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Travel Behavior Inventory: Survey Results
Jonathan Ehrlich, Metropolitan Council

Accessibility and Travel Behavior
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Local Agency Traffic Data Collection

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The Minnesota Local Road Research Board, Minnesota Department of Transportation (MnDOT), and SRF conducted two related projects that focused on county agencies collecting traffic data. The project stakeholders sought to learn more about novel traffic detection options and the effectiveness of the local agencies conducting the data collection instead of MnDOT. The first project tested several non-intrusive and minimally intrusive traffic data collectors to determine which would be suitable for counties with relatively little traffic data collection experience and resources. This evaluation focused on both data accuracy and qualitative aspects, such as ease of setup and data download.

The second project examined pros and cons for three different entities to collect count and classification data: MnDOT, local county, and consultant. Although MnDOT has been an efficient process that has developed over many years, local personnel could benefit from reduced travel time, better knowledge of local roads/construction and coordination with county mowing activities. Additionally, the local agencies could target sites for enhanced vehicle classification counts. Sibley County, which is primarily rural, organized and conducted counts and compared their process to MnDOT’s process. Post-data collection interviews gave insight and lessons learned regarding this alternative data collection process.
This study reports on ongoing development of a rural intersection conflict warning system referred to as the Advanced LED Warning System for Rural Intersections (ALERT) for reducing crashes at rural two-way stop intersections. The ALERT system, now in the second phase of the study, is designed to alert drivers of approaching traffic at sight-restricted intersections, thereby helping them to avoid collisions. Intersections of this type exhibit some of the most fatal crash history across the nation. In addition to notifying the driver, the goal of this project is to create a low-cost solar-powered system which can be easily installed. The ALERT system consists of vehicle detectors which detect vehicles on the major and minor approaches and wirelessly activated LED blinker warning signs that dynamically flash when there is vehicle detection. Building upon earlier system limitations, the new system includes vehicle activated blinker STOP signs which are designed to mitigate the previous observation of drivers ignoring the stop sign and using this system like a traffic signal. To assess the driver behaviors at the test site, almost a year’s worth of video data was collected and a survey of local residents’ reactions were also collected. The analysis of this video data and the survey results are presented.
Minnesota’s County Roadway Safety Plans: Lessons Learned

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The three and one-half year effort to prepare safety plans for every county in Minnesota has been completed – the last six counties received their Plans in September, 2013. The final task involved looking back at the entire process of developing the plans and identified a number of key points about the process itself and conclusions about the actual outcomes.

Decisions made by MnDOT to increase the level of engagement of local agencies in the statewide safety planning effort, to dedicate a fraction of the State’s safety funds for projects on the local system and to add a systemic component (risk based as opposed to exclusive reliance on crashes) proved to be instrumental in actually deploying safety strategies along county roadways. In addition, providing technical support to the counties to conduct the system wide risk assessments and identify safety projects was found to be the best way of helping the counties get to implementation. It is clear that left on their own, virtually none of the counties would have been able to replicate the results achieved by County roadway Safety Plans (CRSP) project.

The Plans were developed through a data driven process that analyzed over 3,300 severe (fatal + serious injury) crashes along the system of county roadways and completed the risk assessment of more than 23,000 miles of roadways segments, 19,000 horizontal curves and 15,000 intersections. The Plans identified priority crash types, a short list of highly effective and low-cost safety strategies and over 17,000 individual safety projects with an estimated implementation cost of $245M.

Finally, the look back at all of the data points to three very important concepts relative to safety along Minnesota’s county system of roadways:

1. Along roadway segments, at curves and intersections the presence of the adopted risk factors was associated with a higher crash density and that the crash density across the entire system increased with presence of additional risk factors.

2. Some previously published research suggests that severe crashes on rural roadways are randomly distributed. The results of the CRSP process supports the notion that severe crashes are widely distributed but the documented relationship between risk factors and crash density supports a conclusion that these crashes are not random and that the use of roadway and traffic characteristics can in fact identify locations that are more at-risk for certain types of crashes.

3. The look back at the crash data identified an interesting and possibly useful relationship between infrastructure based risk factors and driver behavior related crashes. Both high priority rural and urban corridors at-risk for infrastructure related crashes were also found to be more at-risk for a variety of driver behavior related crashes.
Monitoring of Fracture-Critical Steel Bridges

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The collapse of the I-35W Bridge in Minneapolis, MN was not only a structural failure of the bridge, but also caused failure to the transportation system. As a result, adjacent bridges and roads where forced over their capacity causing thousands of hours lost to delay. This transportation failure spurred the need to monitor the Cedar Avenue Bridge, which is vital to the transportation network. The Cedar Avenue Bridge project is part of a larger effort to develop an advanced warning system for fracture critical bridges, which are the most prone to sudden collapse, and therefore require more inspection. Acoustic emission (AE) sensors have been chosen to monitor for early warning signs because they have the potential to detect distress in steel bridge members. Although AE sensors can detect early indications of damage in bridge members, the sensors also detect compression waves from rain, traffic, and bridge creaking. Laboratory notched beam tests have been performed in order to allow the sensor system to differentiate between the compression waves produced by structural distress and background noise. The notched beam tests will simulate structural distress in the bridge and AE sensors will capture the compression waves produced. The AE sensors will then be calibrated to look for distress waves and to ignore ambient noise. This research will provide an efficient and effective method to monitor for early warning signs of failure in the Cedar Avenue Bridge. If this field project is successful, the methods used in this research will allow for AE sensor systems to be deployed on other fracture critical steel bridges.
Anchorage of Shear Reinforcement in Prestressed Concrete Bridge Girders

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The Minnesota Department of Transportation has typically used straight legged stirrups anchored in the tension zone as transverse reinforcement in prestressed concrete bridge girders to facilitate girder construction. This configuration is readily placed by inserting the reinforcement cage into the forms after stressing the prestressing strands. ACI and AASHTO specifications require stirrups to be fabricated with bent legs that encompass the longitudinal reinforcement which serves to anchor the stirrups. Such a configuration is specified to ensure that the stirrup will be able to develop its yield strength with a short anchorage length to resist shear within the web of the girder. AASHTO specifications for anchoring transverse reinforcement are the same for reinforced and prestressed concrete. However, in the case of prestressed concrete bridge girders, the precompression may serve to enhance the anchorage of the transverse reinforcement, thereby enabling the straight bar detail. Pullout tests were performed on 13 subassemblage specimens which represented the bottom flanges of prestressed concrete beams in a number of configurations to determine the effectiveness of straight legged stirrup anchorage in developing yield strains. Additionally, two full-scale prestressed concrete girders were cast with straight legged stirrup anchorage details and tested in flexure-shear and web-shear. The straight leg stirrup anchorage detail was determined to be acceptable for M and MN shaped girders as nominal shear capacities were exceeded and yield strains were measured in the stirrups prior to failure during each of the tests.
Development and Integration of Advanced Timber Bridge Inspection Techniques

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Required timber bridge inspections and assessments have raised concerns among city, county and state engineers about the current practice used in Minnesota. Inspections for timber bridges have been mostly limited to visual inspection, hammer sounding and probing. These techniques have proven appropriate for advanced decay detection, but are inadequate for early stage or internal deterioration. It is critical that efforts be conducted to develop and implement advanced timber inspection techniques into routine bridge inspections in accordance with National Bridge Inspection Standards (NBIS) requirements. In this project, an experienced research team identified and helped implement an inspection protocol for Minnesota’s timber bridges (with an emphasis on timber substructure) that accurately assesses structural condition. Key milestones include the development of standard inspection protocols, integration of the results into bridge data management software, development of a customized inspection manual, outreach training for MnDOT districts, recommendation of equipment purchases, and completion of an economic assessment on the use of advanced inspection techniques. Final implementation of this project will result in improved assessment information that can be used to improve the safety and reliability of Minnesota’s bridges.
Understanding and Enhancing the Value of Freight Economy in Minnesota

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Understanding and Enhancing the Value of Freight Economy in Minnesota is a project led by the State and Local Policy Program at the Humphrey School of Public Affairs. The objective of the study is to explore the value of freight, especially rail, to Minnesota's economy through data analysis and stakeholder outreach and engagement. Now entering its second year, the project recently held a forum on Transportation Policy and Economic Competitiveness at the Humphrey School on September 20, 2013, bringing together a large, diverse group of attendees as well as an influential slate of speakers, featuring U.S. Senator Amy Klobuchar, Chairman and CEO of BNSF Railway Matt Rose, and former Rep. James Oberstar, in addition to many local industry and government leaders for two discussion panels. The study team combined economic data including industry clusters, gross state product, and share specialization with spatial (GIS) analysis to produce a series of maps which told a story of the State's economic recovery from the Great Recession led by greater Minnesota and driven by the success of several rail-reliant industries. Interim findings touch on the importance of rail to the Minnesota economy, the value of the partnership between Class 1 and shortline railroads, the under recognized value of rail infrastructure, the challenge of intermodal transportation policy, and the public perception challenges faced by freight rail. Next steps include vetting the interim findings and exploring in depth case studies through outreach efforts as well as perform some additional data analysis. The team will focus on developing recommendations in the areas of transportation policy as well as the public understanding of freight and freight rail.
This study is being performed for the Grand Forks – East Grand Forks Metropolitan Planning Organization by a consultant team of Olsson Associates and SRF Consulting Group. With an agriculturally-based economy, a connection to BNSF Railway’s Great Northern Corridor, and ancillary development supporting the Bakken oil development, the Grand Forks – East Grand Forks region finds itself strategically positioned for additional rail development. Planning for this additional development is critical to minimize impacts on land use and transportation networks as well as maintain quality of life.

Relying on accessible public data and GIS mapping, the study team is performing two rounds of site viability analysis, examining site characteristics like usable acreage, zoning and land use, transportation access and utility access, as well as cost of extending infrastructure, flexibility of rail design and environmental constraints. This research was complemented by multiple outreach efforts to gain understanding about business needs and how products are being transported. The study also includes evaluating how additional industrial rail development might affect transportation networks and a sensitivity analysis on the impact increased train volumes would have in regards to the existing quiet zones in the MPO area. The preliminary site viability analysis is complete; next steps include the second round site analysis and conceptual rail design. This methodology is well-positioned to be applied to other rail-served communities proactively looking to plan for industrial development and/or capitalize on the economic benefits that rail transportation can offer a local economy. The challenges and opportunities that accompany industrial rail development in rural agricultural areas are common; successfully navigating them requires a combination of rigorous site viability analysis and comprehensive stakeholder outreach. Aggregating case studies like Grand Forks – East Grand Forks could lead to greater
MAP-21, the Moving Ahead for Progress in the 21st Century Act was signed into law by President Obama on July 6th, 2012, which directed the USDOT to establish performance measures for the transportation system. Targets for identified performance measures are to be included in the regional long range transportation plan (the Metropolitan Council’s Transportation Policy Plan, or TPP) and the Transportation Improvement Program (TIP), pending guidance from the USDOT in 2015. In the absence of federal guidance, Metropolitan Council staff has worked to create a performance-based plan built on a structure of Goals, Objectives, and Strategies.

With a TPP draft to be released on May 9, 2014, the presentation will offer a brief summary of minor policy changes in the 2040 TPP but will focus primarily on the process involved in taking existing policies and transforming them into the new format required by MAP-21.
Twin Cities Regional Bicycle System Master Study

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Study Objective:
The Twin Cities Regional Bicycle System Master Study has resulted in a recommended, first-ever, Regional Bicycle Transportation Network including proposed Priority Bicycle Corridors. The regional study effort, led by the Metropolitan Council in partnership with MnDOT and with technical planning assistance from the Toole Design Group, was conducted throughout 2013. The primary goal for the study was to improve the knowledge base of the regional bicycle transportation system to inform the regional bicycle planning process for developing the 2040 update to the Transportation Policy Plan (TPP), the region’s federally-required long range plan. Specific objectives for the study included learning how on-street bikeways and off-road trails interact and how the on and off-road systems serve regional transportation trips.

Approach/Methodology:
The study team used a series of focus groups and public workshops, as well as agency stakeholder engagement, to develop a set of guiding principles for defining the role of the regional bicycle transportation network in serving regional destinations. An analysis framework and methodology were developed using existing and mapped data in GIS to develop and evaluate a network of regional bicycle transportation corridors. The data used included regional socio-economic data for job clusters, areas of racial and economic disparity, and population density. These data were supplemented by layers capturing regionally-significant destinations such as major entertainment centers, colleges and universities, transit stations, and high-visitation state and regional parks. In addition to the existing data sets, the study team also applied user-generated input from interactive online maps and the online bicycle routing tool, Cyclopath (www.cyclopath.org), adding a wealth of actual user data to the analysis.

The scoring of potential network corridors comprised of GIS analyses of ten key scoring criteria that were compiled to obtain a cumulative score for regional bicycle demand along each corridor. The results were then examined through a land use context based on Met Council planning area designations to identify potential priority bicycle corridors. Graduated spacing guidelines were also developed for establishing a network density from the urban core to the suburban and rural areas of the seven-county metropolitan region.

Study Findings/Applications:
The outcome of this study is a set of recommendations for establishing a Regional Bicycle Transportation Network that includes a subset of proposed Priority Regional Bicycle Transportation Corridors. The
study also recommends network spacing guidelines and a framework for developing performance measures to better link facility investments to specific regional goals and objectives.

In addition, a new concept for identifying critical bicycle transportation links was developed to help local governments in defining bike infrastructure projects that would be most essential to the regional system by addressing significant regional barriers to biking. Many of the lessons learned during the study process and the analysis tools that were developed and applied have potential to guide other metropolitan planning organizations in developing regional bicycle networks and priority bicycle corridors.

Policy Implications:
The results of the Regional Bicycle System Study will be used to develop the bicycle component for the region’s 2040 TPP update. The most significant products include a proposed Regional Bicycle Transportation Network map that includes a subset of Priority Regional Bicycle Transportation Corridors; these corridors will be proposed in the TPP as the region’s priorities for investment. These new system maps and the set of guiding principles that were used in their development may inform future regional solicitation processes conducted by the Transportation Advisory Board in allocating federal transportation funds to regional bicycle infrastructure projects.
The Metropolitan Council’s 2030 Transportation Policy Plan (TPP) states that mobility in the Twin Cities metropolitan region is fundamental to its economic vitality and quality of life. However, as the region grows and prospers the expected growth in population and employment will put greater and greater pressure on an already taxed transportation system. The TPP acknowledges that it is unrealistic, both in terms of funding and logistics, to expect to “fix” current and future traffic congestion by building additional highway capacity. Instead, the plan emphasizes the need to invest in strategies that provide increased regional mobility by optimizing and enhancing existing transportation infrastructure.

The TPP recommends a multi-modal transitway system for the Twin Cities that includes commuter rail, light rail transit (LRT), dedicated busways, bus rapid transit (BRT) on both arterial streets and highways, and express bus corridors with transit advantages. Prior to adopting the 2030 TPP, the Metropolitan Council completed the Transit Master Study to determine the feasibility of transitway investments along a long list of corridors in the region. At the time, only LRT and dedicated busway were analyzed for these corridors. Many of the corridors are principal arterial highway corridors and could also be considered for a type of BRT that uses either the highway shoulder or a managed lane, rather than an exclusive right-of-way as is the case with LRT and dedicated busway.

Highway BRT is well suited to meet the needs expressed in the TPP. First, highway BRT is designed to operate on existing highways. Second, the purpose of highway BRT is to provide fast, frequent, all-day service that is cost-effective in serving high-demand regional population, employment, and transit nodes in highway corridors. The high level of service offered by highway BRT is designed to make transit a convenient, attractive option for regional residents.

The Metropolitan Council initiated the Highway Transitway Corridor Study (HTCS) to examine eight corridors. This presentation will explain the concepts developed during the HTCS and will focus on the results of the study. The eight corridors being studied include:

- TH 36
- I-35E North
- I-35E South
- I-94
- TH 65
- TH 169
- TH 212
- I-394
Estimating the Crash Reduction and Vehicles Dynamics Effects of Flashing LED Stop Signs

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A flashing LED stop sign is essentially a normal octagonal stop sign with light emitted diodes (LED) on the stop sign’s corners. Researchers associated with the Minnesota Traffic Observatory at the University of Minnesota conducted a two-pronged investigation of the safety-related effects of flashing LED stop signs: a statistical study to estimate the crash reduction effect following installation of flashing LED stop signs, and a field study looking at changes in the behavior of drivers approaching a stop-controlled intersection, before and after installation of a flashing LED stop sign.

The statistical study focused on the effect of installing flashing LED stop signs at through-stop controlled intersections with undivided major roads. The target crash type was right-angle crashes involving major approach and minor approach vehicles. The study design was an observational before/after study, where a reference group of untreated intersections was used to develop a statistical model for predicting the crash experience without the flashing LED stop signs. A treatment group of intersections, where the flashing LED stop signs have been installed was also identified, and the after installation crash experience was compared to the predicted crash experience in order to estimate the crash reduction effect. The estimated reduction was about 41.5%, but with 95% confidence this reduction could be anywhere between 0% and 70.8%. The conclusion was that installation of the flashing LED stop signs reduced the frequency of angle crashes, but that the magnitude of this reduction is uncertain.

For the field study, an intersection of a two-lane state highway and a two-lane county highway in Chisago County was selected, with standard stop signs on the county highway. During two, three-day periods in June and July 2012, portable video equipment was used to record vehicle approaches at this intersection, and then the standard stop signs were replace with flashing LED stop signs. Video data were then collected for two, three-day period in September and November, 2012. Visual inspection of the video was then done to classify each approach vehicle as “clearly stopped” if it appeared to achieve zero-speed before continuing into the intersection, “clearly not stopped” if it appeared to have non-zero speed throughout its maneuver, and “unclear” if it was not possible to decide between “clear stop” and “clear non-stop.” Arguably the most interesting result from this analysis was that, after installing the flashing stop sign, there was no change in the relative proportion of clear stops to clear non-stop when minor
approach drivers did not face opposing traffic, but that after installation of the flashing LED stop sign the relative proportion of clear stops increased for drivers who did encounter opposing traffic.

In addition, for each of the four field data collection periods, a random sample of 30 minor approach vehicles was selected. Speeds for these vehicles when about 500 feet from the intersection, and average deceleration rates over the final 500 feet were then estimated using trajectory-based methods. Average approach speeds tended to be highest in June, and successively declined in each subsequent period. The average deceleration rates showed a similar pattern.
Generating Time Space Diagram Using Event-Based Traffic Data

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Time Space diagram ((TS)-Diagram) is a popular visualization tool for the evaluation of progression quality along a signalized arterial, and has been used widely in traffic signal operations. Currently, TS-Diagrams can be generated by several popular commercial software packages for the signal retiming using traffic data collected manually, but cannot help for adjustments over time. Using high resolution event-based traffic data, this study proposed an alternative and practical procedure to construct the TS-Diagram. The generated TS-Diagram can be used as a convenient performance evaluation tool to help fine-tuning the traffic signal system in a timely manner. Field examples are demonstrated, with reasonable agreements found for validations using detector data and field rides trajectories. An experiment is carried out to illustrate potential application of the generated TS-Diagram. Recommendations and limitations are discussed.
Update on the Chicago Region’s Interoperable Transit Signal Priority Program

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Transit signal priority (TSP) is being deployed at numerous locations across the country and providing significant benefits to transit operations and the public by reducing transit delay and improving schedule adherence. Deployments to date have been performed by selected transit agencies and generally have targeted specific bus route corridors operated by that agency. Unless a region has consistent TSP equipment and traffic signal controllers, TSP operational challenges will exist when you start expanding TSP deployments on routes that cross jurisdictional boundaries or where corridors include bus operations from multiple transit agencies. To date, no region in the U.S. has developed a completely interoperable TSP system that can communicate with appropriate traffic signals, independent of the type of TSP system on buses.

Recognizing this challenge, the Regional Transportation Authority is undertaking a regional TSP implementation program within the Chicago region. An overview of the project was presented at the May 2013 CTS Research Conference and much has been accomplished since. The project working group has now agreed upon regional standards and guidelines for an interoperable TSP system and work is underway on 8 corridors. Regional standards address bus to intersection communications, common TSP message sets, testing requirements, expected performance measures, etc. Chicago area bus service is provided by the Chicago Transit Authority and Pace Suburban Bus who operate bus routes on Illinois DOT, City of Chicago, and other suburban city routes. In metropolitan areas, regional TSP interoperability is greatly needed to maximize transit operational efficiencies, allow for TSP expansion and enhance ridership attractiveness. RTA is being supported by a team of consultants led by URS Corporation in development of this interoperable system and is pushing the technology envelope with this program. RTA hopes that Chicago’s regional TSP program can serve as a model for all future TSP deployment in the world.
Lessons Learned During Geotechnical Research Deployment: How Organizations Encourage Implementation

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The presentation will summarize lessons learned during research deployment as described at one of this year’s TRB sessions. The following organizations shared their experiences as they encourage implementation and address the following challenge. Many existing organizations in the transportation sector are not capable of implementing innovation with the urgency required in today’s world. Fact-based asset management and risk analyses should be combined with the big ideas courageously offered by employees to foster creativity, innovation, and the implementation of new technology. State DOTs were created to build the interstates, are organized to design and build new roads, and are well-suited to apply existing standards. Many of these organizations are not well-suited to adapt to a changing world, preserve assets, or implement new ideas. This session will share lessons learned by public agencies during geotechnical research deployment and how these organizations influence implementation by establishing a culture of innovation. Key lessons learned from the following TRB presentations will be summarized.

“Innovation at the Crossroads: Exploring the Intersection of Innovation Adoption and Specification Reform in Public Highway Construction”
Shawn Kimmel, Colorado School of Mines

“Establishing a Culture of Innovation in a State DOT: The Significance of Champions”
Clint Adler, Alaska Department of Transportation and Public Facilities

“Implementing the Dynamic Cone Penetrometer and Light Weight Deflectometer in Indiana”
Nayyar Zia Siddiki, Indiana Department of Transportation

“Understanding Your Deployment Strategy from Research Initiation to Project Delivery”
Mark Morvant, Louisiana Department of Transportation and Development
Performance-Based Measurement of Optimum Moisture for Soil Compaction

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Optimal compaction of subgrade materials is required during road foundation construction to maximize the longevity of the road and to minimize required pavement thickness. Unfortunately, due to variation in soils used for subgrade materials and the challenges involved in quantifying the characteristics of these soils, the quality of the subgrade compaction is sometimes less than optimal. Part of the challenge is transferring the optimal compaction and moisture content data from laboratory testing to the field. This research investigated the proficiency of four different instruments at accurately predicting moisture contents of three subgrade soils (loam, silt, silty/clay) commonly used in Minnesota roadway construction projects. The four instruments were; DOT600 (moisture content), WP4C dewpoint potentiometer (matric suction), the Button Heat Pulse Sensor (BHPS) (temperature rise vs. moisture content, and an exudation pressure test device. The DOT600 showed a strong correlation between the output period (measured in micro-seconds) and volumetric water content. The WP4C did not accurately measure matric suction for any of the loam, silt or silt/clay soils at suctions below 250 kPa. Published data shows that the matric suction of soils compacted at optimum moisture content is usually in the range of 200 – 300 kPa. The BHPS showed a strong correlation between measured temperature rise and water content but in its current configuration is not rigorous enough to withstand field conditions. The exudation pressure device was applied to soils compacted in a AASHTO T99 mold at various moisture contents. Water was exuded from the packed cores at the Minnesota-standard pressure of 1.65 MPa (240 psi) near the optimum moisture content. Accurate moisture content readings from any of these instruments may not be as useful as a more precise and simple calibration between the measurement units of the instrument and the optimum moisture content determined from the AASHTO T99 test.
Manufacturers’ Perspectives on Minnesota’s Transportation System: A Pilot Study in Southwestern Minnesota

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MnDOT engaged a key customer segment, manufacturers and carriers in southwest/west-central Minnesota, to understand their needs, challenges, and priorities regarding the transportation system, so that we can better align our work to support their success and the economic vitality of the region and state. Cross-discipline teams from across MnDOT, local economic development organizations, and transportation/economic researchers from the University’s SLPP and Extension Service, interviewed 75 manufacturers and carriers – from CEOs to dispatchers – face-to-face, at their worksites. This process is facilitating on-going communication and partnerships among MnDOT and its customers and stakeholders.

Manufacturers’ concrete, actionable feedback is informing MnDOT improvements to the infrastructure, maintenance, operations, communications, and policy. The scope was focused on low-cost/high-benefit opportunities that can be implemented in one-to-four years. Some of these changes have already been accomplished, are underway, or are in review for upcoming snow and ice and construction seasons. And the process is replicable across Minnesota, which can result in cost-savings for MnDOT and support businesses and economic vitality, statewide.
Mutual Causation in Highway Construction and Economic Development

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This paper investigates the relationship between the growth of road networks and regional development. We test for mutual causality between the growth of road networks (which are divided functionally into local roads and highways) and changes in county-level population and employment. We employ a panel data set containing observations of road mileage by type for all Minnesota counties over the period 1988 to 2007 to fit a model describing changes in road networks, population and employment. Results indicate that causality runs in both directions between population and local road networks, while no evidence of causality in either direction is found for networks and local employment. We interpret the findings as evidence of a weakening influence of road networks (and transportation more generally) on location, and suggest methods for refining the empirical approach described herein.
Monitoring Bicycle and Pedestrian Traffic in Minnesota: A Status Report

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The Minnesota Department of Transportation (MnDOT) is supporting research to evaluate commercially available technologies for monitoring bicycle and pedestrian traffic and to develop standard procedures for estimating non-motorized traffic volumes. This paper will summarize the status of current research. Technologies being assessed include in-street inductive loop counters for counting bicycles; pneumatic tube counters for counting bicycles on streets or trails; combination infrared-inductive loop counters for counting bicycles and pedestrians on shared-use paths; and radio beam counters for counting bicyclists and pedestrians on shared-use paths. Counters are being deployed in collaboration with local agencies in Hennepin County, Minneapolis, Duluth, and Rochester, Minnesota. Results include preliminary assessments of counter accuracy based on comparison with counts from analyses of video tapes. Results also illustrate hourly and daily variation in traffic bicycle and pedestrian volumes. Limitations of technologies are described, and practical challenges in developing comprehensive bicycle and pedestrian traffic monitoring programs are summarized.
Methods for Measuring Regional Trail Traffic: A Case Study of the Three Rivers Park District

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Regional and local recreation and transportation agencies need measures of trail use for planning, managing, and funding regional and local trail systems. In Minnesota, the Metropolitan Council annually collaborates with local park districts to complete counts of users entering trails. These counts are used to produce estimates of trail use. New technologies are becoming available for monitoring trail traffic. Although these technologies do not provide estimates of user-visits, a standard measure used in recreation planning, they do provide traffic counts and measures of hourly, daily, monthly, and annual traffic. Because the technologies provide continuous measures of trail traffic rather than short duration (e.g., two-hour) samples, they provide greater insight into temporal patterns of trail use. The Three Rivers Park district now uses passive infrared counters to monitor trail traffic on its regional trails. This case study summarizes mixed mode (undifferentiated bicycle and pedestrian) trail traffic from several continuous infrared monitors on regional trails operated by the Three Rivers Park District. The paper demonstrates how estimates of trail miles traveled on the entire regional trail network operated by the District can be estimated using a combination of continuous and short-duration monitors. The costs of automated trail traffic monitoring are compared with the costs of field sampling to estimated user visits. The paper concludes with a comparison of tradeoffs of the two methods used to provide information about trail use.
Day-of-Year Scaling Factors and Design Considerations for Non-motorized Traffic Monitoring Programs

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Background: General procedures for non-motorized traffic monitoring programs, including estimation of annual average daily traffic (AADT) from short-duration counts, have not been established.

Methods: Continuous counts of non-motorized traffic were collected from 2011 at 6 locations on the off-street trail network in Minneapolis, MN. We demonstrate a new approach – use of day-of-year factors – for estimating AADT from short-duration counts and illustrate how analyses of variability in monitoring data can be used to design a sampling program for short-duration counts of non-motorized traffic. We also present preliminary results from a traffic monitoring campaign at 80 sites on the off-street trail network.

Results: We have 5 core results that may be useful for developing non-motorized monitoring programs:

1. Day-of-year scaling factors have smaller error than the standard method (day-of-week and month-of-year) in estimating AADT, especially from shorter duration (<1 week) counts.
2. Extrapolation error decreases with the length of the short-duration counts, with only marginal gains in accuracy with counts longer than one week.
3. Error in estimating AADT is lowest when short-duration counts are taken in summer (or spring-summer-fall) months (April-October).
4. The impact of sampling on consecutive (e.g., 5 successive days) vs. non-consecutive days (e.g., 5 separate days in different seasons) on AADT estimation is minimal but reduces labor requirements and is more efficient.
5. We demonstrate in a design scenario how continuous counts at a limited number of sites can be used to develop a more robust traffic monitoring program.
**Policy implications:** Analysts can use day-of-year factors to increase accuracy of estimates of AADT. Analyses of variability in traffic can strengthen the design of traffic monitoring programs. We demonstrate how traffic volumes on a non-motorized transportation network can be characterized by tailoring traffic monitoring concepts used for motor vehicles.
This presentation examines the effects of deliberative dialogues in shaping policy preferences and options to address a complex public problem: sustaining local road systems in rural Minnesota. The nexus of aging road infrastructure in rural areas, rapidly accelerating costs for road repair materials, and declining revenues to support road maintenance and construction is forcing many local governments to make tough choices about which parts of road systems to sustain and which to allow to deteriorate. To test the effects of deliberation on those policy choices, this study recruited 45 diverse stakeholders in a single county to participate in a series of deliberative dialogues on the topic. This was not merely a research exercise: policy makers participated in the dialogues and are now making policy informed by it’s the dialogues. This research is an empirical contribution on the influence of deliberative processes on public service preferences and options. Prior research makes numerous claims regarding the beneficial contributions of deliberative processes to participants’ individual and collective learning and to the quality of policy outcomes. Deliberation permitting participants to become better informed about the policy issues (Jacobs et al. 2009), to empathize with others’ perspectives (Young 2000, Polletta and Lee 2006), to develop an “enlarged view” of the public nature of the policy problem (Reich 1998, Abers 2000), and to discover new policy options (Innes and Booher 2010). However, scholars and practitioners lack measures and data for evaluating whether and how deliberation does in fact have these impacts (Bryson et al. 2013), a gap this work seeks to address.

The analysis is based upon qualitative data gathered from October 2012 to December 2013 through interviews, focus groups, and pre- and post- surveys of participants’ attitudes regarding this complex policy issue. Focus groups were held with each type of stakeholder, followed by an extended policy roundtable for all stakeholders. All meetings involved informational presentations, Q&A with policy-makers, and guided deliberative dialogue on the most controversial policy options (e.g., let roads deteriorate, create a dedicated local sales tax for roads). Participants also completed individual surveys regarding their policy priorities and preferences before participating in any dialogues and at the end of the process. They are now being interviewed to elicit their explanations of observed changes in their concerns and policy preferences. A small group who only took the survey are also being interviewed.

The following preliminary findings will be presented:

- Deliberation participants reframed the issues away from blaming the county government for poor road management to regarding local road systems as a public problem they need to help solve.
- Deliberative dialogues swayed the county engineer to revise his measures for setting priorities to be more attentive to remote areas, where county roads are less traveled but more vital to local residents.
- There was a strong and remarkable shift in attitudes about creating a local sales tax for roads. This occurred at a collective level over the course of each deliberative dialogue and in the aggregate of individual opinions gathered through pre- and post- surveys.
Investigation of the Impact of a Variable Speed Limit System on Safety and Shockwave Generation Along I-94

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The I-94/I-35W commons area in Minneapolis, Minnesota contains the highest crash area in the state with frequent crash-prone conditions generated during recurring congestion. The High Crash Area experiences significant shockwave activity throughout the afternoon peak period, between 2 and 7 PM. A Variable Speed Limit (VSL) system was installed along the corridor to slow upstream traffic approaching queued vehicles at the bottleneck. This study includes a before-after analysis focusing on the safety impacts of this active traffic management system. Crash and near-crash events were observed between midday and after the end of the afternoon peak period to directly examine the effect of the VSL system on safety. These events were used in conjunction with Minnesota State Patrol records to examine the effect of the VSL system on monthly incident rates (normalized to observed volumes). Using the same crash and near-crash event records, loop detector data was used to estimate the speed on the incident lane v. the adjacent lane. No significant change in the crash rate or the relative speeds was observed during the study.

Using shockwave activity as a safety surrogate, the first three afternoon shockwaves of each day were observed to study the onset of congestion. The time of breakdown and delay between successive shockwaves were analyzed for these events. Further, data from machine vision sensors were used to estimate the shockwave characteristics. These investigations revealed no significant impact on shockwave activity or on the particular characteristics of the shockwaves within the corridor.
Using Naturalistic Driving Data to Characterize Driver Behavior in Freeway Shockwaves

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Recent years have witnessed significant efforts at developing and evaluating vehicle-based passive and active safety systems to reduce traffic accidents. In addition, there is a growing interest in using microscopic simulation models to evaluate operational strategies. Both these activities require quantitative characterization of driver behavior in real world situations. Historically such characterizations have been difficult to obtain, but the data available from large-scale naturalistic driving studies (NDS) have the potential to change this situation. However, identifying relevant events from within an NDS database and then reducing the NDS data so as to estimate relevant features of the events are still something of a challenge. Using freeway brake-to-stop events on congested freeways as examples, this study describes methods for identifying relevant events and then estimating event features, such as initial speeds for leading and following vehicles, reaction times for leading and following drivers, and changes in the drivers’ braking rates. A suitably representative sample of such estimates could then be used to support evaluation of vehicle-based safety countermeasures, or provide inputs to traffic simulation models.
An Examination of Safety and Mobility at Open v. Closed Access High Occupancy Toll Lane Facilities in Minnesota

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With most major freeway networks experiencing significant recurring congestion, transportation management agencies have implemented High Occupancy Toll (HOT) lanes to both encourage carpooling and offer a more reliable travel time option for HOV vehicles and tolled SOV vehicles. These HOT lanes are managed to maintain a high level of service regardless of the conditions on the general purpose lanes. However, two different paradigms for these HOT lanes have been developed: open access facilities which allow vehicles to enter and exit the managed lane freely, and closed access facilities which only allow lane changes to occur within predefined 'gate' regions. Both designs are present within the Minneapolis-Saint Paul freeway network, offering an ideal opportunity to examine the advantages of each design. In particular, the safety and mobility of each design was analyzed using shockwaves as a surrogate measure. Major lane-change areas were identified for each corridor: the gates for the closed access design facility I-394 and locations near major interchanges for the open access design facility I-35W. Shockwaves caused by vehicles moving into or out of the managed lane were measured. The location along I-394 which experienced congestion was compared against several locations of frequent lane changing on I-35W, showing no significant overall difference in shockwave activity. The majority of both facilities did not exhibit shockwave-producing lane changes.

Related to this analysis, two methodologies were developed to assist practitioners to design open and closed access facilities. One methodology uses the shockwave data described above to model the likelihood of shockwave activity throughout a corridor and find locations where significant lane changing may lead to a safety concern. These identified areas can then be closed to prevent lane changing activity and improve safety.

The other methodology the lane changing behavior of vehicles to estimate the needed size and location of a gate within a closed access facility to adequately serve vehicles entering or exiting the HOT lane. This is based on vehicle trajectory data collected along the I-35W corridor describing gap selection and lane changing behavior in conjunction with traffic flow parameters describing the general purpose lane conditions. The model relies upon a Monte Carlo sampling framework to determine the Optimal Lane Changing Regions (OLCR) for either an existing or simulated facility.
Concrete pavement rehabilitation strategies can be based on a wide range of factors ranging from political corridor-wide initiatives to actual pavement condition with respect to trigger values. In the plethora of historical records examined it was impracticable to ascertain retrospectively and definitely, the factors that may have triggered all the maintenance activities. However, most of them were based on pavement condition. For a condition-based set of rehabilitation characteristics it is hypothesized that certain attributes of the infrastructure can be deduced. The Weibull distribution being advantageous in its capacity for representation of a wide range of failure or distress-appearance distributions was chosen. Using a large data set of records of maintenance and rehabilitation activities, the threshold time to repairs, the shape factor and the characteristic life of the concrete pavements were determined. The shape-factor obtained showed that the distress characteristics were mainly random and are consequently described by a uniform rate of distress formation. There was also evidence of wear-out distress modes but burn-in characteristics were not represented by the Weibull distributions obtained. The threshold time to failure reduced significantly in the distribution of 4th rehabilitation.

Based on the Weibull characteristics, a tenable set of rehabilitation intervals were proposed conservatively for the current 60-year design.
Living near traffic has been shown in many studies to affect a number of health outcomes adversely. This relationship between traffic and health has been explored using several different approaches. We developed a new metric using traffic count data on all roads in Minnesota and a kernel density calculation to generate a raster of traffic density with 50 meter spatial resolution. In addition, we used the MPCA MNRiskS model to estimate inhalation cancer and non-cancer risks from all inventoried air pollutants from all sources and from on-road mobile sources. These metrics of traffic exposure were compiled by census block groups so that they could be compared with census socio-economic and demographic data. The results show that the air pollution and traffic variables are highly correlated with one another. These environmental variables were all significantly positively correlated with poverty, the fraction nonwhite population, and the fraction black population. They were significantly negatively correlated with home ownership, median home value, the fraction Native American population, the fraction under age 10, the fraction over age 65, and the number of vehicles per household. These relationships can be interpreted as indicating that those on the lower end of the socio-economic scale and some minorities appear to be disproportionately exposed to traffic and to bear disproportionately high health risks as a result.
Evaluation of the Next Generation Hybrid Transit Bus

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Reducing transit bus capital and maintenance costs, exhaust emissions, and noise combined with improving fuel efficiency will improve the competitiveness of bus transit by reducing the cost per passenger mile, improving service and encouraging increased ridership. The goal of this project is to establish the foundation for transformational improvements in bus technology providing the basis for the future selection and use of transit buses. We are determining the appropriate degree of bus hybridization for buses operated in northern climates by quantifying fuel-economy improvements and emissions reductions associated with enhanced bus electrification. In partnership with Metro Transit, BAE Systems, New Flyer, AVL, ThermoKing, Cummins the Center for Transportation Studies and DOE’s National Renewable Energy Laboratory (NREL) we are developing models to evaluate the performance and economics of these technological improvements.

Under urban driving conditions, the power required by the accessories on a transit bus often exceeds the power required for propulsion. Principal accessories include the air conditioning, lights, heating, engine cooling fans, air compressor, power steering pump, and alternator. These accessories are driven in a variety of ways, such as mechanical, hydraulic, or partial or full electrical drive; often inefficiently. These accessories together comprise the “hotel load”. Electrification of accessories may lead to significant energy savings, but confirmation of this is best determined by a real-world, in-use energy audit for a fleet operated in a specific area where the impact of climate, route and other factors can be ascertained. In some cases benefits are derived at lower cost by partial electrification.

Our project directly effects vehicle efficiency measured as fuel consumption. The buses in the Metro Transit fleet consume about 7.2 x 106 gal of diesel fuel per year, and a new standard diesel bus achieves about 4.2 mi/gal. If diesel fuel costs $4.00/gal, then a 10% reduction in fuel consumption realized from modifying the engine fan from a mechanically driven to an electrically driven accessory represents a savings of nearly 2.9 million dollars per year. Thus, by increasing the fuel economy from 4.2 to 4.67 mi/gal Metro Transit can save nearly 2.9 million dollars per year plus CO2 emissions are reduced by approximately 1.6x107 lbs/year. By comparison, a new hybrid bus is expected to achieve somewhere between 5.3 and 6.0 mi/gal. If a fuel economy of 5.5 mi/gal is assumed then the improvement in fuel economy over a standard diesel bus is about 30%, which represents 6.8 million dollars per year in fuel savings if the entire Metro fleet is hybridized, plus there is a corresponding decrease in CO2 emissions.
The Impact of Hiawatha LRT, Neighborhood Design, and Self-Selection on Auto Use

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Many studies have investigated the impact of rail transit and associated development on transit use. However, few have focused on driving. This study explores the effect of Hiawatha LRT on vehicle miles driven. Negative binomial models show Hiawatha residents drive shorter distance than those in urban and suburban control corridors, after neighborhood characteristics are controlled for. Once attitudes are included in the model, the differences become insignificant. Further, self-selection is more important in influencing driving than the built environment. Overall, the LRT affects auto use because it induces new development and enables those valuing transit to better match their attitudes.
Southwest Light Rail Transit

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Craig Lamthe, Ryan Kronzer, Kathryn Hansen
Metro Transit

The Southwest Light Rail Transit (SWLRT) Project (Green Line Extension) will operate from downtown Minneapolis through the southwestern suburban cities of St. Louis Park, Hopkins, Minnetonka, and Eden Prairie, passing in close proximity to the city of Edina. The proposed alignment is primarily at-grade and includes 17 new stations and approximately 15.8-miles of double track. The line will connect major activity centers in the region including downtown Minneapolis, the Opus/Golden Triangle employment area in Minnetonka and Eden Prairie, Methodist Hospital in St. Louis Park, the Eden Prairie Center Mall, and the Minneapolis Chain of Lakes. Ridership in 2030 is projected at nearly 30,000 weekday passengers. SWLRT will interline with Central Corridor LRT (Green Line) which will provide a one-seat ride to destinations such as the University of Minnesota, state Capitol and downtown St. Paul. SWLRT will be part of an integrated system of transitways, including connections to the METRO Blue Line, the Northstar Commuter Rail line, a variety of major bus routes along the alignment, and proposed future transitway and rail lines.

To make SWLRT a reality with revenue operations in 2018, the SWLRT Project Office (SPO) is heavily engaged in a variety of areas of project development. The SPO is proposing a one topic session focused on these varied aspects with presentations from content experts. The following slate of speakers is proposed for the 25th Annual Transportation Research Conference:

- **SWLRT Project Update: Craig Lamthe, AICP, Deputy Project Director – Southwest LRT Project Office.**
  Craig Lamthe will kick off the panel by providing an update on current project scope; schedule and budget/funding; a short overview of the Federal New Starts and environmental processes; and provide a preview of the delivery options to moving the project forward.

- **Technical Issue Resolution during Project Development (formerly Preliminary Engineering): Ryan Kronzer, Design Manager – Southwest LRT Project Office**
  Ryan Kronzer will discuss how the project identified and addressed design issues of the largest Public Work’s project for the State of Minnesota. Ryan will discuss the role and purpose of Issue Resolution Teams (IRTs) and the Technical Project Advisory Committee (TPAC). Ryan will also discuss the local Municipal Consent Process and the new model of integrating the Hennepin County’s Community Works Program’s Transitional Station Area Action Plans (TSAAP) with design.
• **Joint Development / Transit Oriented Development: Kathryn Hansen, TOD & Land Use Manager – Southwest LRT Project Office**
  Kathryn Hansen will discuss recent Metropolitan Council actions to integrate Transit Oriented Development/Joint Development with transitway project development. Kathryn will highlight development opportunities along the SWLRT corridor linking jobs, housing and recreation.

• **Public Involvement for a Mega Project: Sam O’Connell, AICP, Public Involvement Manager – Southwest LRT Project Office**
  Sam O’Connell will discuss the methods of decision-making and public engagement with a five community, 15 mile and 17 station project. Sam will highlight the various methods employed to engage the public; the feedback received; and how public input was used to create a better transitway.
Conflicts of Scramble of Pedestrians in a Roundabout

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This paper studies the performance of single-lane roundabouts with installation of a scramble, a four-decade-old crossing system, to allow heavy volumes of pedestrians to cross. VISSIM microsimulation assessment considers experimental origin-destination (O-D) balanced flow scenarios (total traffic flow into and out of every roundabout approach is the same) with three different pedestrians volumes (low, medium, and high) and with and without scramble. Simulated experiment results indicate that average delay of a roundabout is sensitive to changing pedestrian’s volumes and scramble behavior, before oversaturation occurs. As expected, results indicate scramble affect the rate of pedestrian-vehicle conflicts and roundabout average delays. This study suggests that incorporating scramble pedestrians crosswalks will improve the safety by reducing the conflicts between pedestrian-vehicle, and improve the operation for a roundabout.
Pedestrian crossings are an important feature of the multi-modal transportation system. They enable pedestrians and bicyclists to cross conflicting traffic to access locations on either side of streets and highways.

According to 2013 Minnesota State Statutes, “where traffic-control signals are not in place or in operation, the driver of a vehicle shall stop to yield the right-of-way to a pedestrian crossing the roadway within a marked crosswalk or at an intersection with no marked crosswalk.” Additionally, “Every pedestrian crossing a roadway at any point other than within a marked crosswalk or at an intersection with no marked crosswalk shall yield the right-of-way to all vehicles upon the roadway.”

While the state statute says that a motorist shall stop for a pedestrian that is within a marked crosswalk or crossing at an intersection, the opportunities in which a motorist actually stops for a pedestrian and yields the right-of-way may be few. Additionally, when the traffic volumes are high enough that there are few gaps in traffic adequate for a pedestrian to cross a roadway safely, pedestrians may have a difficult time crossing. Consequently, either case can result in pedestrian crossings that are challenging and result in high delay for the pedestrian, which can lead to pedestrians taking higher risks.

Pedestrian crossing treatments that either reduce the crossing distance or increase driver yield rates have been shown to reduce the potential delay experienced by a pedestrian. While state statutes support the rights of pedestrians at all marked crosswalks and at all intersections, it is of small comfort when a crash between a vehicle and a pedestrian occurs due to a motorist not stopping and yielding the right-of-way to a pedestrian.

Providing safe crossing situations for pedestrians relies on placing crosswalks and other pedestrian crossing treatments at appropriate locations in a way that also allows for pedestrian crossings that result in minimal delay. The Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD) states that crosswalk pavement markings should not be placed indiscriminately and an engineering study should be completed when crosswalk markings are being contemplated at a crossing.

Defining where to place pedestrian crossing facilities including markings, signs, and/or other devices depends on many factors including pedestrian volume, vehicular traffic volume, sight lines, and speed. Additionally, there are locations in which pedestrians would like to cross the roadway, but the traffic volume is so high that there are no adequate gaps in the traffic stream to safely cross. This results in a high delay crossing which then results in a high risk-taking environment, decreasing safety.

A methodology for evaluation of uncontrolled pedestrian crossing locations will be presented. The methodology will take into account both safety and operations. The operational element will present the yielding rates for different treatments and their impact on the pedestrian delay and level of service. Real-
world examples and research results into crossing speeds and yielding rates of additional treatment options will also be presented.

It is anticipated that this research and methodology will be applied by traffic and transportation engineering professionals to provide a standardized procedure in the evaluation and application of potential marked crosswalk locations and treatments.
Newly licensed teen drivers are overrepresented in vehicle crashes and fatalities because they are more likely to engage in risky driving behaviors. A review of crash factors related to teen drivers indicates that speeding, seat belt use, alcohol, and teen passengers are the main risk factors for teen fatalities (Brovold et al., 2007; Simons-Morton et al., 2005). To reduce these significant risks, researchers are working to develop technology-based solutions that help improve safety for teen drivers. This involves installing an in-vehicle system in a teen’s car to provide feedback to the teen driver as well as to parents (Creaser et al., 2011; Farmer et al., 2010; Manser et al., 2013, McGehee et al., 2007). The main goal of teen driver support systems is to provide behavioral modification functions that work in combination with Graduated Driver Licensing program restrictions to assist teens in adopting safer driving behaviors. Using a smartphone mounted on the vehicle’s dashboard, the University of Minnesota’s Teen Driver Support System (TDSS) provides vital safety information to the teen driver, including information about speeding, stop sign violations, upcoming curves, and excessive maneuvers (e.g., hard braking, cornering; Creaser et al., 2011) The TDSS also captures important data such as occupant seat belt status, number of passengers, time of driving, and mileage driven. In addition, the TDSS capitalizes on the important role of parents by immediately sending them reports of risky driving behavior via SMS text messaging. The TDSS also disables other phone functions while teens are driving; all incoming calls are routed to voicemail and outgoing texts and calls are restricted (except 911 emergency calls). Teen driver performance can be reviewed by a parent on a TDSS website that stores driving behavior data, enabling parents to assess driving patterns, reinforce safe behaviors, and address risky behaviors. The website also provides parents with information on teen driving laws and tips for more effectively discussing traffic safety with their teen driver. The University of Minnesota launched a 300-vehicle, 12-month field operational test (FOT) in January 2013 to determine the effectiveness of both the system’s in-vehicle coaching feedback and its parental feedback. The FOT has included the collection of data from a control group engaged in naturalistic driving and two intervention groups: an in-vehicle only coaching group (partial TDSS functionality) and an in-vehicle coaching group with additional parental feedback (full TDSS functionality). Comparisons between the three groups allow researchers to determine if differences in behavior are due to TDSS feedback or to the normal maturation that occurs among teen drivers in the first year of driving. Preliminary results indicate that teens in both intervention groups are showing decreased risky behaviors in comparison to the control group for the first few months of driving (e.g., fewer
speeding incidents). However, teens in the naturalistic control group are still demonstrating the expected risky behaviors associated with distraction, such as making cell phone calls or sending text messages while driving. This presentation will cover preliminary results regarding the effectiveness of the Teen Driver Support System.
Stormwater management is an important issue in the construction of highways and in mitigating the impacts of transportation infrastructure on the water resources. Impervious areas in general are of environmental concern because they are the most important sources of pollutants in urban areas. The degradation of urban waters is primarily caused or facilitated by urban runoff, the majority of which has its origin in roads, rooftops, and parking lots. Practitioners responsible for the design and implementation of stormwater management practices rely heavily on estimates of impervious area in a watershed. However, the most important parameter in determining actual urban runoff is the “effective” impervious area (EIA), or the portion of total impervious area (TIA) that is directly (hydraulically) connected to the storm sewer system. Methods to improve estimates of EIA are not highly researched, and need further investigation.

The most accurate method for quantifying EIA in urban watersheds is the statistical analysis of rainfall-runoff data sets (Boyd et al., 1993; 1994). Without a good comparison to EIA determined from rainfall and runoff data, the other techniques to measure EIA (e.g. GIS techniques) cannot be verified. The overall objective of this study is to develop methods to accurately estimate the EIA using rainfall-runoff data. Beside the investigation on existing method of Boyd et al. (1993), we proposed a Curve Number (CN) based method for determination of the fraction of EIA in urban watersheds. The latter method investigates different CN behaviors in urban watersheds and evaluates CN at the basin scale from rainfall-runoff events. So it will be particularly attractive for practitioners involved in computing and modeling runoff from urban watersheds and design of associated hydraulic structures and stormwater control measures (SCMs). The two methods were applied to gauged urban subwatersheds with different sizes and characteristics within the Capitol Region Watershed District in St. Paul, MN. The results were used to evaluate the potential and the limitations of each method. While the results provide a better understanding
of the urban runoff mechanisms in the watersheds of study, they can be used as accurate estimations of EIA that would benefit a wide range of organizations involved in the design of stormwater control measures and transportation structures.
How much water can swales infiltrate? How can we accurately measure infiltration? This study demonstrates that sufficient measurements of infiltration parameters must be collected to compensate for the large spatial variation of infiltration rates in swales and other stormwater BMP control measures. From our study we have found that in swales and other stormwater BMPs, sufficient measurements of infiltration parameters must be made to compensate for the large spatial variation in infiltration rates. Then, the statistics of the measurements will tell us something valuable about the swale. Roughly 150 infiltration measurements were taken collected at each of three sites (located in the Twin Cities metro area, MN) and 108 at one site in Madison WI by using a Modified Philip-Dunne Infiltrometer. These data were used to analyze the effect of season, spatial variation and soil moisture content on the infiltration capacity of a grassed roadside swale or drainage ditch. The infiltration measurement involved estimating saturated hydraulic conductivity ($K_{sat}$) of the soil and soil suction. Individually measured $K_{sat}$ values at most sites varied by a factor of 100, indicating that large uncertainty can exist with the use of only one measurement. 21 measurements at each site have been used to reduce the uncertainty of $K_{sat}$ around the geometric mean to a factor of between 2 and 4. The spatial and seasonal variation of the infiltration rate of the three vegetative swales in the Twin Cities, MN will be shown.

A computational model has also been developed to estimate the infiltration of roadway stormwater runoff into the swales for given rainfall intensities. This model is a combination of the Green-Ampt assumptions (including $K_{sat}$) for infiltration and the St. Venant equations for routing excess flow in the channel. The model takes into consideration the antecedent moisture condition of the soil, the Green-Ampt parameters for the soil, and the hydraulic properties (geometry and surface roughness) of the channel. A comparison between computed swale outflow and monitored outflow of the Madison swale will be used to show the accuracy of infiltration predictions with proper measurements of $K_{sat}$. The results indicate that most roadside swales can infiltrate a water quality storm of 2.5 cm within the 48 hours recommended to maintain vegetative coverage.
Objective of Research:
The Minnesota Department of Transportation (MnDOT) identified a risk of increased flash flooding as a result of changing precipitation patterns due to climate change. Significant floods in 2010 and 2012 caused widespread damage and highlighted the need for MnDOT to assess the changing vulnerability of the highway system and identify cost-effect options to improve resiliency. The purpose of the project is to better understand the type, location, and reason for asset risks from flash floods. Findings and recommendations from the project inform the parallel effort to develop MnDOT’s first Transportation Asset Management Plan consistent with the Federal MAP-21 transportation authorization.

Methodology/Approach:
The project’s methodology is part of an effort to evaluate the Federal Highway Administration’s (FHWA) Climate Change & Extreme Weather Vulnerability Assessment Framework Draft, November 2012. MnDOT coordinated vulnerability assessments of Minnesota’s trunk highway system from flash flood events in two districts in Northeast (District 1) and Southeast (District 6) Minnesota.

The project includes a system-wide vulnerability assessment and a focused analysis of adaptation options at a specific high-risk facility in each district. The system-wide vulnerability analysis identified highway assets likely threatened by flash floods both now and affected by climate change. Highway assets include segments of the trunk highway network, bridges, and culverts. Risk scores were calculated using asset conditions, capacity, detour length, average daily traffic (ADT)/average daily truck traffic (ADTT), condition of upstream dams, stream stability, and projected change in the 24-hr 100-yr storm precipitation depth by watershed. Flood-prone assets were then ranked and mapped based on risk score. One asset in each District with a high-risk score will be selected for a detailed facility-level adaptation assessment. Hydrologic modeling will be conducted for each asset using projected 20, 50, and 100-year flood event scenarios. Information will generate discharge vs. probability curves for 20-year intervals over the remaining lifespan of the asset. A cumulative cost function and benefit-cost calculation will analyze adaptation and mitigation options. Findings and recommendations from the project parallel the effort to develop MnDOT’s first Transportation Asset Management Plan.

Findings or Results:
By the date of the research conference, we expect to have completed the system-wide vulnerability analysis. Assets will have been rated and ranked as to their vulnerability. These results will provide a
snapshot of vulnerability in the districts. We will also have selected the location for the adaption assessment.

**Potential Applications:**
The system-wide assessment will serve as a model for replication in other parts of the state. The assessment provides both a methodology to identify vulnerable assets and a catalog of at-risk assets in each district. The process to categorize vulnerability can help MnDOT understand the process for incorporating climate change into asset management plans. The list of vulnerable assets will help districts assess needs and for project-level planning and programming.

**Policy Implications:**
At the state level, this project can contribute to Climate Change discussions by providing a methodology to understand and calculate projected climate impacts. The assessment provides both a methodology to identify vulnerable assets and a catalog of at-risk assets in each district. The process may also help MnDOT revise its policies and plans to better address assets potentially at risk in the short- to medium-term.
Laboratory-Based Testing of Culvert Designs for Aquatic Organism Passage

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We evaluated the performance of recessed culverts across a range of geomorphic characteristics representative of Minnesota streams. Recessed culverts are often installed in Minnesota to facilitate aquatic organism passage by providing a natural streambed through the culvert. The least expensive option when installing a recessed culvert is to allow the culvert to fill in with sediment naturally over time; however evidence suggests that although sediment is transported through the control volume, it fails to deposit within the culvert. Hydraulic characteristics responsible for this phenomenon are not fully understood and the inability to maintain a sediment substrate within the culvert could be due to a lack of roughness in the pipe, characteristics of the flood hydrograph, or sediment supply. The objective of this research was to understand the function of a culvert set below the streambed elevation under various sediment transport conditions. Laboratory experiments explored the functionality of a culvert that is prefilled with sediment representative of the stream as a part of the installation process against one that is empty after installation and assessed the need for riprap weirs that protect against headcutting and downstream degradation. The experiments evaluated the development of natural bed roughness structures (steps, pools, ribs, etc.) or the need for artificial roughness installations within the culvert. Research presented will include findings from three sets of experiments: 1) the effect of sediment grain size, slope, and flow hydrograph on sediment transport through a single recessed box culvert, 2) the effect of bed roughness structures on sediment stability in a single recessed box culvert in high-gradient streams, and 3) the effect of culvert offset and skew on sedimentation in multi-barrel culverts.
For the past two decades, MetroTransit and Metropolitan Council have used tiered transit market areas to plan and deploy appropriate transit service in the Twin Cities metro area. Over time, the determination of transit market areas has become more analytic. The transit market index introduced by Council staff in 2009 considered local population concentration, employment concentration, and transit dependency. These factors, measured and summarized for Census block groups, were combined into a simple index intended to represent local level preconditions and potential for transit service.

Recently, MetroTransit and Metropolitan Council staff worked to validate and improve the transit market index, resulting in a renovated index and updated transit market areas in 2013. This project considered the predictive power of past metrics and the additional predictive power gained from urban form metrics. Council staff considered and tested a variety of metrics suggested by the literature on local transit readiness and mode choice behavior (cf. TCRP Report 95: Chapter 17, Transit Oriented Development, 2007). Regression analysis modeling was used to test alternative combinations of factors that incite transit ridership and to determine what relative leverage each factor contributes to ridership response. Through this project, intersection density, a proxy for walkability and connectedness, is revealed to have significant leverage for ridership: Each 1 percent increase in intersection density incites an estimated 0.23 percent increase in ridership. This factor is incorporated in the updated transit market index. Other factors have similar leverage.

Metro Transit uses the transit market index and transit market areas to target capital investment and service deployment. High-frequency local route services and dedicated transitways are deployed in local areas with the greatest local potential for ridership response. The transit market index may be a useful device for understanding local factors that cumulatively make transit service viable.
Travel Behavior Inventory: Activity-Based Model Development

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Following on survey data collection from the 2010 Travel Behavior Inventory, as in past decades, the Twin Cities regional forecast model was reevaluated. The regional forecast model is used for regional planning and project development. As the number and complexity of policy questions asked of forecasts has grown, the traditional four-step forecast process used in the Twin Cities was seen as insufficient.

Along with many other regions, the Twin Cities has developed an activity based model paradigm for future travel forecasts. The model (developed on the Tourcast platform) was developed in the fall of 2013 and spring of 2014. It will be tested throughout 2014 and released later in the year.

The new model structure establishes a modular framework that we hope will serve the region for many years to come, allowing incremental updates as new data becomes available or new complexity is possible or desired. Model flow progresses from population synthesis to long term models (of workplace/school location, auto ownership and transit/toll pass ownership) daily activity models (number and type of tours, intra-household interactions), tour models (mode, destination, and time of day) and trip models (number and type of stops, mode and destination), before network assignment and analysis.

The presentation will focus on the structure of the model and estimation/validation challenges encountered, as well as discuss some of the emerging opportunities for analysis offered by the new model.
The Gaps in Satisfaction with Transit Services Among BRT, Metro, and Bus Riders: Evidence from Guangzhou

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This paper explores transit riders’ satisfaction with Bus Rapid Transit (BRT) and compares BRT with conventional bus and metro services using revealed preference data from Guangzhou, China. A trivariate ordered probit model is developed to examine the effects of various service attributes on riders’ overall satisfactions with the three types of transit. We find that the top three influential attributes for satisfaction with BRT are ease of use, safety while riding, and comfort while waiting. Moreover, transit riders are most satisfied with metro, followed by BRT and conventional bus. The top five attributes that contribute to the difference in the overall satisfaction between BRT and metro are ease of use, comfort while riding, convenience of service, travel time, and comfort while waiting. Based on the findings, we propose specific strategies that can be used to enhance BRT quality of service.
“Public involvement can make or break a project.” We hear this often but in reality there are far too many examples of projects that involved the public and yet were shelved due to political decision-making grid-lock created by those in opposition. How can this be avoided? How can you be responsive to the conflicting demands of all the various stakeholders/interests without compromising your agency’s goals and addressing the needs for the project?

Attendees at this session will review the basics of why it’s important to involve the public, learn how to develop and build consent and how to design a public involvement process that fits your project. Through our experience with various projects across the state, we will provide examples of implementation successes on projects with decades of history and “not in my backyard” mentality. We will also provide examples of how some of the emerging technologies such as mobile GPS/GIS and audience polling techniques can be used to enhance the overall public participation process.
Introducing FHWA's New Visual Impact Assessment Process

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Building on research conducted for the National Cooperative Highway Research Program (NCHRP) and previously presented to Minnesota Transportation Research Conference, Avenue Design Partners in collaboration with ICF International has developed a new Visual Impact Assessment (VIA) process for the Federal Highway Administration (FHWA). It is anticipated that the new process will be delivered as recommended guidance to state departments of transportation in early 2014. The new guidance is intended to better meet the requirements of the National Environmental Policy Act of 1969 (NEPA) that impacts to aesthetics be evaluated as part of the environmental documentation process of projects receiving federal funding. Although states may continue to use their own VIA process, the FHWA anticipates that many, if not most, state departments of transportation will adopt the new FHWA VIA Guidelines. As the primary author of the new guidelines, Craig Churchward will provide a uniquely thorough understanding of the process and its implications for project managers.

The session will provide a technical overview of the new four-step VIA process, emphasizing how a VIA can be conducted to streamline public involvement, diminish controversy, and reduce costs. Those attending the presentation will become familiar with how to tailor the process to a particular project; the level of effort needed to complete a VIA; how to best incorporate the public’s visual preferences into the process; how visual impacts are determined; and how to develop effective mitigation strategies. Although the session will not replace the need for more in-depth training, it will provide practitioners and administrators with a systematic understanding of FHWA’s new VIA process and recognition of how their organization would profit from employing this new technical tool from the FHWA.
Enhance Intersection Safety by Reducing Red Light Running Violations

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Red light running is a significant safety concern that leads to numerous fatal and injury crashes. One of the solutions to enhance intersection safety is to minimize intersection crashes by positively impacting drivers’ behavior through implementing effective field enforcement. However, effective field enforcement requires collecting violation profiles to facilitate targeted field enforcement and providing conclusive visual evidence to prevent potential court contests. This project develops an enhanced red light enforcement system that provides a flexible platform to support police officers to monitor the red light violation events under a real-time manner, and collect conclusive visual evidence to help them effectively issue citations, and generate violation profiles to facilitate targeted enforcements. This presentation updates the project progress and provides more detailed information on system operations, and violation detection effectiveness, focuses on violation data collection, violation profile development, drivers behavior impact, and crash reduction efficiency.
Roundabout facilities have been added to many major cities across the United States in recent years. However, concerns have been noted, especially at multi-lane roundabouts where interactions between entering and exiting vehicles are more complex. The traffic control devices for roundabouts are also not as clearly defined compared to similarly situated signalized intersections. In Richfield, Minnesota a two-lane roundabout exhibited an abnormally high crash rate and local engineers experimented with alternative signing and striping designs to explore potential improvements beyond the standard guidelines. An observational study was conducted that included 216 hours of video records from before (2010), after implementation of alternative control methods (2011), and one-year-after (2012). Each vehicle which entered the roundabout was observed and a database was constructed containing all the violations committed by drivers. Violations were categorized into three major groups: failure to yield, lane change, and improper turn. Additionally, crash records for the roundabout were analyzed across the entire period. These data demonstrated that the majority of collisions are due to failure to yield or improper turn violations. The alternative measures which were implemented showed an improvement in correct lane choice, reducing improper turn violations by a normalized 48% and reduced incorrect lane choice by 53% from before to after. These improvements diminished slightly to 44% and 50% in the one year after observations, respectively. The new signing and striping did not affect the yielding violations observed within the roundabout.
Background:
Crash data is helpful for developing and improving policy and programs. CODES (Crash Outcome Data Evaluation System) enhances crash data by linking it with hospital treatment data. This better identifies severe injuries and describes hospital charges associated with crashes. The National Transportation Safety Board recently described CODES as “… the best available data to properly assess the injury burden …”.

Missing values and reporting errors in the data collection processes may lead to missing links for many of the true links between the crash data and hospital data. If only high-probability links are selected, then the unlinked, low probability, false negatives can make the selected linked cases unrepresentative of the total population of true linked pairs. Similarly, when one or more values are missing for a case, most statistical packages default to discarding any case that has a missing value, which may introduce bias or affect the representativeness of the results; substituting missing values with the mean value for a variable may preserve a case for analysis, but will still result in an unrepresentative data set because of the inaccurate quantification of variance.

To be able to include low-probability matches in outcome studies and to account for missing data, the CODES process completes five imputations; that is, missing links and missing values are determined five times resulting in five complete datasets. As a result, analyses yield valid statistical inferences that reflect the uncertainty associated with having low-probability true links and the true variance associated with variables having missing data. Once all links and missing values have been imputed, the data set can then be analyzed using specialized techniques and software (such as SAS PROC MIANALYZE).

Multiple imputation is the best way to impute low probability and missing links as well as missing data. Yet many transportation professionals and investigators may find it awkward and/or impractical to analyze the multiple data sets associated with multiple imputation due to the specialized software and statistical methodology needed. A single imputation method would be preferable for simplicity and ease of analysis. However, a single imputation data set would have to be shown to have statistical characteristics similar to that of a corresponding multiple imputation data set.

Methods:
Minnesota 2009 crash and hospital data were used to create both a multiple imputation CODES data set and a single imputation CODES data set using LinkSolv software, incorporating probabilistic and imputed linkages. SAS PROC MI and IVEware were used to impute missing values. The multiple...
imputation and single imputation data sets were then compared on a variety of statistical characteristics. The linked crash data set contains hundreds of variables; a subset of these was selected for inclusion in the single imputation dataset. The parameter of interest is the hospital charges/costs, with consideration of how other factors influence it. Additional selected variables of influence included age, speed, injury severity, vehicle ejection, weather conditions, light conditions, and crash configuration.

**Results:**
The standard errors are compared between the multiple imputation and single imputation data sets. The standard errors are very similar between the various imputation methods; however, the stochastic regression method for missing value imputation gave the best results. Nonetheless, the multiple imputation data sets still provided the best estimates of the variance.

**Conclusions / Policy Implications:**
Multiple imputation is still the preferred method for creating a CODES data set, compared to single imputation methods. However, stochastic regression single imputation shows significant promise for creating a public use data set for transportation professionals and investigators. Stochastic regression is the least biasing single imputation method, considering the estimated standard errors. Nonetheless, such a public use data set might be limited to generating hypothesis for further analyses, rather than drawing conclusions as one might do with a multiple imputation data set. Findings from this analysis are being incorporated into the creation of public use CODES data sets for multiple years. Availability of these data sets will be further discussed at the presentation.
A Comprehensive System for Real-time Monitoring and Broadcasting of Truck Parking Availability

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Commercial heavy vehicle (CHV) drivers are required under federal Hours Of Services (HOS) rules to rest and take breaks to reduce driving while fatigued. CHV drivers and operators must balance compliance to the HOS rules against on-time delivery requirements as well as shorter lead times to plan their trips, thereby making location and parking availability of rest area facilities more critical. Without timely, accurate parking availability information, drivers are left with the dilemma of continuing to drive fatigued, drive beyond HOS CHV operation limits, or to park illegally on highway shoulders or ramps—all potential safety hazards.

A comprehensive truck parking availability system is summarized that is currently being deployed along several truck rest areas along Interstate 94—a key regional freight corridor passing through the state of Minnesota. The system is based on integrating multiple Commercial Off-The-Shelf cameras to directly extract per-space occupancy in real-time. Other efforts in the past have focused on counting vehicles at ingress and egress points of the facility to indirectly estimate parking occupancy—which are prone to estimation errors over time and require frequent ‘re-zeroing’ procedures. Direct parking space monitoring has distinct advantages over such systems in that errors are ephemeral and do not accumulate over time. In addition, parking space usage can be directly monitored thereby providing detailed performance information of the facilities.

To analyze system performance, raw (imagery) and processed detection data were harvested over extended periods exhibiting various environment and weather conditions. General up-to-the-minute detection accuracy thus far indicates per-parking space occupancy can be detected with an overall accuracy of 99%. Implications for monitoring occupancy and parking behaviors during extreme weather events will be discussed. Scalable system architecture to broadcast parking information was developed utilizing open-source software and standardized interfaces. Information portals will be presented that allow 3rd party information providers, roadside information infrastructure, and CVH operators, the ability to obtain and disseminate real-time parking information for truck parking facilities along the corridor, thereby enabling comprehensive corridor-wide truck parking information.
Using National Performance Management Research Data Set to Generate Statewide Performance Measures

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As outlined in the Moving Ahead for Progress in the 21st Century Act (MAP-21), the States are required to establish performance targets that reflect the performance measures established by the U.S. Department of Transportation (USDOT). The USDOT has identified and recommended critical performance measures, methodologies and standards for data collection, potential issues related to deployment, and usability of performance measures in addressing issues at local, state and federal levels. In July 2013, FHWA has announced a National Performance Management Research Data Set (NPMRDS) to support its FPM and Urban Congestion Report (UCR) programs. The NPMRDS includes probe vehicle based travel time data (for both passenger and freight vehicles) for all National Highway System (NHS) facilities. The NPMRDS provides opportunities for public agencies to generate performance measures, such as mobility, delay, and reliability. These measures can provide information to support regional transportation planner in identifying bottleneck, infrastructure improvement needs, and operational strategies to promote efficient traffic movement. This presentation explores the feasibility to generate performance measures for both passenger and freight vehicles in the Twin Cities metro area.
In 2010 and 2011 the Metropolitan Council conducted several major surveys as part of its decennial Travel Behavior Inventory. At the 2011 CTS conference, initial findings from the 2010 Transit On-Board survey were presented. At the 2012 CTS Conference, an overview of the entire survey project was presented, as well as a look ahead at plans for forecast model improvements. In spring 2013, home interview survey methods and challenges were discussed.

In 2013, results from the household interview survey were released. Between December 2010 and February 2013 over 14,000 households in the 19-county region filled out single-day diaries recording their personal travel. Information was collected on the household level (household structure, vehicle availability, income), person level (age, sex, employment/school status, educational attainment, possession of transit pass or MnPASS transponder), and trip level (location, activity, mode, price, and number of travelers). Survey participants were recruited and data was collected by phone, mail, and web in order to broaden the survey’s reach.

The 2013 TBI provides a unique opportunity to learn about the extent of all travel, especially non-work travel. This presentation will focus on what can be learned about linked trips/tours in the region, and the importance of demography in travel.

GPS Home Interview Survey: Between May 2011 and November 2011, all members (age 12+) of over 250 households in the 19 county region carried a GPS receiver for seven days, and filled out a single day personal travel diary. The survey collected the same type of data as the home interview survey. It was used to validate portions of the larger diary survey. This presentation will also discuss challenges encountered using GPS data, and recommendations for potential future gps-only comprehensive surveys in the region.
This study analyses data from the Metropolitan Councils Travel Behavior Index survey of the Metropolitan Twin Cities region. It compares the time allocated for various activities as reported in the survey over time. The mean activity time allocation for travel, home, work, shopping, and other is computed for the survey respondents and a t-test is used to determine if the activity times are changing over time. The dummy variables of gender and employment status are used to look at changes among those groups. The study shows a general, if slight, increase in time spent at home and in the number of people who work from home, as well as a decrease in time spent traveling. These changes are attributed to both the economy and the rise of the internet.