WINTER 2016

florida department of transportation

Research Showcase

SOLUTIONS FOR WRONG-WAY DRIVING/PG 1

florida department of transportation

Research Showcase

The Florida Department of Transportation *Research Showcase* is published to provide information regarding the benefits of FDOT-funded research.

Managing Editor
J. Darryll Dockstader

Editor
Jessica VanDenBogaert
jessica.vandenbogaert@dot.state.fl.us

Writers/Graphic Design
Charles Brown
Jessica VanDenBogaert

Printer
Harvest Press

Front Cover
The Tampa skyline at sunset

Governor
Rick Scott

Secretary of Transportation
Jim Boxold

FDOT Research Center
605 Suwannee Street, MS 30
Tallahassee, FL 32399-0450
(850) 414-4615
http://www.fdot.gov/research

IN THIS ISSUE

AASHTO RAC Region 2 Sweet 16: Solutions for Wrong-Way Driving 1

Researchers Develop Tools to Tackle the SHRP2 Naturalistic Driving Study 7

Where Are They Now? Ternary Concrete Blends 10

Meet the Project Manager: Raj Ponnaluri 11

Meet the Principal Investigator: Neil Charness 12

In the Journals 13

Further Reading 14

AASHTO RAC Region 2 Sweet 16:
SOLUTIONS FOR WRONG-WAY DRIVING

Between 2009 and 2013, 280 wrong-way crashes occurred on limited-access highways in Florida, resulting in 75 fatalities and more than 400 injuries. Many of these drivers were young and impaired by alcohol, drugs, or both. Though rarer than an average traffic crash, limited-access wrong-way crashes are dangerous and often fatal. One of the causes of these incidents is that drivers may be confused by the choices they have to make at a highway interchange. To help drivers make safe and proper choices, FDOT sponsored a suite of projects to fully understand the issue and investigate design and human factors issues related to wrong-way driving.

UNDERSTANDING THE ISSUE:
Statewide Wrong Way Crash Study

FDOT commissioned a study by Kittelson and Associates to quantify the number of wrong-way crashes and find common contributing factors. This project, Statewide Wrong Way Crash Study, quantified the location, time of day, manner, and severity of wrong-way crashes occurring on Florida's limited-access highways between 2009 and 2013. From a pool of more than 6,300 possible wrong-way crashes, 280 were confirmed through detailed review of the crash reports. Crashes were included in the study if they involved a wrong-way entry on a ramp or driving on the mainline against the direction of traffic. The researchers excluded crashes that involved a U-turn followed by wrong-way driving or reversing on the mainline or ramps. Overall, researchers found time of day, age, and alcohol and/or drug use to be contributing factors.

Of these 280 wrong-way crashes, more than half resulted in an injury and 18% resulted in a fatality. The majority of crashes (55%) and 70% involving a fatality occurred between midnight and 6:00 A.M. In fact, during this time frame, wrong-way crashes were 4.1 times more likely when compared to the typical time distribution of crashes on Florida's limited-access highways.

Drivers under 30 years old accounted for 42% of wrong-way crashes. However, this age group represents 50% of all crashes on limited-access highways in Florida, so the proportion of those involved in wrong-way crashes and those involved in all crashes is similar. For drivers over 75, this trend does not hold. Older drivers accounted for 4.6% of wrong-way crashes. This is more than three times the proportion of older drivers in all crashes on limited-access highways, which is 1.4%.

Alcohol or drug use was present in 45% of wrong-way crashes, which is consistent with the results found during the literature review (widely cited at 50%). When compared to all crashes on limited-access highways, in which less than 3% of crashes involve alcohol or drugs, wrong-way crashes are 16 times more likely to involve an impaired driver.

The researchers also classified the crashes by location to identify interchange types that may be more susceptible to wrong-way entry. They found that wrong-way entries by interchange matched very closely to the distribution rates of those interchange types across the state. Therefore, interchange type did not seem to be a factor of wrong-way entries. For example, while diamond and partial diamond interchanges were the site of 49.1% of wrong-way crashes, these interchanges are found at 55.7% of ramps in Florida. Please see the table above for further information.

ABOUT THE SWEET SIXTEEN:

Each January, the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Council (RAC) Value of Research Task Force solicits states to submit recently completed research projects as examples of transportation excellence through research. By mid-May, each of the four RAC regions selects its top four research projects as the AASHTO Research Sweet Sixteen. These projects are showcased during the AASHTO RAC and Transportation Research Board (TRB) State Representatives summer meeting in July and poster session at the next TRB Annual Meeting.

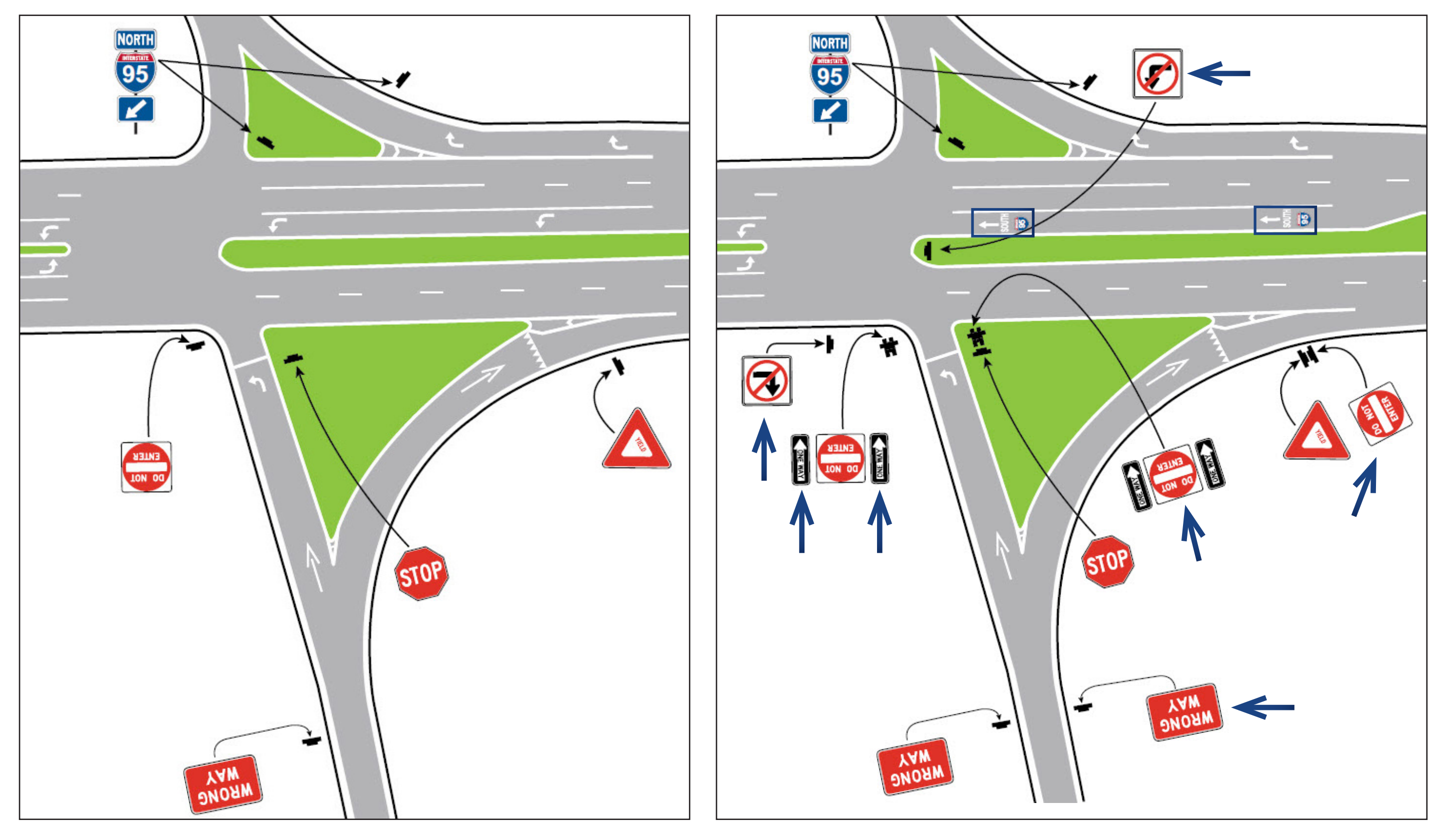
This year, FDOT's suite of wrong way driving research was chosen as a member of the Sweet Sixteen for Region 2. This is the second year in a row that an FDOT project has been selected.

Interchange Type	Statewide Distribution Proportion	Wrong Way Crash Score Proportion
Diamond/Partial Diamond	55.7%	49.1%
2 Quadrant/Partial Cloverleaf	25.5%	22.7%
Trumpet	6.0%	8.3%
Direct Connection Design	5.7%	3.9%
Y Intersection	3.0%	3.1%

As reported in the *Statewide Wrong Way Crash Study*, the proportion of wrong-way crashes by interchange type largely corresponds to the proportion of that type of interchange on the State Highway System, suggesting that one particular interchange is not more prone to a wrong-way crash.

With input from FDOT district Traffic Operations staff, the researchers selected 40 sites for field observation and assessed the conditions of those interchanges both during the day and at night to qualitatively assess lighting conditions and sign visibility and retroreflectivity. In general, signage met and, in places, exceeded the minimum requirements of the *Manual for Uniform Traffic Control Devices* (MUTCD). However, the researchers found that the intersection geometry and space allowed room for improvement (e.g., bigger signs, more signs). Lighting levels varied widely, with some locations having both high-mast and street lighting, some with high-mast lighting only, and some with no lighting. The unlit and limited lighting interchanges rely heavily on sign retroreflectivity. FDOT is currently in the process of adding lighting to all currently unlit interchanges.

Factoring in the results of the historical analysis and field reviews, the researchers recommended a multi-tiered system of countermeasures to reduce driver confusion. The lowest tier, Level 1a, is tied to the current MUTCD and FDOT minimum standards. The next level of countermeasures (Level 1b) called for an increase in the FDOT minimum standards to include optional MUTCD signage, larger signs, lower mounting height for Wrong Way



Level 1a (right) reflects the current FDOT and MUTCD requirements for a diamond intersection. Level 1b (left) shows the new minimum level of signage recommended by the *Statewide Wrong Way Crash Study*. A modified version of Level 1b was adopted with the January 2016 revision of the FDOT *Plans Preparation Manual*.

signs, increased use of retroreflective sheeting, increased pavement markings, and shaped median openings that restrict/deter wrong-way movements, among others. For more information on Levels 1a and 1b, please see the images on the previous page.

The researchers then recommended two different levels of countermeasures for potential improvements at interchanges. Level 2 implementation includes an additional entrance ramp directional sign assembly on the opposite side of the ramp, freeway-sized signs or larger, a second set of Wrong Way signs at staggered height, placing Wrong Way signs on the back of any existing structures, a retroreflective sheeting border around Wrong Way signs, and replacing circular green with through green arrows on outside lane signal heads.

For interchanges with potential for wrong-way entries, the researchers recommended a top tier of countermeasures incorporating dynamic signage and intelligent traffic systems: LED-illuminated Wrong Way signs with radar detection; red in-pavement flashing lights that create the illusion of a stop bar on the exit ramp; flashing reflective pavement markers along the exit ramp edge; and wrong-way radar detection integrated with closed-circuit television and the Traffic Management Centers. This higher level of communication, up to and including connected vehicle applications, would allow for early detection and apprehension of wrong-way drivers who enter the mainline.

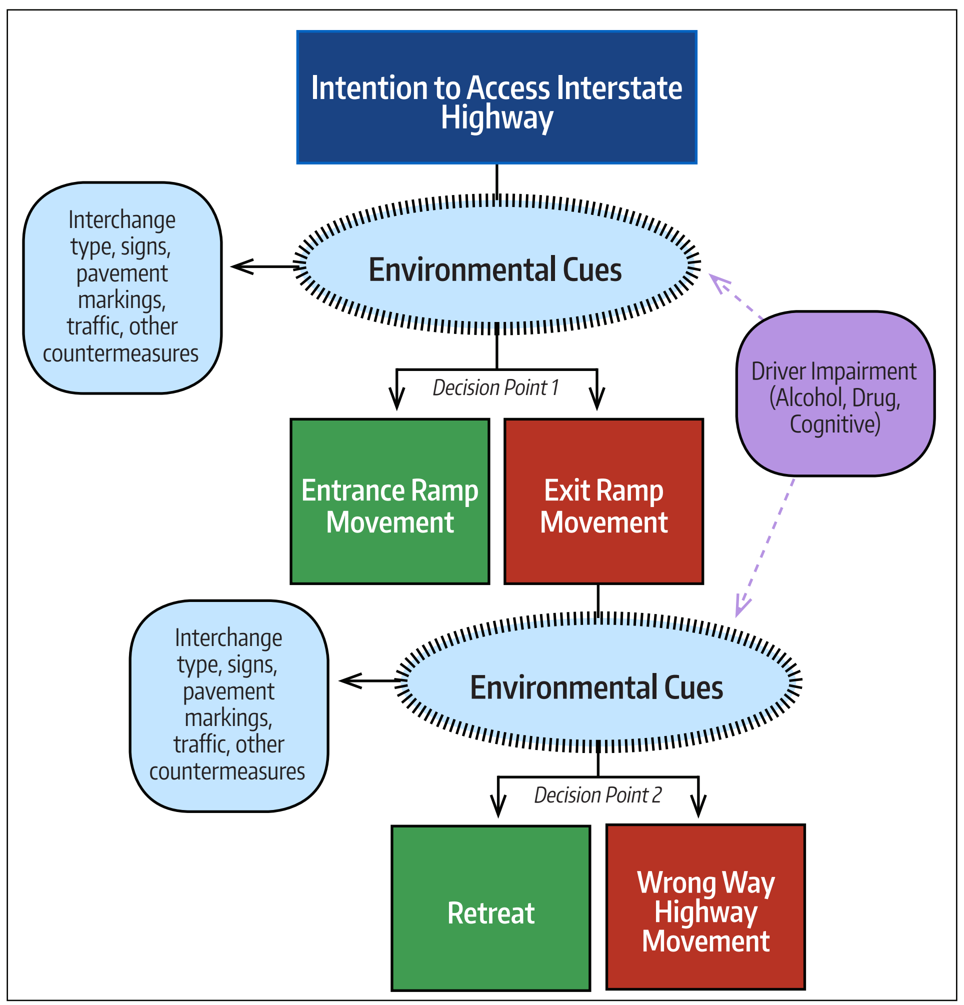
Overall, this project gave FDOT staff a better understanding of wrong-way crashes, identified problematic locations, and provided recommendations for reducing the potential for wrong-way entry. However, what it did not do is address the common element at every intersection - the driver.

UNDERSTANDING THE DRIVER DECISION PROCESS

To learn how drivers respond to the different levels of countermeasures, the FDOT Traffic Engineering staff turned to human factors research, which, in transportation, is the study of the interactions between drivers and their environment, including signage.

FDOT contracted with Florida State University researchers to understand how drivers interpreted signage, in particular, the cues drivers rely on to understand how to enter a limited-access highway. The research also explored driver reaction in a simulated environment and when the driver is impaired, as by alcohol use.

The researchers constructed a series of tasks to measure and interpret the way a driver makes the decision to enter an off-ramp. They chose a cue-based framework. Road geometry, pavement markings, signage, and the behavior of other traffic are all cues that drivers consider when deciding where to go and how to get there. For example, while a yellow edge on the right side of the road and a white line on the left would signal that one is driving the wrong way on an interstate ramp, this cue is likely less noticeable than a retroreflective Wrong Way sign.



A conceptualization of the cue-based decision making process that a driver follows while determining how to access an interstate highway shows the importance of easily understandable environmental cues in making the correct turn.

Two experiments were conducted to determine if, following the cue-based hypothesis, wrong-way entries can be reduced by adding additional cues – more specifically, the Level 1B recommendations from the *Statewide Wrong Way Crash Study*.

In the first experiment, 120 study participants (80 younger drivers with a mean age of 23 and 40 older drivers with a mean age of 72) were shown pictures of entrance and exit ramps for a short period of time, meant to simulate a single glance. Participants were then asked if they had seen an image of an entrance ramp. Overall, participants accurately identified 92% of exit ramps and 88% of entrance ramps. However, accuracy across exit ramps differed dramatically: one exit ramp was identified correctly 100% of the time while another exit ramp was identified correctly only 16% of the time.

Upon further analysis, the researchers found that drivers were less likely to misidentify as entrances the exit ramps at which a greater number of different types of cues were installed. Ramp images with three to six visible countermeasures were shown to participants. Images with six countermeasures performed better than images with three, four, or five countermeasures. Interestingly, this effect was similar for both younger and older groups.

In the second experiment, participants navigated a diamond interchange (modeled on the junction of I-75 and University Parkway in Sarasota that was identified in the *Statewide Wrong Way Crash Study* as problematic) in a simulated environment four different times: both eastbound and westbound with the minimum MUTCD standards and then again in both directions with the enhanced Level 1B recommendations from the *Statewide Wrong Way Crash Study*.

A participant wearing an eye-tracking device in the driving simulator portion of the project navigates the how-to tutorial before tackling the countermeasure scenarios.

Older participants all drove in a daytime simulation while younger participants all drove in a night-time variation. These conditions ensured consistency with the time of day most associated with wrong-way crashes by each group. Half of the younger participants completed the scenario under conditions that mimicked drug or alcohol impairment, simulated by wearing goggles that distort vision and responding to distractions created by the addition of another task (i.e., being asked to remember the number of times a specific letter was said to them during a scenario). Ultimately, this created three

	Exited Left		Did Not Exit Left	
Minimum Countermeasures	Left Turn Wrong Way	Right Way	Missed All Exits	Right Turn Wrong Way
Younger	0	38	2	0
Younger (Impaired)	2	32	6	0
Older	1	31	7	1
Total	3	101	15	1

	Exited Left		Did Not Exit Left	
Enhanced Countermeasures	Left Turn Wrong Way	Right Way	Missed All Exits	Right Turn Wrong Way
Younger	0	38	2	0
Younger (Impaired)	0	32	8	0
Older	0	34	6	0
Total	0	104	16	0

different groups of drivers: older, unimpaired younger, and impaired younger.

At the beginning of the scenario, drivers were given only a direction of travel and a travel destination. To reach their destination, they would need to rely on the environmental cues to make a left turn onto an entrance ramp with minimal simulated traffic. As the behavior of other drivers serves as a strong cue regarding ramp type, this removal of the potential cue of another car ensured that the drivers were influenced by the countermeasures and signage, not the traffic.

Of 130 participants in the minimum standard scenario, four made some type of wrong-way turn while 15 missed the entrance entirely. Interestingly, in the enhanced countermeasure scenario, no wrong-way turns were observed while nearly the same amount, 16 drivers, did not turn. Tables 10 and 11 detail the results of the simulator scenarios. These results, while from a relatively small pool of participants, suggest that the enhanced system of countermeasures is effective at preventing driver error.

OUT IN THE FIELD

Complementing the statewide study and human factors research were the Florida's Turnpike Enterprise and FDOT District 7 pilot tests of different countermeasure technologies in the field to judge their effectiveness at reducing wrong-way driving. At 17 exits of Florida's Turnpike and the Sawgrass Expressway in south Florida, Wrong Way signs bordered with red LED lights were installed. These blinker signs are a standard Wrong Way sign bordered with LED lights that flash red when a wrong-way vehicle is detected by the connected radar system. When the radar is activated, the alert system snaps a picture of the offending vehicle and alerts the Traffic Management Center (TMC). Since the signs were installed in October 2014, 23 drivers have attempted to go the wrong way at the monitored exits in South Florida; all but one driver self-corrected and turned around (~96% success rate).

In Tampa, the FDOT District 7 Traffic Engineering Office partnered with the University of South Florida Center for Urban Transportation Research to pilot red Rectangular Rapid Flashing Beacons (RRFBs). Prior to the installation of the red RRFBs, the researchers surveyed citizens to determine their reactions to, and understanding of, this countermeasure with regard to entrance and exit ramps and their effect on adjacent roadways. The survey results showed that respondents preferred a "more is better" approach to the RRFB – lights on top and bottom of Wrong Way signs posted on both sides of the ramp.

The RRFB configuration developed through the survey was installed in Tampa at two off-ramps with different geometries: one long and wide, and one short and narrow. The researchers went into the field to determine how this RRFB configuration affected driver behavior on the adjacent arterial. Because most wrong-way crashes occur at night, data were collected for two nights prior to installation of the RRFBs to establish a baseline of behavior. Once the RRFBs were successfully installed, the researchers triggered them, either manually or with a test car making a wrong-way entry. The researchers observed the behavior of the drivers on the arterial and compared their actions with the control, watching especially for sudden decelerations, sudden stops, and sudden lane changes. Little to no change in driver behavior was observed in the two nights of observation, both according to observation and statistical analysis.

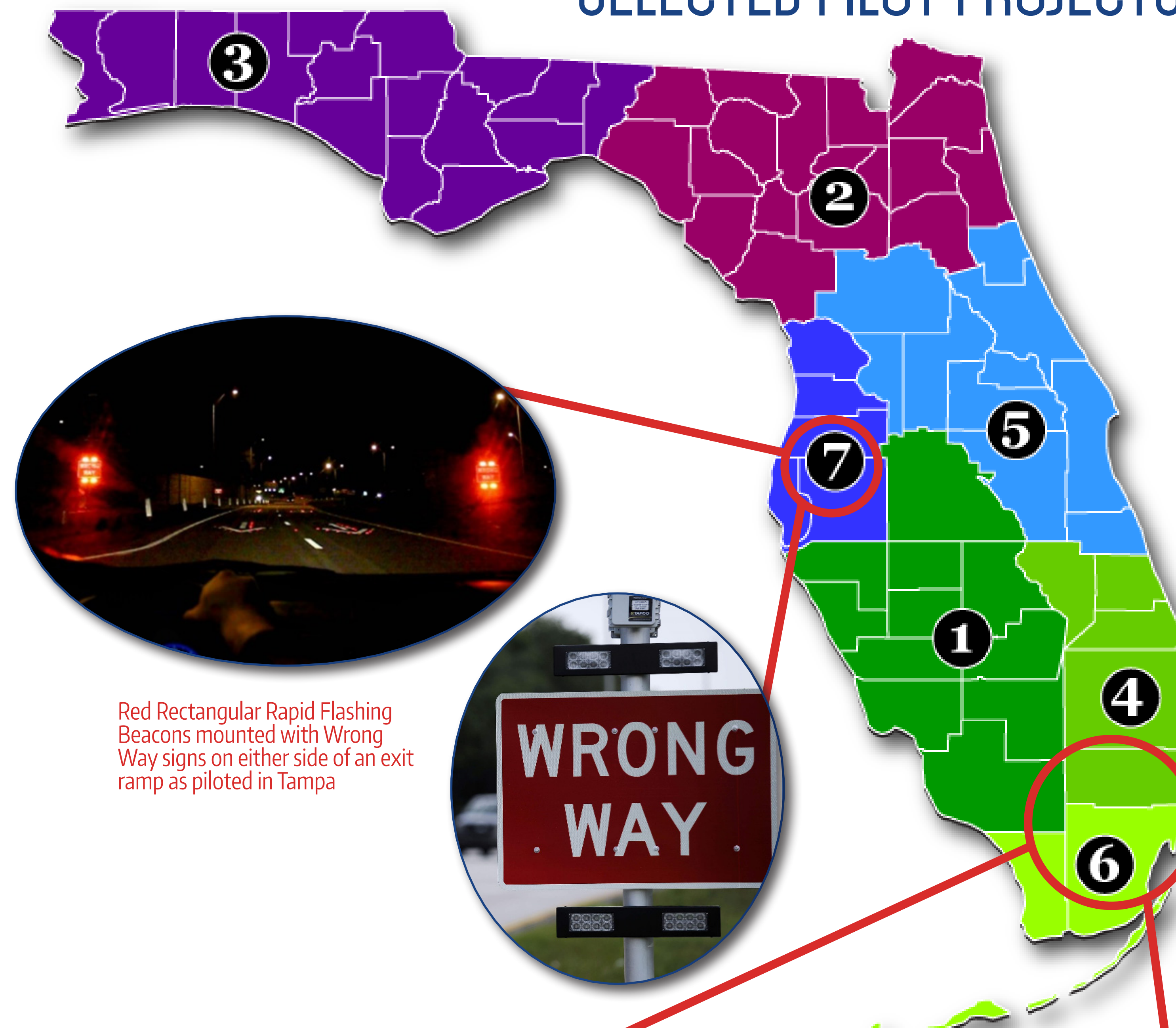
Following the pilot study, red RRFBs were placed at six intersections along interstates in the Tampa Bay area. In addition to alerting drivers to incorrect ramp entry, the RRFBs take and send a picture of the vehicle to local law enforcement and to the local TMC, which can post warnings to dynamic message signs in the area. While hard numbers are not yet available regarding the performance of the new signage at these six intersections, anecdotal evidence suggests that they are deterring wrong-way driving.

LOOKING FORWARD

Currently, the University of South Florida, Florida International University, and Florida State University are collaborating on a project to compare several countermeasures being piloted in Florida and identify the most effective. Top candidates will be selected for further testing in the field and via simulation. This research will contribute to decision-making regarding the development of new guidance and future implementation of wrong-way countermeasures. ▪

Final Reports available at www.fdot.gov/research

SELECTED PILOT PROJECTS



Red Rectangular Rapid Flashing Beacons mounted with Wrong Way signs on either side of an exit ramp as piloted in Tampa

A wrong-way driver triggers the automated notification system on Florida's Turnpike.

A Wrong Way sign with LEDs is triggered by radar when a driver makes a wrong way entry.

RESEARCHERS DEVELOP TOOLS TO TACKLE THE SHRP2 NATURALISTIC DRIVING STUDY

The nature of research tends to be cumulative. One project builds on others, directly and indirectly. Research projects answer some questions but often ask new ones and, in the process, researchers create tools that improve the efficiency of the research process itself.

THE NATURALISTIC DRIVING STUDY

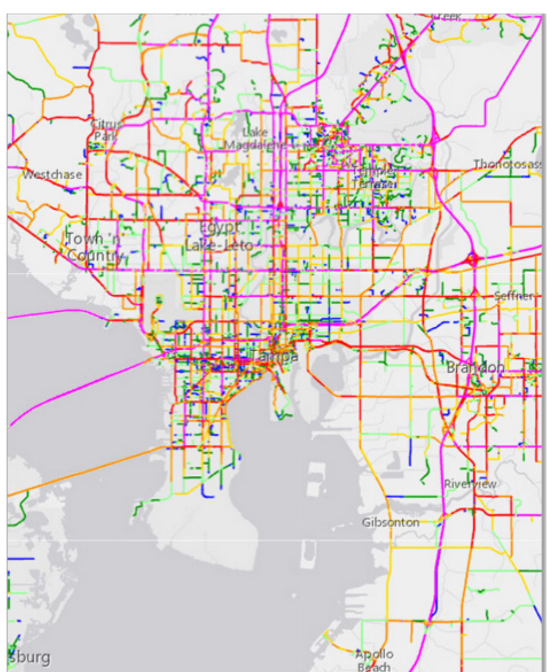
The Second Strategic Highway Research Program (SHRP2) generated many products that state DOTs, other transportation agencies, and researchers can employ to improve the way they plan, operate, maintain, and ensure safety on the road. SHRP2 focus areas included Capacity, Reliability, Renewal, and Safety.

Following the SHRP2 program, the Federal Highway Administration worked with the American Association of State Highway and Transportation Officials to develop an Implementation Assistance Program (IAP) to provide funding and resource support to accelerate SHRP2 product adoption. Seven rounds of IAP solicitation spanning more than three years successfully involved the nation in implementing SHRP2 products.

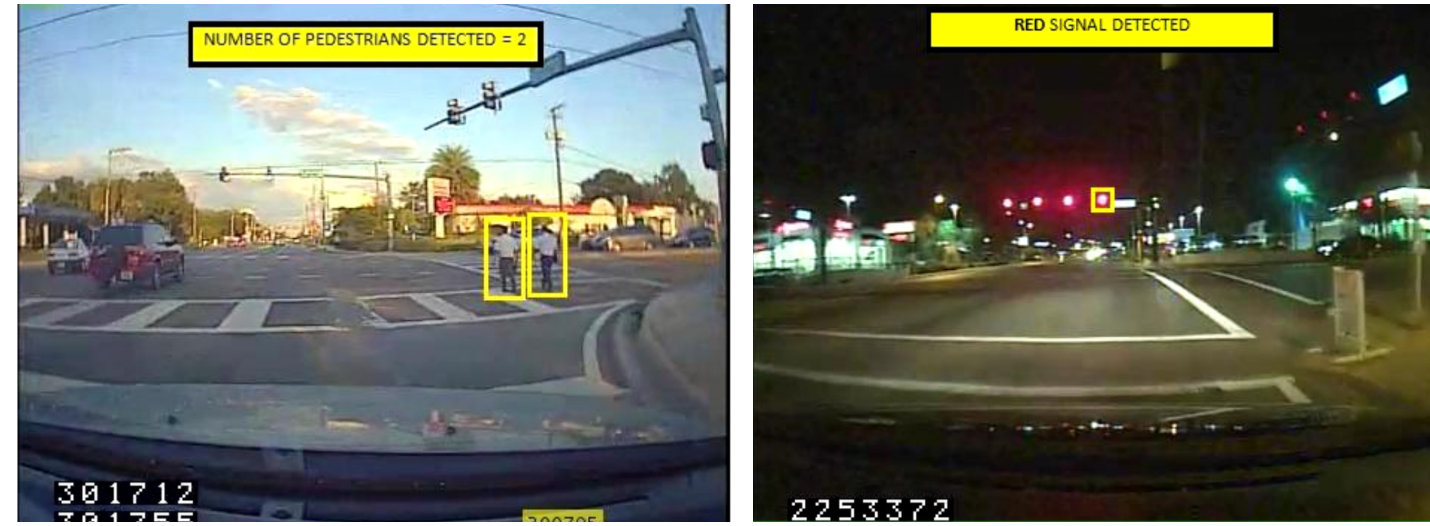
Unlike the other areas, the safety focus was not distributed across theme-relevant projects but comprised a single, major Naturalistic Driving Study (NDS) that involved studying the behaviors of 3,000 drivers on the roads in six U.S. cities, one of which was Tampa, Florida. The chief products of the research are the NDS database and a companion Roadway Information Database (RID). The largest study of its kind, the NDS provides unparalleled opportunity for conducting transportation safety research.

The data acquisition system (DAS) used on each participant vehicle recorded a staggering amount of data. The DAS included forward radar, four video cameras, accelerometers, vehicle network information (such as braking and accelerator activity), GPS, eye tracking, and lane tracking. In total, the NDS database comprises some 2 petabytes of data, equivalent to 2,000,000 gigabytes (a typical smart phone holds about 30 gigabytes) and is maintained at the Virginia Tech Transportation Institute (VTTI).

The Roadway Information Database (RID) contains complementary data about the roadways the NDS drivers used. The RID combined existing roadway information



The SHRP2 Naturalistic Driving Study captured an unprecedented amount of video, sensor, and trip data which researchers can use to gain new insights into the actions, reactions, and decision making of drivers. The Tampa Bay area was one of six regions selected for data collection.



The Automatic Video Processing Tool (AVPT) identifies pedestrians (left) and red traffic signals (right) in segments of video from the NDS. These segments will be flagged for review and analysis by the researchers.

sources with additional data collected on NDS routes. Similar to the NDS, RID data are exhaustive, including number of lanes, lane type and width, grade, superelevation, beginning and end points of a curve, curve radius, lighting, rumble strips, median type, paved shoulder width, speed limit sign locations, location of intersections, the number of approaches, and the traffic control devices. The RID database is maintained at the Center for Transportation Research and Education (CTRE) at Iowa State University.

Safety/NDS appeared only in IAP Round 4: 10 states were awarded 11 proof-of-concept projects and would be allowed to compete for countermeasure development and countermeasure deployment support in two successive selections.

FDOT received IAP funding twice to study the interactions between drivers and pedestrian features at signalized intersections and to evaluate the readiness of, and provide user feedback on, the NDS and RID databases. The researchers were successful in an initial project that used a limited dataset and were funded to develop safety countermeasures using a much larger dataset in a second project. If successful, FDOT will receive additional funding to implement the developed countermeasures.

PROOF OF CONCEPT STUDY

FDOT contracted with the University of South Florida Center for Urban Transportation Research (USF CUTR) to use the NDS and RID to develop a more detailed, nuanced understanding of how drivers and pedestrians interact with each other and their environments. The researchers, Drs. Pei-Sung Lin and Achilleas Kourtellis, participated in the SHRP2 research in Tampa and would for the IAP projects study how drivers react to existing pedestrian features (e.g., pedestrian signs, pedestrian signals, traffic signals, crosswalks, and pavement markings) at signalized intersections, with and without the presence of pedestrians.

The team focused on four signs: Stop Here on Red, No Turn on Red, Turning Vehicles Yield to Pedestrians, and Right on Red Arrow After Stop. These countermeasures are specifically placed to encourage compliant behavior in drivers and reduce the conflicts between vehicles and pedestrians at intersections. The research would investigate which, or which combination, of them is most effective.

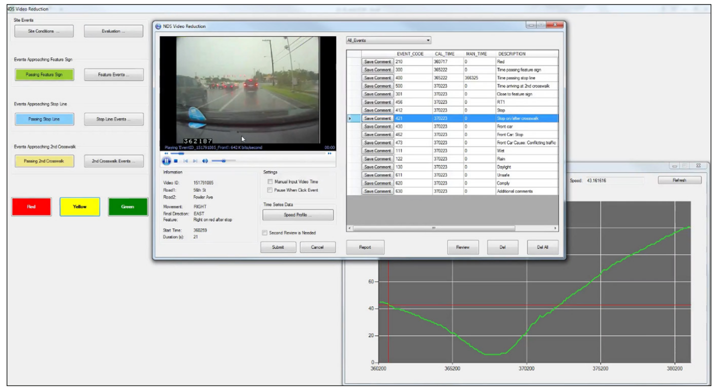
The researchers used trip density maps provided by VTTI to choose intersections with the desired pedestrian features: four sets of three intersections with similar annual average daily traffic counts, trip densities, and geometries. Each set consisted of two intersections with the target pedestrian feature and a control intersection with no pedestrian signage.

They then worked with VTTI and CTRE to acquire the necessary NDS and RID trip data needed for analysis. A total of 2,430 trips were obtained and divided into short and long segments passing through the defined intersections.

To manage the overwhelming amount of data available for analysis, the research team developed two custom software tools: the Automatic Video Processing Tool (AVPT) and the Data Reduction and Analysis Tool (DRAT). The AVPT automatically detects and tracks pedestrians and traffic signal indications. Raw video is processed and segments with a detected pedestrian presence are flagged for further review, identifying the number of pedestrians and location relative to the vehicle. The researchers can use AVPT to select video segments with both pedestrian presence and a red traffic light.

This processing dramatically reduces the amount of time needed for manual video review. One hour of video can be reduced to approximately 30 seconds of relevant footage needed for analysis, complete with contextual information. The research team estimates this tool has a 90% success rate at identifying criteria-defined video segments.

Once the correct video segments are identified with the AVPT, the researchers use DRAT to review and analyze these video segments and the corresponding sensor data, effectively turning raw data into information. Using the dashboard, the researchers can mark videos with specific events and features that are saved in a back-end database for easy analysis. The DRAT dashboard also couples the associated RID information

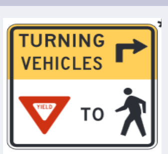


The Data Reduction and Analysis Tool (DRAT) combines identified video segments with the corresponding data to assist researchers in performing detailed analysis of driver interactions with pedestrian features.

and sensor information with the video file to synchronize all of the available data.

Once the video segments are reviewed and marked, the research team then cataegorizes them based on driver behavior. Compliant behaviors were categorized into two groups: a feature group (intersections with the pedestrian feature) and a control group (compliant behavior that occurred at intersections without a pedestrian feature).

The two groups are then compared statistically to see if the proportion of observant driver behaviors is higher in the feature group. The higher the proportion of compliant behaviors observed, the better the safety performance of the feature. The researchers can also perform statistical comparisons between different driver groups based on characteristics such as gender, age, and risk group.

Pedestrian Feature	Compliance Rate	Increased Compliance
	70%	✓
	67%	
	67%	✓
	55%	✓

In the first project, the No Turn on Red sign had the highest rate of compliance at 70%, followed by the Right on Red Arrow after Stop and Turning Vehicles Yield to Pedestrians signs each at 67%, and Stop Here on Red at 55%. Three of the four features – Stop Here on Red, No Turn on Red, and Right on Red Arrow after Stop – statistically increased the likelihood of compliant behavior as compared to the control groups. Female drivers and middle-aged drivers tended to comply with the features more consistently than other groups.

As a preliminary study, the sample size was relatively small, but sufficiently demonstrated the team's ability to leverage NDS and RID to reach meaningful conclusions. Indeed, a successful by-product of the project was the development of the AVPT and DRAT, which the researchers effectively exercised as promising tools for managing large amounts of data. Results of the second project are due in mid-2017.

USING NDS DATA FOR BICYCLING

The SHRP2 NDS is forecasted to support up to 20 years of safety-related research, and that work is just beginning. However, the influence of the NDS can already be felt outside of its original travel mode. While the NDS focused solely on cars and drivers, it has inspired a similar effort for bicycles.

On a national scale, bicycling as a mode of transportation is becoming increasingly popular. Unfortunately, bicyclists experience disproportionate rates of injuries and fatalities when compared to travelers using other roadway vehicles. As the number of bicyclists on Florida's roads increases, FDOT is looking to better understand the choices bicyclists make and their interactions with other road users. Increased understanding can lead to better bicycle facility planning, design, and engineering improvements, as well as law enforcement and education initiatives, to mitigate the unique risks faced by bicyclists.

Once again, FDOT looked to the team from USF CUTR that had worked on the SHRP2 NDS in Tampa to leverage their experience with automobile-based NDS and conduct a naturalistic bicycling study. Drs. Lin and Kourtellis have developed a Bicycle Data Acquisition System (BDAS) to collect and analyze naturalistic bicycling behavior from 100 participants in the Tampa Bay area. The BDAS includes video cameras at the front and rear of the bike; accelerometers and gyroscopes to detect speed, lean angle, and surface disruptions; and other sensor data. Participant routes are recorded via GPS, and their proximity to passed objects and vehicles, lane positions, and other data are recorded for analysis.

The data collected from this study will provide a wealth of information regarding bicycling behavior on roadways, sidewalks, and intersections that can be used for numerous research projects in the future. The project is scheduled to conclude in March 2017.

And so it goes: one project builds on another, yielding new understandings and raising new questions. Researchers gain experience and develop the tools they need to improve the research process and open up new avenues for exploration. ▪

Final Reports available at: www.fdot.gov/research

Where are they now?

ALTERNATIVE TERNARY CONCRETE BLENDS

Editor's Note: We will occasionally revisit older research projects and take a look at how they have benefited the transportation sector since they were concluded.

Many Florida transportation structures are set in marine environments and must be as resistant to chlorides as possible. Previously, FDOT specified that concrete for these harsh environments must be a defined blend of Portland cement, fly ash, and silica fume, metakaolin or ultra-fine fly ash (all identified as highly reactive pozzolans). However, these pozzolans can be expensive and require additional attention to finish and cure. This prompted FDOT to look for alternatives that produce Portland cement concrete with good chloride resistance.

In a 2009 research project, researchers with the University of Florida identified proportions of alternative supplementary cementitious materials to replace the more expensive highly reactive pozzolans without sacrificing adequate protection for reinforcing steel in extremely aggressive environments.

In 2011, following additional testing and refinement, FDOT Specification Section 346 "Portland Cement Concrete" was revised to allow the use of the alternative ternary blends first identified in the University of Florida research project. Proportions were defined for each application or type of concrete placement. Ranges were provided for the amount of cementitious materials needed to ensure the protection of reinforcement against chlorides and sulfates. Allowing a range of materials provides contractors with some flexibility based on material availability but still ensures that FDOT receives a quality product.

There are three primary benefits to alternative blends: the ternary blends allow for reduced cement content, which reduces initial cost; they do not require expensive highly reactive pozzolanic (HRP) materials; and the maintenance costs of these structures is reduced over time.

Florida's aggressive environments require concrete that is resilient to the elements but easy for contractors to work with and inexpensive to produce. Alternative blends may provide cost-effective solutions.

Alternate concrete mixtures provide a way to meet the performance requirements of concrete in extremely aggressive environments at a reduced cost. The ternary blend mixes are easier for concrete producers to batch and should be available at a lower cost without compromising the service life of structures.

In a ternary blended mix, the cement constituted 30 to 40% of the cementitious materials as compared to a conventional mix where the cement makes up 80% of the cementitious materials. Cement, the highest cost component of the concrete mix, is replaced with a portion of fly ash and slag, which both cost much less than cement.

At this time, a cubic yard of concrete costs between $300 to $600 to place, depending on the class of concrete, the steel required for the structure, and the complexity of the placement. The use of ternary blends may reduce the cement content of a cubic yard of concrete by 240 lbs. or roughly $14 - $15 per cubic yard. Although this appears to be only a slight savings, the savings could be substantial if applied to all the concrete on a project.

HRPs are usually used in concrete mixes installed in extremely aggressive environments and, as such, are not used in all concrete mixes. However, pre-stressed pile producers use HRP mixes in all of the piles they produce as they do not always know which piles are being used in which environment type. Removing these HRPs from the production of piles and other concrete structures will reduce costs. Currently, piles using conventional HRP mixes cost between $500 and $600 per pile. A ternary blend pile is estimated to cost $252 per pile, a 50% cost savings. These costs represent materials only and are based on 2014 values .

As time passes, it becomes increasingly necessary to look for new and different ways to keep costs as low as possible without sacrificing the integrity of our transportation infrastructure. ▪

Final Report available at: www.fdot.gov/research

meet the project manager:
RAJ PONNALURI, TRAFFIC ENGINEERING AND OPERATIONS

Most of the state roads in Florida that get people from their homes to the places they want to be – work, shopping, entertainment – are arterial roads. Arterials collect traffic and connect users as efficiently as possible to other parts of the region and the interstates. The effective functioning of an arterial system is critical to our daily lives and to the steady and efficient operation of our cities.

To address the growing needs of the state's arterial system, FDOT is developing a comprehensive State Arterial Management Program (STAMP) in the State Traffic Engineering & Operations (STEO) division. The program is being led by Dr. Raj Ponnaluri, the State Arterial Management Systems Engineer, who serves in the Transportation Systems Management and Operations (TSM&O) section of STEO. Ponnaluri focuses on issues needing attention or new technologies on the horizon, and his enthusiasm for this work is infectious.

Ponnaluri describes his role in FDOT Central Office as one of providing policy support, developing guidance and standards for statewide implementation, and promoting consistency across the districts. In that role, he often becomes involved with issues that have statewide significance, recognizing that the best practices of one district are transferable to other districts. In this way, Central Office can support district planners and engineers by offering a wide variety of tested solutions in the TSM&O realm.

One of Ponnaluri's primary focus areas is the implementation of TSM&O in the state of Florida. As Florida roads become more heavily used and the land and funds to expand them become more limited, there is an increasing need to manage the existing infrastructure for maximum efficiency. TSM&O takes a broad approach toward this issue, for example, by providing drivers with traveler information as they drive, better monitoring of highway conditions that leads to real-time information for drivers and responders, efficient traffic signal operations, coordination with local agencies, and improved practices all the way from planning, project development and environmental impact (PD&E), and design to construction, operations, and maintenance. TSM&O helps transform the use of available tools in the toolkit for solving reliability and safety problems on roadways.

Ponnaluri has worked with the FDOT Research Center to manage many research projects that directly target areas of traffic engineering and operations, arterial management, wrong-way driving (WWD), and TSM&O. Several of these projects involve human factors and engineering applications to road safety, traffic signal systems, and the TSM&O mainstreaming process, each of which has a profound impact on the safety and efficiency of arterial roadways.

One ongoing project being managed by Ponnaluri concerns evaluating the effectiveness of advanced signal control technologies (ASCT) in improving traffic flows on arterial corridors. ASCT dynamically allots the available green time in signal cycles and optimizes signal timing to increase vehicle throughput at signalized intersections. This project aims to understand the benefits of ASCT, if any, and to identify areas to improve the effectiveness of an ASCT deployment, including providing training and technical support.

Dr. Ponnaluri is also looking forward to the results of a research project that goes to the heart of the TSM&O process: how to better accommodate TSM&O in the project development process. Currently, TSM&O is used with existing infrastructure, but incorporating TSM&O practices into project development would broaden its scope "horizontally" and help prepare the transportation system for coming innovations like connected and autonomous vehicles. Considering all the electronic sensors and computer systems that have been installed and integrated under the Intelligent Traffic Systems (ITS) program, TSM&O takes this system to the next level, preparing to leverage ITS capabilities to support future technologies.

Ponnaluri finds research rewarding as research takes each aspect of a very complex and extensive transportation system to the "next level." Ponnaluri thrives on the way that research projects make him think, keep up with the state of the art, and introduce the latest innovations. One of the pleasures of this work, he states, is working with so many different researchers and institutions, and making sure that FDOT staff, consultants, researchers, and the industry at large will have an opportunity to make their contribution to the advancement of transportation practice in Florida.

He speaks most appreciatively of researchers he works with who deliver work that has real application potential. While he respects the theoretical work that must always go on, he admires the focus researchers have on solving actual problems. This real-world focus, he says, has a great impact on students. Ponnaluri says that an increasingly complex transportation system needs more students who leave the university with an understanding of the transportation industry and conditions in the field, students who are ready to get work with the actual systems being used.

All this involvement with research and his other duties keeps Ponnaluri quite busy, but he says that as long as he has time to give research projects the attention they deserve, he is eager to work on them. Research is one of the many tools he uses to drive forward FDOT's vision of an increasingly safe, efficient, and integrated transportation system. ▪

meet the principal investigator:
NEIL CHARNESS, FLORIDA STATE UNIVERSITY

"Playing chess, not checkers" means using a complex and in-depth understanding to skillfully manage situations. For Dr. Neil Charness, this expression applies both literally and figuratively.

Charness's career did indeed begin with chess. He was an avid player in college. Then, in the 1970s, at Carnegie-Mellon University he studied for his doctorate with Dr. William Chase, who with his colleague, Nobel Laureate Dr. Herbert Simon, performed landmark studies of chess skill and the role of memory in expertise. Dr. Charness's early research also employed chess and chess players. However, when he extended these studies to bridge players, Charness was led – "by accident" – to gerontology, the study of older individuals and aging. In studying age-related effects on skilled performance, Charness's interest was piqued when his subjects demonstrated typical age-related memory effects, but no decrease in skill with age.

This is where chess comes in figuratively. Though Charness once focused his work narrowly, he now takes a holistic view, bringing more players with a wider range of skills into the game. His approach is based on human factors, the study of how people interact with other systems. Rather than isolating psychology, Charness emphasizes how "cognitive and physical exercise, good nutrition, social interaction, and technological interventions" combine to produce positive outcomes for older adults.

Through numerous affiliations, Charness brings theoretical, laboratory, field, and policy perspectives to projects that work from concept to application. He assembles teams with wide-ranging expertise from FSU programs such as the Institute for Successful Longevity (ISL) and the Center for Accessibility and Safety for an Aging Population (a USDOT Tier 1 University Transportation Center). He also works with the multi-university Center for Research and Education on Aging and Technology Enhancement (CREATE), directed by Dr. Sara Czaja, University of Miami.

Charness has brought these personal and institutional strengths to bear on several FDOT research projects as FDOT seeks to provide a safer transportation environment and greater mobility to Florida's large population of older adults. In projects ranging from testing whether fluorescent yellow sign sheeting improves perception and comprehension to the acceptance by older Floridians of automated vehicles, Charness uses his human factors approach and collaborates with colleagues in other disciplines to develop solutions.

To many of his FDOT projects, Charness brings two strategies. First, he conducts lab and field-based behavioral studies, which provides insight into raw performance and how lab studies compare with field studies. Second, while many studies compare younger and older adults, Charness includes middle-aged adults as well because many changes seen in older adults begin in middle age.

Charness's current project for FDOT is Human Factors Guidelines to Develop Educational Tip Cards for Aging Road Users (BDV30-977-15). Often, research like this for older people is thin and must be adapted from similar research done with other groups. Charness's studies will help expand this literature. Experimentally, tip cards have been designed to educate older drivers about how to respond to a flashing yellow arrow, a rectangular rapid flashing beacon, or a flashing right turn signal with a pedestrian indication.

These signals can confuse drivers who have not been taught their meaning. Older drivers who have studied the cards and some who have not will be tested in a driving simulator to see if the card assists them in making correct decisions when they encounter new signal types.

Because of the integration of educational tool design and evaluation, this project's results will generate principles of usability and guidelines that can be used in other media, such as websites or public service announcements. All aspects of design will be considered in these guidelines, such as layout and design, fonts, color, and contrast.

The project employs a method with which Charness has built considerable expertise: the use of driving simulators. Charness says that simulators provide an opportunity to test driving behaviors – even potentially dangerous ones – with little risk to the participants. For example, a recent FDOT project on which Charness worked addressed the issue of drivers who try to use an exit ramp to enter a highway. Wrong way entrances can lead to crashes that are 12-27 times more likely to be fatal than other types of crashes, and they are generally attempted by either older drivers during the day or younger, usually impaired, drivers at night. The simulator is ideal for this because wrong way entrances are relatively rare and more rarely observable. The driving simulator can provide more subtle measures of driver confusion (e.g., slowing near an exit ramp) and makes it much easier to test a wide variety of countermeasures. Pilot projects based on these findings are now being conducted.

Charness has found his involvement with transportation and with FDOT rewarding. He enjoys the fact that FDOT research does not sit on a shelf somewhere but has a near-term impact on policy and practice. Charness is likely to see more positive impacts of his work as FDOT and Florida continue to move toward an integrated multimodal transportation system that focuses on the users rather than the vehicles. ▪

IN THE JOURNALS

The following selection of articles has been recently published by principal investigators on the results of FDOT-funded research projects. For a complete list, please see the Research Center website.

Abdullah, A.B.M., Jennifer A. Rice, H.R. Hamilton, and Gary R. Consolazio. "Experimental and Numerical Evaluation of Unbonded Post-tensioning Tendons Subjected to Wire Breaks." *Journal of Bridge Engineering* 21, no. 10 (2016): 04016066. doi:10.1061/(asce)be.1943-5592.0000940.

Abdullah, A.B.M., Jennifer A. Rice, Natassia R. Brenkus, and H.R. Hamilton. "Full-scale Experimental Investigation of Wire Breakage Detection in Deviated Multi-strand Tendon Systems." *Journal of Civil Structural Health Monitoring*, Vol. 6 no. 2 (2016): doi:10.1007/s13349-016-0158-7.

Abdullah, A.B.M., Jennifer A. Rice, H.R. Hamilton, and Gary R. Consolazio. "An Investigation on Stressing and Breakage Response of a Prestressing Strand Using an Efficient Finite Element Model." *Engineering Structures*, Vol. 123 (2016): doi:10.1016/j.engstruct.2016.05.030.

Chen, Hongyun, Aldo Fabregas, and Pei-Sung Lin. "Landscaping of Highway Medians and Roadway Safety at Unsignalized Intersections." *Accident Analysis & Prevention*, Vol. 90 (2016): doi:10.1016/j.aap.2016.02.006.

Groetaers, Matías, Gary R. Consolazio, and David J. Wagner. "Development of an 1100C Crushable Nose Surrogate Vehicle for Low-Speed Impact Testing of Breakaway Hardware." *Transportation Research Record: Journal of the Transportation Research Board*, No. 2588 (2016): doi:10.3141/2588-14.

Harper, Zachary S., Samuel T. Edwards, Gary R. Consolazio, and Kurtis R. Gurley. "Drag Coefficients for Construction-Stage Stability Analysis of Bridge Girders under Wind Loading." *Journal of Bridge Engineering* (2016): doi:10.1061/(asce)be.1943-5592.0000988.

Kantrales, George C., Gary R. Consolazio, David Wagner, and Sam Fallaha. "Experimental and Analytical Study of High-Level Barge Deformation for Barge–Bridge Collision Design." *Journal of Bridge Engineering*, Vol 21, no. 2 (2016): doi:10.1061/(asce)be.1943-5592.0000801.

Kesler, Michael S., Peter Feldtmann, Edward S. George, Steven M. Duke, and Michele V. Manuel. "Effect of Plasma Marking on the Fatigue Properties of Grade 50W Steel." *Journal of Materials in Civil Engineering*, Vol. 28, no. 9 (2016): doi:10.1061/(asce)mt.1943-5533.0001588.

Lin, Pei-Sung, Zhenyu Wang, Rui Guo, and Achilleas Kourtellis. "A Pilot Study on Interactions between Drivers and Pedestrian Features at Signalized Intersections—Using the SHRP2 Naturalistic Driving Study Data." *Bridging the East and West* (2016). doi:10.1061/9780784479810.009.

Lin, Pei-Sung, Seckin Ozkul, and Chester Chandler. "Evaluation on the Perceived Effectiveness of Red RRFB Configurations to Reduce Wrong-Way Driving." *Bridging the East and West* (2016). doi:10.1061/9780784479810.024.

Michalaka, Dimitra, Ruoying Xu, Joseph J. Page, Ruth L. Steiner, Scott Washburn, and Lily Elefteriadou. "Roundabouts as a Form of Access Management." *Transportation Research Record: Journal of the Transportation Research Board*, No. 2556 (2016): doi:10.3141/2556-01.

Roessler, Justin, Weizhi Cheng, Joshua B. Hayes, Lin Shou, Christopher Ferraro, Chang-Yu Wu, Michael Bergin, and Timothy G. Townsend. "Evaluation of the Leaching Risk Posed by the Beneficial Use of Ammoniated Coal Fly Ash." *Fuel*, Vol. 184 (2016): doi:10.1016/j.fuel.2016.07.041.

Shams, Kollol, Hamidreza Asgari, and Xia Jin. "Valuation of Travel Time Reliability in Freight Transportation: A Review and Meta-analysis of Stated Preference Studies." *Transportation Research Part A: Policy and Practice* (2016): dx.doi:10.1016/j.tra.2016.08.001.

So, Jaehyun Jason, Aleksandar Stevanovic, and Peter Koonce. "Estimating Performance of Traffic Signals Based on Link Travel Times." *Journal of Advanced Transportation*, Vol. 50, no. 5 (2016): doi:10.1002/atr.1375.

FURTHER READING

AASHTO RAC Region 2 Sweet Sixteen: Wrong-Way Driving

Statewide Wrong Way Crash Study
http://www.fdot.gov/research/Completed_Proj/Summary_TE/statewide.wrong.way.crash.study.pdf

Project Manager: Raj Ponnaluri, Traffic Operations and Engineering
Principal Investigator: Kittelson & Associates

BDV30-977-10 Driving Simulator Studies of the Effectiveness of Countermeasures to Prevent Wrong Way Crashes

Project Manager: Raj Ponnaluri, Traffic Operations and Engineering
Principal Investigator: Walter R. Boot, Florida State University

BDV25-977-29 Comparing Countermeasures for Mitigating Wrong-Way Entries onto Limited Access Facilities

Project Manager: Raj Ponnaluri, Traffic Operations and Engineering
Principal Investigator: Pei-Sung Lin, University of South Florida

Tackling the SHRP2 Naturalistic Driving Study

BDV25-977-16 Understanding Interactions Between Drivers and Pedestrian Features at Signalized Intersections

Project Manager: Darryll Dockstader, Research Center
Principal Investigator: Pei-Sung Lin, University of South Florida

BDV25-977-13 Naturalistic Bicycling Behavior Pilot Study

Project Manager: Trenda McPherson, Safety
Co-Project Manager: Stephen Benson, Research Center
Principal Investigator: Pei-Sung Lin, University of South Florida

BDV25-977-26 Understanding Interactions Between Drivers and Pedestrian Features at Signalized Intersections, Phase 2

Project Manager: Joe Santos, Safety
Co-Project Manager: Stephen Benson, Research Center
Principal Investigator: Pei-Sung Lin, University of South Florida

Alternative Ternary Concrete Blends

BD545-35 Durability and Mechanical Properties of Ternary Blend Concrete

Project Manager: Mike Bergin, Materials
Principal Investigator: H.R. Hamilton, University of Florida

WINTER 2016

Research Center
605 Suwannee Street, MS 30 Tallahassee, FL 32399-0450
(850) 414-4615
http://www.fdot.gov/research/