Semi-Annual Program Progress Performance Report
for the
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The Pennsylvania State University
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Martin T. Pietrucha, Director
Mid-Atlantic Universities Transportation Center
814-863-3954 mtp5@psu.edu

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INTRODUCTION

The Mid-Atlantic Universities Transportation Center (MAUTC) is comprised of six universities—Morgan State University, The Pennsylvania State University (Penn State)(lead),University of Maryland, University of Virginia, Virginia Polytechnic and State University (Virginia Tech), and West Virginia University—and is located in Federal Region 3. MAUTC has served as the Region 3 regional UTC since the program's inception in 1987.

In the past, MAUTC primarily served as a conduit of research funding for its member institutions. Each institution conducted its own program of activities—research, education, and technology transfer—to respond to the priorities of the U.S. Department of Transportation's strategic goals as well as the institutions' state departments of transportation, which were the primary sources of matching funds, and other in-state stakeholders.

ACCOMPLISHMENTS

Major Goals:

MAUTC is organized as a single entity serving multiple, non-university stakeholders who are part of the transportation enterprise of the mid-Atlantic region. Each member institution received $300,000 (base funds) to be used for any purpose eligible under the grant, including research, student support, workforce development, technology transfer and administrative costs. The remaining funds are distributed, through a competitive proposal process, among the following programmatic areas:

Pooled Research Funds

A portion of Penn State's funds was escrowed for pooled research projects to encourage member institutions to conduct joint research that would address regional transportation issues. Each member institution has participated in at least one regional proposal.

Advanced or applied research that is performed by multiple universities or funded by multiple sponsors is eligible for funding. Any combination of universities and public and/or private matching funds are eligible. Public sector stakeholders, i.e. the Region 3 state DOTs, are given the right of first refusal for use of the federal funds in this program area. Proposals are solicited quarterly by the MAUTC Project Selection Committee, comprised of representatives of each of the MAUTC universities and from the DOTs in the states that are home to the MAUTC universities.

Accomplishments:

Nine collaborative research projects began during this reporting period:

Structural Health Monitoring to Determine Long-term Behavior of AFRP Composite Bars in Prestressed Panels for Field Deployment, *Morgan State University and University of Virginia*

- Preliminary testing is underway to assess the bond strength of aramid fiber reinforced polymer (AFRP) composite bars in prestressed concrete panels. The beams have been constructor and various techniques to ensure proper anchorage of the bars are being investigated.

  The impact of this research will provide results as to how these AFRP bars perform when exposed to accelerated aging conditions. The results will also provide more confidence and add to the database of structures and their ability to provide longer service life for bridge decks, which will be more sustainable and durable. This research can lead to the use of these designs for other marine structures like wharves and seawalls and other types of retaining walls where conventional steel reinforcement is used and can be vulnerable when near environments where steel can corrode with time and exposure. The project has the potential to lead to commercialization of an anchorage system that can be used with these bars for bridge structures.

  There was some delay in beginning this project as graduate students had to be hired and trained. This has been addressed and progress is moving steadily forward.

Using Mobile Probes to Inform and Measure the Effectiveness of Macroscopic Traffic Control Strategies on Urban Networks, *Penn State and Virginia Tech*

- Techniques to estimate network-wide conditions using mobile probe data have been developed. The techniques have been tested using idealized micro-simulation networks. Large scale control strategies are in development and are being tested. To date, the findings have shown that the techniques can be quite accurate and are a very useful way to monitor traffic within an urban network.
- The methods developed in this project may be implemented in the field using actual probe data to develop macroscopic traffic relationships as well as real-time traffic state monitoring. A workshop will be offered to introduce practitioners to the concept of macroscopic traffic models and to demonstrate their usefulness for real-time application.

Modeling the Dynamics of Driver's Dilemma Zone (DZ) Perception using Machine Learning, *Virginia Tech, Morgan State University and Penn State*

- Driver simulator runs were conducted with 42 participants and the data was analyzed. The team identified and assessed the significant factors that affect the definition of DZ through a driver simulator study. Machine learning and agent-based modeling techniques were used to develop dynamic models for DZ related driver behavior. The research methodology and findings were presented during two sessions at Penn State's annual

Transportation Engineering and Safety Conference. The final report was submitted, a presentation was made at the agent-based conference in Blacksburg, Virginia in October, and two papers will be presented at TRB in January 2014.

Findings include: Drivers were found to learn from their past experience. Drivers learning that the yellow duration was longer than what they anticipated do not tend to "go" more in dilemma zones. Rather, they tend to be more conservative and err on the side of stopping. Reinforcement learning techniques were used to train agents to mimic driver's behavior and they were found to be superior to statistical techniques.

The results of this project will lead to improved modeling of driver behavior in dilemma zones and will have an impact on the design of optimal control methods which could lead to a new line of design in the signal controllers industry. Improved modeling of driver definition and behavior in dilemma zones will have significant impact on the design of optimal control methods and the assessment of intersection safety. This will ultimately lead to saver intersection designs which could save lives. As this study focused on the driver learning aspect, it sheds light on the benefits of training and educating drivers about dilemma zone issues, which could be applied in the driver education process when applying for a driver's license.

Smart Concrete Bridge Girders Using Shape Memory Alloys (SMA), *University of Virginia and Penn State*

- The broad research goal of this project is to investigate the development of post-tensioned (SPT) bridge girders by activating the shape memory effect of SMAs using the heat of hydration of grout. Researchers are characterizing the microstructure of commercially available alloy compositions and a custom composition. Presentations were made by Asheesh Lanba, Ph.D. candidate at Penn State, at the American Society for Composites 28th Technical Conference and at Materials Science and Technology Conference and Exhibition.

  Off-the-shelf commercially available materials will not meet the operational requirements. The team is investigating custom compositions and thermo-mechanical treatments that will meet their requirements. The research team is working with a material supplier to cast custom alloy composition ingots and a separate manufacturer to form the materials into specimens. It is expected that costs will increase, but have not been determined yet.

Integration of Multi-modal Transportation Services, *Morgan State University, Penn State, University of Maryland*

- Literature reviews have been conducted. Models of bus operations have been formulated and tested for relatively small numerical cases and algorithms for managing ridesharing operations between one major terminal and many trip origins or destinations are being adapted from previously developed algorithms for airport shuttle services. Methods for coordinating vehicle arrivals and departures at transfer stations have been formulated.

The models have been designed to minimize total system costs and focus especially on missed-connection delays and slack times built into schedules.

Needs, Barriers and Analysis Methods for Integrated Urban Freight Transportation, *University of Maryland, Morgan State University and West Virginia University*

- A literature review revealed that most urban freight operations occur in a multi-echelon system. The West Virginia University research team has focused on developing two echelon facility location models with uncertainty in demand from customers. An outer approximation algorithm was developed so solve the model. Morgan State University took the lead to develop a survey to understand public/private sector stakeholder opinions on various issues associated with urban truck movements and freight delivery systems. The research team developed optimization models for urban freight delivery systems. The University of Maryland research team developed preliminary models which accounted for truck tours in location models.

A Feasibility of Bridge Deck Deicing Using Geothermal Energy, *Penn State and Virginia Tech*

- Different key variables that can potentially influence the operation of the proposed ground-coupled deicing system have been identified. Some of these variables are weather conditions (i.e., temperature, wind, cloud cover), inlet and outlet temperatures of the fluid circulating within the bridge deck, radius of circulation tubes, fluid circulation rate, and loop spacing and length. Thermal and mechanical behavior of different components of the proposed system has been characterized. A series of heat exchange tests have been performed at PSU on an instrumented model geothermal pile installed in a large soil tank. A series of thermal tests have been performed at VT on a model-scale bridge deck to investigate the operational and performance characteristics of the proposed technology. Numerical models have been developed to evaluate thermal performance of geothermal pile and bridge decks under thermal loading. Developed numerical models have been refined and verified based on data obtained from Tasks 3, 4, and 5 and using existing analytical solutions. Findings from this research have been disseminated through technical papers in peer reviewed journals and presented in conference and technical meetings.

Drivers' Willingness to Pay Progressive Rate for Street Parking, *Morgan State University and Virginia Tech*

- The literature review and survey questionnaire have been prepared. Data collection has begun and the descriptive and economic analysis will be done after all of the data has been collected.

Use of Probe Data for Arterial Roadway Travel Time Estimation and Freeway Medium-term Travel Time Prediction, *Virginia Tech and University of Maryland*

- The research team has developed and published five algorithms for predicting travel time (see Products). The team is gathering data to test the algorithm along I-66 in Northern Virginia.

  A delay of six months is anticipated as it has taken that long to get weather, detector, and other sources of data. A request for a time extension will be submitted.

Workforce Development/Student Support

Developing the next generation of transportation professionals is a critical component of MAUTC's mission. Each member institution may submit a proposal to provide direct support to university students, graduate or undergraduate, or to fund activities that encourage pre-college or pre-engineering college students, especially those from underrepresented or disadvantaged groups, to students in science, technology, engineering, and mathematics (STEM) fields and consider transportation a career, improve the content knowledge and professional skills of the STEM teacher workforce, or improve the transportation-related resources available for learning STEM subjects.

Teacher Transportation Institute (TTI), *Morgan State University*

- The first session was held July 22 through August 2, 2013 and the second session was held November 2 through December 14, 2013. Twelve teachers from eight different schools attended the first session, and ten teachers from nine different schools attended the second session.

  The goals and objectives of the program were to provide teachers to become aware of the connections between science, technology, engineering and math (STEM), transportation, and related careers; research and explore STEM careers associated with transportation; underscore the importance of STEM education to students and parents; develop teachers' awareness of transportation as an option for post-secondary education and career path; and conduct research on transportation careers, modern traffic roundabouts, and connected vehicles.

  Participants discussed the impact of the traffic roundabout and connected vehicles on the environment and safety and conducted traffic feasibility studies and used scientific and mathematical principles to analyze their data. They were taught to construct a scale of a traffic roundabout. The teachers also experienced driving scenarios behind the wheel of a driving simulator and became more aware of the hazards of distracted driving. The teachers were taught to go beyond the basics of what students need to know into what engineers do to approach a new problem.

Workforce Development/Professional Development

The development of tomorrow's transportation workforce is critical to maintain and improve the safety and efficiency of our transportation system. As much as 50 percent of the transportation workforce is due to retire in the next several years, which will create a large knowledge gap that must be filled.

These funds are available for activities that will help to further develop the knowledge, skills, and abilities of the transportation professionals for both personal development and career advancement. Activities may include, but are not limited to, on-site or distance education in the form of conferences, short courses, webinars, seminar series, tutorials, communities of practice, individual consultation, and technical assistance.

Preston Educational Engineering Resources (PEER), *West Virginia University*

- Researchers are working with the EdVenture Group in Morgantown, West Virginia, West Virginia Department of Transportation, Preston County middle and high school teachers, and Preston County Schools Technology Integration Specialists on the Preston Engineering Educational Resources (PEER) program. A workshop was conducted explaining the program to nearly 40 high school and middle school teachers to seek their input on the program. The response was very positive. Successful undergraduate and graduate engineering students, close in age to the middle and high school students, were recruited for the purpose of building relationships with and mentoring middle and high school students. The WVU engineering professors and undergraduate and graduate students worked with the EdVenture Group in developing pre-activity, lesson plans, lecture material, and post activities to expose middle and high school students to three topics in transportation engineering – sight distance, network analysis, and traffic signals. These lesson plans were checked to ensure that they satisfied core curriculum learning objectives. Feedback was obtained from the teachers. The WVU students then visited each middle and high school and conducted one day workshops. Similar workshops will be conducted in the spring semester. One female graduate student, one female undergraduate student, and one male undergraduate student are involved in this project.

Conference on Agent-Based Modeling in Transportation Planning and Operations, *Virginia Tech*

- In the past twenty years, transportation professionals and researchers have been incorporating individual person characteristics as a collection of autonomous decision-making entities called agents in modeling on the planning side the traveler daily activities in terms of route and mode choices, trip chaining, trip substitution, early or late departures, and in evacuation planning and emergency management, and in the traveler's willingness to use toll roads and HOT lanes. On the operations side, several researchers are introducing individual traveler characteristics called agents in modeling the acceleration and braking behaviors of drivers, their car following and lane changing maneuvers, and in particular, aggressive driving that is leading to car manufacturers' adoption of eco-driving to name a few approaches.

Agent-based modeling allows the researchers and users to keep the personal traveler identity or a collection of them as agents intact through the modeling process and consequently allow the users to trace and make use of the agents' characteristics in their planning and operations of transportation facilities. In contrast to aggregate-based modeling, agent-based modeling looks at a system, not at the aggregate level, but at the level of its constituent units. Agent-based modeling provides by far a more natural description of the system, flexibility in representing the system, and captures emergent phenomena as a result from the interaction of individual entities.

The conference was held September 30 – October 2, 2013, in Blacksburg, Virginia. The objectives of the conference were to present the current state-of-the-art/science in agent-based modeling in transportation, provide the lessons learned from current research, define where the future lies in the field, and determine the steps necessary to ensure its success. Thirty-four people attended the conference.

Development of Digital Instructional Modules for Transportation Professionals Overviewing the Fundamentals of How to Obtain Soil Properties in Practice, *University of Virginia*

- Nine online lab modules that transportation professionals can use as a reference to learn how to conduct, interpret, and apply geotechnical lab tests used in practice to determine engineering soil properties were created. The modules were produced and distributed through the Virginia Transportation Training Academy for use by highway design professionals throughout Virginia and are posted on YouTube. The Transportation Training Academy made these videos available through their website for use by other universities or state DOTs that wish to offer these instructional videos as reference tools within their own highway design communities. The modules include:

    - Specific Gravity
    - Grain Size Distribution: Coarse-Grained and Fine-Grained
    - Atterberg Limits Test
    - Compaction (Standard and Modified Proctor)
    - Permeability (Constant and Falling Head)
    - Consolidation
    - Direct Shear
    - Unconfined Compression Triaxial Test
    - Consolidated Undrained Triaxial

The videos improve transportation education by informing non-engineering professions, or those engineers who might not have taken a soils class, of the basics of the most commonly used geotechnical testing procedures. The videos are also an accessible resource for undergraduate geotechnical classes.

Implementation and Technology Transfer

Publications and presentations are the standard method by which faculty, researchers and students disseminate the knowledge garnered through their research. In addition, MAUTC will

use social networking sites such as Facebook, LinkedIn, and Twitter to communicate research activities and findings.

These funds will be available to help fund conferences, workshops, webinars, etc. to further the adoption of new-to-the-user products or procedures by the transportation community.

Webinars to Disseminate Information and Results from University of Virginia and Virginia Tech MAUTC Research Projects, *University of Virginia and Virginia Tech*

- This project has been delayed due to administrative issues. Planning for the webinars will begin in spring 2014. A no-cost time extension was granted through December 2014.

MADONNA Workshop

- Despite the fact that traffic signals have critical and direct impacts on traffic safety, delay, and the environment, there are no off-the-shelf optimization tools for system-wide assessment and/or upgrade of control hardware/software to improve the overall signal system performance. Signal equipment upgrade decisions are often made based on subjective experience of senior traffic engineers. This research and implementation effort aims to capitalize on a recent successful research development, Multi Attribute Decision-making Optimizer for Next-generation Network-upgrade and Assessment (MADONNA), that emerged during a research project conducted to address needs raised by Virginia northern region. The work will extend the system to address the regional needs in all other Virginia Department of Transportation (VDOT) districts.

  The team has developed a decision support tool in a user-friendly format that can be used in making optimal system upgrade decisions. The next step is to develop comprehensive workshops and train VDOT engineers with detailed example data and outcomes and provide outreach and professional development opportunities for VDOT engineers. The research team will help VDOT Central District with their upgrade decisions.

Estimation Tools for Advanced Transportation Models, *University of Maryland*

- The main objective of this project is to make new methods for transportation model estimation accessible to a wider audience and to bring advances in transportation modeling to practice. In the first phase of this project, the research team has been developing a new graduate class centered on advanced demand models. The materials have been organized and will be made available on a dedicated website at the end of the project. The course has been offered at the National Chiao Tung University in Taiwan to an international audience and was recorded with the objective of reaching a larger audience.

  The team is working on the software for demand model estimation. The team is finalizing both the material for the course and the software to include dynamic discrete choice models. Dynamic discrete choice models are new in transportation demand

modeling. A small number of groups are trying to implement similar concepts. The model and software developed by this team are the first that have been fully estimated and validated.

This multidisciplinary project brings together economics, optimization and computer science and a faculty member and Ph.D. student in applied mathematics are contributing to the research. The project is designed to impact transportation education with the design of a new graduate class, to contribute to research by developing cutting edge modeling techniques, and to technology transfer by delivering software and special courses for practitioners and agency representatives.

Base Funds

Each Center university has solicited proposals and is working with its respective departments of transportation to select projects. Faculty are also reaching out to others within the Center to find common interests for collaborative proposals.

New Projects:

Bridge Deck Cracking: Effects on In-Service Performance, Prevention, and Remediation, *Penn State*

- The condition of the nation's aging infrastructure has been of the highest concern in recent decades. The National Academy of Engineering (NAE) has recently included the restoration and improvement of urban infrastructure on its list of the "Top 14 Engineering Challenges" facing our society.

  The main objectives of this project are (1) to identify the causes of early-age cracking in concrete bridge decks, (2) to provide recommendations for effective prevention of early-age cracking, (3) to assess the effect of cracks on the long-term durability and performance of concrete bridge decks, and (4) to identify the best and most cost-effective (on a life-cycle cost basis) remediation practices and optimum time to remediate, to extend the life of bridge decks.

Map-based Localization to Assist Commercial Fleet Operations, *Penn State*

- The goal of this project is to initiate research of map-aware vehicles. This topic considers how the vehicle's position information is robustly obtained and used with pre-stored map information for the purposes of driver assist, vehicle automation, and autonomy, specifically for commercial vehicles.

Safety Performance Functions, *Penn State*

- The objective of this project is to develop state-specific Safety Performance Functions (SPFs) consistent with the American Association of State Highway Transportation

Officials (AASHTO) Highway Safety Manual (HSM), reflecting conditions on Pennsylvania roads with Pennsylvania drivers. The SPFs support the integration and implementation of the HSM within PennDOT's policies and procedures for project delivery and program management.

Trenchless Technology Settlement Investigation, *University of Virginia*

- Researchers will compare two different methods that could be used to detect voids in the installation of pipes through trenchless technology. The first technology examined will be FutureScan, a robot outfitted with a radar system that can scan voids by being placed directly in the pipe. The FutureScan method is a new method developed by CUES Inc. and Louisiana Tech. The second method will be Ground-Penetrating Radar, which will be compared to the results from the FutureScan technique.

  Recommendations on settlement monitoring resulting from this study will be added to the recommendations previously written as to ways that the current version of VDOT policies regarding trenchless technology oversight could be improved.

Sinkhole Risk Assessment along Roadway Construction, *University of Virginia*

- This research will use the risk assessment method developed by Zhou and Beck and adapt it to roadway conditions in the Ridge and Valley province of Virginia. The sinkhole formation factors that this study will attempt to identify with available data in Virginia will include: soil type, sinkhole groupings/previous occurrences, water table levels, stream presence/groundwater flow, roadway location, and karst mapping data. If available, each of these factors will contribute in calculating the sinkhole risk formation score for segments of area along a specific roadway located in the Ridge and Valley province. Risk formation scores will then be translated into risk sinkhole formation probabilities of low, medium, or high and then mapped along the roadway.

  A preliminary risk map has been created in GIS for ½ mile on either side of Interstate 81 in Rockingham County, Virginia. The map correlates soil type, slope, and probability of flooding in a simple calculation of overall risk.

Multimodal Enhancements to Public Private Partnerships, *University of Virginia*

- During a meeting with Virginia's Public Private Partnership (P3) Office, it became clear that what hampers implementation of "multimodal" projects is their financial viability. This research will examine Public Private Transportation Act (PPTA) projects in other states and ask (1) were such projects multimodal (if not, why not?), and (2) how the multimodal aspects were implemented for such projects. The research is being coordinated with the Virginia P3 office.

Area Coverage Provided by Vehicle-to-Vehicle (V2V) Communication in an Urban Network, *Virginia Tech*

- Connected Vehicle research has emerged as one of the highest priorities in the transportation field. The information obtained from Connected Vehicles has the potential of providing local and area-wide traffic management solutions which is desperately needed in most large urban areas. The reliability and the frequency of this transmitted information have to be addressed to ensure that the users can properly utilize this information to solve traffic management issues. This research investigates the area covered in space and in time by V2V communication in an urban network based on different market penetration rates of equipped vehicles and wireless communication coverage distances. The research will give the analyst the ability to assess the coverage level and the frequency of the information obtained from the equipped vehicles for different penetration scenarios, and determines the utility of the investment for different vehicle systems deployment levels. These study findings will be useful for making decisions about investments in cooperative vehicles in relation to the expected increase in traffic efficiency.

Use of Persistent Wide-Area Video for Transportation Planning Operations, *Virginia Tech*

- Persistent wide-area video, in combination with PVLabs' integrated Tactical Content Management System (TCMS) spatio-temporal capability, automatically identifies and captures every vehicle in the video view frame, storing each with a discrete ID and time-stamped location. This unique data capture can provide not only comprehensive count information but also, more importantly, vehicle track information. The researchers will evaluate possible uses of an existing one square mile data capture in an urban area to establish its efficacy in supporting transportation planning and operation activities. Tasks will include developing a track data model, relating tracks to Origin-Destination matrices, relating tracks to traffic characteristics, and developing and evaluating one or more proof-of-concept models for traffic assignment and for quantifying traffic characteristics at a microscopic spatio-temporal level.

Regional Coordination in Public Transportation: Lessons for the U.S., *Virginia Tech*

- Spatial expansion of metropolitan areas has extended daily travel patterns beyond administrative service areas of public transportation agencies. Coordination of transit services throughout metropolitan areas could offer seamless and convenient travel options that attract motorists who are used to connected regional roadway networks. However, transit service in the U.S. metropolitan areas remains fragmented.

  This study identifies lessons in regional coordination for transit from metropolitan areas in Germany, Switzerland, and Austria with over 30 years of experience of regional coordination in so-called *Verkehrsverbunds* (regional transit authorities). *Verkehrsverbunds* have increased transit ridership and financial efficiency and help account for 5 to 10 times more transit trips per capita there than in the US. Lessons from

Germany, Switzerland, and Austria are meaningful because of comparable federal structures of government, standards of living, and levels of motorization.

Initially, this project highlights challenges in regional coordination of transit in the US using the regions in the middle/south Atlantic Census region (e.g. Washington (DC), Richmond, and Philadelphia regions) as case studies. The main part of the study documents trends in ridership, financial efficiency, and administrative structures of *Verkehrsverbunds* in Germany, Switzerland, and Austria using case studies from large and small regions, such as Berlin, Stuttgart, Freiburg, Basel, Zurich, or Vienna. The goal is to identify successful policies and administrative structures that foster regional collaboration.

Ongoing:

Durability Assessment of Prefabricated Bridge Elements and Systems, *Morgan State University*

- The literature review is in progress. Researchers met with the Maryland State Highway Administration (SHA) to arrange additional visits to precast plants to make observations and follow-up per critical data that is needed, especially for statistical analysis. A preliminary draft of the database was completed and reviewed. The research team will continue working to improve it based on feedback received from Maryland SHA.

  Identifying process improvements and ways to handle quality control at the precast plants and in the field will help the state highway administration meet performance measures per their business plan. This, in turn, can lead to the development of quality control practices based on the durability assessment for Maryland and other states. The project has the potential to lead to commercialization of a database that can be used in the Mid-Atlantic region to make better quality prestressed bridge specimens and products.

Evaluation of Waste Concrete Road Materials for Use in Oyster Aquaculture—Field Test, Phase II, *Morgan State University*

- A field test was conducted to test the impacts of recycled concrete aggregate (RCA) on the aquatic community structure and oyster recruitments. Three different materials, RCA, oyster shell and RCA and oyster shell were used. Two sites in the Chesapeake Bay were selected to conduct the field test. The results indicate that there are no significant differences of aquatic community structure and oyster recruitments with the use of either RCA oyster shell or a 50/50 mix of the two. RCA materials, if used an alternative material for oyster reef construction, replacing natural oyster shell, will not have any adverse ecosystem impacts.

Stainless Steel Prestressing Strands and Bars for Use in Prestressed Concrete Girders and Slabs, *Morgan State University*

- The goal of this project is to identify stainless steel manufacturers, in concert with SHA Office of Materials Technology and Office of Structures, Bridge Design Division, to

verify the material properties and other facts about the material to determine its feasibility and accessibility. A survey was administered to a cross-sectional group of consultants, practitioners, academics and other personnel. A literature review is in progress.

Optimal Bridge Retrofit Strategy to Enhance Disaster Resilience of Highway Transportation Systems, *Penn State*

- The goal of this project was to identify the optimal bridge retrofit technique(s) to enhance disaster resilience of highway transportation systems due to earthquake and flood hazards. A reinforced concrete bridge in the La Cienega-Venice Boulevard sector of Santa Monica (I-10) freeway in Los Angeles, California, was selected as the test bed bridge. This bridge was severely damaged during the 1994 Northridge earthquake primarily due to shear failure of one of the bridge piers.

  Finite element models of the bridge were developed to numerically simulate the damage scenario. Fragility curves, which represent the probability of bridge failure under certain intensity of earthquakes, were developed to represent seismic vulnerability of the bridge.

  Through modeling, the bridge was retrofitted with steel jackets to study the effect of bridge retrofit on seismic performance of the bridge. Results showed that seismic retrofitting of bridge piers with steel jackets could significantly improve bridge seismic performance. A cost-benefit analysis was also conducted and found that the benefit from seismic retrofitting is higher than the retrofit cost if the bridge can be serviceable for 30 to 50 years post retrofit.

Nondestructive Evaluation of Warm Mix Asphalt through Resonant Column Testing, *Penn State*

- The goal of this project was to determine if nondestructive resonant column testing could be used to characterize warm mix asphalt (WMA) properties. Researchers modified the specimen assembly systems for the resonant column tester through manufacturing of specialty platens and increasing the mass by manufacturing specialty brass wings to accommodate asphalt concrete samples rather than soil samples. A temperature control unit to control the temperature during testing was assembled and validated through trial testing. WMA concrete was tested to characterize its stiffness/damping. The equipment proved capable of producing results on resonant modulus of asphalt concrete, comparing different WMA additives.

  See http://www.mautc.psu.edu/projects/projectdetails.aspx?p=psu for the full report.

Urban and Suburban Safety Performance Functions, *Penn State*

- The objective of this research is to develop and implement state-specific Safety Performance Functions (SPFs) for differing functional classes in Washington State. Researchers created a detailed, comprehensive geometric database for the entire two-lane rural system and interim models have been developed. The interim models have been viewed as significant by the Washington State Department of Transportation technical

panel at a meeting in September 2013 and recommendations were made to continue the effort to completion with an implementable set of models.

Evaluating the Clearview Typeface System for Negative Contrast Signs, *Penn State*

- The objective of this project is to compare the legibility distance of the negative contrast Clearview Typeface System with that of Standard Highway Alphabets on regulatory signs in the daytime and nighttime with older and younger motorists.

Estimating the Post-Earthquake Capacity of Damaged Bridge Girders, *Penn State*

- An analytical residual capacity model has been developed and validated against the results of detailed finite element analyses and existing experimental data. A sensitivity analysis was performed on the analytical residual capacity model to understand which input factors the residual capacity estimation (i.e. model output) is most sensitive.

  The literature review yielded valuable experimental data that is being used to verify the capability of detailed finite element models for: (1) capturing the earthquake response and (2) capturing the residual gravity load carrying capacity. Furthermore, the literature review has yielded analytical models developed to predict the residual capacity of reinforced concrete columns failing shear. The research team will build upon these models to develop a unified model capable of estimating the residual capacity for flexure and shear type failures.

  The research team has used the results of the sensitivity analysis to simplify the analytical model for estimating the residual capacity of reinforced concrete columns for flexure and shear type failures.

  The improved analytical model will benefit state departments of transportation officials by providing a tool for the rapid post-earthquake assessment to support decision-making regarding the functionality of a bridge following an earthquake.

How Can We Maximize Efficiency and Increase Person Occupancy at Over-crowded Park and Rides, *Penn State*

- The purpose of this study is to perform a comprehensive assessment of several key park and ride facilities in the Central Puget Sound Region. A literature search has been conducted and an audit of the existing use of 10 facilities in the region to obtain estimates of person occupancy of parked vehicles. Findings from the audit indicate that lots are over-crowded and the person occupancy of most parked cars is very near one. The team designed, pre-tested and redesigned a survey that will be administered in the next period to determine key travel patterns and behaviors.

Potential Use and Applications of Reclaimed Millings, *Penn State*

- PennDOT District 1-5 has a shortage of high-quality available coarse aggregate and has developed the innovative procedure of breaking down and sorting recycled asphalt pavement (RAP) to recover the older high-quality aggregate for use. The focus of this project is to find uses for the remaining asphalt and fines such as an adapted fog/sand seal and cold-recycled asphalt leveling course.

  A state-of-the practice review, lab testing on samples of reclaimed millings was completed and the results were provided to PennDOT. A draft of the pilot project recommendations was completed and submitted to PennDOT for their consideration.

Robust Evacuation Planning with Optimal Shelter Location and Sizing, *University of Maryland*

- The goals of this project are to develop the necessary conceptual framework, mathematical models and algorithmic steps for determining the optimal location of shelters or other types of safe havens and required capacities to supplement existing emergency egress plans.

  Four stochastic programs were formulated, each of which recognizes uncertainty in the realization of potential emergency scenarios. Different scenarios may induce different behaviors or decisions to reduce risk exposure. For each approach, evacuees were either assigned to an exit or location of refuge and told which path to use to reach the location or to choose their own paths to exits or places of refuge chosen to minimize their own risk exposure. The benefits of, and relationships between, these approaches will be analyzed once run results have been obtained.

  This research makes a significant contribution to the state-of-the-art. A table was constructed to show the gap in current knowledge and how this work fills the gap. It is included in a manuscript that is being considered for publication.

Exploring the Linkages among Urban Form, Travel Behavior, and Health with Person-Level Data from Smart-Phone Applications, Phase II

- This project aims to realize the interaction between the built environment, travel behavior, and public health by the use of smartphone applications. Smartphone applications have been developed to collect subjects' complete activity data. The application automatically records data for long periods without user intervention. Information regarding general health, chronic conditions and dietary and other habits are recorded through a web-based health survey. The built environment characteristics of the immediate home and work locations of the travelers are measured using residential and employment densities, level of mixed use, street connectivity, and distance from the Central Business District (CBD). An urban score has been developed, low score indicating low-density suburban area and high score indicating high-density with well-mixed and pedestrian friendly neighborhood. These variables are combined with

information acquired from the health survey and trip variables such as mode, departure time and duration from the data from the application.

The data collected from the survey and the application would help understand whether there are significant differences between different groups with different socio-demographic characteristics, neighborhood of residence and general health. The impact of travel behavior and the urban form on an individual's health has been discussed for many years but the lack of appropriate data has stopped researchers from accurate conclusions. This research shall allow detailed data to be collected to test various hypotheses on the various effects of an individual's travel behavior.

Application of Variable Speed Limits in Recurrent Congestion, *University of Maryland*

- The goals of this project are to develop a variable speed limit (VSL) control algorithm for recurrent congestion applications; create a ramp metering control algorithm designed to supplement VSL control; establish planning and deployment guidelines for VSL or VSL paired with ramp metering; explore the conditions that warrant VSL or VSL combined with ramp metering; generate mobility and safety benefits models for VSL and VSL paired with ramp metering to be used for decision making and planning.

  During this reporting period, the VSL and ramp metering control algorithms were established. The creation of these control algorithms inherently led to the establishment of guidelines for both control strategies. Next, the study identified several critical factors that may influence the performance of these traffic control strategies. These factors were used to design an experiment testing a realistic range of values for each control variable. The full factorial experiment design was then used to create traffic scenarios to be created in a simulated environment. Each scenario was simulated under three control strategies (No control, VSL alone, and VSL with ramp metering). The results from these simulations were then used to calculate both safety and mobility performance measures for each scenario, under each control strategy. The initial results show that nearly all the simulated scenarios show substantial improvements in safety from the controlled strategies.

  Through this study, the team has developed a unique VSL control algorithm along with a supplemental ramp metering control algorithm using real-time data.

  If the developed models are used and the associated VSL and ramp metering strategies are implemented, the motoring public may reap benefits in terms of improved safety and reduced travel times in peak periods. These benefits may also be paired with reduced fuel consumption and emissions.

The Impact of Data Source on Travel Time Reliability Assessment, *University of Maryland*

- Traffic congestion and associated impacts such as air pollution pose major concerns to the public. While drivers are used to the daily congestion and plan for it, the unexpected change in travel time pattern causes dissatisfaction the most. This project supports

Travel Reliability of the Maryland SHA Business Plan and investigates the effect of data source on freeway travel time reliability assessment on a major corridor covering sections of I95 South, I495 West and I270 North.

Study results indicate that the reliability performance measures derived from the Bluetooth and INRIX data are significantly different from each other, when fifteen minutes time intervals are considered. By increasing the time interval, the difference of some measures (the mean, skewness statistics, and 85th and 80th percentile travel time measures) becomes less significant. In addition, based on this empirical study, measures like standard deviation, percent variation, width statistics, buffer index, and misery index are more sensitive to the data sources compared with measures like the mean, skewness statistics, PTI, 95th, 90th, 85th and 80th percentile travel time measures. Therefore, the measures that are less sensitive to the data source are desirable for performance evaluation purposes.

A technical report was submitted to the Maryland State Highway Administration and a presentation was given at the 2013 IRF World Meeting.

Integration of Multi-modal Public Transportation Systems, *University of Maryland*

- The goals of this project are: (1) to explore the number of actual trips generated based on transit fares and time factors such as in-vehicle time, waiting time, and access time, (2) to design elastic demand functions and welfare formulations for conventional and flexible bus services, (3) to solve complex optimization problems using a mathematical optimization technique (i.e., genetic algorithm), (4) to understand the impact of financial subsidies on demand and system performance, and (5) to disseminate research findings to the public (by means of journal publication).

  A relevant literature review has been conducted. Elastic demand functions, which are functions of fares and other time factors, were formulated for conventional and flexible bus services. The transit system welfare functions, which are the sum of supplier and consumer surpluses, were developed. Two constrained optimization problems were developed: (1) maximum social welfare objectives with service capacity constraints and (2) maximum social welfare objectives with service capacity and financial constraints. A solution method for solving complex optimization problems (in order to provide transit planning decisions) was developed. The developed models were evaluated through various numerical case studies.

  Preliminary findings indicate that when transit demand is sensitive, a social welfare maximization approach instead of a minimum cost objective is desirable. Transit planners can use the findings to decide what types of transit services are desirable and what fares should be charged for various transit services with given subsidy amounts.

Performance Evaluation of Damage-Integrated Girder Bridges, *University of Virginia*

- The primary objective of the proposed research is to create a framework for integrating the most common damage mechanisms into a measure of system performance and correlate impacts of damage on system reserve capacity and redundancy of routine highway bridges.

  The major activities to date have included the development of full non-linear models of two composite bridges that have been tested to failure. The numerical models were able to simulate the entire characteristic response of the test results and provided a justification for defining the ultimate system capacity of composite steel girder bridges. In addition to the full non-linear models, the project team has been successful in developing element-level models with damage features common to steel girder bridges. The damage modeling techniques have also been integrated in to the system models with success.

  The results from the integration of the damage into the system models have demonstrated numerically the significant reserve capacity available from this type of bridge, but have also demonstrated the influence that various damage mechanisms can have on the overall system performance including capacity and ductility reductions

  A key outcome from the current progress is that the project team has established a mechanism to define the remaining capacity (or reserved capacity) inherent to intact composite steel girder bridge systems. This represents an important finding considering the occurrence of recent bridge failures in the United States and serves as the foundation for understanding the remaining capacity of damaged structures.

  The project has been extended to August 31, 2014, to provide additional time for developing and refining the models.

Alternative Intersections Comparative Analysis, *Virginia Tech*

- The primary goal for this project is the development of a new methodology to analyze alternative intersection designs to be performed at the preliminary engineering stage of design. Making alternative intersections more readily analyzed at the preliminary engineering phase is a key step in expanding the implementation of these designs, increasing the safety and mobility of the surface transportation network.

  The literature search on eight intersection designs has been completed. A literature review for the three existing analysis methodologies has also been completed. A comparison of the Critical Sum method to HCM delay has been completed for conventional intersections and the geometric design of five alternative intersections has been done. The research team is working with researchers from Leidos, North Carolina State University, the University of Florida and Wayne State University to collect nationwide field data on the operation of alternative intersections.

Effects of Major Transportation Incidents and Disruptive Events, *Virginia Tech*

- Researchers are investigating the change in demand, the network performance, and the applicability of congestion mitigation strategies for three major incidents that occurred in the Northern Virginia area: (1) the 2009 Metrorail crash, (2) the 2011 earthquake, and (3) the 2012 crane collapse. The project will lead to better understanding of the similarities and differences between extraordinary disruptive events and more common incidents.

  Preliminary findings of the three incidents include: (1) the Metro crash did not cause a significant change in the traffic volumes on Interstate 66. The crash had a noticeable short-term effect on Metro ridership. The five Metro stations on the east leg of the line had the most percentage decrease in ridership in 2009, as the crash happened on that leg on the red line. (2) The impact of the earthquake is very different from that of the crane accident. The impact is mainly manifested via a congestion shift: the congestion occurred earlier than usual and the congestion occurred on more locations on I-95 South. (3) The impact of the crane accident is very similar to some common severe incidents during which multiple lanes are blocked. The crane accident caused severe congestion near the incident section on VA-267. From the INRIX data, there was no obvious impact of the crane accident upon adjacent major roads like VA-7 and I-66.

Investigate Attractiveness of Toll Roads, *Virginia Tech*

- The goal of this project is to develop a model to predict the percentage of traffic volume selecting toll roads over free roads in response to tolls to avoid congestion.

  Detailed traffic volume has been extracted from the original Washington DOT database for the route, SR167, for the years 2005 and 2008. Data has been obtained for the dynamic toll information on SR 167 as well for the same years. Data has been requested for the split of high occupancy vehicles (HOV) and single occupancy vehicles (SOV).

Winter Weather Demand Considerations, *Virginia Tech*

- Researchers are examining the effects winter weather has on travel demand. Specifically, the project involves developing a better understanding of the complexities associated with travel decisions during snow storms.

  IRB approval for the survey has been obtained the survey protocol has been finalized. Implementing the survey has been delayed due to switching to a phone-based approach to reduce costs. The survey is expected to be conducted in early 2014.

PRODUCTS

Submitted:

Chandrashekaran, S. and Banerjee, S. (2013). Retrofit Optimization for Resilience Enhancement of Bridges under Multihazard Scenario, *Journal of Structural Engineering*, ASCE.

Chandrashekaran, S. and Banerjee S. (2013). Retrofit Optimization for Resilience Enhancement of Bridges under Multihazard Scenario, *Journal of Structural Engineering* ASCE.

Faturechi, R., S. Isaac, E. Miller-Hooks and L. Feng. "Emergency Shelter Design for Geographic and Building Environments using Stochastic and Robust Optimization," in review for publication in the *European Journal of the Operational Research*.

Gheitasi, A. and Harris, D.K., "A Systematic Approach for Quantifying System Reserve Capacity of Redundant Composite Steel Girder Bridges", Structure and Infrastructure Engineering.

Gheitasi, A. and Harris, D.K., "A Performance-Based Framework for Bridge Preservation Based on Damage-Integrated System-Level Behavior". Transportation Research Board 93rd Annual Meeting, Washington, D.C.

Gheitasi, A. and Harris, D.K., "Effect of Deck Deterioration on Overall System Behavior, Resilience and Remaining Life of Composite Steel Girder Bridges". ASCE Structures Congress 2014 (Boston, MA)

Kramer, A.C., Ghasemi-Fare, O., and Basu, P. Laboratory thermal performance tests on a model heat exchanger pile in sand. Special issue of Geotechnical and Geological Engineering – Thermo-mechanical Response of Soils, Rocks, and Energy Geostructures, Springer, under review.

Liu, Y., and C. Cirillo (2013) "Measuring Transit Service Impacts on Vehicle Ownership Choices in U.S. Metropolitan areas".

Accepted:

Gayah, V.V. and Gao, X. (2013) The effect of adaptive green duration control on the Macroscopic Fundamental Diagram. *93rd Annual Meeting of the Transportation Research Board,* 12-16 January, Washington DC.

Gayah, V.V. and Dixt, V.V. (2013) Using mobile probe data and the macroscopic fundamental diagram to estimate network densities: Tests using micro-simulation. *92nd Annual Meeting of the Transportation Research Board,* 13-17 January, Washington DC.

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Ghasemi-Fare, O. and Basu, P. (2013). An annular-cylinder source model for heat transfer through energy piles. *Compendium of papers and technical presentation* in *92nd Transportation Research Board Annual Meeting*, Washington, D.C., January 13-17.

Ghanipoor S. and M. Abbas. Dynamic Driver's Perception of Dilemma Zone: Experimental Design and Analysis of Driver's Learning in a Simulator Study. Transportation Research Board Annual Meeting, Washington, DC, January 2014.

Ghanipoor S. and M. Abbas. Predicting Driver's Decision in Dilemma Zone in a Driving Simulator Environment using Canonical Discriminant Analysis. Transportation Research Board Annual Meeting, Washington, DC, January 2014.

Kramer, A. C. and Basu, P. (2014). Performance of a model geothermal pile in sand. *Physical Modelling in Geotechnics – Proceedings of the 8th International Conference on Physical Modelling in Geotechnics (ICPMG) 2014, v 2, pp. 771-777, Perth, Australia.*

Liu, Y., Tremblay J.M. and C. Cirillo (2014) "An integrated model for discrete and continuous decisions with application to vehicle ownership, type and usage choices". Presented at *93rd TRB Transportation Research Board*, Washington DC, January 2014 (under review for publication).

Nagle, A.S and Gayah, V.V. (2013) The accuracy of network-wide traffic state estimations using mobile probe data. *93rd Annual Meeting of the Transportation Research Board*, 12-16 January, Washington DC.

Olgun, C.G. and Bowers, G.A. (2013). Chapter 12: Ground-Source Bridge Deck Deicing Systems Using Energy Foundations. Energy Geostructures: Innovation in Underground Engineering, Eds. L. Laloui and A. DiDonna, Iste-Wiley, in press.

Sutman, M. and Olgun, C.G. (2013). Temperature Effects on Soil Behavior In Relation to Ground-Sourced Bridge Deck Deicing Systems. 92nd Annual Meeting of the Transportation Research Board, Washington, D.C. , January 13-17, 2013.

Presented/Published:

Asheesh Lanba, presenter and co-author. "NiTi-based SMAs for Self-Post-Tensioned Bridge Girders." American Society for Composites 28th Technical Conference, Sept. 9-11, 2013, The Pennsylvania State University, University Park, PA.

Asheesh Lanba, presenter "Martensitic Transformation Morphology and Tailoring Wide Hysteresis Shape Memory Alloys." Materials Science & Technology 2013, October 27-31, Montreal, Quebec, Canada.

Chen H., Rakha H., and McGhee C. (2013), "Dynamic Travel Time Prediction using Pattern Recognition," 20th ITS World Congress, Tokyo, Japan, October 14-18 [Paper: 4108].

Chen H. and Rakha H. (2014), "Agent-Based Modeling Approach to Predict Experienced Travel Times," Presented at the 93rd Transportation Research Board Annual Meeting, Washington DC, January 12-16, CD-ROM [Paper # 14-3851].

Chen H. and Rakha H. (2014), "Data-driven Particle Filter for Multi-step Look-ahead Travel Time Prediction," Presented at the 93rd Transportation Research Board Annual Meeting, Washington DC, January 12-16, CD-ROM [Paper # 14-0824].

Chen H. and Rakha H. (In press), "Real-time Travel Time Prediction using a Data-driven Particle Filter Approach," Transportation Research Part C: Emerging Technologies.

Elhenawy M., Chen H., and Rakha H. (In press), "Dynamic Travel Time Prediction using Genetic Programming" Transportation Research Part C: Emerging Technologies.

Faturechi, R., L. Feng, E. Miller-Hooks and S. Isaac. "Stochastic and Robust Optimization Approaches to the Design of Evacuation Systems in Buildings," presented at INFORMS, Minneapolis, October 2013.

Gayah, V.V. and Dixit, V.V. (2013) Using mobile probe data and the macroscopic fundamental diagram to estimate network densities. Accepted for publication in *Transportation Research Record*.

Ghasemi-Fare, O. and Basu, P. (2013). A practical heat transfer model for geothermal piles. *Energy and Buildings*, Vol. 66, pp. 470 – 479, Elsevier.

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Miller-Hooks, E., R. Faturechi, L. Feng and S. Isaac. "Emergency Shelter Design for Geographic and Building Environments using Stochastic and Robust Optimization," presented at the International Conference on Stochastic Programming, invited mini-symposium, Bergamo, Italy, July 2013.

Olgun, C.G., Abdelaziz, S.L., Martin, J.R. (2013). Long term performance of heat exchanger piles. Proceedings of CPEG 2013, Coupled Phenomena in Environmental Geotechnics, July 1-3, 2013, Torino, Italy.

Venkittaraman, A. and Banerjee, S. (2013). Enhancing Resilience of Highway Bridges through Seismic Retrofit, *Earthquake Engineering and Structural Dynamics*, DOI:10.1002/eqe.2392.

"Seismic Resilience of Highway Bridges:, MS Thesis by Mr. Ashok Venkittaraman, The Pennsylvania State University, University Park, PA, 2013.

Other products:

Abbas M. and S. Ghanipoor. Modeling the Dynamics of Driver's Dilemma Zone Perception Using Agent Based Modeling Techniques. Conference on Agent-Based Modeling in Transportation Planning and Operations, 2013.

Digital Instruction Modules for Transportation Engineering Overviewing the Fundamentals of How to Obtain Soil Properties in Practice, https://www.youtube.com/channel/UC70NDo0sFtxm0TMUlgvT40g

Conference on Agent-Based Modeling I Transportation Planning and Operations website, http://www.cpe.vt.edu/abmconf/

PARTICIPANTS AND COLLABORATORS

MAUTC is forging a strong relationship with the state departments of transportation within the region. Representatives from the Pennsylvania Department of Transportation (PennDOT), Maryland State Highway Administration (MSHA), Virginia Department of Transportation (VDOT)/Virginia Center for Transportation Innovation and Research (VCTIR) and West Virginia Department of Transportation are on the committee to review and select pooled projects for funding.

Nine collaborative research projects are currently underway with faculty and graduate student participation from two or more Center universities:

- A Feasibility Study of Bridge Deck Deicing Using Geothermal Energy – Penn State and Virginia Tech
- Drivers' Willingness to Pay Progressive Rate for Street Parking, Morgan State University and Virginia Tech
- Integration of Multimodal Transportation Services – Morgan State University, Penn State, and University of Maryland
- Modeling the Dynamics of Driver's Dilemma Zone Perception Using Machine Learning Methods for Safer Intersection Control – Virginia Tech, Morgan State University, Penn State
- Needs, Barriers, and Analysis Methods for Integrated Urban Freight Transportation – University of Maryland, Morgan State University, West Virginia University
- Smart Concrete Bridge Girders Using Shape Memory Alloys – University of Virginia, Penn State
- Structural Health Monitoring to Determine Long-term Behavior of AFRP Composite Bars in Pre-stressed Concrete Panels for Field Deployment – Morgan State University and University of Virginia
- Use of Probe Data for Arterial Roadway Travel Time Estimation and Freeway Medium-term Travel Time Prediction – Virginia Tech and University of Maryland
- Using Mobile Probes to Inform and Measure the Effectiveness of Macroscopic Traffic Control Strategies on Urban Networks – Penn State and Virginia Tech

Other partners and collaborators external to the MAUTC consortium include:

AECom, Inc.
Contribution: Personnel

Ben Gurion University of the Negev, Beer Sheva, Israel
Contribution: In-kind support

EdVenture Group, Morgantown, West Virginia
Contribution: Secondary Education expertise and curriculum certification; in-kind cost share

Israel's Homefront Command
Contribution: In-kind support

Maryland State Highway Administration, Hanover, Maryland
Contribution: Financial support

North Carolina State University, Raleigh, North Carolina
Contribution: Field data, in-kind support
Pennsylvania Department of Transportation
Contribution: Financial support; in-kind support

Science Applications International Corporation (SAIC), McLean Virginia
Contribution: Field data; financial support

The Maryland Oyster Advisory Committee
Contribution: Personnel

University of New South Wales, Sydney, Australia
Contribution: Collaborative research

University of Florida, Gainesville, Florida
Contribution: Facilitating work with the HCS software and the HCQS committee

Virginia Center for Transportation Innovation and Research, Charlottesville, Virginia
Contributions: Financial support; personnel; collaborative research

Wayne State University, Detroit, Michigan
Contributions: Data collection
West Virginia, Department of Transportation, Morgantown, West Virginia

IMPACT

- More high school students from rural areas will be exposed to engineering and related fields as a course of study through West Virginia University's PEER project. High

school students will have role models as WVU students who are from rural West Virginia mentor them in STEM fields. There will be an increase in the available workforce for application of STEM disciplines in transportation.

- More than 40 graduate students are involved in research projects which expose them to cutting edge research, and provide opportunities for them to increase understanding of transportation issues in the region and improve their skills of analyzing data and formulating solutions. Students are often working in multi-disciplinary teams, which increase their understanding of the complexities of transportation issues.

- Digital instructional modules on how to obtain soil properties developed by the University of Virginia will help to enhance transportation education by giving professionals a reference by which to learn or review the geotechnical tests that are used to classify soils. The videos can be used in the geotechnical discipline as a teaching tool for undergraduate students. The lab videos will increase the informational resources offered by the Transportation Training Academy (TTA) and the University of Virginia.

- The health monitoring of AFRP composite bars in prestressed concrete is enabling the training of engineers who will then be more knowledgeable and able to design and facilitate the construction of bridges with AFRP bars. Special knowledge in advanced concrete design and prestressed concrete designs is very important and necessary for the development of this research. The project has the potential to lead to commercialization of an anchorage system than can be used with these bars for bridge structures, which is the biggest challenge and opportunity.

- The benefits of evaluating waste concrete road materials for use in oyster aquaculture may enable the Maryland SHA to achieve their goal of taking waste materials and recycling them into environmentally responsible projects. This will reduce the need for landfill disposal of the material and allow SHA to participate in a project that will support the restoration of the Chesapeake Bay.

- Modeling driver's dilemma zone (DZ) perception expands the knowledge of transportation researchers on dilemma zone drivers' behavior and learning aspect. Improved modeling of driver definition and behavior in dilemma zone will have significant impact on the design of optimal control methods and the assessment of intersection safety. A graduate student and research associate are being trained on driver behavior, simulation, and agent-based modeling techniques. The new model will be embedded in VISSIM simulation through the use of external driver model dynamic link library (DLL). A workshop will be conducted in the next reporting period and will be instrumental in disseminating knowledge obtained in this project. Improved modeling of driver definition and behavior in DZ will have significant impact on the design of optimal control methods and the assessment of intersection safety. This will ultimately lead to safer intersection designs and can save lives. Furthermore, as this study is focusing on driver learning aspect, it sheds light on the benefits of training and educating drivers about DZ issues. This information could be applied to the driver education process when applying for a driver's license.

- By analyzing highway bridges under earthquake and flood hazards, the project combines various aspects of structural, transportation, hydrology and geotechnical engineering. Hence, the scope of the project is well aligned with the interdisciplinary nature of civil engineering. The project also dealt with probability, statistics and reliability. Through the cost-benefit analysis, the project has impacts on engineering economics.

- The research team has opened up a channel of communication with various stakeholders in the Baltimore area to listen to practitioners' thoughts on needs and barriers for integrated freight transportation. The mathematical models developed in this project are large-scale nonlinear or linear mixed integer programs. These are extremely difficult problems to solve and normally require intelligent solution techniques and heuristics. The solution algorithms developed for solving the complex formulations in this work can be applied to a number of real-world domains with location and routing decisions such as transit routing. Transportation costs comprise a significant component of the final commodity prices. Optimizing urban delivery systems can lead to reduced commodity prices and increased profit margins for the freight operators. An optimized urban freight system will also help alleviate congestion, emissions, and poor air quality related issues.

- The methods developed in the two-lane rural safety performance functions for Washington State DOT significantly aid the development of programs aimed at reducing fatalities and injuries on the highway system.

- Improved analytical models to estimate the post-earthquake capacity of damaged bridge columns will provide a tool for the rapid post-earthquake assessment to support decision-making regarding the functionality of a bridge following an earthquake.

- Students are being exposed to new methods of research, working in interdisciplinary teams, and learning to apply what they've learned in the classroom to solve complex transportation problems.

CHANGES/PROBLEMS

Nothing to report.