natural aging over 12 months produces results with more variability. Long-term oven aging also reduces the phase angle of asphalt mixtures, reducing their ability to dissipate stresses. Thus, a higher percentage of RAP and long-term aging can significantly reduce the stress relaxation capacity of asphalt mixtures and hence, accelerate thermal cracking.

Traffic Impact Analysis for Multimodal Corridors in Salt Lake City, Utah

Milan Zlatkovic, University of Wyoming
Yu Song, University of Utah
Aleksandar Stevanovic, Florida Atlantic University

Transportation and planning agencies in the Salt Lake City, Utah region have recognized the need for multimodal transportation that would facilitate all transportation modes, and have

begun working together towards achieving this common goal through increasing capacities, implementing innovative solutions and designing with all system users in mind. Some of the corridors are more challenging when it comes to multimodal transportation and require detailed analysis. This paper describes a multimodal traffic impact analysis for four of those corridors: Foothill Drive, 1300 E, 700 E and State Street. The needs for changes and improvements are recognized for these areas, and this study performed alternative analysis and comparisons of potential improvements for car, transit and bicycle modes. The alternatives include exclusive bus and bicycle lanes, and BRT implementation and reversible lanes based on the current and projected needs for these corridors. The analysis was performed through traffic microsimulation. The results show that these alternatives, in combination with geometric and operational optimization, have a potential to improve the overall transportation system. Person-based delays can be significantly reduced (30% – 60% depending on the corridor), with an overall increase in speeds especially for transit modes. For all corridors, it is important to offer more travel choices through increased transit service and options for non-motorized traffic, equally considering efficiency and safety for all travel modes.

Identifying Network-wide Critical Transportation Links under Disaster Disruptions: Multiple-Scenario and Probability-Based Simulation Approach

Nima Haghighi Naeini
Seyed Kiavash Fayyaz Shahandashti, University of Utah
Xiaoyue Cathy Liu, University of Utah
Steven Bartlett, University of Utah

Critical infrastructure systems have received significant attention over the past several decades. Transportation system is among many critical lifelines that communities or any urban areas are dependent on. Disruption analysis of transportation infrastructure thus is important to ensure the prevention, preparedness, response and recovery from any risks. In the context of transportation network, identifying critical links under disaster disruption scenario can help guide pre-disaster preparation and post-disaster recovery efforts. Previous studies for disaster-based transportation network analysis were not carried out within a probabilistic context, owing to analysis methods that either look at single link impact or focus on specific disruption scenario. We advance existing knowledge by presenting a probabilistic approach to simulate various disruption scenarios and identify the most critical links within the network. Our method takes advantage of Monte Carlo simulation, network-wide demand modeling, and regression analysis to address the probabilistic nature of disaster effect and capture the joint impact of links failures. Applying to the Salt Lake County transportation network in the State of Utah, our analysis effectively categorizes the links based on their vulnerability and criticality for disaster prevention and preparedness. The proposed method can be easily transferable to different transportation networks regardless of scale, topology, and the type of the disasters that might impose disruption.

Predicting Day and Night Traffic Volumes on Rural Roads for Statistical Road Safety Modeling

Anusha Musunuru, University of Utah
Ran Wei, University of Utah
Richard Porter, VHB

Statistical road safety modelers have commonly used some combination of segment length and traffic volume as measures of exposure. Traffic volume is usually represented in statistical road safety models with average annual daily traffic (AADT), which turns out to be a highly influential right-hand-side variable for regression models of expected crash frequency. Models that use AADT alone do not explicitly capture differences in traffic volume patterns throughout the 24-hour day, which can also have significant effects on safety performance. This study adds to the existing literature by developing more disaggregated estimates of traffic volumes for day and night conditions in rural areas and modeling road safety using those estimates. The proposed approach is demonstrated using data from all ATR stations in Utah, with subsequent safety analysis focused on rural, two-lane horizontal curve segments. Universal kriging, along with multiple covariates, proved to be an effective spatial technique for predicting day and night traffic volumes at unmeasured locations using data from permanent traffic recording stations. Predicted day and night traffic volume estimates were incorporated into statistical road safety models of the expected number of crashes on rural, two-lane horizontal curves to determine how this “new” information impacts safety model estimation results. The parameter estimate for the predicted ratio of night-to-day traffic volume was positive and statistically significant, verifying the hypothesis that horizontal curves with higher proportions of traffic at night are expected to experience more crashes than similar curves with higher proportions of traffic during the day.

Toward True Multimodal Transportation Accessibility: Data, Measures, and Methods

Ivana Tasic, University of Utah
Claire Bozic, Chicago Metropolitan Agency for Planning (CMAP)
Eric Hanss

The measure of accessibility becomes particularly relevant in the era when applications and user information based on real-time data feed become factors of major influence on traveling choices and behavior. From the likelihood of choosing alternate modes of transportation, to travel time reliability, and the overall ability to reach desired destinations, transportation accessibility is the measure that truly represents the success of complex multimodal transportation systems from both users and transportation practitioners perspective. This paper presents spatio-temporal measures of accessibility for pedestrians, bicyclists, and transit users, using the case study of the City of Chicago. The paper summarizes the current challenges in the area of accessibility measurement methodologies, the impediments to implementing accessibility as a performance measure, and the benefits of achieving multimodal accessibility. The goal of this paper is to demonstrate how multimodal accessibility can be used to characterize the quality of transportation service on the city-wide level, and identify the potential benefits and challenges to developing and implementing accessibility measures as a

part of the transportation performance measurement efforts that have a direct influence on transportation policy development. The results show the presence of inequity and clear lack of integration of pedestrian, bicyclist, and transit options, particularly outside of the downtown core area of the city.

Spatial Sampling with Fisher Information for Optimal Maintenance Management and Quality Assurance

Xiaoyue Cathy Liu, University of Utah
Zhuo Chen, University of Utah

Maintenance management has been relying heavily on collecting asset condition information to plan for maintenance activities and budget allocation. Data collection is often conducted on a sampling basis due to the resource constraints. There is thus a perceived need for an effective sampling framework to determine statistically representative samples that would reflect the true Level of Maintenance (LOM) condition at state/region/station level, yet is also flexible to accommodate agencies' requirements. This paper presents a systematic approach for designing a sampling scheme for maintenance activity optimization. The proposed method addresses "how much and where" the agencies would need to collect asset data with the maximum information retained for LOM estimation. The method integrates Fisher information with spatial sampling technique that can be customized based on local agencies' requirements, such as station-balanced, spatially-balanced, or others. The framework is showcased via an example application of the *Signage Repair & Replace* database maintained by the Utah Department of Transportation (UDOT). Four sampling methods that might be tempered to various needs are implemented with sampling results presented and compared against ground truth asset inventory using similarity analysis. The proposed framework lays a strong theoretical foundation for the maintenance asset sampling and is effective for estimating the LOM at state/region/station levels for budget allocation. The method can be easily transferable and adopted by any agencies for optimal maintenance management.

Information-Based Infrastructure Sampling Method with High-Dimensional Clustering and Locality-Sensitive Hashing Algorithm

Zhuo Chen, University of Utah
Xiaoyue Cathy Liu, University of Utah

An information-based sampling method for infrastructure condition inspection is proposed in this study. The method complements existing literature by carrying out the inspection activities on the roadway segment basis, and selecting sample segments that contain multiple types of infrastructures for accurately estimating their respective levels-of-maintenance (LOMs). The sampling framework consists of two components: current condition estimation and high-dimensional cluster analysis. Current condition estimation integrates historical inspection records and provides prediction for cluster analysis. High-dimensional cluster analysis represents the core part of the sampling framework, which employs Locality-Sensitive Hashing algorithm and spectral sampling. Locality-Sensitive Hashing algorithm defines the similarity between segments, and spectral sampling assigns segments into clusters with similarity matrix.

The proposed method outperforms simple random sampling method which is widely used in practice, especially under the circumstances where LOM varies greatly within infrastructures. The highlight of the proposed method is the selection of samples that can fulfill the sampling requirements for collecting multiple infrastructures' information simultaneously. The method is implemented using the infrastructure management records in the State of Utah from September, 2014 to March 2016. The proposed information-based sampling method is a potentially useful tool for agencies to effectively conduct infrastructure inspection and can be easily adopted by any sampling process with samples containing multiple features.

Heart Rate Detection for Driver Monitoring Systems

Francesco Biondi, University of Utah
James Coleman, University of Utah
Joel Cooper, Precision Driving Research, Inc.
David Strayer, University of Utah

Current driver monitoring systems use steering behavior and driver ocular parameters as inputs. As NHTSA level-2 and 3 vehicles are introduced into the market, more accurate monitoring systems are needed. This study aims to investigate whether average heart rate may be used as an accurate metrics of mental workload. Participants with different age ranges drove on-road vehicles and interacted with vehicles' infotainment. Results showed that the average heart rate measured via a commercial-use heart monitor increased during the interaction with the vehicle's infotainment system compared to the single-task condition. Further, as the task became more demanding, younger drivers showed a higher heart rate compared to older drivers. These results are of the primary importance for the design of adaptive workload monitoring systems.

General Transit Feed Specification Data-Enabled Social Computing Toolbox for Dynamic Transit Accessibility Analysis

Seyed Kiavash Fayyaz Shahandashti, University of Utah
Xiaoyue Cathy Liu, University of Utah

The social functions of urbanized areas are highly dependent on and supported by the convenient access to public transportation systems, particularly for the less privileged populations who have restrained auto ownership. To accurately evaluate the public transit accessibility, it is critical to capture the spatiotemporal variation of transit services. This can be achieved by measuring the shortest paths or minimum travel time between origin-destination (OD) pairs at each time-of-day (e.g. every minute). In recent years, General Transit Feed Specification (GTFS) data has been gaining popularity for between-station travel time estimation due to its interoperability in spatiotemporal analytics. Many software packages, such as ArcGIS, have developed toolbox to enable the travel time estimation with GTFS. They perform reasonably well in calculating travel time between OD pairs for a specific time-of-day (e.g. 8:00 AM), yet can become computational inefficient and unpractical with the increase of data dimensions (e.g. all times-of-day and large network). In this paper, we introduce a new algorithm that is computationally elegant and mathematically efficient to address this issue. An

open-source toolbox written in C++ is developed to implement the algorithm. As a case study, City of St. George's transit network is used to showcase the accessibility analysis enabled by the toolbox. The experimental evidence shows significant reduction on computation time. The proposed algorithm and toolbox presented is easily transferable to other transit networks to allow transit agencies and researchers perform high resolution transit performance analysis.

Low-Temperature Performance of Aged Hot Asphalt Mixtures Containing Reclaimed Asphalt Pavement

Abu Sufian Mohammad Asib, University of Utah
Pedro Romero, University of Utah
Yang Li, University of Utah
Daniel Sudbury, University of Utah
Faramarz Safazadeh, University of Utah

At low temperatures, stiff asphalt concrete roads can crack if it cannot relax thermal tensile stress. Long-term oxidative aging during the service period and current practice of adding Reclaimed Asphalt Pavement (RAP) make Hot Mix Asphalt (HMA) pavement more brittle which is susceptible to thermal cracking during freezing weather. Thus, research on the combined effect of long-term aging and RAP at low temperature is necessary. In this study, by binder substitution, RAP was added to virgin binder and aggregates at variable proportions to prepare Superpave® HMA mixes. The mixes were then aged for 1, 3 and 5 days in a forced-draft oven at 80 °C and their performance were evaluated using the Bending Beam Rheometer (BBR) at -18 °C. The long-term aging effect was also investigated after conditioning the BBR specimens containing 0% and 20% RAP on the roof in natural exposure and their performances were evaluated in BBR at different intervals. It was found that long-term aging would not affect low-temperature performance for samples with RAP contents less than 10%. However, aging effect is significant on RAP contents higher than 10%. Lab aging facilitates rapid stiffness growth in a short period under a constant temperature while natural aging over 12 months produces results with more variability. Long-term oven aging also reduces the phase angle of asphalt mixtures, reducing their ability to dissipate stresses. Thus, a higher percentage of RAP and long-term aging can significantly reduce the stress relaxation capacity of asphalt mixtures and hence, accelerate thermal cracking.

Impact of Traffic Signal Control Parameters on Frequency and Severity of Intersection-Related Crashes

Dusan Jolovic, New Mexico State University
Abhisek Mudgal, Texas A&M Transportation Institute
Ivana Tasic, University of Utah
Aleksandar Stevanovic, Florida Atlantic University
Peter Martin, New Mexico State University

While previous research in the area of intersection crash modeling mostly distinguishes between signalized and unsignalized intersections, this paper provides a detailed insight into

the association of signal timing parameters with intersection-related crashes. Crash data were collected for 148 urban signalized intersections in Fort Lauderdale, Florida, for 11 years. Crash frequency is modeled using negative binomial regression, while distinguishing between the crashes that occur upstream and downstream of the intersection. Crash severity is modeled using multinomial logit model for three crash categories: no injury, possible injury, and severe injury or fatality. The results obtained from the crash frequency models clearly show how signal timing parameters have higher influence on crashes that occur upstream of the intersection, as expected. It is found that the average annual daily traffic (AADT) volume, cycle length, offset, number of phases and all-red clearance time have significant impact on intersection crash frequency. Severity of the crashes which were intersection related was influenced by the speed limit, AADT, all-red clearance time, left turn phase setup, number of signal phases, number of approach lanes, split time, and cycle length. Crash frequency models obtained and presented in this paper show the potential for future exploration of developing separate models for crashes that occur upstream and downstream of the intersection. Developed severity models show the need for future consideration of signal timing parameters when modeling intersection-related crashes.

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Critical infrastructure systems have received significant attention over the past several decades. Transportation system is among many critical lifelines that communities or any urban areas are dependent on. Disruption analysis of transportation infrastructure thus is important to ensure the prevention, preparedness, response and recovery from any risks. In the context of transportation network, identifying critical links under disaster disruption scenario can help guide pre-disaster preparation and post-disaster recovery efforts. Previous studies for disaster-based transportation network analysis were not carried out within a probabilistic context, owing to analysis methods that either look at single link impact or focus on specific disruption scenario. We advance existing knowledge by presenting a probabilistic approach to simulate various disruption scenarios and identify the most critical links within the network. Our method takes advantage of Monte Carlo simulation, network-wide demand modeling, and regression analysis to address the probabilistic nature of disaster effect and capture the joint impact of links failures. Applying to the Salt Lake County transportation network in the State of Utah, our analysis effectively categorizes the links based on their vulnerability and criticality for disaster prevention and preparedness. The proposed method can be easily transferable to different transportation networks regardless of scale, topology, and the type of the disasters that might impose disruption.

Application of Regression Trees to Predict the Frequency of Crashes

Richard Porter, University of Utah
Larry Cook, University of Utah

Presented in the workshop, "Alternative Statistical methods to Assess Highway Safety Performance." The workshop compared current statistical analysis methods used in traffic safety research with alternative methods.

Use of CODES Data Traffic Safety Research

Richard Porter, University of Utah
Larry Cook, University of Utah

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UNIVERSITY OF WYOMING

Five-Step Process for Implementing Low-Cost Safety Improvements on Unpaved Roads

Khaled Ksaibati, University of Wyoming

Presented in the workshop "Unpaved Roadway Safety Research: Development of a National Agenda." A white paper from the research will present research ideas and problem statements that focus on safety policy, planning, identification, evaluation, and implementation of safety issues and improvements on unpaved roadways.

Pavement Management System for Low-Volume Paved Roads

Marwan Hafez, University of Wyoming
Khaled Ksaibati, University of Wyoming
Rebecca Atadero, Colorado State University

The most important issue in managing low-volume roads (LVRs) is to define standards and practices applied on roads. In recent years, transportation agencies have dealt with considerable challenges for managing LVRs. These challenges include reductions in maintenance budgets; impact of industrial activities; and ineffective treatments applied on paved roads. The Wyoming Technology Transfer Center (WYT ^{2}/LTAP) conducted online surveys as part of a research project conducted jointly with the Colorado Department of Transportation. The objective of the surveys is to document what the transportation agencies, including state departments of transportation (DOTs), are doing to face these challenges. Four online surveys were sent to the TRB low-volume roads committee, eight DOTs, local governments in Colorado, and the material advisory committee in the Colorado DOT. These surveys have an average of 26 questions dealing with pavement management system (PMS) specifications recommended for low-volume paved roads. Seventy-one transportation agencies

responded to the survey. This paper summarizes the responses to the survey showing innovative programs, procedures, and products that are successfully meeting LVRs management needs.

Developing Performance Models for Treated Gravel Roads to Evaluate the Cost-Effectiveness of using Dust Chemical Treatments

Mohammer Okok, University of Wyoming
Promothes Saha, University of Wyoming
Khaled Ksaibati, University of Wyoming

The objective of this study is to develop a long term performance model to predict the service life of treated gravel roads. Fugitive dust emissions from 11 recently treated gravel roads located in five different counties in the state of Wyoming were measured periodically for 12 months. Visual survey ratings of the 11 roads were taken each time. Surfacing moisture samples were collected. Traffic speeds and volumes by class were also collected using a two-tube traffic counting system. Surfacing aggregate samples were collected and their gradations were determined. Performance curves were developed for each of the selected 11 roads. A comprehensive long term performance model was developed that predicts the service life of treatment on gravel roads. A life cycle cost analysis comparison study was also conducted to compare the cost of maintaining untreated gravel roads with the cost of maintaining treated gravel roads. Statistical analyses generated regression models that allowed the prediction of factors significant to the service life of treatment on gravel roads. It was found that the daily traffic, the percentage of fines in the soil, and the annual rainfall had the highest contribution to road deteriorations and increase in dust generation. Dust treatment was found to have a service life of one year before dust emission rates went back to before treatment levels. The life cycle cost analysis indicates that the initial cost of applying dust suppressant treatment to gravel roads is expensive. However, it will increase the road service life and significantly reduce dust generation.

Exploring the Impacts of Heavy Rain on Speed and Headway Behaviors Using the SHRP2 Naturalistic Driving Study Data

Mohamed Ahmed, University of Wyoming
Ali Ghasemzadeh, University of Wyoming

Inclement weather events affect not only surface condition and vehicle performance, but also drivers' behavior and performance. Road-user characteristics and behavior are among the most important elements influencing the driving task. The ability to see objects that are in motion relative to the eye, "dynamic visual acuity", and the reaction process such as speed and headway selection are of utmost importance for safe driving. Adverse weather conditions can result in a sudden reduction in visibility on roadways, which leads to an increased risk of crashes. Although many studies have focused on highway safety in relation to adverse weather and road conditions, driver behavior and performance are absent from these studies. Although

the second Strategic Highway Research Program (SHRP2) has collected the most comprehensive Naturalistic Driving Study (NDS) data, identifying NDS traces in various weather conditions could be a daunting task. In this study, a unique procedure of identifying inclement weather trips in the SHRP2 NDS data was developed. Moreover, the Roadway Information Database (RID) and NDS data were used to assess and compare drivers' behavior and performance in adverse and clear weather conditions. Preliminary descriptive statistics, ordered probit regression model, and GIS analyses showed significant behavior and performance differences between driving in heavy rain and clear weather conditions under different traffic states. While this study is exploratory in nature, it unlocks new horizons of assessing the impacts of adverse weather conditions on driver behavior and performance using one of the most comprehensive Naturalistic Driving Study data that have ever been collected in the US.

Tree-Based Ordered Probit Approach to Identify Factors Affecting Work Zone Weather-Related Crash Severity in North Carolina Using the Highway Safety Information System Data Set

Ali Ghasemzadeh, University of Wyoming
Mohamed Ahmed, University of Wyoming

Work zone crashes are still on the rise due to the aging of US roads and the increase in traffic demand. Investigation of crash characteristics and determining contributing factors in work zones is one of the most important issues in many traffic safety studies. The effect of work zones on traffic safety can be exacerbated by weather conditions. A sudden reduction in visibility may intensify the severity of work zone crashes. Although many studies have investigated work zone crashes, research that investigates the impact of adverse weather conditions on work zone crashes is lacking. In this study, The Highway Safety Information System database for North Carolina was used to identify the characteristics of work zone weather-related crashes. A Tree-based Ordered Probit, a relatively recent and promising combination of nonparametric machine learning (decision tree) and classical statistics (ordered probit) techniques, was utilized to gain a better understanding about the effects of various factors on different work zone crash related injury and crash severity in adverse weather conditions. The results showed that Tree- based Ordered Probit model has a better prediction accuracy compared to conventional Ordered Probit Model. Lighting conditions, number of vehicles involved in a crash, road characteristics, number of occupants, land use, presence of traffic control devices, and two types of crashes (sideswipe and rear-end crashes) were identified as the most important factors in work zone weather-related crash severity.

Probit-Decision Tree Approach to Analyze Effects of Adverse Weather Conditions on Work Zone Crash Severity Using Second Strategic Highway Research Program Roadway Information Data Set

Ali Ghasemzadeh, University of Wyoming
Mohamed Ahmed, University of Wyoming

Identifying risk factors for road traffic injuries is one of the main priorities of transportation agencies. More than 12,000 fatal work zone crashes were reported between 2000 and 2013. In

spite of recent efforts on improving work zone safety, the frequency and severity of work zone crashes are still a big concern for transportation agencies. The effect of work zone on traffic safety is shown to be intensified by adverse weather conditions. Although many studies have been conducted on different work zone safety-related issues, there is a lack of studies that investigate the effect of adverse weather conditions on work zone crash severity. This paper utilized probit-decision tree; a relatively recent and promising combination of machine learning technique and conventional parametric model, to identify factors affecting work zone weather-related crashes severity using a unique dataset collected by the second Strategic Highway Research Program Roadway Information Database. The key strength of this technique lies in its capability of alleviating the shortcomings of both parametric and non-parametric models. The results were compared to a conventional probit model and the proposed probit-decision tree is considered a better technique that outperformed the conventional probit regression because of its high estimation accuracy, robustness and reliability, and its ability of estimating marginal effects of risk factors.

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located in five different counties in the state of Wyoming were measured periodically for 12 months. Visual survey ratings of the 11 roads were taken each time. Surfacing moisture samples were collected. Traffic speeds and volumes by class were also collected using a two-tube traffic counting system. Surfacing aggregate samples were collected and their gradations were determined. Performance curves were developed for each of the selected 11 roads. A comprehensive long term performance model was developed that predicts the service life of treatment on gravel roads. A life cycle cost analysis comparison study was also conducted to compare the cost of maintaining untreated gravel roads with the cost of maintaining treated gravel roads. Statistical analyses generated regression models that allowed the prediction of factors significant to the service life of treatment on gravel roads. It was found that the daily traffic, the percentage of fines in the soil, and the annual rainfall had the highest contribution to road deteriorations and increase in dust generation. Dust treatment was found to have a service life of one year before dust emission rates went back to before treatment levels. The life cycle cost analysis indicates that the initial cost of applying dust suppressant treatment to gravel roads is expensive. However, it will increase the road service life and significantly reduce dust generation.

Investigating Challenges Affecting the 4Es of Transportation Safety on the Fort Peck Reservation

Trenna Terrill, University of Wyoming
Khaled Ksaibati, University of Wyoming

Indian Reservations have suffered from high severe and critical crash rates for decades. Recently the United States Department of Transportation has recognized the need for assistance on tribal lands and traffic safety. The National Strategic Highway Safety Plan towards the concept of zero deaths have integrated the 4Es of traffic safety that establish goals and objectives linked to reducing critical motor vehicle crashes. The same concepts of the 4Es can be applied to tribal lands in decreasing the amount of fatal and serious injuries on their roadways through engineering, enforcement, education, and emergency medical services. This paper analyzes the 4Es of transportation safety and relatable challenges that the Fort Peck Reservation in northeastern Montana has faced. It also provides an in depth look at how the Fort Peck tribes overcome these challenges. This paper can be used by other tribes to review similar challenges on their reservation, and provide concepts they may be able to adopt within their community. This paper will help tribes across the nation integrate new and improved highway safety and livability plans that meet their own local needs as a tribal community.

Driver's Lane Keeping Ability in Heavy Rain: Preliminary Investigation using the SHRP2 Naturalistic Driving Study Data

Ali Ghasemzadeh, University of Wyoming
Mohamed Ahmed, University of Wyoming

There is a lack in studies that have examined the impact of weather conditions on driver's lane-keeping performance. Many driver behavior studies have been conducted in simulated environments. However, no studies have examined the impact of heavy rain on lane-keeping

ability in naturalistic settings. This paper utilized data from the second Strategic Highway Research Program (SHRP2) Naturalistic Driving Study (NDS) to provide better insights into driver behavior and performance in clear and rainy weather conditions. In particular, a lane-keeping model was developed using logistic regression to better understand factors affecting drivers' lane-keeping ability in different weather conditions. One interesting finding of this research is that heavy rain can significantly increase the standard deviation of lane position, which is a very widely used method for analyzing lane-keeping ability. More specifically, drivers in heavy rain are 3.8 times more likely to show a higher standard deviation of lane position than in clear weather condition. An additional interesting finding of this study is that drivers have a better lane-keeping ability in roadways with higher posted speed. The results of this study could provide a better understanding of the complex effects of weather conditions on driver's lane-keeping ability and how drivers perceive and react in different weather conditions. The results from this study may also provide insights to automate the activation and deactivation of Lane Departure Warning (LDW) systems.

Estimation of Pavement Serviceability Index through Android-Based Smartphone Application for Local Roads

Waleed Aleadelat, University of Wyoming
Khaled Ksaibati, University of Wyoming

The Wyoming Technology Transfer Center (WYT ^{2}/LTAP) is in the process of developing a Pavement Management System (PMS) for county paved roads in Wyoming. The PMS, which is being developed uses the Present Serviceability Index (PSI) as a main pavement performance parameter. This PMS depends on Pavement Condition Index (PCI), International Roughness Index (IRI), and pavement rutting as explanatory variables to estimate PSI. This study researched new explanatory variables measured by using smartphones' sensors to estimate PSI. It was found that the variance of the signals (time series acceleration data) acquired by smartphones accelerometers could work as a very good explanatory variable to estimate PSI. Two models were developed with high significance (R^2higher than 0.9) to predict PSI using the variance of smartphones signals. The initial validation results suggested that using these models could predict, with high certainty, the actual PSI values. The difference between the predicted and the actual PSI values was not statistically different. The study was performed on 20 roadway segments extracted from the Wyoming county roads PMS database. In addition, the selected segments had various lengths and geometric features reflecting various roadway segments under any PMS. The proposed methodology is intended to lower the cost of measuring county roads pavement conditions by estimating PSI directly without the reliance on the direct measurement of pavement condition parameters.

Investigating Safety-Effectiveness of Wyoming Snow Fence Implementations along a Rural Mountainous Freeway

Thomas Peel, University of Wyoming
Mohamed Ahmed, University of Wyoming
Noriaki Ohara, University of Wyoming

Blowing and drifting snow is a problematic and dangerous aspect of interstate travel in the state of Wyoming. The control of snow and maintenance of roadways during the winter months is a large task for many state and local agencies. Snow can create numerous dangerous situations by affecting various roadway factors such as vehicle control, roadway surface, and visibility. In areas such as the inspected 19-mile section of Interstate 80, snow fences have become a common and practical method for mitigating the problem faced with large quantities of snow near or on the traveled way. Wyoming is a state that deals with a high amount of adverse weather related crashes during the winter season. Snow fence implementations have historically indicated a slight decrease in such crashes using a naïve before-after analysis. In this study, the safety effectiveness of snow fence implementations was investigated using a more rigorous quantitative-based approaches such as a before/after analysis with Empirical Bayes (EB) utilizing a Wyoming-specific Safety Performance Functions (SPFs), as well as odds ratio. Crash modification factors (CMFs) were estimated for various crash types and severity levels. The results from this paper indicate that the implementation of snow fences contributes to a significant increase in safety effectiveness for interstate use during the winter. Specifically, it was found that during adverse weather conditions, snow fences decrease total crashes, and fatal and injury crashes by about 25% and 62%, respectively.

UTAH STATE UNIVERSITY

Highway Asset Inventory Data Collection Using Airborne Lidar

Yi He, Utah State University
Ziqi Song, Utah State University
Zhaocai Liu, Utah State University

Highway assets, including traffic signs and signals, light poles, guardrails, culverts, are essential components of transportation networks. They guide, warn, and protect drivers and regulate traffic. To manage and maintain the regular operation of the highway system, state departments of transportation (DOTs) need reliable and up-to-date information about the location and condition of highway features. Different techniques have been employed to collect highway inventory data. These techniques range from the simplest manual inventory method to methods that involve advanced technology, e.g., light detection and ranging (LiDAR). The focus of this paper is to analyze the capability and strengths of airborne LiDAR in highway inventory data collection. A field experiment was conducted to collect airborne LiDAR data, and an ArcGIS-based algorithm was proposed to process the data. The results demonstrate the effectiveness of our proposed algorithm as well as the feasibility and high efficiency of airborne LiDAR for highway inventory data collection.

Optimal Deployment of Dynamic Wireless Charging Facilities for an Electric Bus System

Zhaocai Liu, Utah State University
Ziqi Song, Utah State University
Yi He, Utah State University

Diesel engine buses still comprise the majority of the bus fleet in the United States even with the problem of diesel exhaust and greenhouse gas emissions. Electric buses, which generate no emissions on the road, provide a promising green alternative for bus fleets. However, electric buses have suffered from their limited travel range and time-consuming recharging time. The technique of dynamic wireless charging, which allows electric buses to charge while traveling, can effectively alleviate the drawbacks of electric buses. Using the dynamic wireless charging technology, electric buses can operate with smaller batteries, and the stationary recharging time at the base station could be shortened. The key design variables of deploying dynamic wireless charging facilities for an electric bus system are the battery size and the location of the wireless charging facilities. In this paper, we addressed the problem of selecting the optimal locations of the wireless charging facilities and designing the battery size for an electric bus system simultaneously. A mathematical model that is a mixed integer linear program was developed with the objective of minimizing the total implementation cost. And the model was demonstrated with a real-world bus system. The results demonstrated that the proposed model could effectively solve the optimal deployment problem of dynamic wireless charging facilities for an electric bus system.

What Influences Children's Evacuation Route Choice? A Questionnaire Based Method

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Children's evacuation is a critical but challenging issue. Unfortunately, existing research fails to effectively describe children's evacuation behavior, which is probably due to the lack of empirical/experimental data. In this paper, an experiment based on a questionnaire designed as a printed map is conducted with children aged 8-12 years to investigate children's route choice behavior during the process of evacuation. 173 effective questionnaires were obtained, and the corresponding data is analyzed. The statistical results demonstrate that position, congestion, group behavior, and backtracking behavior have significant impacts on children's route choice, while gender and guidance have no prominent impacts, and age prominently impacts backtracking behavior exclusively. The above findings may help engineers devise effective evacuation schemes for children.

Contributory Factors to Injury Severity of Work-Zone-Related Crashes in New Zealand

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Upgrading, rehabilitation, and maintenance often take place on existing roads in New Zealand. The adverse effects of poor road condition and reduced road width, due to the presence of work zone, on the safety of road users and workers at the sites have been a concern. Studies have been conducted to examine the risk factors contributing to the occurrence of road crashes in work zones in different countries. Slow and stopped vehicles near the work zones were found the primary cause of crashes and casualties in work zones. However, excessive speed of passing traffic has been recognized as a crucial factor contributing to work zone related crashes in New Zealand. In this study, we attempted to examine the effect of possible risk factors contributing to severe injury and fatality of work zone-related crashes in New Zealand. A multinomial logit regression model was established to measure the association between crash severity and factors including road environment, vehicle attributes, driver behavior and crash circumstance, based on the information on 453 road crashes during the period from 2008 to 2013. Results indicated that time period and vehicle involvement were deterministic to crash severity of crashes at the work zone. This should imply the improvements required in traditional temporary traffic management and work zone treatments and introduction of innovative technologies such as in-vehicle warning system for the enhancement of road safety in the long run.

Highway Drainage Grate Detection and Recognition Based on Aerial Image Processing

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This paper presents an automatic highway drainage grate detection and recognition algorithm using aerial images. Drainage systems that remove storm water from highways are crucial factors for maintaining highway safety. The information of drainage assets on highway systems is essential for state Departments of Transportation (DOTs) or local agencies to manage and upgrade drainage features. However, the significant number of drainage grates in the US highway system can make the manual detection and analysis costly and time-consuming. To address these challenges, this paper proposed a method that is able to directly extract drainage grates from aerial photos of highways. The method consists of three main stages: 1) road segmentation to narrow detection range and increase detection accuracy; 2) preliminary extraction of drainage grates according to the color information of the grates; 3) further detection of drainage grates using their shape information. Totally, 20 aerial images with 289 drainage grates were tested based on our method, and we reached an 89.3% detection rate. From the result, we can conclude that the proposed algorithm is efficient and accurate in detecting highway drainage grates from aerial images, and aerial photography could be a new source to help relevant departments manage drainage systems.