

# TranSearch

## DELAWARE CENTER FOR TRANSPORTATION

YOUR MAIN RESOURCE FOR TRANSPORTATION EDUCATION,  
RESEARCH & TECHNOLOGY TRANSFER

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Dare to be first.



**Delaware Center  
for Transportation**

**Department of Civil and  
Environmental Engineering**

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## 2013 Transportation Infrastructure Forum



Based on the overwhelmingly positive feedback from the more than 300 participants at the 2013 Transportation Infrastructure Forum, the event turned out to be a huge success. The forum was held at the University of Delaware's Clayton Hall where representatives from federal, state and local transportation agencies; private transportation companies and consulting firms; students, faculty and research staff from the University of Delaware and other academic institutions in the region, as well as a variety of civic groups actively participated in all of the day's events. Opening remarks were made by Delaware Governor Jack Markell, UD President Patrick Harker, DelDOT Secretary of Transportation Shailen Bhatt, DelDOT Director of Planning Drew

Boyce, and DelDOT Assistant Director of Planning Ralph Reeb. They praised the efforts of the Delaware Center for Transportation staff and UD faculty for having done an outstanding job in conducting quality research, technical training and public service for DelDOT and other transportation organizations in the region. Since the Forum also coincided with the 25th anniversary of the Center, the speakers noted this special occasion and expressed their unanimous support for the continuation of this joint cooperative effort. Dr. Ardeshir Faghri, Director of the Delaware Center for Transportation provided some quick facts and highlighted some of the major accomplishments of the Center including: the implementation of results-based research, completion

of 200 different technical training courses, the establishment with the UD Mechanical Engineering Department of the Zero-Emission Hydrogen Fuel Cell Bus program sponsored by the Federal Transit Administration, the establishment of a federally supported University Transportation Center, and the joint operation of the Center's many programs with the School of Public Policy & Administration. Since the Center's inception, nearly 200 undergraduate students, 120 Masters and 35 doctoral students have been involved with different center projects and have graduated and gone out to become transportation industry and academic leaders in the United States and abroad. On an annual basis, the Center sponsors a Research Showcase, a Principal Investigator/Project Manager meeting, hosts a series of Distinguished Guest Speakers from the United States and abroad, sponsors field trips for undergraduates, and publishes two newsletters, among other activities. Following the morning introductory session, Forum participants elected to attend one of the twelve break-out sessions which had been organized to reflect the different divisions within Transportation Infrastructure. These sessions were Aviation, Rail &



*State of Delaware,  
Governor Jack Markell*



*University of Delaware,  
President Patrick Harker*



*Delaware Transportation  
Secretary, Shailen Bhatt*



*Delaware Center for  
Transportation Director,  
Ardeshir Faghri*



Marine; Design; Construction, Pavement & Materials; Environment; Multi-Modal Safety; Traffic & ITS; Bridge & Structures; Administration & Government Policy; Transit & Public Transportation; Maintenance; Planning; and Local Issues. Each of the sessions included three moderators who helped guide the discussions and then delineate the most important issues within each session.

The afternoon luncheon speakers included Professors Willett Kempton and Ajay Prasad of the University of Delaware. Professor Willett Kempton is a faculty member in the School of Marine Science and Policy within the College of Earth, Ocean and Environment. He is also the Research Director of the Center for Carbon Free Power Integration. During his address, Professor Kempton spoke about two of his nationally and internationally recognized research projects related to transportation. The first was Grid-Integrated Vehicles (GIV), and the second was the Vehicle-to-Grid (V2G) Technology.

Regarding his GIV program, he noted that the flow of power in and out of an electric-drive vehicle can be valuable to the electric grid, but only if it is provided precisely when needed. Professor Kempton's research

team has developed a set of interacting technologies, policies, and market strategies to achieve this value, while meeting driving requirements of vehicle owners. Regarding his V2G research program, he noted that electric-drive vehicles, whether powered by batteries, fuel cells, or gasoline hybrids, have within them the energy source and power electronics capable of producing the 60 Hz AC electricity that powers our homes and offices. When connections are added to allow this electricity to flow from cars to power lines, we call it "vehicle to grid" power, or V2G. Cars pack a lot of power. One properly designed electric-drive vehicle can put out over 10kW, the average draw of 10 houses. The key to realizing economic value from V2G are grid-integrated vehicle controls to dispatch according to power system needs. Professor Kempton, at the conclusion of his speech, invited attendees to see one of his V2G vehicles which was parked right outside of Clayton Hall.

Dr. Ajay Prasad, who is a Professor of Mechanical Engineering and Director of the Fuel Cell Research Laboratory, spoke about his internationally renowned research related to the Hydrogen Fuel Cell Bus Program. The University of Delaware is currently operating two

22-foot, 22-seat transit buses with hydrogen fuel cell/battery hybrid powertrain. The University has equipped them with a comprehensive set of sensors and a data logging system, allowing detailed monitoring of all major components in the powertrain. They are used as part of the campus shuttle bus service, and for demonstrations and public outreach. In addition, they are used as a research platform to study new fuel cell system components and control strategies. Dr. Prasad also brought one of his Hydrogen Fuel Cell buses to Clayton Hall and invited interested parties to a free ride.

The forum concluded with a "wrap-up" session where all participants came together to get an overview of the most important issues that were discussed in each break-out session.

The identified problem statements and all the issues raised during each session will be published in a document by DCT staff and will be widely distributed.

All in all, the Forum provided an excellent environment for all interested parties to freely express their ideas about improving the transportation system in the State of Delaware and the surrounding region. ■



*Professor Willett Kempton speaks on Grid-Integrated Vehicles (GIV) and Vehicle-to-Grid (V2G) during lunch at the Transportation Forum*

## Message from the Director



**Ardeshir Faghri,  
Director**

*that we had been planning for the last two years took place on November 13, 2013, with all the components running smoothly and without any glitches. All the program participants including the companies that sponsored the Forum, the morning and afternoon keynote speakers, session moderators and student note-takers showed up on time and contributed greatly to the event. The 320 attendees consisted of students, staff and faculty from the University of Delaware and other academic institutions within the State of Delaware and other states; local, state, and federal*

### *January 2014*

*I would like to start my message by wishing all of our readers a happy and prosperous 2014. For DCT, 2013 ended on a high note. The Transportation Infrastructure Forum*

*government representatives; private companies and consulting firms; as well as civic group representatives. All expressed their respective opinions about improving the transportation system in our region. I would like to take this opportunity to express my gratitude to all those who contributed to the success of our Forum including:*

- *The morning and afternoon speakers: Delaware Governor Jack Markell, University of Delaware (UD) President Patrick Harker, Delaware Department of Transportation (DelDOT) Secretary Shailan Bhatt, DelDOT Director of Planning Drew Boyce, Assistant Director of Planning Ralph Reeb, and UD Professors Ajay Prasad and Willett Kempton.*

- *The moderators: Marcia Scott, Ralph Reeb, Jeff Reigner, Mark Luszczyk, Holly Rybinski, Adam Catherine, Mark Harbeson, Raymond Harbeson, Shilpa Mallem, Allan Zarembski, Bobbie Geier, Eugene Cipriani, Stephen Williams, Edward O'Donnell, Matheu Carter, Charles O'Donnell, Kelehiwot Manahiloh, Jennifer Pinkerton, Thomas*

*Clements, Silvana Croope, Adam Weiser, James Burnett, Lt. William Hargrove, Martin Wollaston, Cathy Smith, David Gula, B.J. DeCoursey, Patrick Kennedy, Tigist Zegeye, Jennifer McConnell, Jason Hastings, Joseph Volk, Paul Imhoff, Marianne Walch, Diane Calloway, Sue McNeil, Jason Arndt, and Alan Kercher.*

- *The note-takers: Chris Kelly, Eric Archibald, Dewan Hossain, John Cronin, Laura Graefe, Brittany King, Majid Talebi, Jeremy Rothwell, Kadir Ozden, Jessica Graham, Ali Shariati, Susan Yi, and Mosi London.*

- *And finally, the wonderful staff: Sandi Wolfe, Matt Carter, and Ellen Pletz deserve a great debt of gratitude for having gone out of their way to make sure all the programs in the Forum were conducted successfully.*

*The Forum is over and done with, but the Center continues to sponsor many interesting and useful programs. As always, please check our web site at <http://www.ce.udel.edu/dct/> for all DCT-related information.* ■

## ASHE Students Visit Fort McHenry Tunnel...and More

Once again, students from the American Society of Highway Engineers at University of Delaware (ASHE@UD) found time in their academic schedules to see some behind the scenes activities in the engineering world and network with practitioners in the First State Section of ASHE.

An early fall semester walk with Dr. Rusty Lee along Cleveland Avenue in Newark gave students a look at how UD graduate students and DelDOT work together to examine corridor congestion issues and develop short and long term solutions. In early November, students attended Punkin Chunkin (which raises money for scholarships and organizations that benefit youth and the local community) in Bridgeville,



*Prof. Rusty Lee leads ASHE Students to examine congestion issues along Cleveland Avenue*

a favorite among engineers. Towards the end of the semester, they were guests of a team of engineers at

the Maryland Transportation Authority for a tour under, over, and through the Fort McHenry Tunnel in Baltimore, Maryland.



*ASHE Students tour the Fort McHenry Tunnel*



But it wasn't all steel toed boots and safety vests. On a beautiful September day, students assisted First State Section with its annual golf outing at Back Creek (the proceeds of which support engineering scholarships). Students again attended First State Section's monthly



*ASHE students Dan Calabro & Claire McGinnis attend the Golf Outing*

dinner meetings and the Board of Director's meetings. December provided a true dress up opportunity with the ASHE Christmas Gala at the University of Delaware's Goodstay Center in Wilmington.

Between all this, they also found time to travel to Temple University and meet with students there who hope to form the second such student chapter of ASHE in the nation. And finally, they invited University of Delaware Vice President Alan Brangman to speak about long term plans for campus construction, transportation planning, and the challenges of construction logistics on the UD campus.

As the semester closed, their annual election of officers set the stage for the presidential gavel to be passed from Matthew Galenas to Paul Reutter who, together with Devyn Lozzi, Vybav Hiraesave, Benjamin Fisher, and



*UD's Vice President Alan Brangman speaks to the ASHE Students on the challenges of construction and transportation logistics on the UD campus*

Dana Aronowitz are now charged with coordinating a great set of site visits, speakers, and professional networking for 2014.

## Engineering Circuit Rider Assists Local Agencies

The Delaware T<sup>2</sup>/LTAP Center's Circuit Rider is a free resource for municipalities and other local agencies. Over the summer, the Circuit Rider oversaw engineering interns for Delaware City and Cecil County Public Works.

In Delaware City, Rob Harker was selected to inventory and assess the condition of pavement, curbs, sidewalks, curb ramps, and signs throughout the city as part of their goals to advance asset management and provide a framework for updates to the business district and other areas. Rob's organized and diligent approach resulted in great data and graphical deliverables for the city that will be great tools as they take the next steps in managing their transportation assets.

In Cecil County, the T<sup>2</sup>/LTAP Center assisted Public Works in finding Alexandra Rioux, a Master's student in structures, to inventory and assess their small bridge structures and she turned out to be a perfect match for their need. We also helped their Roads Division find Benjamin Fisher, an undergraduate engineer; the Circuit Rider trained Ben so that he could inventory and assess traffic signs along Cecil's 600+ mile rural network.

Meanwhile, the City of Harrington asked for help with its pavement management and the Circuit Rider began a pavement distress evaluation in the fall. By this spring, we should be able to deliver a comprehensive status of pavement distress for all of the city-maintained streets.

Our 2009 asset inventory work in Milton resurfaced with some follow up questions and the Circuit Rider provided information and analysis to assist them going forward.

Finally, in Lewes, the Circuit Rider finished up work on two efforts requested earlier last year (all-way stop conditions and speed zones) and also acted as liaison with DelDOT on a pedestrian signal concern.

These are just a few examples of how the Delaware T<sup>2</sup>/LTAP Center's Circuit Rider can assist municipalities and other local agencies. If you think your agency might benefit from this free resource, contact Matt Carter at (302) 831-7236 or at [matheu@udel.edu](mailto:matheu@udel.edu) and he'll be happy to come meet with you to better understand your challenges and goals.



# IPA Publishes Two Curbside Intercity Bus Industry Reports

"Bolt for a Buck!" This slogan for BoltBus, a leader in the new curbside intercity bus industry, epitomizes the hype behind the low-cost, yield-management pricing strategy that appeals to cost-conscious travelers. A combination of cheap fares, yield-management pricing, convenient point-to-point travel, on-board WiFi, and modern marketing has contributed to the appeal and popularity of the new curbside intercity bus industry. This mode of travel is especially popular among the Millennial generation who own fewer cars and drive less than their predecessors. With over seven million passengers in 2011, and 7.5 percent growth between 2011 and 2012, the industry represents the fastest growing mode of transportation in the United States—outpacing air and rail.

The Institute for Public Administration (IPA) at the University of Delaware (UD) has released two reports that focus on transportation policy issues related to the unprecedented growth of the industry. Published in August 2013, ***Curbside Intercity Bus Industry: Transportation Opportunities and Challenges*** highlights issues stemming from the deregulation of the

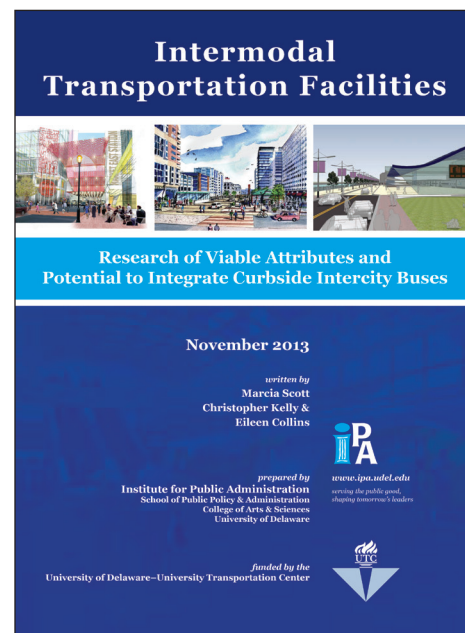
industry, its unprecedented growth, and its fragmented regulatory environment.

Curbside intercity buses are characterized as those that generally do not operate from bus terminals, arriving and departing from designated curb locations along city streets. The industry began in the late 1990s when Chinese immigrants began offering low-cost service between major Chinatown neighborhoods in the Northeast Corridor (NEC). Low fares began to attract new riders and other major bus companies began to capitalize on the success of Chinatown carriers. Today the industry can be divided into two main categories—Chinatown (non-corporate) operators and corporate carriers like BoltBus, Megabus, and DC2NY.

Along with the growth of the industry came major transportation policy problems. Loading and alighting of passengers on busy streets has created curbside management issues for cities. High-profile accidents have also heightened concern for safe motorcoach operations. In 2011, eight serious motorcoach crashes resulted in 28 occupant fatalities. Unethical operators have blemished the industry by operating unsafely to cut costs, changing identities to evade enforcement, and using brokers to sell tickets for travel on buses with questionable safety records. Despite the passage of the Commercial Motor Vehicle Safety Act of 2012, within Moving Ahead for Progress in the 21st Century (MAP-21) legislation, IPA's report highlights significant challenges and opportunities that need to be addressed to sustain the growth and resiliency of the industry. Effectiveness of policies and regulations are dependent upon sufficient federal funding and resources, multi-jurisdictional coordination, effective enforcement of safety regulations, and consumer outreach and education.

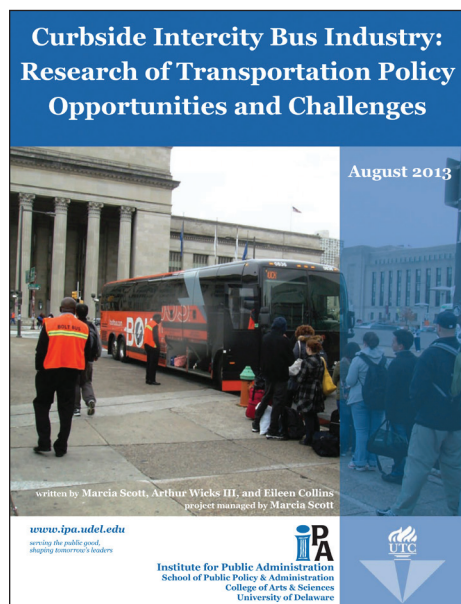
Follow-up on several topics of research was suggested, including the need to plan for and invest in intermodal transportation facilities that serve and facilitate connections among all modes of transportation. A November 2013 publication by IPA, ***Intermodal***

***Transportation Facilities: Research of Viable Attributes and Potential to Integrate Curbside Intercity Buses,***



explores this topic. While barriers to intermodalism exist, report findings suggest that development and investment in intermodal facilities—that include curbside intercity buses—will promote a more integrated and sustainable transportation system.

The University of Delaware's University Transportation Center (UD-UTC), whose theme was resiliency of transportation corridors, supported IPA's research. IPA Policy Scientist Marcia Scott lead the research endeavor, authored both reports, and presented findings at Session 834, ***"Intercity Buses from the Heartland to the Big City,"*** at the Transportation Research Board's 93rd Annual Meeting in Washington, D.C. in January 2014. Other research team members and co-authors include former UD-UTC Fellows Arthur Wicks (MPA '12) and Eileen Collins (MA '13), and IPA Graduate Public Administration Fellow Christopher Kelly (MPA '14). Both reports may be downloaded from IPA's website at: [www.ipa.udel.edu/publications/transportation.html](http://www.ipa.udel.edu/publications/transportation.html).



# IPA Launches Online Delaware Complete Communities Planning Toolbox

The Institute for Public Administration (IPA) at the University of Delaware has launched the **Delaware Complete Communities Planning Toolbox** on its existing Complete Communities website (completecommunitiesde.org).

The online *Toolbox* is designed to build local government's capacity to develop complete-communities planning approaches, implementation tools, and community engagement strategies. *Toolbox* resources will help communities plan for and manage growth, consider benefits of better community design, spur reinvestment in older communities, protect natural and environmental resources, understand the connection between land-use and transportation planning, promote placemaking as an economic development strategy, combat sprawl, and make more efficient use of limited funds for growth-related needs. *Toolbox* content will continue to be crafted and updated to advance the complete-communities policy framework.

An introduction to the *Toolbox* is provided on the **Getting Started** page. The **Planning Tools** section comprises the five elements of a complete community (Complete Streets, Efficient Land Use, Healthy & Livable, Inclusive & Active, and Sustainable & Resilient) and describes a variety of land-use and transportation planning tools and techniques available for use by Delaware local governments.

The **Community-Design Tools** section provides community-design strategies that move toward an "architecture of place." The visually-oriented section features the *Complete Communities, Designing Better Places Video Series* that is adapted from the American Planning Association (APA) award-winning series, produced by the North Carolina Department of Commerce Division of Community Assistance.

The **Public-Engagement Tools** section explains the need to incorporate "high-tech and high-touch"

community engagement approaches. It includes case-study examples from planning organizations in the region.

Policy Specialist Sarah Pragg designed the *Toolbox*, which features a viewer-friendly format with scrolling banner, YouTube videos, and other interactive content.

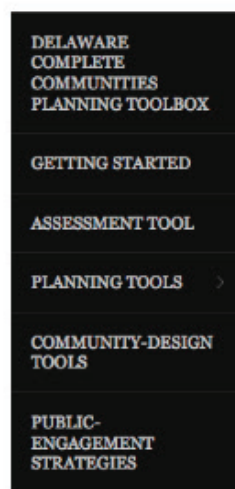
Content development was a cooperative venture among IPA Policy Scientist Marcia Scott; Policy Specialist Ted Patterson; graduate Public Administration Fellows (PAFs) Tyler Berl (MA '14), Jessica Graham (MA '14), Jeremy Rothwell (MA '14), and Alexa Scoglietti (MA '14); and undergraduate PAFs Elizabeth Catt (BA '15) and George Weiler (BA '13).

The production and design of the website was made possible by funding from the Delaware Department of Transportation in partnership with the Delaware Office of State Planning Coordination.

## Complete Communities DELAWARE Project Site

attractive, inclusive, efficient, healthy & resilient places

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# Research

Following are the projects funded for our FY14 Annual Research Program. The start date is based on when the notices to proceed are issued by the Delaware Department of Transportation.

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## REHABILITATION OF FATIGUE-CRACKS IN STEEL BRIDGES: EVALUATION OF FATIGUE-CRACKS IN THE FIELD AND LABORATORY TESTING

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This project aims at creating a new holistic strategy to rehabilitate and monitor these problematic areas. Field measurements to determine actual experienced strain will be performed combined with laboratory experiments to evaluate solution strategies.

### Principal Investigators:

Thomas Schumacher, Jennifer McConnell and Erik Thostenson, Departments of Civil and Environmental Engineering and Mechanical Engineering

### Project Manager:

Barry Benton, Bridge Management

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## DEVELOPMENT OF A STATEWIDE TRAVEL SPEED SURVEY

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This research seeks to substantially improve statewide travel speed and travel time monitoring by considering a range of data sources while also creating a statewide data set to meet immediate performance measure needs, respond to concerns, support policy decisions, and evaluate impacts of growth and effects of remedial actions.

### Principal Investigator:

David Racca, Center for Applied Demography and Survey Research

### Project Manager:

Mark Eastburn, Division of Planning

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## AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS – PILE DOWNDRAG DESIGN PROVISIONS

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This project focuses on assessment of the new AASHTO LRFD bridge design specifications for pile downdrag, and the associated implications for the design of future deep foundation projects in the State of Delaware.

### Principal Investigator:

Chris Meehan, Department of Civil and Environmental Engineering

### Project Manager:

Jason Hastings, Bridge Design

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## RESEARCH TO INTEGRATE MASTER PLANS WITH THE LOCAL DEVELOPMENT APPROVAL PROCESS

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This project will research best practices and set forth strategies to integrate local government master plans with local government processes to attract developers to “market-ready” sites. Research outcomes will be summarized in a downloadable and user-friendly “how-to guide” for Delaware local governments.

### Principal Investigator:

Marcia Scott, Institute for Public Administration

### Project Manager:

Ralph Reeb, Division of Planning

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## DELAWARE TRANSPORTATION LIGHTING INVENTORY AND ASSESSMENT

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Lighting infrastructure needs will be inventoried and assessed in selected areas in Delaware that feature multiple modes of transportation and motorized and non-motorized transportation routes. The inventory will consist of mapping formal and informal lighting stock within a given geographical area to determine target areas for enhancement. The research will result in a compilation of lighting policies for areas within Delaware.

### Principal Investigators:

Martin Wollaston and Ted Patterson, Institute for Public Administration

### Project Manager:

Ralph Reeb, Division of Planning

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## INTEGRATING ZERO-VALENT IRON AND BIOCHAR AMENDMENTS IN GREEN STORMWATER MANAGEMENT SYSTEMS FOR ENHANCED TREATMENT OF ROADWAY RUNOFF – PHASE II

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This continuing project will evaluate two technologies involving the addition of biochar and/or zero-valent iron to existing and new stormwater facilities which will reduce nutrients from DelDOT stormwater discharges.

This phase will be the field demonstration.

### Principal Investigators:

Dan Cha and Paul Imhoff, Department of Civil and Environmental Engineering

### Project Manager:

Marianne Walch, Maintenance and Operations

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## FY14 GPS TRAVEL TIME AND DELAY DATA COLLECTION AND ANALYSIS

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This project entails data collection during peak travel times on roadway segments throughout the state. Each segment will be traveled at least four times for maximum accuracy. Once data collection is completed, data will be transformed into the GIS database and transported to the ARCGIS software.

### Principal Investigator:

Arde Faghri, Department of Civil and Environmental Engineering

### Project Manager:

Mark Eastburn, Division of Planning

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## DEVELOPMENT OF CAPACITY ADJUSTMENTS FOR ADAPTIVE CONTROL SYSTEMS

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This research will compare data on current practices around the country and compare this to conditions along Delaware roads to see if the computed capacities compare to observed behavior. Comparing predicted behavior with data from the Traffic Management Center, this research will further develop the “true” capacity for a segment.

### Principal Investigator:

Rusty Lee, Department of Civil and Environmental Engineering

### Project Manager:

Gene Donaldson, Transportation Management Center

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## FY14 DELAWARE SIGNAL TIMING ENHANCEMENT PARTNERSHIP (DSTEP), CORRIDORS 7 & 8

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The goals of the DSTEP project are to involve students in traffic engineering services for DelDOT, to develop a continuous research program that addresses DelDOT’s needs while minimizing the use of DelDOT’s resources, and to maintain a high level of quality so that DelDOT may apply the results to improve intersection operations across the state.

**Principal Investigator:**

Rusty Lee, Department of Civil and Environmental Engineering

**Project Manager:**

Gene Donaldson, Transportation Management Center

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**FY14 LAB BASELINE SERVICE**

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The objectives of this project are to establish the Delaware Center for Transportation ITS Lab as a state of the art facility with three main focus areas: 1) service to DelDOT; 2) training for DelDOT and support classroom instruction; and 3) research for faculty and students.

**Principal Investigator:**

Rusty Lee, Department of Civil and Environmental Engineering

**Project Manager:**

Gene Donaldson, Transportation Management Center

## CONTINUING ACTIVE RESEARCH PROJECTS SPONSORED BY DELDOT

*As each project is completed, a final technical report will be available on the DCT website: <http://www.ce.udel.edu/dct>.*

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**INCREMENTAL PARK AND RIDE DEMAND MODEL**

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The objectives of this research project are to develop a model to estimate the number of incremental parking spaces required as a result of proposed residential or commercial development for railway and bus-based park & rides. Ending 8/31/14

**Principal Investigator:**

Bintong Chen, Lerner College of Business and Economics

**Project Manager:**

Cathy Smith, Delaware Transit Corporation

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**REVIEW OF EXISTING PAVEMENT CONDITION RATING SYSTEM**

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This project will analyze the accepted level of variation among the various measurement methods. This would allow the agency to switch between methods (and vendors) with more confidence that the results are valid. Ending 8/31/14

**Principal Investigator:**

Nii Attoh-Okine, Department of Civil and Environmental Engineering

**Project Manager:**

Jennifer Pinkerton, Materials and Research

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**PAVEMENT MARKINGS AND SIGNING TO SUPPORT SENATE BILL 120**

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The various treatment options and signing to assist with safer bike lanes and intersections as mandated by state code will be evaluated through a survey instrument and test sites. Ending 8/31/14

**Principal Investigator:**

Rusty Lee, Department of Civil and Environmental Engineering

**Project Manager:**

Mark Luszcz, Traffic Management Center

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**EVALUATION OF SMART GROWTH DEVELOPMENT PATTERNS AND EFFECTS ON TRANSPORTATION**

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This project will identify and evaluate the effects of: 1) alternate locations in Delaware for hypothetical residential and mixed-use communities, and 2) alternate street forms and interconnectivity levels for these hypothetical communities in Delaware. Ending 8/31/14

**Principal Investigator:**

Rusty Lee, Department of Civil and Environmental Engineering

**Project Manager:**

Mike DuRoss, Division of Planning

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**VERIFICATION OF DESIGN OF A NOVEL MECHANICALLY STABILIZED EARTH (MSE) WALL AT THE CHRISTIANA INTERCHANGE**

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During the construction of the Christiana Interchange, instrumentation donated by an Italian company will be utilized in an abutment to measure readings which will help DelDOT with future designs and specifications. Ending 7/31/15

**Principal Investigator:**

Dov Leshchinsky, Department of Civil and Environmental Engineering

**Project Manager:**

Barry Benton, Bridge Management

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**ABANDON, REPAIR OR IMPROVE ROADS IN THE FACE OF CLIMATE CHANGE?**

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The objective of this research is to provide DelDOT with a defensible strategy for determining whether to

maintain road repeatedly damaged by flooding and to develop decision trees to quantify systematically the impacts of the decision to abandon, repair or improve a road given the uncertainty associated with climate change. Ending 8/31/14

**Principal Investigator:**

Sue McNeil, Civil and Environmental Engineering

**Project Manager:**

Rob McCleary, Chief Engineer

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**CAPACITY OF REINFORCED CONCRETE MOMENT FRAME CULVERTS**

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This research project will assess the latest bridge analysis procedures and conduct full-scale laboratory experiments to develop a new evaluation methodology specifically for concrete moment frame culverts. Ending 8/31/14

**Principal Investigator:**

Thomas Schumacher, Department of Civil and Environmental Engineering

**Project Manager:**

Ping Jiang, Bridge Management

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**FY13 DELAWARE SIGNAL TIMING ENHANCEMENT PARTNERSHIP (DSTEP)**

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The goals of the DSTEP project are to involve students in traffic engineering services for DelDOT, to develop a continuous research program that addresses DelDOT's needs while minimizing the use of DelDOT's resources, and to maintain a high level of quality so that DelDOT may apply the results to improve intersection operations across the state. Ending 2/28/14

**Principal Investigator:**

Rusty Lee, Department of Civil and Environmental Engineering

**Project Manager:**

Gene Donaldson, Transportation Management Center

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**FY13 LAB BASELINE SERVICE**

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The objectives of this project are to establish the Delaware Center for Transportation ITS Lab as a state of the art facility with three main focus areas: 1) service to DelDOT; 2) training for DelDOT and support classroom instruction; and 3) research for faculty and students. Ending 8/31/14

**Principal Investigator:**

Rusty Lee, Department of Civil and Environmental Engineering



**Project Manager:**

Gene Donaldson, Transportation Management Center

**FY13 TRAVEL DEMAND MODELING SUPPORT**

Support for this project will assist DeIDOT with the development, maintenance, application and evaluation of a travel demand forecasting model. The model supports planning studies for Delaware's MPOs and various DeIDOT sections on an as-needed basis. Ending 8/31/14

**Principal Investigator:** Rusty Lee, Department of Civil and Environmental Engineering

**Project Manager:**

Mike DuRoss, Division of Planning

**BASELINE MONITORING AND TESTING OF THE INDIAN RIVER INLET BRIDGE (IRIB)**

This project is phase 2 of the long-term structural health monitoring (SHM) system on the Indian River Inlet Bridge. These funds will be used to conduct various baseline tests, studies, and analyses to characterize the baseline performance of the bridge as a permanent record for the future. DeIDOT will be able to understand how the as-built bridge is functioning

and through long-term monitoring, will be in a better position to efficiently and effectively manage this significant resource. Ending 6/30/2014

**Principal Investigators:**

Tripp Shenton and Michael Chajes, Department of Civil and Environmental Engineering and College of Engineering

**Project Manager:**

Barry Benton, Bridge Management

## V2G partnership UD, Honda partner on vehicle-to-grid technology



UD's Willett Kempton with a Honda Accord Plug-In Hybrid.

Honda has joined a demonstration project for experimental vehicle-to-grid (V2G) technology aimed at providing a potentially valuable energy storage resource to the nation's electrical grid while providing for more cost-effective ownership of plug-in electric vehicles.

The Honda technology builds off of the research conducted by the University of Delaware and now supported by NRG Energy Inc.

NRG and UD, through their V2G joint venture, came online early in 2013 with the world's first revenue-generating vehicle-to-grid project, demonstrating the controls, regulatory requirements and market

participation rules for selling energy storage from vehicles into the PJM Interconnection Regulation Market.

Honda is supplying an Accord Plug-In Hybrid with added V2G capabilities to the University's Science, Technology and Advanced Research (STAR) Campus to jointly investigate the potential of this technology to benefit the electrical grid, vehicle owners and society.

"The participation of global automakers like Honda will help demonstrate and refine the technology," said Willett Kempton, professor in UD's College of Earth, Ocean, and Environment and research director of the University's Center for Carbon-Free Power Integration. "The University of Delaware has been developing the technology so that vehicle batteries can be used not only for mobility but also for grid services. It is a big step toward a future with widespread availability of the technology to have Honda join our demonstration with their V2G-capable car."

"This technology has the potential to support both a cleaner and more efficient power grid and a more positive ownership experience for EV customers," said Steven Center, vice president of the Environmental Business Development Office of American Honda Motor Co. Inc. "With V2G technology, a network of PEVs (plug-in electric vehicles) becomes essentially a distributed energy storage system. It makes for an even stronger value equation for plug-in vehicles, with benefits for both the community and the vehicle user."

Using smart grid technology, the V2G system is able to monitor the status of the grid to determine whether the grid requires additional power sources that can respond rapidly, or the grid requires power demands that can absorb transitional power supply.

Such a system has the potential to reduce or eliminate the fluctuation of the grid, which can occur more frequently when renewable energy

sources are introduced to the grid. Electric vehicle owners potentially benefit from supporting a more stable power grid, which can lead to reduced utility costs for the vehicle owner.

"As the U.S. adds more intermittent resources to the grid, finding a lower cost energy storage technology that also benefits electric vehicle drivers is a great opportunity," said Denise Wilson, NRG executive vice president and president, New Businesses. "We see this demonstration by Honda as an important step in the development of vehicle-to-grid technology."

The demonstration is conducted in the area served by PJM Interconnection, which controls electricity supply in 13 states and the District of Columbia.

About UD's College of Earth, Ocean, and Environment

UD's College of Earth, Ocean, and Environment (CEOE) strives to reach a deeper understanding of the planet and improve stewardship of environmental resources. CEOE faculty and students examine complex information from multiple disciplines with the knowledge that science and society are firmly linked and solutions to environmental challenges can be synonymous with positive economic impact.

The college brings the latest advances in technology to bear on both teaching and conducting ocean, earth and atmospheric research. Current focus areas are ecosystem health and society, environmental observing and forecasting, and renewable energy and sustainability.

### About Honda

Honda is a leader in the development of leading-edge technologies to improve fuel efficiency and reduce CO2 emissions. Honda has led the Union of Concerned Scientists (UCS) rankings of

overall vehicle environmental performance since 2000, and a Honda vehicle has topped the list of America's greenest vehicles from the American Council for an Energy-Efficient Economy (ACEEE) for 11 out of the past 12 years. In 2006, Honda became

the first automaker to announce voluntary CO2 emissions reduction targets for its global fleet of automobile, power sports and power equipment products and its global network of manufacturing plants. In 2011, the company set a new CO2

emission reduction targets for 2020, including a 30 percent reduction in CO2 emissions from its products compared with 2000 levels.

## Capacity of Reinforced Concrete Moment Frame Culverts

With an inventory of around 300 in the State of Delaware, reinforced concrete moment frame culverts (RCMFC) comprise a crucial element of the state's transportation infrastructure. In order to comply with highway bridge code regulations related to the load which these structures can handle, bridge engineers use computer models and load rating software to determine if all legal trucks can pass across safely. If not, the Delaware Department of Transportation (DelDOT) is required to post the structures that don't pass so that larger trucks are prohibited from crossing. One of the challenges that bridge engineers have been facing lies in the modeling assumptions regarding a special reinforcing bar detail (Rebar 'A') commonly used when these structures were built in the 1940s. Often, the contribution of the corner rebar is neglected

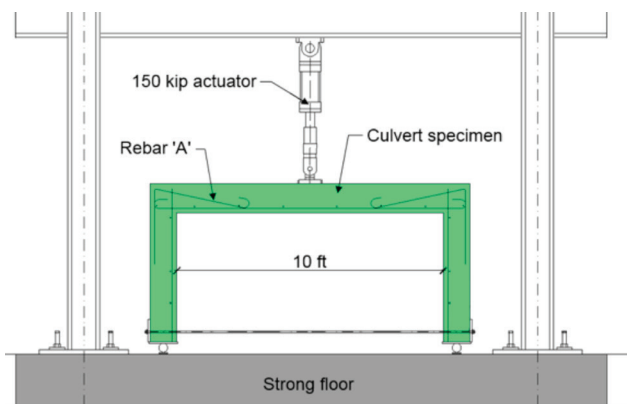
which results in insufficient capacity to carry all legal loads. In the field, however, these structures perform very well overall and have not caused problems in the past.

Dr. Thomas Schumacher, an Assistant Professor in the Department of Civil and Environmental Engineering, is investigating if the current load rating procedures used by the agency are overly conservative by combining experimental and analytical research to develop a new evaluation

methodology suitable for Delaware's RCMFCs. Dr. Schumacher's research is in the area of inspection, monitoring, and maintenance of civil infrastructure. He and his research team just recently finished an experimental testing program on five full-scale RCMFCs in the Structures Laboratory on the UD campus. The specimens were modeled after existing RCMFCs and designed to include the special detail. Each specimen was loaded in a different configuration in order to determine the behavior and ultimate capacity of these structures.

The test results are still being analyzed, but preliminary findings indicate that the special reinforcing detail performs satisfactorily with respect to strength and its contribution should be included when the total capacity of an RCMFC is calculated.

The benefits of this research project include better knowledge of the behavior and actual capacity of RCMFCs with this type of corner reinforcing detail. More accurate capacity predictions will ensure that DelDOT postings are assigned on an objective and consistent basis.



*Photo 1 shows Dr. Schumacher and his graduate student Tim Porter looking for cracks in the corner. All cracks are marked to document the progression of cracking with increasing loads.*



*Photo 2 shows a culvert specimen during testing with the DelDOT bridge engineers Ping Jiang and Jason Arndt (far left and far right, respectively).*



*Photo 3 shows the first culvert specimen when it failed. This occurred when the hydraulic actuator reached a force of 58 kips.*



# Research Pays Off: Traffic Sign Recognition using Sparse Representations and Active Contour Models

ADU-GYAMFI YAW OKYERE AND NII ATTOH-OKINE

*Adu-Gyamfi Yaw Okyere, Graduate research assistant, Department of Civil and Environmental Engineering, University of Delaware.*

*Nii Attoh-Okine, Professor, Department of Civil and Environmental Engineering, University of Delaware.*

Automated traffic sign recognition remains an integral component of road sign inventory programs administered by transportation agencies. However, current practices for traffic sign recognition are labor-intensive and time-consuming. This research presents a novel traffic sign recognition algorithm that can be integrated into the traffic sign management systems of infrastructure managers. The methodology proposes the use of a multiscale principal component pursuit (mPCP) for traffic sign location detection by decomposing each video frame into a background (captures trees, cars, illumination, etc.) and foreground image (captures traffic sign information).

## PROBLEM

The need for developing reliable traffic sign recognition (TSR) systems has received much attention in recent years for various important reasons. Infrastructure managers frequently take an inventory of traffic signs to evaluate their conditions. This aids transportation agencies to make useful decisions regarding safety of drivers and pedestrians. The increasing development of intelligent and automated vehicles or driver guidance systems is also one area that fuels the design of robust features for accurate detection and interpretation of traffic signs. Traditional methods of traffic sign recognition is carried out by manually reviewing video-log images. However, this approach is time-consuming and costly for network level evaluations.

## SOLUTION

The application of image processing and artificial intelligence technology is becoming a more popular technique due to its robustness, speed and practicability. This research develops a complete vision system for automating traffic sign recognition from video-logs. The achievement of this research covers two key areas of TSR: traffic sign location and sign boundary extraction. The challenge of locating traffic signs in an image is solved by a multiscale principal component pursuit (mPCP) approach. The mPCP provides a distinct separation between the background (captures trees, cars, pedestrians, etc.) and foreground (capturing traffic sign information) component of each video frame. The mPCP also reduces the effect of lighting variation on the

detection process by collating it in the background image. Contributions of this work are in two fold. First, the introduction of sparse representations for background separation and traffic sign detection is new to the field. Second, a unique method for the application of active contour models for road sign boundary extraction is presented. The present study resolves limitations of recent applications and improves practical application of the algorithm through automatic initialization of active contours.

## METHODOLOGY COLOR SEGMENTATION

Color segmentation is a very important step required for TSR. In this work, the relationship between RGB components is used to segment each image into its component color channels. The sensitivity of RGB colors to light variation is noted.

## ROAD SIGN DETECTION

This step looks at how to discriminate between a candidate road sign and the image scene background. Two main procedures are used: multiscale image decomposition and sparse representations.

- Step1: Multiscale Image Decomposition (MID). The goal of MID is to enhance trend-like (dominant) features in the foreground while blurring out non-salient information.
- Step2: Sparse Representation. Uses Principal Component Pursuit to separate background information from original scene. This enables us to detect the location of road sign in the image scene.



Figure 1. Background separation results for selected scenes.

## MULTISCALE PRINCIPAL COMPONENT PURSUIT (MPCP)

The mPCP uses multiscale image decomposition and sparse representation of images for image scene understanding. As explained in the preceding section, multiscale image decomposition improves the scene contrast by removing components capturing scene illumination. The PCP will then take the resulting image and begin the background separation process. Each scene is considered as a superposition of a low-rank component and a sparse component. The sparse component captures the linear patterns in the scene's foreground (traffic sign), while the low-rank component corresponds to the background information (background-trees, cars, pedestrians, etc.). Figure 1 presents sample results of the application of the mPCP for scene background subtraction and traffic sign location detection.

- Define contour location on image (Contour initialization): The effectiveness of active contour models is dependent on the initial location of the contour on the image. Thus, if the contour is far away from the location of the road sign, accurate boundary description may not be achievable. The contour may not be attached to the traffic sign when maximum number of iterations is reached. Also, to improve system speed, it is important to find an automated means of initializing the contour within the vicinity of the traffic sign. So far, there is no automated way of doing this. Figure 3 presents sample results of using the methodology developed.

## APPLICATION

The proposed methodology was implemented and tested with video-log data from an urbanized area in Newark, Delaware. Evaluation of the proposed methodology was conducted using video-log data. The performance of the system developed is tested against the Canny and Hough based TSR algorithms. The test results indicate that the mPCP-Active Contour based TSR algorithm remarkably outperforms the selected benchmark algorithms with the highest detection rate (92.6%) and precision (87.2%). This demonstrates the potential for practical application of the proposed methodology in reality. At the current stage, this system can be used by

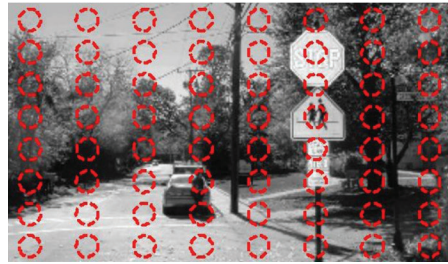


Figure 2. Contour types.

transportation agencies by integrating it into their sign inventory programs. Overall, the system offers a safe, fast and effective methodology for TSR.

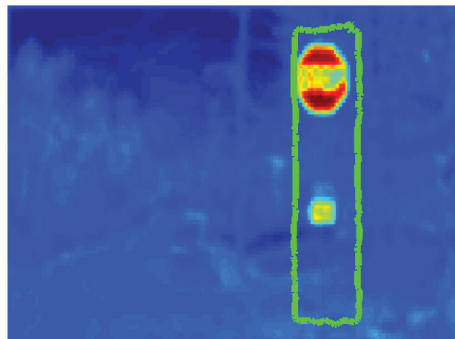
## TECHNICAL BENEFITS

The active contour models show promise in detecting different types of traffic signs in very noisy environments. Their ability to split and match different topologies of the image data is essential for accurate sign location and shape detection. The

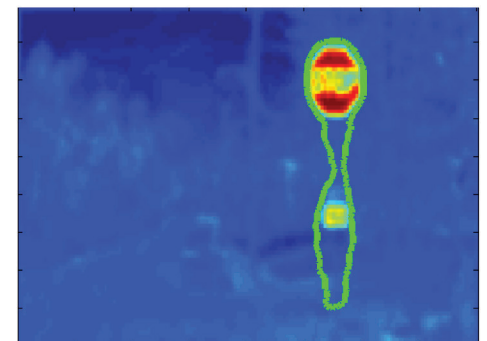


introduction of a model approach to sign boundary or geometry extraction was very useful. Their ability to split and match different topologies of the image data is essential for accurate shape detection especially when compound signs are encountered. The active contour model has proved a useful tool for detecting different types of traffic signs in noisy environmental conditions. Also, automating the initialization of contours is remarkably important to the application of the algorithm.

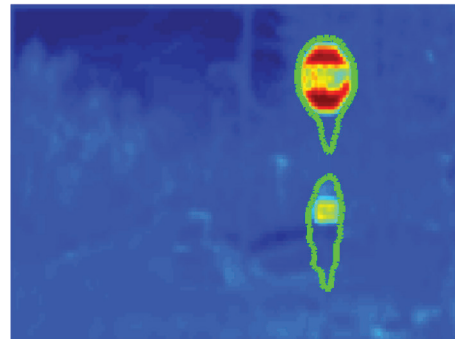
a). Contour Initialization



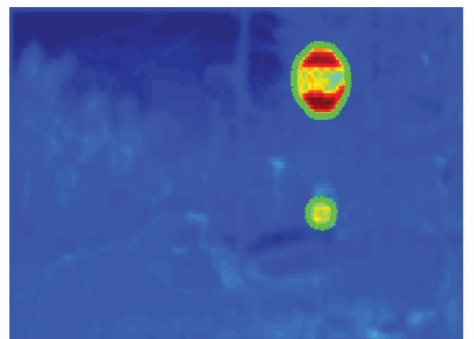
b). Contour location after 5 iterations



c). Contour location after 10 iterations



d). Contour location after 15 iterations





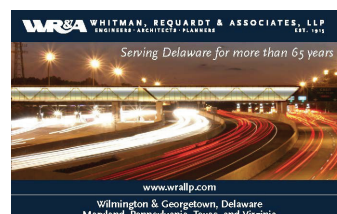
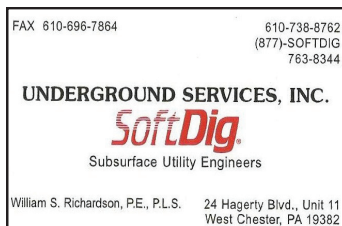
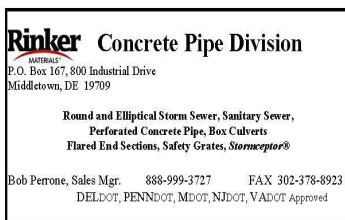
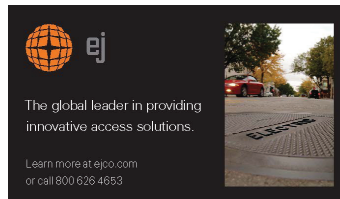


*We would like to express our sincere gratitude to the following sponsors who helped make our 2013 Transportation Infrastructure Forum a success!*

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The mission of the Delaware Center for Transportation is to improve the movement of people, goods, and ideas, and be viewed as a valuable resource for transportation-related issues and challenges within the state, the mid-Atlantic region and beyond.

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UTC NEWS  
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## RESILIENCY OF TRANSPORTATION CORRIDORS

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WINTER 2014

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Engineering communications team

## Director's Message

September 2013 saw the closeout of our UD-UTC grant. Funded in October 2006, we are proud of our accomplishments. Throughout this edition of the newsletter we list and describe many of these accomplishments. UDUTC has delivered:

33 Projects

45 Reports

75 Papers

108 Students participating/participated in research

26 graduates in transportation (MS and PhD) , and 65 outreach events involving 2222 people

When you look through the list of projects focused on our theme of "Resiliency of Transportation Corridors" you see the contributions to public transportation, environmental, infrastructure and security research. When we selected the theme we realized that "resilience" was an important concept but in the past seven years it has become the focus of many research efforts and experience with Hurricane Irene in 2011 and Sandy in 2012 made us more aware of how important our transportation corridors are and the many meanings of resiliency.

The titles in the lists of projects and reports tell you about the diversity of topics related to this theme. An in depth review of the affiliations of the researchers and authors will tell you that we have engaged civil engineers, environmental engineers, social scientists, planners, decision

scientists, public administrators, planners and public policy analysts. We have also interacted with communities, state Departments of Transportation, regional planning organizations and federal transportation agencies through interviews, workshops, presentations and meetings. We have also greatly benefited from the support of Delaware Department of Transportation, the Delaware Center for Transportation and the Delaware T2 Center.

As we continue our work as part of the consortium led by CAIT at Rutgers we hope to grow these collaborations and partnerships. In September we learned that CAIT was awarded a National University Transportation Center and we are delighted to be part of the consortium. The focus is again on state of good repair and we look forward to continued collaboration. The other consortium members are  
Columbia University (New York)  
New Jersey Institute of Technology  
Princeton University (New Jersey)  
University of South Florida  
University of Texas, El Paso  
Utah State University  
Virginia Polytechnic Institute and State University

Again, this newsletter highlights both UDUTC and CAIT at UD activities. Please watch our website for future events.

### Sue McNeil

Professor, Department of  
Civil & Environmental Engineering



## ***Most Recent UD-UTC Reports and Publications***

The following UD-UTC project reports have recently been submitted:

**Ames, David, Sue McNeil, Michelle Oswald, Rebekah Gayley,** "Evaluating the Current State of BOSFOLK Transportation Corridor and Indicators of Resiliency," Final Report, University of Delaware University Transportation Center, June 2009. <http://www.ce.udel.edu/UTC/amesmcneil.html>  
**McNeil, Sue, Rachel Davidson, Earl Lee, Joseph Trainor, Tricia Wachtendorf, Laura Black, Sarah Dalton, Charles Mitchell, and Gabriela Wasileski,** "UTC/DelDOT Infrastructure Security and Emergency Preparedness," Final Report, University of Delaware University Transportation Center, August, 2009. [http://www.ce.udel.edu/UTC/McNeil\\_Wachtendorf\\_Lee\\_08.html](http://www.ce.udel.edu/UTC/McNeil_Wachtendorf_Lee_08.html)

**Oswald, Michelle, Sue McNeil, David Ames and Weifeng Mao,** "Delaware's Transportation Adaptation in Response to Climate Change," Final Report, University of Delaware University Transportation Center, December 2011. [http://www.ce.udel.edu/UTC/downloads2013/Ames\\_McNeil\\_FinalReport\\_ClimateChange.pdf](http://www.ce.udel.edu/UTC/downloads2013/Ames_McNeil_FinalReport_ClimateChange.pdf)

**Kropat, Elisa and Earl (Rusty) Lee,** "The Impact of Disruptions along the I-95 Corridor on Congestion and Air Quality," Final Report, University of Delaware University Transportation Center, May 2013. [http://www.ce.udel.edu/UTC/Lee\\_Corbett\\_2010.html](http://www.ce.udel.edu/UTC/Lee_Corbett_2010.html)

**Shenton III, Harry W, and Peter Seymour,** "Resiliency of Bridges on the BOSFOLK Corridor," Final Report, University of Delaware University Transportation Center, August 2013. [http://www.ce.udel.edu/UTC/downloads2013/UTC\\_Final\\_Report\\_Shenton\\_Seymour.pdf](http://www.ce.udel.edu/UTC/downloads2013/UTC_Final_Report_Shenton_Seymour.pdf)

[UTC/downloads2013/UTC\\_Final\\_Report\\_Shenton\\_Seymour.pdf](http://www.ce.udel.edu/UTC/downloads2013/UTC_Final_Report_Shenton_Seymour.pdf)

**Laybourne, Mindy and Earl (Rusty) Lee,** "Developing Hybrid Measures of Performance for Signalized Intersections," Final Report, University of Delaware University Transportation Center, August 2013. [http://www.ce.udel.edu/UTC/downloads2013/Lee\\_Laybourne\\_FinalReport.pdf](http://www.ce.udel.edu/UTC/downloads2013/Lee_Laybourne_FinalReport.pdf)

**Scott, Marcia, Arthur Wicks III and Eileen Collins,** "Curbside Intercity Bus Industry: Research of Transportation Policy Opportunities and Challenges," Final Report, Institute for Public Administration and University of Delaware University Transportation Center, August 2013. [http://www.ipa.udel.edu/publications/intercity-bus-report-2013\\_08-26.pdf](http://www.ipa.udel.edu/publications/intercity-bus-report-2013_08-26.pdf)

**Schumacher, Thomas, Andrew Chen, Samet Ozturk, and Nii Attoh-Okine,** "Development of Rapid Assessment Tools for Structural Parts after Extreme Events," Final Report, University of Delaware University Transportation Center, November 2013. [http://www.ce.udel.edu/UTC/downloads2013/Schumacher\\_UD-UTC%20Final%20Report%20Development%20of%20rapid%20assessment%20tools.pdf](http://www.ce.udel.edu/UTC/downloads2013/Schumacher_UD-UTC%20Final%20Report%20Development%20of%20rapid%20assessment%20tools.pdf)

**Scott, Marcia, Christopher Kelly and Eileen Collins,** "Intermodal Transportation Facilities: Research of Viable Attributes and Potential to Integrate Curbside Intercity Buses," Final Report, Institute for Public Administration and University of Delaware University Transportation Center, November 2013. [http://www.ipa.udel.edu/publications/intermodal\\_report\\_final\\_2013-12-6-web.pdf](http://www.ipa.udel.edu/publications/intermodal_report_final_2013-12-6-web.pdf)

**Overby, Lynnette Young,** "The Effects

of Learning through the Arts on Transportation Knowledge and Skills of Elementary School Students, University Students and Classroom Teachers," Final Report, University of Delaware University Transportation Center, December 2013. [http://www.ce.udel.edu/UTC/downloads2013/Overby\\_FinalReport\\_Complete.pdf](http://www.ce.udel.edu/UTC/downloads2013/Overby_FinalReport_Complete.pdf)

**McConnell, Jennifer, Diane Wurst, Gillian McCarthy and Matthew Sparacino,** "Investigation of Load-Path Redundancy in Aging Steel Bridges," Final Report, University of Delaware University Transportation Center, December 2013. [http://www.ce.udel.edu/UTC/downloads2013/McConnell\\_FinalReport\\_Complete.pdf](http://www.ce.udel.edu/UTC/downloads2013/McConnell_FinalReport_Complete.pdf)

**Edwards, Geoff,** "Resilient Cartography: Using Interactive Online Mapping to Represent Corridor Mobilities," Final Report, University of Delaware University Transportation Center, December 2013. [http://www.ce.udel.edu/UTC/downloads2013/Resilient\\_Cartography.pdf](http://www.ce.udel.edu/UTC/downloads2013/Resilient_Cartography.pdf)

Recent papers from UD-UTC projects include:

**Overby, Lynnette, Heather Beach, Paige Glassman, Yael A. Haislip, Julie Luzier, Rachel Schotz, Teagan Thomas,** "Formative and Summative Assessments for Dance Interarts/Interdisciplinary Projects," Journal of Dance Education, Volume 13, Issue 1, 2013.

**Li, Qiang Joshua , Leslie Mills, Sue McNeil, Nii-Attoh Okine,** "Integrating Potential Climate Change into the Mechanistic Empirical Based Pavement Design," Canadian Journal of Civil Engineering, Published on the web 28 June 2013, 10.1139/cjce-2012-0465

## Newest CAIT at UD Projects

Five new projects were initiated in this period.

Four projects are CAIT at UD projects and one is a collaborative project with Rutgers. Each is briefly described below.

### ***GUIDELINES FOR EMBEDMENT LENGTH OF CARBON FIBER REINFORCED POLYMER (CFRP) STRIPS IN NEAR SURFACE MOUNT (NSM) RETROFITTED CONCRETE STRUCTURES***

**Principal Investigator: Nakul Ramanna**

#### **Abstract:**

The NSM-CFRP method for retrofitting is becoming an effective way of strengthening reinforced concrete structures compared to the conventional external bonded retrofitting (EBR) technique. This can be attributed to increased stiffness and strength resulting from the significantly more effective bonding in the NSM method. In this method grooves are cut on the concrete surface, epoxy is filled in and then CFRP reinforcement is inserted in the slits. The commonly used CFRP reinforcements for strengthening in the NSM method are round and square/rectangular bars. Recent studies have shown narrow rectangular CFRP strips to be highly effective and more economical than round or rectangular bars in resisting static, fatigue and impact loads. However, research highlights the need to provide larger development length for these strips than what is recommended by ACI 440.2R-08 to avoid premature failure. There is also clear lack in the literature for the recommended embedment length of CFRP strips in concrete owing to limited experimental data. It is also noteworthy that the development length formula for rectangular reinforcements given in ACI 440.2R-08 is only applicable to normal strength concrete (i.e. up to 5000 psi) and it does not distinguish between flexural and compression strengthening. However, in-situ concrete strengths are often found to be well above this limit and CFRP strips are known to perform differently in tension and compression. As a result, the use of same formulation for both cases cannot be justified. Finally, although rectangular in nature, CFRP strips should be treated differently than conventional square/rectangular reinforcements due to higher stress concentrations at

the edges. All these factors provide impetus for this research project.

**Status:** The project begins in January 2014. A graduate student is being recruited to work on the project.

### ***UNDERSTANDING THE RELATIONSHIPS BETWEEN HOUSEHOLD DECISIONS AND INFRASTRUCTURE INVESTMENT IN DISASTER RECOVERY: CASES FROM SUPERSTORM SANDY***

**Principal Investigator: Sue McNeil and Joseph Trainor**

**Collaborators: Steve Munson, New York State Department of Transportation**

#### **Abstract:**

Hurricanes, storms and floods damage roads, bridges, transit lines and other elements of our transportation infrastructure. Restoring the transportation infrastructure is widely recognized as an important element of short-term recovery as the reconstruction of the built environment and the other elements of the long term recovery are dependent on a functional transportation system. However, in the long term, changes in development and settlement patterns occur and additional or different investments in transportation infrastructure are required to deliver safe and efficient transportation. We know very little about how, where, when and why these changes occur. This exploratory research project aims to better understand the role transportation infrastructure plays in the disaster recovery process. By documenting transportation infrastructure damage and repair, conducting interviews to understand community and household attitudes, and researching incentives and resources related to household decisions regarding relocation and rebuilding in two communities impacted by Hurricane Sandy we will better understand how to provide transportation infrastructure recovery activity that meets the needs of communities impacted by disaster.

The purpose of this study is to

- 1) better understand how households decide to either resettle in a new location or rebuild in situ following a disaster including how that decision is influenced by the state of the infrastructure, and
- 2) determine what critical elements of those decisions

could be used to inform planning models.

Initial data will come from semi-structured interviews with households that have decided to stay as well as those planning to leave areas affected by Hurricane Sandy.

**Status:** The literature has been completed and a draft survey developed. A collaboration has been developed with Sea Bright, New Jersey and Oakwood Beach, Staten Island, New York. Sea Bright is planning to undertake a housing survey and we have been working with the community to develop relevant questions.

### ***EXPLORATION OF VIDEO-BASED STRUCTURAL HEALTH MONITORING TECHNIQUES***

**Principal Investigator: Thomas Schumacher and Nakul Ramanna**

**Collaborators: HNTB**

#### **Abstract:**

Structural health monitoring techniques (SHM) have become a useful means to document in-service load tests or collect long-term data from ambient traffic on bridges or other civil structures. Most of the used SHM data acquisition systems consist of physical sensor networks that are attached to the structure's surface, and transmit collected data either wired or wirelessly to a hub. From there the data is downloaded to a laptop or transmitted via Internet connection to the bridge engineer. The sensors record data from external stimuli such as temperature, humidity, or load, or internal structural responses such as strain or displacement. In order to save deployment time and costs, remote sensing approaches have more recently been studied for SHM applications such as laser vibrometers, LIDAR, GPS, or image-based methods. These techniques are promising for global monitoring, i.e. modal analysis, but often lack the desired resolution for accurate dynamic response characterization or effective local damage detection. One reason is that typically only a small finite number of points can be monitored simultaneously which leads to sparse data. In addition, these techniques are still expensive and require specialized equipment that needs to be operated by trained technicians. Some researchers have used videos to detect vehicle location and correlate that with structural response measured by traditional sensor networks. This project, however, proposes a different approach. Motivated by



the recent wide availability of inexpensive high-quality high-speed digital video cameras combined with innovative video signal processing algorithms, it is time to consider the next generation of monitoring techniques that uses the captured digital video to extract information of structural dynamic performance directly. This research project will address a need for a novel inexpensive, remote, and easy-to-deploy sensing technology for SHM applications.

Status: A presentation has been made at "Review of Progress in Nondestructive Evaluation" in Baltimore in July, 2013. A paper has appeared in *Sensors* summarizing progress to date.

## **ASPHALT: RHEOLOGY AND STRENGTHENING THROUGH POLYMER BINDERS**

**Principal Investigator: Pam Cook and Nii Attoh-Okine**

**Collaborators: Delaware Department of Transportation**

### **Abstract:**

The strength and longevity of pavements can be enhanced by the addition of various materials, for example; polymer modifiers. Desirable properties of the pavements, such as having elasticity and having increased viscosity, can work to increase the lifetimes and load resistance of the roadway. Polymer additives increase the cost of the pavement so that modeling in collaboration with laboratory studies are both necessary to show the benefits of adding the polymers, and of which and how much polymer must be added. The polymer asphalt mixture must be compatible with engineering requirements over a large range of temperatures (that is phase separation should be prevented in the pouring and in the cooling/solidification process, shear thinning at moderate temperatures aids in the pouring/spreading process) to prevent poor and uneven physical properties. The goal is that the polymer/bitumen mixture forms a continuous network binding the asphalt inclusions.

Status: The project begins in January 2014.

## **DEFINING AND QUANTIFYING STATE OF GOOD REPAIR (SGR) FOR THE PEDESTRIAN NETWORK**

**Principal Investigator: William DeCoursey and Ardashir Faghri**

**Collaborators: WILMAPCO**

### **Abstract:**

State of Good Repair (SGR) has been the subject of rigorous study for several years in the United States. Numerous studies have explored SGR in relation to highways, bridges, and public transportation. The pedestrian network, based on a preliminary literature review, seems to have received decidedly less attention.

What then is a State of Good Repair for pedestrian networks in a variety of settings (urban, suburban, and rural)? How can SGR be quantified in ways that take into account factors more nuanced, but certainly including, the physical condition of the pedestrian surface in the public right-of-way (customer satisfaction, traffic fatalities, social media, transit ridership, network connectivity and utility)? More generally, how can transportation professionals achieve and maintain a pedestrian network that is safe, reliable, and keeps the customer satisfied?

Status: Progress to date includes:

- collected and distilled at least three dozen academic and trade sources on SGR, as it relates to pedestrian infrastructure and compiled them into a 40+ page literature review.
- held three meetings with Dr. Faghri and Matt Carter to keep DTC advised of our progress.
- has developed a draft definition of SGR and a draft grading/performance matrix for ascertaining SGR in a variety of pedestrian contexts.

Next steps involve assembling and engaging an expert panel to quantify and rank various factors related to SGR (this is being accomplished through our partner agency, WILMAPCO). The expert input, literature review, and final matrix will be combined into a deliverable document.



*Students in Civil Infrastructure Systems Participate in a Visual Pavement Assessment Exercise.*

## **ENHANCING REMOVAL IN STORMWATER TREATMENT FACILITIES FOR TRANSPORTATION**

**Principal Investigator: Paul Imhoff and Pei Chu**

**Collaborators: Quihong Guo, Rutgers, and Delaware Department of Transportation**

### **Abstract:**

Stormwater discharge from roadways is a point source of pollution and thus subject to regulation under the NPDES permitting program. As a co-permittee along with municipalities, State DOTs must comply with Total Maximum Daily Load (TMDL) regulations for bacteria and nutrients and work towards achieving prescribed waste load allocations. TMDL is the maximum amount of a pollutant that a waterbody can receive without violating the water quality standards. In Delaware, nutrient loading to surface waters is one of the leading causes of water quality impairment, and in order to meet water quality standards in the state's nutrient impaired waterways TMDL regulations require the systematic reduction of all point source discharges of nitrogen and phosphorus into these waterways - including those from roadways. Stormwater treatment technologies, such as detention ponds, can remove nutrients effectively. However, the increased nutrient removal required by TMDL regulations will be costly, since more real estate is required for increased treatment with existing technologies. New treatment technologies are needed that significantly reduce the footprint required for stormwater systems treating roadway runoff - which would result in significant cost reductions for State DOTs.

Status: Project will begin in January 2014.



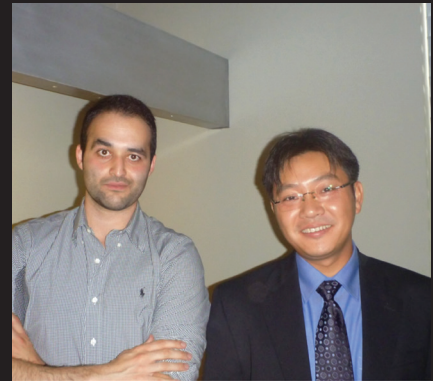
## Brownbag Discussions

This Fall the UDUTC hosted three brownbag discussions. The first, held October 16, was focused on the collaborative project led by Professor Jie Gong from Rutgers. The brownbag “Big Data: Opportunities and Challenges in Asset Management,” was presented by Professor Gong and his graduate student Farbod Farzan. They introduced the concept of “Big Data” and then presented a tutorial on big data software. The presentation showed some applications of big data to the analysis of LIDAR data capturing the post-Sandy damage. Discussion focused on other big data applications relevant to transportation.

The second brownbag seminar was presented on October 23 by graduate students Farzana Atique (Civil and Environmental Engineering) and Ryan Burke (Disaster Science and Management). The seminar titled “Updating the Transportation

Performance Index and Better State-of-Good-Repair Indicators” reviewed the concept of the TPI and the updating of the TPI for 2010 and 2011. Ryan presented his work on assessing the changes in the TPI based on long range transportation plans.

The final brownbag on November 20 covered two projects. Professor Nii Attoh-Okine presented his work on “Multi-Resolution Information Mining and a Computer Vision Approach to Pavement Condition Distresses,” and Professor Pam Cook and PhD candidate Yun Zeng (both from Math) presented their collaborative project with Professor Attoh-Okine titled “Mathematical Modeling and Experimental Responses of Polymer Modified Asphalt.” It was interesting to hear the perspective of mathematicians on civil engineering infrastructure problems!



**Farbod Farzan and Professor Jie Gong from Rutgers**

## CAIT at UD Publications and Presentations

- Schumacher T, Shariati A. (2013). Monitoring of Structures and Mechanical Systems Using Virtual Visual Sensors for Video Analysis: Fundamental Concept and Proof of Feasibility. *Sensors*. 13(12): 16551-16564. DOI: 10.3390/s131216551.
- Schumacher, T. and Shariati, A. (2014). Video-Based Structural Health Monitoring. Technical

communication during the AFF40(1) committee meeting at the Transportation Research Board (TRB) 93rd Annual Meeting. Washington, D.C. January 12-16.

- Shariati, A. and Schumacher, T. (2013). Video-Based Techniques in Structural Health Monitoring. *Review of Progress in Nondestructive Evaluation (QNDE)*. Baltimore, MD. July 21-26.

- London, Mosi and Sue McNeil, (2013). “Capturing Changes in Investment, Demand and Policy Using the Transportation Performance Index”, Presented at the 13th World Conference on Transport Research, Rio de Janeiro, July.



## Distinguished Lectures and Traveling Lecture

CAIT at UD participated in two webinars as part of the CAIT Traveling Lecture Series. In September, Hui Li from Harbin Institute of Technology presented a webinar “Structural Health Monitoring in Mainland China”. Students from CIEG 655 Civil Infrastructure Systems also attended the webinar. A lively discussion followed the webinar as students attempted to

balance the cost of SHM versus the added data. Also in September, Thomas Abdallah from New York City Transit presented a webinar “MTA NYC Transit Sustainability.” The webinar included some spectacular photos of damage following Hurricane Sandy and discussion of the implications for MTA.

## Participation in TRB Annual Meeting

Again University of Delaware faculty and students participated in the Transportation Research Board annual meeting held in Washington DC in January 2014 as listed below. Where applicable, paper numbers are listed in parentheses.

### **Airport Asphalt Pavement Profile Analysis: Ensemble Empirical Mode Decomposition**

**Approach** (14-4498), Yaw Okyere Adu-Gyamfi and Nii Attoh-Okine, University of Delaware; Regis Martins Rodrigues and Silvio Rodrigues Filho, Instituto Tecnológico de Aeronáutica, Brazil; Offei Adarkwa, University of Delaware

**Safety IDEA Project 23: Reducing Wheel Climb at Switch Points to Reduce Derailments**, Allan M. Zarembski, University of Delaware

**Development of Expert System for Effective Countermeasure Identification at Rural Unsignalized Intersections** (14-3494), Rebecca Frey, Johnson, Mirmiran & Thompson; Ardeshir Faghri and Mingxin Li, University of Delaware

**Traffic Sign Recognition Using Sparse Representations and Active Contour Models** (14-

2997), Yaw Okyere Adu-Gyamfi and Nii Attoh-Okine, University of Delaware

**Cost-Benefit Analysis of Vehicle-to-Grid-Capable Electric School Bus Compared with Traditional Diesel School Bus** (14-2155), Lance Noel and Regina McCormack, University of Delaware

**Cost-Benefit Analysis of Added Cycling Facilities** (14-3486), Mingxin Li and Ardeshir Faghri, University of Delaware

**Natural Gas Versus Conventional Fuel for Waterborne Freight Transport: Life-Cycle Emissions Assessment with Case Studies**, James J. Winebrake, Rochester Institute of Technology; James J. Corbett and Heather Thomsen, University of Delaware

**Impact of Disruption Uncertainty and Network Configuration on Roadway Vulnerability** (14-4201), Mohammad Saied Dehghani and Gerardo W. Flintsch, Virginia Polytechnic Institute and State University; Sue McNeil, University of Delaware

**Development of Carbon Nanotube-Based Sensing Approach for Structural Health Monitoring of Civil Infrastructure**, Hongbo Dai, Thomas Schumacher, and

Erik Thostenson, University of Delaware

**Linking Land Form and Development Location to Multimodal Travel Demand: Case Studies of Transportation and Land Use Studies in Delaware** (14-4397), Scott Michael Thompson-Graves, Whitman, Requardt & Associates, LLP; Michael DuRoss, Delaware Department of Transportation; Earl Lee and Sara E. Patterson, University of Delaware; Eric Sundquist and Bill Holloway, State Smart Transportation Initiative

**Performance of Uncoated Weathering Steel Highway Bridges Throughout the United States** (14-1139), Jennifer Righman McConnell, Harry Shenton, Dennis R. Mertz, and Dhilvinder Kaur, University of Delaware

**Curbside Intercity Bus Industry: Research on Transportation Policy Opportunities and Challenges**, Marcia S. Scott, University of Delaware Transportation Infrastructure Vulnerability and Performance, Nii Attoh-Okine, University of Delaware

## Upcoming Events and Opportunities

Brown bags for Spring 2014 and DCT/UTC Distinguished Lectures for Spring 2014  
See <http://www.ce.udel.edu/UTC>

### **Research Showcase**

**May, 2014** – Research Showcase, Dover, DE  
Annual Interuniversity Symposium on

Infrastructure Management (AISIM)

**June 20-21** – Virginia Tech - <https://sites.google.com/site/aisim10vt/>

Abstracts are due March 1.

3rd Advance Infrastructure Management Bootcamp

**June** – Virginia Tech- <https://sites.google.com/site/aisim10vt/the-bootcamp>

### **Deadlines**

**February 28, 2014**– CAIT at UD proposals are due see <http://www.ce.udel.edu/UTC>

**February 28, 2014**- Summer undergraduate research applications and interns

## Contact Us

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