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UNIVERSITY OF DELAWARE

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Rapid replacement

ARTICLE BY DIANE KUKICH

Novel technology applied to replace aging bridge

PHOTO BY MAJID TALEBI MAY 23, 2017

America's bridges received a grade of C+ on the 2017 Infrastructure Report Card, put out by the American Society of Civil Engineers (ASCE). Aging is a factor in this score — almost four in 10 of the 614,387 bridges in the U.S. are 50 years or older, and the average age keeps climbing.

But repair and rehabilitation are extremely costly — the most recent estimate puts the nation's backlog of bridge rehabilitation needs at $123 billion.

In 2013, the Delaware Department of Transportation decided to explore the effectiveness of a novel rapid replacement approach for a two-lane bridge just north of the C&D canal that was nearing the end of its useful service life. They collaborated with researchers at the University of Delaware on design and construction of a new bridge, which continues to be monitored via a custom-designed instrumentation system.

The old bridge was replaced with what is known as a *geosynthetic reinforced soil integrated bridge system* (GRS-IBS). Developed and promoted by engineers at the Federal Highway Administration, this system lends itself to rapid and cost-effective construction.

Christopher Meehan, the Director of the Delaware Center for Transportation, explains that the novel design borrows from the field of retaining walls, where geosynthetic materials — including textiles, grids, strips and nets— are used to provide tensile reinforcement to soils, enhancing their overall strength and stability.

"It turns out that concepts from these technologies can also be applied to bridges, saving money and reducing construction time," Meehan says. "The new bridge is basically a composite bridge structure that incorporates GRS abutments and prefabricated bridge superstructure elements. This approach eliminates the costly downtime associated with cast-in-place concrete, which can take a few weeks to a month to cure."

For this project, the GRS abutments were constructed by laying locally available concrete masonry blocks in rows, filling behind them with gravel and covering the wall facing elements and backfill with a geosynthetic fabric. This process was repeated in layers to build each bridge abutment, and then a precast-concrete bridge superstructure was placed on top of the abutments.

Next, some finish work was performed to bring the approach ways up to the grade of the bridge, and the entire bridge and roadway area was then paved. The resulting bridge superstructure spans approximately 37 feet, with a clear span over the inlet channel of a little more than 28 feet.

The UD research team provided extensive technical support on the project, including designing and implementing a custom structural health monitoring system that comprises more than 150 sensors to continuously monitor the bridge's long-term performance.

Meehan credits graduate students Majid Talebi, Tyler Poggiogalle, Dan Cacciola and Matthew Becker with making significant contributions to the design, construction and monitoring process.

A new bridge replacement system allows for rapid and cost-effective construction. Photo by Majid Talebi May 23, 2017

"The DelDOT journey to construct a GRS-IBS bridge actually began when Chris approached us with the idea to construct and monitor one of these innovative structures," says Barry Benton, formerly chief bridge engineer at DelDOT and a 1992 graduate of UD in civil engineering.

"From the very inception of the project, he worked closely with us to choose a location and assist in both the design and the monitoring plan. Since this was to be the first GRS-IBS bridge in Delaware, it was very important for us to understand how it would perform."

DelDOT has since built another GRS-IBS bridge in Sussex County, which is performing well to date. Benton believes that this technology will yield the largest cost savings if an internal maintenance crew can be trained to do the work.

"The beauty of the system is that it can be constructed quickly with small equipment, so it's a perfect fit for utilizing the talents of our own staff," he says.

Meehan calls the GRS-IBS an accessible technology that can be built almost anywhere.

"Geosynthetic reinforced soil structures are well-suited for construction all over the world, as geosynthetic materials are fairly light and can be easily imported," he says.

"Beyond that point, various types of walls and bridge abutments can be constructed using locally sourced materials, with little need for cast-in-place concrete. The resulting structures are cost-effective and fairly forgiving with respect to settlement and lateral deflection, and they have been shown to perform relatively well in earthquakes."

Message from the Director

As I write this, Hurricane Irma is approaching the coast of Florida. Currently, a Category 5 hurricane, Irma is the strongest hurricane in the Atlantic basin outside of the Caribbean Sea and Gulf of Mexico in the National Hurricane Center records. It follows immediately on the footsteps of Hurricane Harvey, which made landfall in Aransas County, Texas as a Category 4 Hurricane. Hurricane Harvey brought with it extensive rainfall, with many locations in the Houston area observing at least 30 inches of precipitation, and some locations observing more than 50 inches. The damage and loss of life wrought by Harvey was extensive, and our thoughts and prayers are with those affected by both of these storms, as well as other hurricanes that will no doubt form during this year's hurricane season.

Given the recent damage from Harvey, many residents in Florida are wisely evacuating as Irma advances. These storm evacuations, and storm evacuations in general, can result in some of the highest traffic volumes in our transportation network, and perhaps represent one of the most urgent and time sensitive uses of the transportation infrastructure that we build. Getting the public out of the way of an advancing storm safely and efficiently can be a real challenge, as the time window from when an evacuation order is given and when a storm makes landfall is often short. It is our responsibility as engineers to plan and design for these extreme events to the best of our ability, as civil engineers must always "hold paramount the safety, health and welfare of the public" (ASCE Code of Ethics, Canon 1).

More locally in Delaware, major news this past month included the signing by Governor Carney of Executive Order #14, which creates a 19 member advisory council on Connected and Autonomous vehicles. This event indicates the high priority the current leadership in Delaware places on the advancement of autonomous vehicle technology within the state, and shows foresight and anticipation of the new requirements that autonomous vehicles will have on our transportation, safety, and cyber security networks in Delaware. There are many exciting changes coming to our transportation infrastructure in the near future, and I envision that the next 10 to 20 years will bring about changes that were still being written about in science fiction novels only a short time ago.

The following newsletter contains articles detailing research that is being conducted on driverless vehicles at the University of Delaware, and also examines the challenges that Delaware faces with building a coordinated mobility and specialized transportation network that serves the entire state in a cost efficient manner. Two developments in innovative bridge construction techniques are presented, including geosynthetic reinforced soil integrated bridge system technology and the use of ultra-high performance concrete to overlay prestressed concrete box beams. An article by UD researchers on the use of Bluetooth technology for travel time measurements shows how this technology can be an effective replacement for vehicle-mounted GPS technology, which has been used by the Delaware Department of Transportation for the past 20 years for travel time estimation at peak hours across the state. Additional research project updates, information about on-going transportation related activities, and recommendations for new and improved safety protocols and safety awareness training can all be found within. Of particular note is the safety coins issued by the Federal Highway Administration Safety and Design Technical Service Team to DCT team members Rusty Lee and Matheu Carter. Congratulations to Matt and Rusty for their leadership in this critical area!

UD's Meehan named ASCE Fellow

BY JULIE STEWART

Three percent of the 150,000 members of the American Society of Civil Engineers are Fellows.

This honor is given to ASCE members who have made significant contributions to the field of civil engineering and enhanced lives in the process. Just three percent of the organization's more than 150,000 members hold the honor of Fellow.

Meehan, an associate professor and the Director of the Delaware Center for Transportation, specializes in geotechnical engineering, with particular interests in soil mechanics and soil shear behavior, slope stability, foundation engineering, geosynthetics, soil-structure interaction, soil and site improvement, intelligent compaction, and levee system design.

"This is clear evidence that Chris's engagement with and involvement in the geotechnical community is having an impact," says Sue McNeil, professor and chair of the Department of Civil and Environmental Engineering. "If you have had an opportunity to hear Chris talk about any of his projects you know that he identifies interesting problems, finds innovative solutions grounded in sound engineering principles, and approaches each problem with passion and enthusiasm. He also engages graduate and undergraduate students in the research."

Meehan joined the UD faculty in 2006, the same year he completed his Ph.D. at Virginia Tech. He is also the director of the Delaware Center for Transportation, which conducts research, development, and educational activities to advance transportation in Delaware and beyond. He has been a member of ASCE since 1996. Among other professional career honors, he received a 2012-2013 Fulbright U.S. Scholar Grant and a National Science Foundation CAREER Award in 2009.

Meehan has written dozens of refereed journal articles, including seven so far this year. The National Science Foundation, the National Aeronautics and Space Administration, the Department of Defense, the Delaware Department of Transportation, and the Delaware Solid Waste Authority support his research.

ASHE@UD to Host Regional Student Chapter Conference

The student chapter of the American Society of Highway Engineers at the University of Delaware, ASHE@UD, will host the first of what is hoped may be annual conferences for ASHE student chapters in the region. The half day conference will take place in Newark on September 30th and is expected to draw from student chapters at the University of Maryland, Temple University, Widener University, Drexel University, Rowan University, and possibly others.

Some 60 students and professional members of ASHE are expected to attend the conference to share experiences, challenges, and solutions relative to establishing and maintaining student involvement, but the bulk of the conference will be dedicated to elements of leadership and the transition from student to professional in those critical first few years.

Eric Kramer, President of ASHE@UD, said that the University of Delaware student chapter was looking forward to hosting the regional conference and, "we think it will be a great opportunity to meet ASHE students from other universities, gain some new insights into the professional world, and showcase UD's strong emphasis on leadership development."

ASHE's National Student Chapter Committee began organizing the regional conference when member John Caperilla (Borton-Lawson and the ASHE Delaware Valley Section) suggested it nearly a year ago. The student officers of ASHE@UD were enthusiastic when Committee Chair Matt Carter (Delaware T^2/LTAP Center and ASHE First State Section) asked them if they would like to host the first conference, since UD was centrally located among student chapters in the region.

Student chapter involvement such as ASHE@UD has been influential for students by elevating their awareness of career opportunities and learning how to maximize their professional effectiveness in those crucial early years. It is expected that this regional conference will leverage the effect of these individual student chapters and enhance the experience of students throughout the region. Stay tuned to hear how it went.

Safe and sound

ARTICLE BY DIANE KUKICH PHOTO BY MAY 17, 2017

Delaware Center for Transportation engineers recognized for work to improve traffic safety

Highway safety has become a complex issue in an era when roads built primarily for cars are now being shared by increasing numbers of pedestrians, cyclists, and skateboarders.

"It's time to throw away the rule book because the safety equation has gotten really complex," says Rusty Lee, director of advanced traffic operations for the Delaware Center for Transportation (DCT). "We want people out walking and biking, but now we have to figure out to keep everyone safe, and that's going to require taking a new look at the entire system."

Lee and Matheu Carter, an engineer and circuit rider with the Technology Transfer (T^2) Center housed within DCT at the University of Delaware, were recently recognized with safety coins issued by the Federal Highway Administration Safety and Design Technical Service Team.

Lee was recognized for his efforts serving on the Every Day Counts 3 Data Driven Safety Analysis (EDC-3 DDSA) Team.

EDC3 is the third round of a program called Every Day Counts, which features 11 technologies and practices that can shorten the project delivery process, enhance durability and safety, and improve environmental sustainability. The focus is on providing efficiency through technology and collaboration.

"Rusty's professional and academic experience was valuable in providing critical information that helped the development and deployment of the EDC-3 DDSA program," says FHWA safety engineer John McFadden.

Carter was recognized for his efforts in rebuilding the Low-Cost Safety Improvement Workshop, which was developed in 2004 to provide information for local and state transportation agencies on a variety of traffic safety problems and remedies to address them.

"The workshop material was completely reviewed and updated in a year-long effort and then piloted in Delaware in 2016," McFadden says.

Carter emphasizes that the appreciation he and Lee received for their work actually goes two ways.

"The FHWA Resource Center has brought tremendous assets to transportation agencies here in Delaware," he says. "We're a very small state, so we can do things here that are more challenging in larger states."

"At the same time, for the past three or four years, Delaware has been first in the nation for pedestrian fatalities per capita," he adds. "That's not a No. 1 statistic that we want to brag about, so we're doing everything we can to work with agencies and communities to change that number."

For Carter, FHWA's Low-Cost Safety Improvement Workshop represents a wealth of "low-hanging fruit" — for example, simple signage and vegetation trimming — that can be plucked for relatively big payoffs.

Lee sees safety as sitting at the convergence of law, research, and common sense, which can make it a challenging issue to address in the real world.

"We're also struggling with the social dynamic of human behavior, but we're trying to do that from the perspective of people trained as engineers," he says. "We need to stop creating administrative checklists and start coming up with ideas that can be implemented tomorrow and have an immediate impact."

About the T^2 Center

The T^2 Center was formerly within DelDOT and is now part of the Delaware Center for Transportation. The T^2 program organizes annual workshops for transportation providers, offers technical assistance with transportation issues via a "circuit rider" who visits Delaware's towns and cities, and distributes research and other reports from universities and government agencies.

Delaware Bridge Project Uses Ultra-High Performance Concrete

Reprinted with Permission - EDC News, August 17, 2017, US Dept. of Transportation, FHWA, Center for Accelerating Innovation

PHOTOS BY NICHOLAS DEAN, DELDOT

The Delaware Department of Transportation (DelDOT) received an Accelerated Innovation Deployment Demonstration program award to use an ultra-high performance concrete overlay on a bridge replacement project in Blackbird. The project involves replacing corrugated metal pipe arches with prestressed concrete box beams on concrete stub abutments with the UHPC overlay. Using UHPC is expected to result in a strong, high-quality bridge that will require fewer future repairs. DelDOT, which is replacing the bridge during a full road closure on a section of Blackbird Station Road, expects to reopen the road to traffic by mid-September.

DCT Hosts 14th Annual Research Showcase

The Delaware Center for Transportation (DCT) hosted its 14th annual transportation research showcase on Wednesday, May 3rd at the University of Delaware's Paradee Center in Dover, Delaware. The showcase offered the opportunity for project investigators and graduate students to display posters and share progress on research projects to DelDOT representatives and other interested parties. Showcased were currently funded projects in the areas of environment, pavement & materials, planning, soils, bridges & structures, plus traffic and intelligent transportation systems (ITS).

Also included were projects from the University Transportation Center (UTC) program. This year we welcomed visitors from various agencies which included: DelDOT; Federal Highway Administration; Advanced Infrastructure Design; TY Lin International; DNREC; Geo-Technology Associates; Whitman, Requardt & Associates, and Wallace Montgomery. The showcase shifted the timeframe from 1:00 to 3:00 and offered a light lunch along with the popular scoops of ice cream from the University's UDairy Creamery.

DelDOT personnel Pamela May, Omar Simpson, and Danny Macchione attend the 2017 Showcase.

UD Graduate Student Will Baker explains his project on Compaction Control Data.

Tibor Toth and Eric Best present their project at the DCT Annual Research Showcase

RESEARCH

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

IRIB ONGOING STRUCTURAL HEALTH MONITORING

The Indian River Inlet Bridge represents a significant investment in infrastructure for the State of Delaware. This funding supports ongoing evaluation of the bridge and preservation of its state-of-the-art structural health monitoring system. Ending 8/31/2019

Principal Investigators: Michael Chajes and Tripp Shenton, Department of Civil and Environmental Engineering

Project Manager: Jason Arndt, Bridge Design

SNOW PLOW ROUTE OPTIMIZATION

The goal of this research is to develop a mathematical model for optimizing snowplow routing in order to minimize the total snowplow truck travel distance and travel times. Ending 5/4/18

Principal Investigator: Mingxin Li, *Department of Civil and Environmental Engineering*

Project Manager: Jason McCluskey, Division of Planning

FIELD MEASUREMENT OF THE DYNAMIC IMPACT FACTOR FOR BURIED CULVERTS

This research is aimed at filed investigation of the actual dynamic load effects on buried culverts. The final product is expected to be a refined methodology for estimating the impact factor for buried culverts. Ending 11/4/17

Principal Investigator: Kalehiwot Manahiloh, *Department of Civil and Environmental Engineering*

Project Manager: Ping Jiang, *Bridge Section*

INTEGRATING ZERO-VALENT IRON AND BIOCHAR AMENDMENTS IN STORMWATER

Data from a field demonstration stormwater treatment system using biofilter media amendments for removing nitrogen will be used to develop preliminary guidelines for DelDOT, which will assist the agency with compliance of the Total Maximum Daily Load (TMDL) regulations for bacteria and nutrients in surface waters. Ending 5/6/18

Principal Investigators: Paul Imhoff, Daniel Cha, Pei Chiu, Julia Maresca, Department of Civil and Environmental Engineering, Mingxin Guo, Delaware State University

Project Manager: Mark Harbeson, Transportation Management Center

EVALUATION OF NEW DATA SOURCES FOR PLANNING AND OPERATIONS FY16 AND FY17

This project will provide DelDOT a demonstration of what some new sources of cell phone data can provide for information and how it would be useful for both operations and planning. Ending 12/31/17

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

Project Manager: Michael DuRoss, *Division of Planning*

FY17 REGIONAL TRAVEL DEMAND MODELING SUPPORT

Assist DelDOT with developing, maintaining, applying and evaluating its travel demand forecasting model, which is used not only by DelDOT but also by the state's two metropolitan planning organizations. Ending 12/31/17

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

Project Manager: Michael DuRoss, Division of Planning

2017 DELDOT MUNICIPAL AGREEMENTS PROJECT

The goals of this project are for student interns to conduct a careful review of all known agreements that exist between DelDOT and Delaware municipalities, documenting the boundaries of the agreement and its applicability to roadways systems. Ending 12/31/17

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

Project Manager: Karen Brittingham, Division of Planning

FALL 2016 AND SUMMER 2017 PROCESSING OF DELDOT-TMC BLUETOOTH DATA FOR TRAVEL TIME AND SPEED MEASUREMENTS

This project entails transforming raw Bluetooth data into a useable form for DelDOT and processing the data into average time and speed between sensors and comparing average speed with posted speed limit to get an indication of delay. Ending 8/31/18

Principal Investigator: Ardeshir Faghri, Department of Civil and Environmental Engineering

Project Manager: Mark Eastburn, Division of Planning

ITS SUPPORT FOR BICYCLE AND PEDESTRIAN APPLICATION DEVELOPMENT FY17

The aim of this project is on development of software tools and application that focus on the needs of pedestrians and cyclists. Ending 12/31/17

Principal Investigator: Chandra Khambhamettu, Computer and Information Sciences

Project Manager: Paul Moser, Division of Planning

STATEWIDE TRAFFIC DATA ANALYSIS AND EVALUATION FY17

With the effective involvement of student resources, the program will provide an economical option for DelDOT to make measurable improvements to signal corridor operations, reduce congestions and improve air quality. Ending 5/31/18

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

Project Manager: Gene Donaldson, TMC Operations

FY17 COMPLETION OF THE DELDOT CONSTRUCTION INTERN PROJECT

This project's goals is to supplement the current DelDOT Construction Manual with web links and videos to provide additional support to construction inspectors. UD undergraduate students will intern within the 301 construction project. Ending 8/31/18

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

Project Manager: Javier Torrijos, *Division of Planning*

EXPLORATORY FIELD MONITORING OF PILE DOWNDRAG

The goal of this project is to measure field data related to the performance of installed deep foundation elements that are used to provide structural support for bridges.

Principal Investigator: Christopher Meehan, Department of Civil and Environmental Engineering

Project Manager: Jason Hastings, Bridge Section

DEVELOPING METHODOLOGIES TO CONVERT TIME OF DAY PERSON SCHEDULES TO TRAVEL DEMAND MODEL INPUTS FOR EVALUATION OF PRT SYSTEM DESIGNS

This research will investigate modeling pedestrian behavior on a college campus using university student schedules, both graduate and undergraduate. Ending 6/8/19

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

Project Manager: Michael DuRoss, Division of Planning

WHAT INNOVATIVE APPLICATIONS AND UTILIZATIONS OF TMC DATA COULD BE IMMEDIATELY IMPLEMENTED?

This research project will evaluate all raw data collected by the Traffic Management Center (TMC) and how this data can be transformed into useful forms and used by different divisions within DelDOT. Ending 6/8/19

Principal Investigator: Ardeshir Faghri, Department of Civil and Environmental Engineering

Project Manager: Mark Eastburn, Division of Planning

HOW CAN 'BIG DATA' BE UTILIZED TO ENHANCE THE TRANSIT PLANNING PROCESS AND TRANSIT USER'S EXPERIENCES?

The focus of this research is to better understand how current and prospective transit users are able to use and respond to transit system operations through technology, social media, and 'big data'-type resources. Ending 6/8/19

Principal Investigator: Mingxin Li, Department of Civil and Environmental Engineering

Project Manager: Jared Kauffman/Bruce Allen, Division of Planning

WHAT ARE THE LATEST INNOVATIVE APPROACHES TO INTRA-AGENCY SKILL-BASED RESILIENCY, MOST APPROPRIATE FOR DELDOT?

The main objective of this research is to evaluate the most recent developments in the area of skill-based resiliency. Strategies most appropriate for the unique context of DelDOT will be listed and ranked. Ending 6/8/19

Principal Investigator: Mingxin Li, Department of Civil and Environmental Engineering

Project Manager: Silvana Croope, Division of Planning

Bluetooth Data for Travel Time Measurements

BY ARDE FAGHRI, MINGXIN LI

Bluetooth technology emerged over twenty years ago and has been continuously improved throughout the years to meet higher applications. Initially invented to replace the need of physical data cables, Bluetooth offers users a quick and easy way to share data files over a wireless network. Essentially, Bluetooth operates by sending and receiving radio signals from one Bluetooth device to another. For Bluetooth devices to be recognized by another Bluetooth device, a code or commonly referred to as a MAC address, is uniquely assigned to each and every Bluetooth device. Through pairing, Bluetooth devices "remember" these MAC addresses so that the devices may be

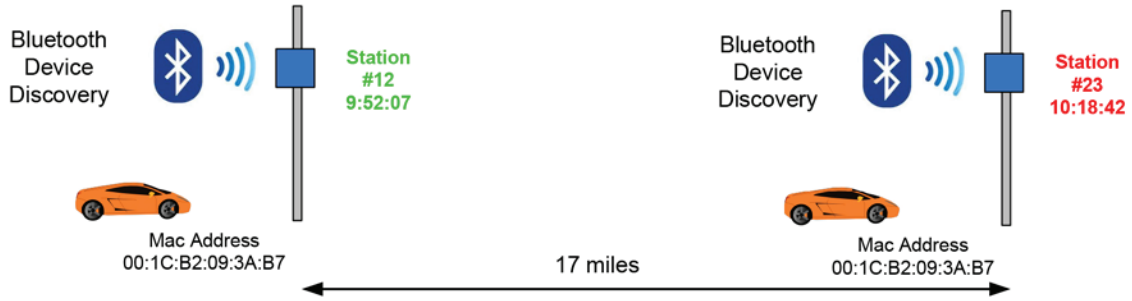


Figure 1 *Bluetooth technology for travel time measurement*

interconnected.

Traffic engineers and researchers have utilized the potential opportunities that exist with Bluetooth and have implemented this technology into traffic monitoring techniques. Recently, Bluetooth has become an alternative to former methods of travel time measurement, such as GPS probe vehicles, ALPR cameras, speed sensors, and aerial photography. Bluetooth as a method of travel time measurement works by deploying a pair of Bluetooth sensors along a roadway segment. The distance between the sensors is recommended to be greater than one mile. By emitting a signal out, the Bluetooth sensor waits to receive a signal back from any Bluetooth-enabled device that may be carried by the driver or passengers. If the Bluetooth sensor receives a response, the Mac address and timestamp of that signal is anonymously recorded (***Figure 1***).

From 1996 to Fall 2016, the Delaware Department of Transportation (DelDOT), with the help of the Civil and Environmental Engineering Department at the University of Delaware, used GPS technology for the purpose of travel time and delay time measurement. In the Fall 2016, the use of GPS technology for travel time estimation in the state concluded the Bluetooth method was adopted.

There are several differences between the GPS method and the Bluetooth method. The first and foremost difference between the two methods is recording delay time and delay reason. In the GPS method, one person in the data collection team is responsible to record both the time duration and reason for the delay. Delay is defined as the time when the vehicle is traveling below 5 (mph). Although this process contains possible human errors, it is still usable to enhance traffic flow conditions because planners and engineers are informed of the reasons of delay on a road, and they can plan mitigation strategies accordingly. In the Bluetooth method, delay time and delay reason are not recorded, so, the GPS method is more useful from this point of view.

The second difference between the two methods is the duration of collecting data. Bluetooth devices collect data 24 hours a day, seven days a week. However, in the GPS method, data is collected for peak hours in the morning and evening. It is worth mentioning that peak hours vary by days and season. For example, in the fall, morning peak hours on weekdays are 6AM to 8AM and on Saturdays are 9AM to 12 PM. The advantage of data availability for 24 hours a day is that off-peak hour data is accessible. On the other hand, processing this amount of data is

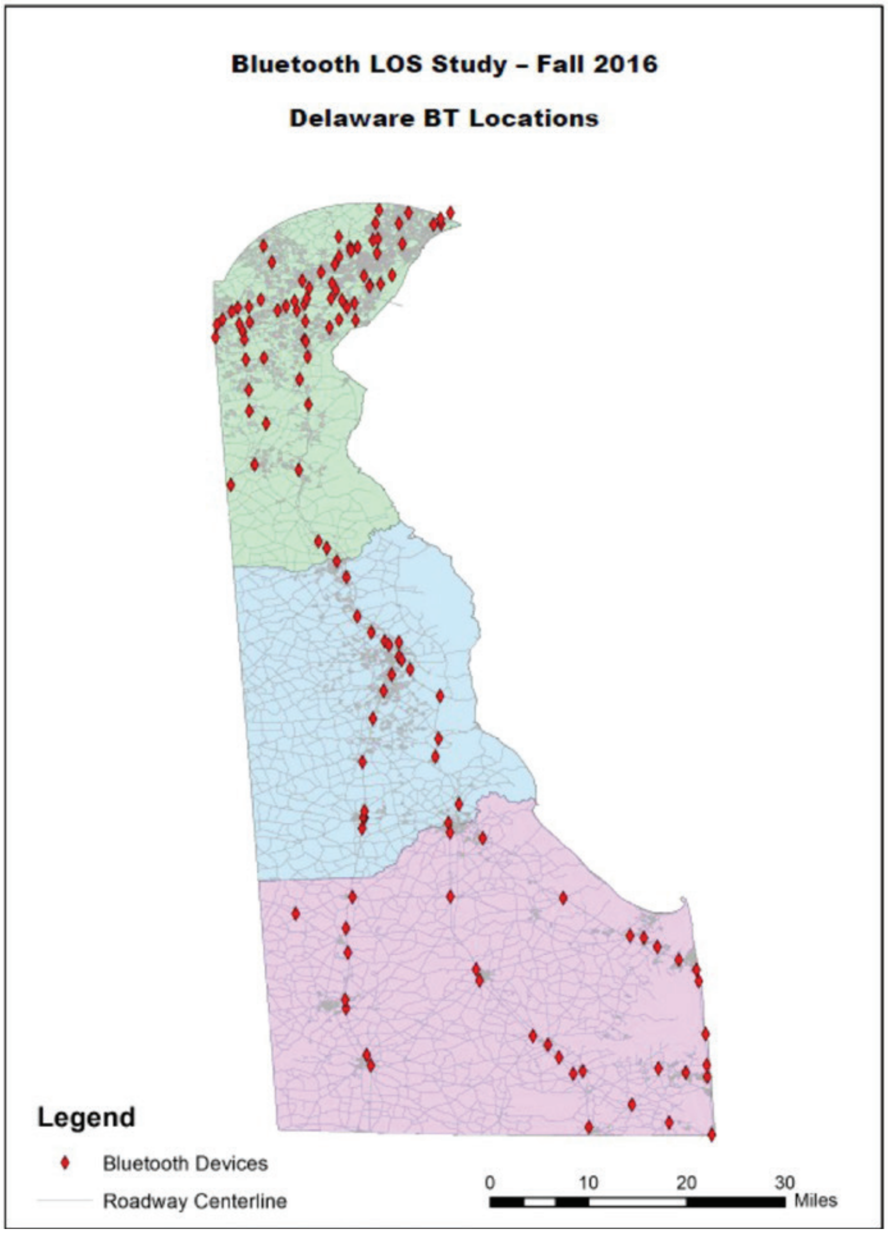
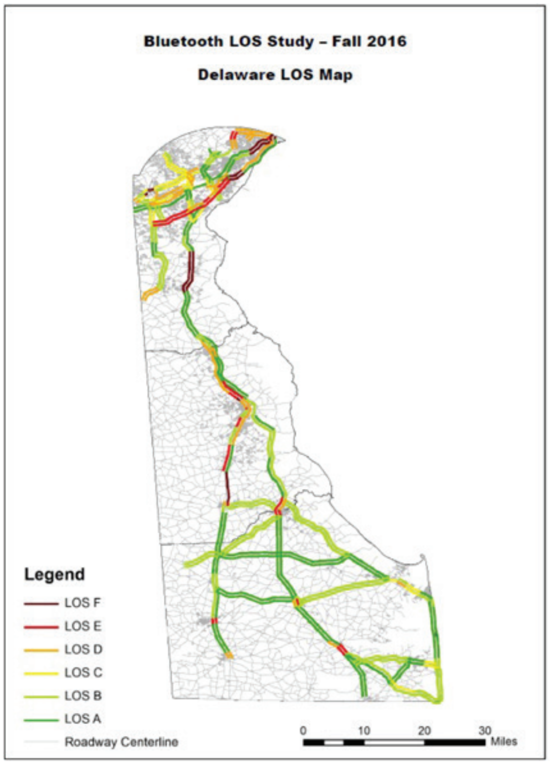
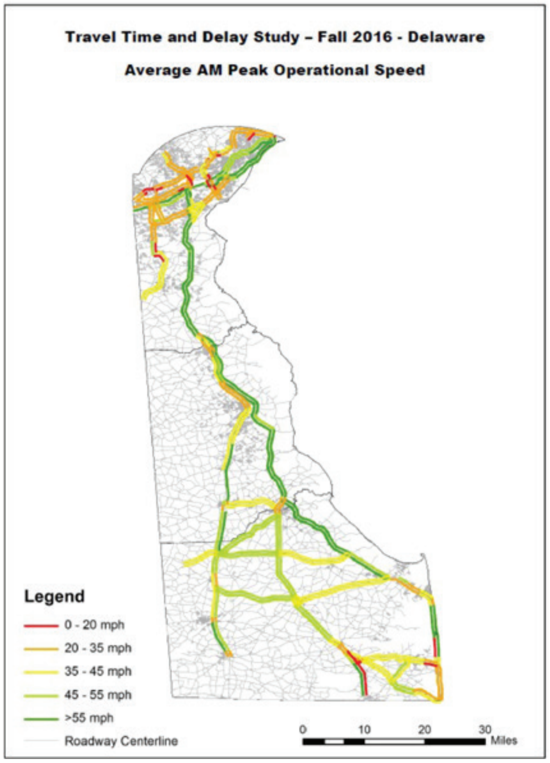


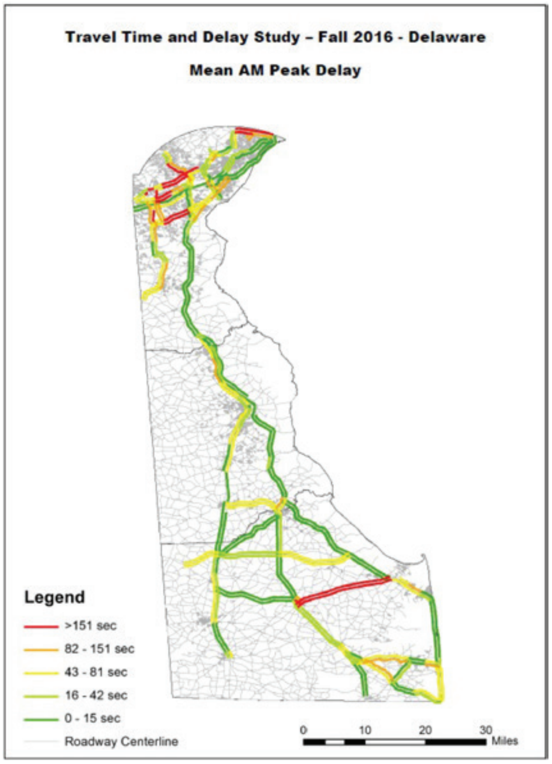
Figure 2 *Delaware Bluetooth Locations*



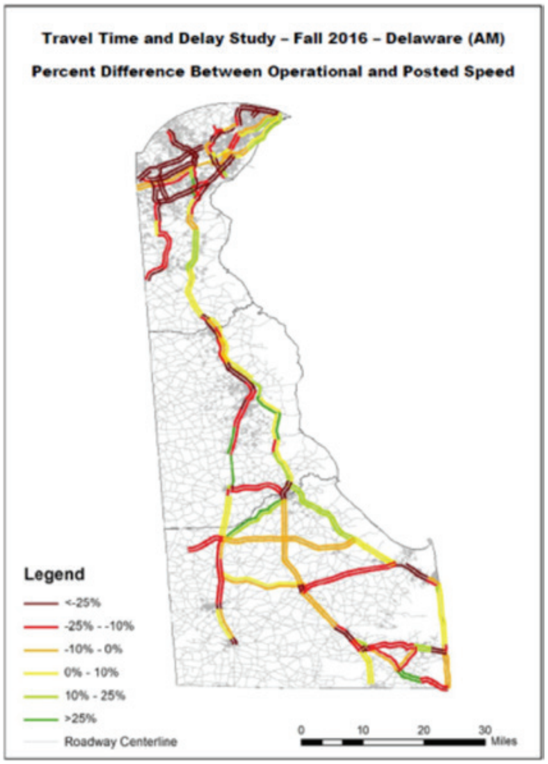
(a) Level of Service (LOS)



(b) Average peak operational speed, AM



(c) Mean peak delay



(d) Percent difference between average operational speed and posted speed limit

***Figure 3** Bluetooth travel time and delay study.*

not only costly but also time consuming, which can be a disadvantage of the Bluetooth method.

There are 131 Bluetooth devices in Delaware which provide a significant coverage of roadways in comparison with other states (***Figure 2***). New Castle County has 70 devices, Kent County has 27, and Sussex County has 34 Bluetooth devices. Number of observations, mean travel time, and median travel time for every 15-minute interval are recorded for each segment throughout the state. Segment can be described as the section of a roadway between two consecutive Bluetooth devices.

There are 146 segments in New Castle County, 55 in Kent County and 87 in Sussex County. In addition, there are a few segments that are located between two counties. 9 segments are between New Castle County and Kent County, and 10 segments are between Kent County and Sussex County. Most of the segments are two-way roadways; however there are a few segments that are located on one-way roads.

The data that is used in this study for travel time measurement was obtained from the Delaware Department of Transportation (DelDOT). The given processed data represents September and October 2016 Bluetooth recorded data for New Castle County, Kent County, and Sussex County. Each 24-hour is divided into 15-minute time interval starting from 12:00 (AM) to 12:00 (AM) the next day. For instance, data for September 2nd, 2016 was recorded from 09/02/2016, 12:00 (AM) to 09/03/2016 12:00 (AM).

Delaware Department of Transportation (DelDOT) believe that the Bluetooth system valuable because it can provide continuous, real-time coverage of the transportation system, which enables the calculation of statewide travel time reliability metrics (***Figure 3***). Also, based

The Delaware T²/TLAP Center Questionnaire

The Federal Highway Administration requests that we characterize our contacts more precisely. To help make sure that we have your contact information correct, and keep you in our database, last month, we sent out a questionnaire to all those on our current email distribution list. If you have not already responded and wish to continue to receive newsletters, technical bulletins and information on training workshops, etc. from the Center, please click here https://delaware.ca1.qualtrics.com/jfe/form/SV_3fyvj3k8Z4IIzZj to update your information. It will only take one minute of your time to complete. Please feel free to share the link with your colleagues who may not be on our distribution list and wish to benefit by our occasional outreach.

The Use of Crowdsourcing Tools in Active Transportation Planning

BY MARCIA SCOTT

Active transportation planning is usually informed through a combination of engineering studies, traditional data collection methods, and public involvement. Transportation planners are now recognizing the value of supplementing traditional active transportation data collection methods with participatory planning processes that incorporate community-driven, or "crowdsourced" data.

Crowdsourcing refers to the process of obtaining information, insight, and knowledge through web and mobile applications. Crowdsourcing in active transportation planning—specifically for bicycle planning—is a way to gain localized knowledge and better understand user behavior in order to prioritize and target bicycle infrastructure investments.

Supported by the Delaware Department of Transportation (DelDOT), researchers at the Institute for Public Administration (IPA) at the University of Delaware (UD) conducted applied researched on crowdsourcing tools during national Bike Month in May 2017. IPA policy scientist Marcia Scott and public administration fellow Savannah Edwards (MPA 2017) targeted two bicycle-related events in Newark, Del. as opportunities for "event-centric" crowdsourcing to engage, disseminate, and collect information from bicyclists.

Bike-to-School Week at Downes Elementary School

In conjunction with the Wilmington Area Planning Council's (WILMAPCO's) Safe Routes to School Program, a Bike-to-School Week was planned from May 8 – 12, 2017 at John R. Downes Elementary School (Downes ES) in Newark to pilot and obtain public feedback on a pop-up, buffered bike lane demonstration project. In addition to WILMAPCO and IPA, Bike-to-School Week activities were organized in collaboration with Downes ES, DelDOT, BikeNewark, the Newark Bike Project, City of Newark, and UD's chapter of Engineers without Borders (UD-EWB).

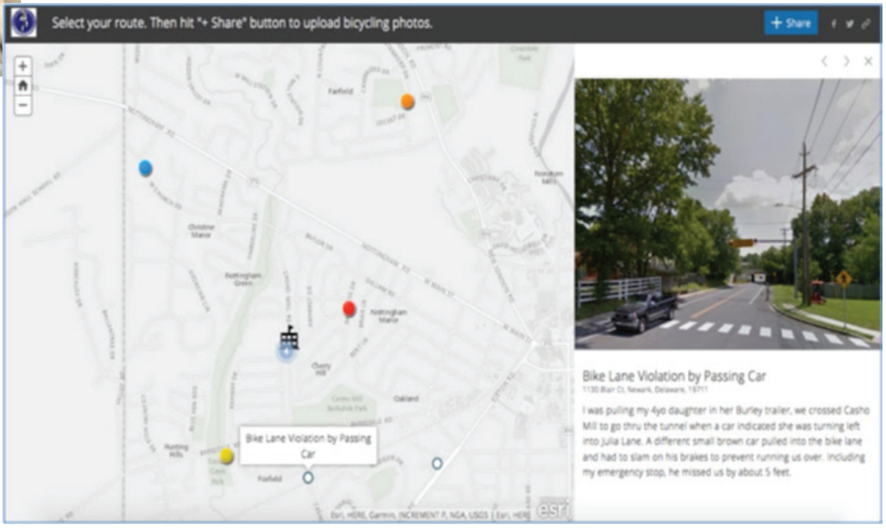
Civil and environmental engineering faculty member Abigail Clarke-Sather formerly served as UD-EWB's faculty advisor. Under her direction, UD-EWB's ReachOut Chair Christopher Kitson (MEEG 2018) and other members were instrumental in planning/designing/constructing a temporary pop-up, buffered bike lane along Casho Mill Road during Bike-to-School Week. A buffered bike lane was simulated using temporary barrels, paint, other markings, and signage. The event kicked off on May 8, with four guided bicycle rides to school led by Newark Mayor Polly Sierer, Newark police officers, and UD-EWB volunteers Kitson, George Wieber (CHEG 2018) Jordan Shuff (BMEG 2020) and Noah Kennedy (CHEG 2019).

Dr. Clarke-Sather directs UD-EWB volunteers in set up of Casho Mill Pop-Up Bike Lane Demo Project

The bike trains allowed Downes ES students and their families to travel together from various neighborhoods to experience the pop-up bike lane and provide feedback. The demonstration project remained in place until May 12, which allowed community members to also experience and provide feedback on the pop-up bike lane.

IPA's Scott and Edwards developed crowdsourcing tools to gain feedback from the students' parents and community members on the bike lane demonstration project. Social media posts, press releases, school newsletters, a website, flyers, lawn signs, and a community information meeting were used to promote the event and solicit community input. Signs posted along Casho Mill Road encouraged parents and community members to "rate your ride" via an online survey, and "tell your story" using an online GIS Crowdsourcing Story Map. The story map instructed participants to upload photos and comments regarding their experience using the pop-up bike lane. Two Piktocharts were designed to summarize outcomes of the survey and crowdsourcing GIS tools for Bike-to-School Week (see: https://goo.gl/1eQXcW and https://goo.gl/jpuADx).

IPA's Savannah Edwards and BikeNewark's Susan Grasso conducted outreach at a community meeting held at Downes ES during Bike-to-School week



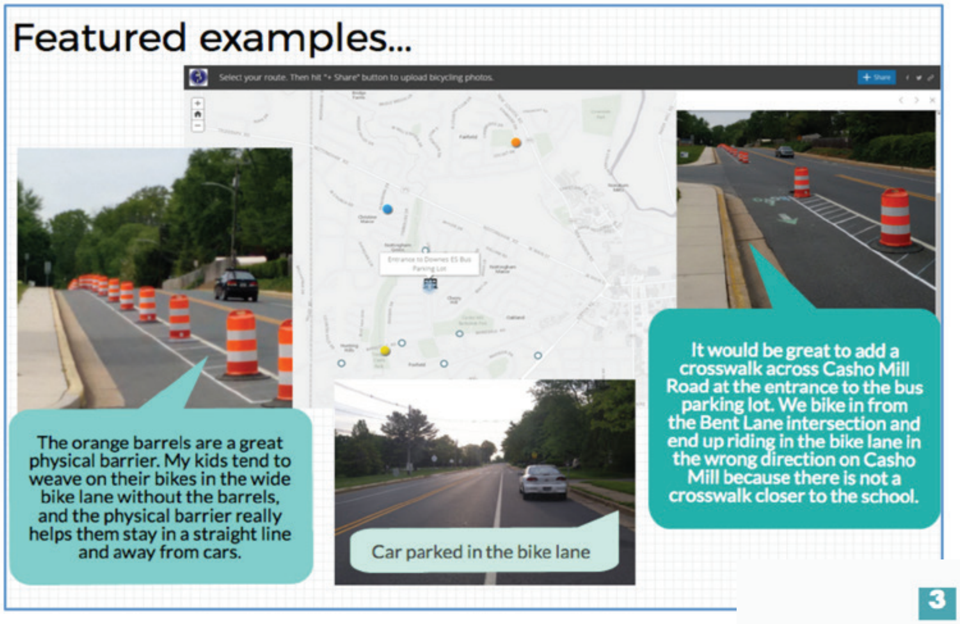
Crowdsourcing GIS Story Map (http://arcg.is/2n7ZggN)

Bike-to-Work Day in Newark, Del.

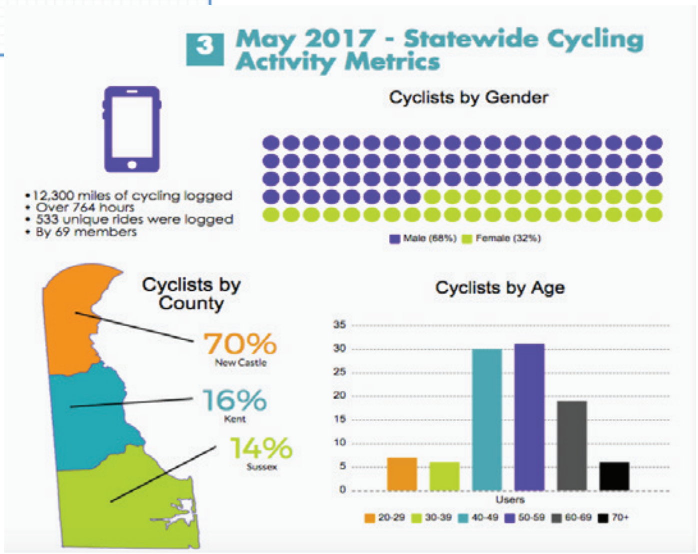
Newark's celebration of national Bike-to-Work Day on May 19, 2017 was organized by BikeNewark in partnership with the City of Newark, UD, DelDOT, and the Newark Bike Project. Bicycle commuters rode in teams with captain-led "bike trains" that departed from six locations and culminated with a celebration at UD's Mentors' Circle.

The 2017 event included a team "challenge" through Motivate the First State (MTFS), a campaign designed to inspire Delawareans to get active and make their activities count toward charity. Participants were encouraged to download and use the Plus3 Fitness App to record bike riding activities during May. Participants could also join a team in the MTFS clubhouse to participate in Newark's Bike-to-Work Day Challenge and compete against other teams to earn points.

IPA, in collaboration with DelDOT, tested the Plus3 Fitness App as a source of crowdsourced data for active transportation planning in Delaware. While there were 120 bike commuters during the event, few participated in the MTFS Newark Bike-to-Work Day Challenge. However, the applied research project generated useful bicyclist activity data, via the Plus3 app, that can potentially be used by DelDOT to track bicycling activity and generate activity metrics plan that may be used to plan for improvements to the state's bicycle and pedestrian infrastructure. This data could supplement other data used by DelDOT to make decisions about active transportation policies, plans, and projects. A Piktochart (https://goo.gl/jpuADx) visually displays general activity and statewide cycling metrics in May 2017 and outcomes of a



Crowdsourcing GIS Story Map (http://arcg.is/2n7ZggN)



Driverless Delaware?

ARTICLE BY ANN MANSER

PHOTO BY KATHY F. ATKINSON

UD researchers consider potential impact of autonomous vehicles

With the demand for self-driving vehicle technology accelerating among automakers and ridesharing businesses, policymakers nationwide have started planning for what many see as a transportation revolution.

In Delaware, the state Department of Transportation (DelDOT) asked researchers in the University of Delaware's Institute for Public Administration (IPA) to examine what might happen when — in the not-so-distant future — vehicles are likely to travel the state's roadways without a human at the wheel.

"We're a car culture in the United States, and autonomous vehicles [AVs] represent a very big change," said Philip Barnes, associate policy scientist in the IPA who conducted the research with doctoral student Eli Turkel, an IPA graduate fellow. "The old ways of doing things are going to change, and policies are going to have to change, too."

But, he said, those transportation policy changes won't be defined until planners know more about the impact AVs will have. That's the question Barnes and Turkel addressed in the 35-page report they recently completed for DelDOT.

The issues examined in the report include such topics as roadway safety, traffic congestion, jobs and the economy, revenue for state and local governments and residential development patterns.

"We can expect a lot of benefits from the use of AVs, but there are a lot of challenges and potential negative impacts, too," Barnes said.

In the report, he points out that Ford has said it will be selling AVs in the next five years and that most analysts expect modest sales of such vehicles by the late 2020s. Those same analysts predict "widespread adoption" of the technology through the 2030s and '40s.

In exploring the effects of what the report calls "the impending autonomous vehicle revolution" in Delaware, highway safety tops most observers' list of potential benefits. With a recent average of about 100 traffic fatalities annually in Delaware, the state could reasonably expect widespread use of AVs to save a significant number of lives each year, as the vehicles' guidance systems recognize the need to slow down, stop or change lanes in time to avoid accidents.

That same technology will mean a decrease in congestion, Barnes said, with traffic flowing easily around lane closures and other obstacles and merging smoothly without the usual stop-and-go pattern that human drivers follow.

Predictions are that AV passengers will have faster and more productive commutes to work — with time behind the wheel replaced by time to read, work or nap in the passenger seat. That's a positive impact, Barnes said, but urban planners wonder if the long-term effect will be increased suburban sprawl as commuting becomes less unpleasant and workers are willing to move farther from their job sites.

For another group, individuals with disabilities that prevent or restrict their own driving, AVs will mean being able to own a car and travel independently.

Barnes noted that this very independence raises more policy questions: Will the state still need to issue driver's licenses? If not, will there be an age limit for riding in an AV, or will 10-year-olds be able to take themselves to soccer practice? And will the cost of buying a new AV create a two-tiered system where lower-income people won't share in the immediate benefits?

Another policy issue addressed in the report is the revenue that governments now receive from fines paid for traffic violations, a source of income that could virtually disappear with no drivers to break the law. The insurance industry also needs to consider how to adjust to a future with few traffic accidents other than those potentially caused by a technology failure, Barnes said.

In Delaware, the report notes, DelDOT has implemented technological and infrastructure improvements that position the state well in preparing for testing, operation and deployment of AVs.

"If action is taken now, Delaware could position itself to be a leader in the autonomous vehicle area," the report concludes, recommending an accelerated pace of planning and coordination among state agencies.

A copy of the report is available here. http://www.ipa.udel.edu/publications/autonomous-vehicles-2017.pdf

Building a Coordinated Mobility and Specialized Transportation Framework in Delaware: Statewide Mobility Forum Engages Service Providers in Delaware

BY JULIA O'HANLON, POLICY SCIENTIST

MARCIA SCOTT, POLICY SCIENTIST

Institute for Public Administration

As part of a multi-phase applied research project with the Delaware Transit Corporation (DTC), the University of Delaware's Institute for Public Administration (IPA) has been working with DTC staff and statewide transportation and social service providers, to develop strategies and recommendations on implementing a statewide mobility management and coordination plan.

In addition to researching federal policy requirements and national mobility management and coordination best practices, IPA, in fiscal year (FY) 16, coordinated and facilitated county-based workshops and a statewide mobility forum. These activities gathered stakeholder and service provider feedback on Delaware's ongoing mobility management challenges. They also served to obtain input on opportunities to develop additional community partnerships, leverage existing services, and identify potential pilot projects in each of Delaware's three counties.

- Delaware's changing demographics, coupled with increasing needs of Delaware's transportation-disadvantaged populations, and new federal, mobility coordination regulations, are driving the state's mobility coordination agenda. Recurring themes and ongoing challenges discussed at the county workshops and statewide forum include the following:
- Delaware's ongoing mobility and specialized transportation challenges are exacerbated by the state's increasing senior population and demands on current public transit options
- Primary "demand drivers," beyond changing demographics, include disconnects between land-use and transportation/ transit, and requested paratransit trips for non-emergency medical transportation
- Unmet mobility needs and service gaps extend beyond DTC's reach and should include alternative, community-based services besides those provided at the state agency level
- Recognition of current Federal Transit Administration (FTA) policies and initiatives are imperative and should provide the basis for developing the state's contemporary mobility management framework
- Consideration of national and regional best practices, along with the expansion of new partnerships among the public, private, and nonprofit sectors, are key components of improving the state's transportation services and mobility framework development

To assess the overall "state of mobility management" in Delaware, information was obtained on various human-services transportation provision and provider organizations through survey research and outreach. This involved preparing and administering surveys of Section 5310 program transportation providers and general specialized transportation stakeholders in Delaware. Between January and May 2016, IPA worked with identified stakeholders and key transportation service providers throughout Delaware to conduct three county-based workshops. Survey outcomes provided the basis of workshop discussion and engagement.

Greatest Specialized Transportation Challenges in Delaware, Ranked by County Workshop Participants

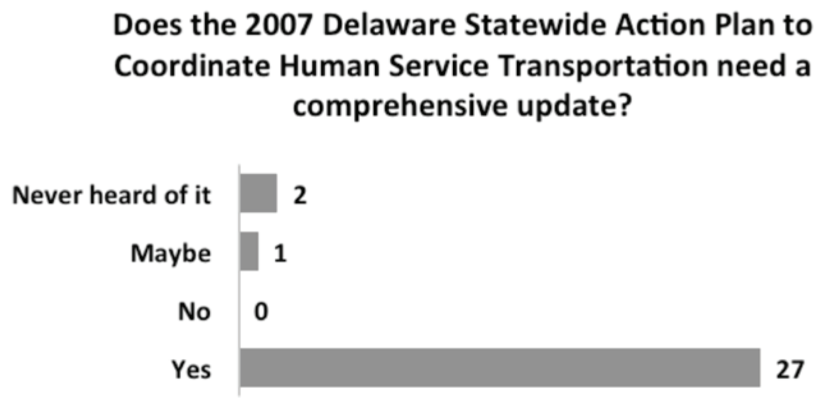
Rank	New Castle County	Sussex County	Kent County
1	"Demand Drivers" of Specialized Transportation	Coordination Challenges among Service Providers	Coordination Challenges among Service Providers
2	Coordination Challenges among Service Providers	"Demand Drivers" of Specialized Transportation	Unmet Needs and Gaps in Service Delivery
3	Unmet Needs and Gaps in Service Delivery	Specialized Transportation Efficiency Issues	Specialized Transportation Efficiency Issues

Common Themes

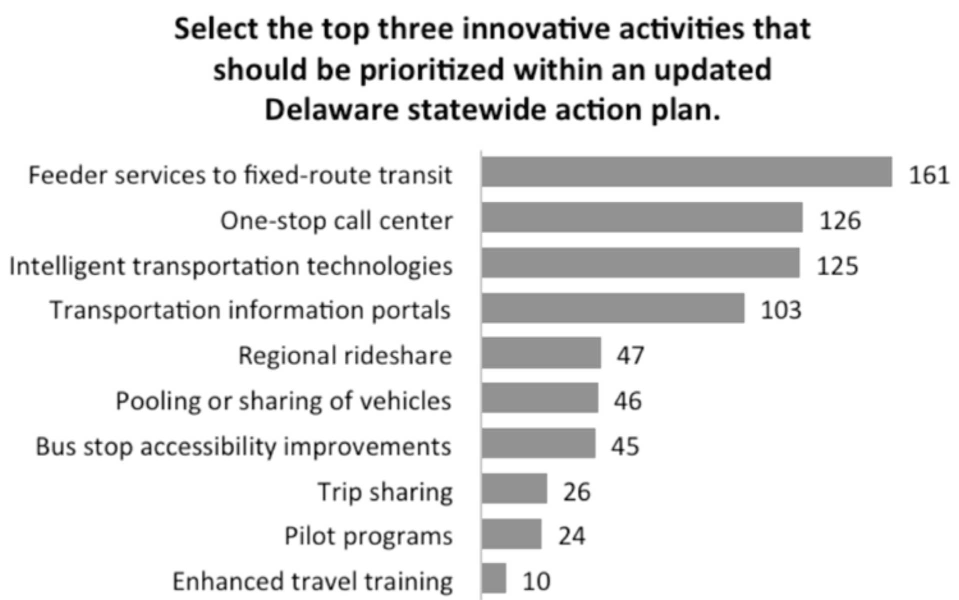
Several common themes were identified in the workshop summaries. These included a(n)

- Need for improved information management and dispersal among current providers
- Agreement that a "one-size-fits-all," statewide mobility coordination solution is unrealistic and inappropriate
- Desire for organized transportation "hubs" with "feeder" systems designed to help fill service gaps in more rural, less densely populated areas while better utilizing vehicles and current systems

Poll Reflects Consensus on the Need for an Updated Statewide Action (Coordinated) Plan



Poll Reveals Top Interests in Innovative Mobility Strategies in Delaware



Of the approximately 30 forum participants who participated in a polling session, a majority indicated that the Delaware Statewide Action Plan is in need of a comprehensive update. Given the federal government's current transportation and mobility coordination policy priorities, an update could make Delaware more competitive when applying for federal funding. Additionally, an updated plan would generate new state goals and objectives that align with services and initiatives already underway. Forum participants also ranked innovative activities that they believed should be prioritized within an updated plan. The highest-ranked activity was feeder services to fixed-route transit, followed by a one-stop call center, and intelligent transportation technologies.

Additional information about the county-based workshops, statewide forum, as well as recommendations on moving the state's mobility management framework forward, please visit IPA's final written report: www.ipa.udel.edu/publications/mobility-management-report-2017.pdf. Based on this first phase of work, the following recommendations aim to support and advance initiatives currently underway by the DTC to reduce cost pressures for all transit modes, address unrestricted and costly use of paratransit services, and create alternative and affordable transportation options for all Delawareans, especially state's transportation-disadvantaged populations. This includes veterans, no-car households, disabled youth, and seniors.

- Advance a mobility management framework in Delaware
- Update the Delaware Statewide Action Plan to Coordinate Human Service Transportation
- Support realignments to Delaware's federal transit funding to support mobility coordination among public and private providers in Delaware

IPA, in the next phases of this work (FY 17 and 18), is working with DTC on developing a formal outreach plan that will help inform an updated Statewide Human Services Coordination Plan. Continual policymaker support and agency leadership is needed to implement recommendations and improve Delaware's mobility framework. Working with community stakeholders, local transportation providers, and the medical community on comprehensive transit options for community-based services such as non-emergency medical appointments, as well as jobs and social services, requires leveraging existing programs while identifying new and innovative opportunities for public-private partnerships.

Research Pays Off:

Online scheduling and pricing for electric vehicle charging

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We design strategy-proof online scheduling and pricing mechanisms for Electric Vehicle (EV) charging in a competitive environment. EV drivers submit their requests for charging services dynamically over time, and they can name their own price on the charging services. The mechanisms schedule EV charging and determine charging prices considering the incentives of both EV drivers and power providers. In addition, our online mechanisms do not assume availability of information about future demand. Our charging mechanisms are preemption aware, allowing flexibility on when charging takes place. This is in alignment with power providers' load-balancing goals. We perform extensive experiments to investigate the performance of our mechanisms compared to that of the optimal offline mechanism. We analyze the various properties of our mechanisms, in particular, we prove that they are strategy proof; that is, truthful reporting of price and amount of charging is a dominant strategy for self-interested EV drivers.

PROBLEM

Widespread adoption of electric vehicles (EVs) is in alignment with sustainable transportation goals in their social, economic, and environmental aspects. Achieving large-scale adoption of EVs presents a number of challenges resulting from a current lack of supporting technologies/infrastructures and difficulties in overcoming technological barriers. Currently, EV drivers face long vehicle charging cycle times. In addition, they may face long waiting times and uncertainty over the availability of charging facilities. As EV usage for the daily commute increases, enabling the ability to recharge these vehicles both in and away from base locations (e.g., residential locations) becomes more important. For example, some EV drivers may want to recharge their EVs at their destination locations such as workplaces, where their vehicles are parked for an extended duration. On the other hand, high electricity consumption of EVs is a major concern for electric utility companies, making the load management of micro grids a challenge. The existing electricity infra-structure may not be capable of providing the power to satisfy the surge in power demand under these situations.

Although the utility companies will in the long-run work to address capacity shortages, they can significantly benefit from the development of scheduling and pricing mechanisms for EV charging that are cost-effective while providing good services. They seek to deploy mechanisms that lead to a balanced network load over time. One way to reach a better load balance is dynamic and preemption-aware scheduling. However, the problem of efficient scheduling and fair pricing of EV charging services is challenging, especially as both EV drivers and power providers can be seen as self-interested parties. EV drivers are interested in minimizing their costs and maximizing convenience, whereas utility companies would like to maximize their profits. When an EV is available for charging over an extended period (e.g., 8 am to 4 pm), charging mechanisms can service that request (i.e., provide the charge) either in one continuous time slot or in several discrete shorter time slots. A charging interruption may occur due to arrival of other urgent requests or the need for grid load balancing and necessitates preemption of scheduled requests.

SOLUTION

To ensure that the micro grid capacity constraints are not exceeded and those users who value the electricity the most are allocated and scheduled, we introduce the problem of preemption-aware Online Scheduling And Pricing (OSAP) for EV charging. The OSAP problem, given uncertainty about future arrivals, involves real-time scheduling and pricing of requests released over time (i.e., EVs that require a certain amount of charging by their departure) that share a scarce and perishable resource (i.e., electricity that is limited).

METHODOLOGY

We first solve an integer program to find the optimal schedule for the offline version of the problem, where all information about future supply and demand is known to the scheduler. We then construct an optimal offline mechanism using the offline scheduler and the pricing scheme. In addition, we design a family of online mechanisms that solve the OSAP problem, where the requests arrive dynamically over time. The mechanisms are model free, making no assumption about future demand, and they are invoked when a user places a new request or additional electricity capacity becomes available.

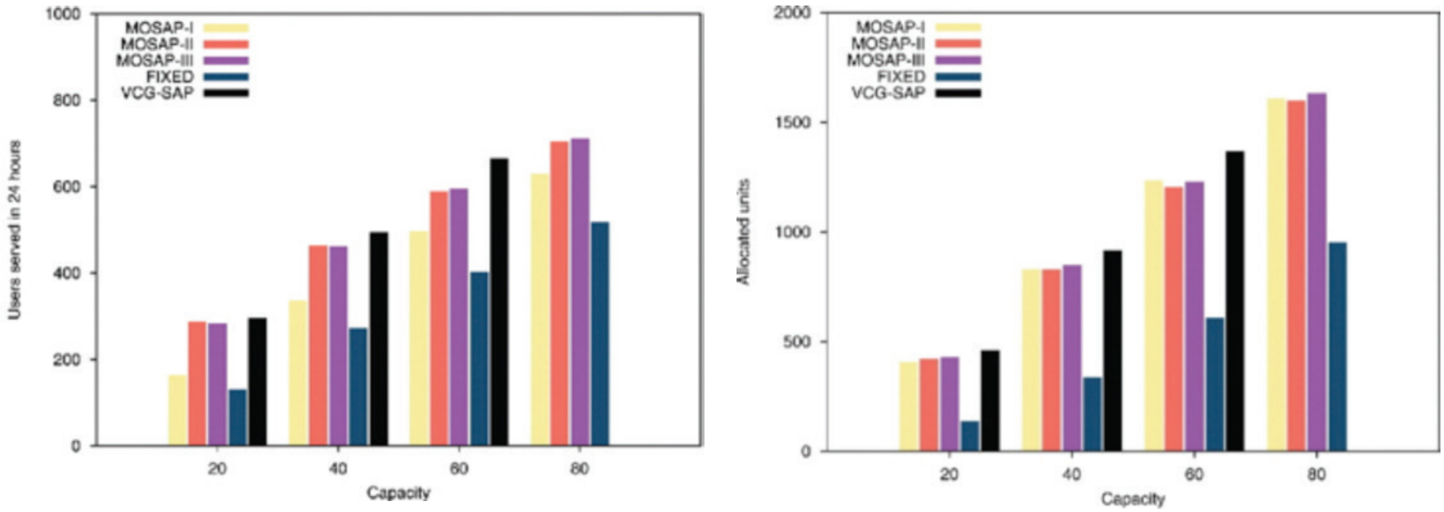

Fig. 1 *Sensitivity analysis of available capacity: (a) total served users; (b) Total allocated units with payment.*

Figure 1(a) shows the average number of served users whose entire requests are scheduled by the mechanisms. The results show that the number of served users increases by all the mechanisms with an increase in capacity. Figure 1(b) shows total allocated units with payment obtained by the mechanisms. These results show that the family of online mechanisms (MOSAP-X) is capable of allocating the entire requests of users close to that of optimal solution.

TECHNICAL BENEFITS

The dynamics of charging requests and the fact that utility providers need to consider load balancing necessitate designing preemption-aware online mechanisms for EV charging. In real-world settings, both the capacity of the utility provider and the arrival rate of charging requests can vary over time. We analyzed both of these scenarios. We developed a framework for EV charging considering the incentives of both utility providers and EV drivers. Our framework brings about a win–win situation in which EV drivers can receive their charging requests at lower prices, and utility providers can sell their unused capacity while considering their load-balancing objectives. We introduced the problem of online scheduling and pricing for EV charging and designed a family of online mechanisms. We proved that our mechanisms are strategy proof, where truthful reporting is a dominant strategy for users. We performed extensive experiments that showed that the mechanisms are not only capable of finding close-to-optimal solutions but are also very fast and obtain high revenue. These results show that the family of online mechanisms also provides these services obtaining high revenue, close to optimal welfare, and small execution time, while at the same time, users do not need to strategize to interact with the mechanism. The promising results make our approach suitable for scheduling and pricing EV charging in real time.

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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