Final Report

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Strategies to Mitigate Wrong-way Driving Incidents on Arterials

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DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

METRIC CONVERSION TABLE

U.S. UNITS TO SI* (MODERN METRIC) UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.400	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.610	kilometers	km
mm	millimeters	0.039	inches	in
m	meters	3.280	feet	ft
m	meters	1.090	yards	yd
km	kilometers	0.621	miles	mi

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		AREA		
in^2	square inches	645.200	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.590	square kilometers	km^2
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.470	acres	ac
km^2	square kilometers	0.386	square miles	mi^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		VOLUME		
fl oz	fluid ounces	29.570	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
NOTE: volumes greater than 1,000 L shall be shown in m^3.				

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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16. Abstract

The goal of this research effort was to identify strategies to mitigate wrong-way driving (WWD) incidents on arterials in Florida by developing a scenario-based WWD crash mitigation approach to address two specific needs: *which arterial corridors are prone to WWD incidents* and *which WWD incident category needs addressing on these corridors*. The WWD crash data analysis was based on five years of crash data from 2012-2016. During the analysis period, a total of 2,879 crashes were identified as potential WWD crashes on state-maintained non-limited access facilities in Florida. Police reports of these 2,879 crashes were reviewed in detail. Of the 2,879 potential WWD crashes, only 1,890 crashes (i.e., 65.6%) were categorized as actual WWD crashes resulting from vehicles traveling the wrong way. Most of these WWD crashes occurred at night, and over 50% occurred at or near intersections. On average, nearly 7% of all WWD crashes on non-limited access facilities resulted in a fatality, and 52.5% resulted in an injury.

A Geographic Information System (GIS)-based spatial clustering analysis was used to identify top 10 WWD crash hotspots within each FDOT District, based on the number of WWD crashes and the Equivalent Property Damage Only (EPDO) scores. A detailed analysis was conducted to identify specific roadway geometric and demographic factors contributing to WWD crashes at the WWD crash hotspots in each FDOT District. For each WWD crash hotspot in each district, one or more of the following roadway geometric and demographic factors that contributed to WWD crashes were identified: one-way streets; signalized intersections; stop-controlled intersections; absence of WWD signs; impaired drivers; and/or drivers age 65 years and older. Moreover, critical signalized and stop-controlled intersections along all the state roads within each of the WWD crash hotspots were identified. The study results help shape near-term and long-term planning and policy directives for mitigating WWD incidents on non-limited access facilities.

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EXECUTIVE SUMMARY

A wrong-way driving (WWD) incident involves a vehicle traveling opposite to the legal flow of traffic on a direction-separated highway, freeway or arterial, or access ramp (NTSB, 2012). The majority of previous studies concerning WWD crashes have focused on freeways. This could be because WWD crashes that occur on freeways draw more media attention, involve more vehicles, cause extended freeway closures, and result in more fatalities per crash. Although WWD crashes on limited access facilities receive more attention, WWD crashes are more frequent on arterial streets compared to freeways.

Mitigating WWD crashes on arterials is complicated because there are multiple access points along these non-limited access facilities. In other words, there are many possible locations where a driver may enter the facility the wrong way, and it is difficult to have some type of WWD countermeasure(s) at each of these access points. Analyzing WWD crashes to identify factors that affect their frequency and severity is crucial in selecting the most suitable countermeasure(s) for deployment.

The goal of this research effort was to identify strategies to mitigate WWD incidents on arterials in Florida by developing a scenario-based WWD crash mitigation approach to address two specific needs: *which arterial corridors are prone to WWD incidents* and *which WWD incident category needs addressing on these corridors.*

WWD Mitigation Strategies

To date, there has been considerable research addressing WWD on freeways, while there are very few studies that have analyzed WWD incidents on non-limited access facilities. Several states, including Florida, have deployed Intelligent Transportation Systems (ITS) technologies and Transportation Systems Management & Operations (TSM&O) strategies at off-ramps and on freeway mainline segments to mitigate WWD incidents in real-time. However, very few strategies, if any, have been deployed along non-limited access facilities. New and emerging technologies, including thermal camera systems, radar detection, integrated on-road detection, tracking, and notification systems, in-vehicle systems, and sign identification systems, etc., are proving to be successful in preventing WWD crashes on freeways. These applications, though more readily applicable to limited access facilities, could be adapted to an extent, to non-limited access facilities as well.

The frequency and severity of WWD crashes could be reduced through the 4 E's of traffic safety: *Engineering*, *Education*, *Enforcement*, and *Emergency Response*. Since *Engineering* countermeasures cannot completely mitigate WWD incidents, it is crucial to consider *Education, Enforcement,* and *Emergency Response* strategies to effectively address the WWD issue. This research project has explored the need to conduct public outreach activities in addressing the WWD issue in Florida. A workshop, offered at the Statewide Community Traffic Safety Team (CTST) Coalition Meeting, could potentially be useful once the root causes for WWD incidents on arterials are determined. Stakeholders to be included in the discussion would include the Florida Highway Patrol (FHP), media personnel, District Public Information Officers (PIOs), CTSTs, District Safety Engineers (DSEs), District Traffic Operations Engineers (DTOEs), local Law Enforcement Organizations (LEOs), and safety advocates, including the American Automobile Association (AAA), Mothers Against Drunk Driving (MADD), etc.

WWD Crashes on Arterials

The WWD crash data analysis was based on five years of crash data from 2012-2016. During the analysis period, a total of 2,879 crashes were identified as potential WWD crashes along the state-maintained non-limited access facilities in Florida. Police reports of these 2,879 crashes were obtained and reviewed in detail. Of the total of 2,879 potential WWD crashes from 2012-2016, only 1,890 crashes (i.e., 65.6%) were categorized as actual WWD crashes resulting from vehicles traveling the wrong way.

On average, nearly 7% of all WWD crashes on arterials resulted in a fatality, and 52.5% resulted in an injury. Over 95% of WWD crashes occurred within 450 ft from where the drivers potentially entered the wrong way. A considerable number of WWD crashes (over 50%) occurred at or near intersections, and a large proportion of the wrong-way drivers (38%) turned the wrong way at a signalized intersection. Divided facilities also experienced a high number of WWD crashes, and a high proportion of fatal WWD crashes. WWD crashes on undivided facilities, although relatively rare, resulted in a high proportion of fatal crashes.

About 13.5% of all arterial WWD crashes occurred on one-way streets. However, the fatality rate for WWD crashes on two-way streets (7.5%) was over three times greater than for one-way streets (2.4%). WWD warning signs were present at fewer than 51% of the one-way streets where WWD crashes occurred. Nearly 95% of two-way streets where WWD crashes occurred had no WWD warning signs.

The highest number of WWD crashes (38.6%) involved drivers age 35 to 64, with nearly 9% of these crashes resulting in a fatality. Although drivers age 65 and older were involved in only 16% of the 1,890 WWD crashes analyzed, 7.6% of these WWD crashes were fatal. Nearly 36% (680 of 1,890 crashes) of WWD crashes involved intoxicated (either alcohol, or drugs, or both) drivers. Of the 130 fatal WWD crashes, 82 crashes (63.1%) involved intoxicated drivers.

In terms of both WWD crash frequency and crash severity, the most critical time was found to be from midnight to 6 AM and from 6 AM to noon. WWD crashes that occurred along the corridors with no street lighting were found to be relatively more severe compared to those that occurred along the corridors with street lighting. Over 55% of all WWD crashes occurred during dark conditions, and over 64% of all fatal WWD crashes occurred during dark conditions.

WWD Crash Hotspots on Arterials

A Geographic Information System (GIS)-based spatial clustering analysis was used to identify top 10 WWD crash hotspots within each FDOT District, based on the number of WWD crashes and the Equivalent Property Damage Only (EPDO) scores. Between the years 2012 to 2016, a total of 702 WWD crashes occurred at the identified hotspots, constituting 37.1% of the total 1,890 WWD crashes on arterials in Florida during the same analysis period. Supplemental documents provided with this report include a Google Earth file (.kmz) with the spatial locations of these hotspots.

Over 90% of WWD crashes within hotspots occurred at (or near) intersections or on divided roadways. Only 1.5% of WWD crashes within hotspots that occurred at or near intersections resulted in a fatality, while over 6% of WWD crashes that occurred on divided facilities were fatal.

Approximately 43% of the wrong-way drivers turned the wrong way at a signalized intersection, which most often resulted in a crash at the same intersection. Approximately 20% of the wrong-way drivers were found to have turned the wrong way from a driveway.

Approximately 26% of WWD crashes within hotspots occurred on one-way streets. Only 1.1% of these crashes resulted in a fatality, while the proportion was 3.3% for crashes that occurred on two-way streets. Wrong-way drivers were found to travel for relatively longer distances on divided facilities than undivided facilities, and these crashes often resulted in fatalities and injuries.

WWD crashes along the corridors with WWD warning signs were found to be relatively less severe compared to the WWD crashes along the corridors with no WWD warning signs. The absence of street lighting resulted in WWD crashes with greater severity, compared to those that occurred along corridors with street lighting.

Overall, 27.5% of all WWD crashes within the hotspots were found to be DUI-related. Nearly 6% of all DUI-related WWD crashes were fatal while only 1.6% of all non-DUI-related WWD crashes were fatal. WWD crashes involving drivers age 65 and older were found to be more severe.

WWD Countermeasure Implementation Plan for Arterials

A Google Earth locations file (.kmz) showing the spatial locations of the identified WWD crash hotspots was provided with this report as a supplement. An Excel file (.xlsx) was also provided and includes a detailed discussion about the roadway geometric and demographic factors contributing to WWD crashes at the WWD crash hotspots on state-maintained non-limited access facilities in each FDOT District.

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ACRONYMS AND ABBREVIATIONS

AAA	American Automobile Association
ADOT	Arizona Department of Transportation
ARBM	All Road Base Map
BAC	Blood alcohol concentration
CARS	Crash Analysis Reporting System
CCTV	Closed-circuit television
CTST	Community Traffic Safety Team
CV	Connected vehicle
DMS	Dynamic message sign
DOH	Department of Health
DOT	Department of Transportation
DSE	District Safety Engineers
DTOE	District Traffic Operations Engineers
DUI	Driving under the influence
EMS	Emergency Medical Services
EPDO	Equivalent property damage only
FDOT	Florida Department of Transportation
FHP	Florida Highway Patrol
FLIR	Forward-looking infrared
GIS	Geographic Information System
GPS	Global Positioning System
HSMV	Highway Safety and Motor Vehicles
IIRPM	Internally illuminated raised pavement marker
ITS	Intelligent Transportation Systems
LED	Light-emitting diode
LEO	Law enforcement organization
MADD	Mothers Against Drunk Driving
MUTCD	Manual on Uniform Traffic Control Devices
OBU	On-board unit
PDO	Property damage only
PIO	Public information officer
PSA	Public service announcement
RIDOT	Rhode Island Department of Transportation
RCI	Roadway Characteristics Inventory
RRFB	Rectangular rapid flashing beacon
S&PM	Signing and pavement marking
TMC	Transportation management center
TSM&O	Transportation Systems Management & Operations
TTI	Texas Transportation Institute
TWLTL	Two-way left-turn lane
TxDOT	Texas Department of Transportation
UBR	Unified Basemap Repository
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
WSDOT	Washington State Department of Transportation
WWD	Wrong-way driving

CHAPTER 1
INTRODUCTION

1.1 Background

Wrong-way driving (WWD) is defined as the movement of a vehicle in a direction opposite to the one designated for travel (Ponnaluri, 2018). The predominant crash types resulting from WWD are head-on crashes or opposite-direction sideswipes from two vehicles moving in opposite directions on the roadway. These crashes generally cause more incapacitating injuries and fatalities than non-WWD crashes.

Annually, WWD crashes result in about 350 fatalities nationwide and make up 3% of all crashes that occur on high-speed divided highways (National Transportation Safety Board [NTSB], 2012). Although WWD crashes on freeways usually attract more media attention, involve more vehicles, cause extended freeway closures, and result in more fatalities per crash, WWD crash events on arterial roadways are more frequent. The likelihood of a WWD crash occurrence was found to be 2.3 times greater on arterials than on freeways (Ponnaluri, 2018). WWD crashes on freeways, although relatively more severe, constitute only a small fraction of all WWD crash events on the state highway system. For instance, from 2011-2015, of the 6,888 WWD crashes that occurred on the public roadway network in Florida, only 4% (281 crashes) occurred on freeways, while the remaining 96% (6,607) of WWD crashes occurred on non-limited access facilities (Alluri et al., 2018). These statistics warrant the need to analyze and address WWD crashes on non-limited access facilities.

Since limited access facilities generally have few exit/entry points, tackling the WWD issue is relatively easy. Deploying WWD countermeasures at the off-ramps that are more susceptible to WWD incidents could significantly reduce WWD incidents on freeways. Conversely, mitigating WWD crashes on arterials is more complicated because arterial facilities typically have multiple access points; in other words, there are many possible locations where a driver may enter the facility driving the wrong way. Therefore, it is difficult, and perhaps even impossible, to implement a WWD countermeasure at each access point.

Not surprisingly, the majority of WWD research and deployment efforts to date have focused on mitigating WWD incidents on limited access facilities. The recommended countermeasures range from traditional roadway signing and pavement marking (S&PM) improvements to more sophisticated WWD incident detection and mitigation methods that detect, track, and respond to wrong-way drivers in real-time. Analysis of WWD incidents on non-limited access facilities (e.g., arterials) has been sparse, and researchers have only begun to investigate WWD incidents on arterials. To the best of the authors' knowledge, this research is one of the very few attempts to analyze WWD incidents on non-limited access facilities.

1.2 Research Objective

The goal of this research effort was to identify strategies to mitigate WWD incidents on arterials in Florida by developing a scenario-based WWD crash mitigation approach to address two specific needs: *which arterial corridors are prone to WWD incident* and *which WWD incident category needs addressing on these corridors.*

This objective was achieved through extensive *data visualization* and *spatial analyses* in ArcGIS. The macroscopic analysis involved aggregating WWD crashes over selected geographic areas and spatially analyzing WWD crashes to identify factors that may contribute to WWD incidents. This approach has the potential of shaping long-term planning and policy directives for mitigating WWD incidents across the state, especially on non-limited access facilities.

1.3 Report Organization

The rest of this report is organized as follows:

- Chapter 2 discusses the WWD mitigation strategies on non-limited access facilities and the use of technology to deter WWD incidents.
- Chapter 3 explores the potential of conducting either a workshop or a series of public outreach activities on addressing the WWD issue on non-limited access roadways in Florida.
- Chapter 4 presents the descriptive statistics of WWD crashes on arterials used in the analysis.
- Chapter 5 focuses on the framework adopted to identify WWD crash hotspots on arterials in Florida.
- Chapter 6 analyzes the WWD crash hotspots on state-maintained non-limited access facilities in Florida. It also identifies the specific WWD crash contributing factors at each of the WWD crash hotspots in each FDOT District.
- Chapter 7 provides a summary of this research effort, and relevant findings and conclusions.

CHAPTER 2
EXISTING WRONG-WAY DRIVING MITIGATION STRATEGIES

This chapter focuses on WWD mitigation strategies on non-limited access facilities and the use of technology to deter WWD incidents. Existing studies that have analyzed WWD crashes on arterials are discussed, and traditional and emerging WWD countermeasures to mitigate WWD crashes on arterials are presented.

2.1 Existing Wrong-way Driving Studies on Arterials

Although considerable research has been conducted on addressing WWD on freeways, very few studies have analyzed WWD incidents on non-limited access facilities. Vaswani (1973) conducted one of the first studies that analyzed and compared WWD crashes on arterials and freeways. The study found the fatality and injury proportions of all crashes on limited access facilities to be 0.016 and 0.42, respectively. However, the WWD crash fatality and injury proportions on limited access facilities were found to be 0.47 and 1.18, respectively. Similar WWD crash statistics were observed for non-limited access facilities with fatality and injury proportion findings of 0.22 and 1.03, respectively. The study concluded that the fatality and injury rates of WWD crashes on arterials were approximately 2.8 times and 2.2 times greater than the fatality and injury rates of non-WWD crashes, respectively (Vaswani, 1973).

A recent study by Ponnaluri (2016) compared the probabilities of WWD crashes on freeways and arterials. WWD crash data were analyzed, and the results were compared to data gathered from a survey administered to transportation professionals and general road users. Based on 60 survey responses (30 each from the transportation professionals group and the general road users group), WWD crashes on arterials were found to be two times more frequent than WWD crashes on freeways, resulting in an odds ratio of 2.16. Ponnaluri (2016) next analyzed 2003-2010 WWD crash data in Florida using binomial logistic regression. The analysis was based on 999,456 crash records and showed that the odds ratio of a WWD crash was 2.29 on arterial roadways (i.e., non-limited access facilities) compared to freeways (i.e., limited access facilities), consistent with the survey results. The study concluded that WWD crashes are more frequent on non-limited access facilities; however, fatal WWD crashes are more frequent on limited access facilities (Ponnaluri, 2016).

Ponnaluri (2018) extended his previous work on WWD by conducting a more comprehensive evaluation of WWD crashes on arterials and freeways. The primary goal of this study was to compare WWD crashes on arterial corridors with WWD crashes on freeways and highlight the need for investigating WWD crashes on arterials. Using crash data gathered in the previous study (Ponnaluri, 2016), 3,823 (3.84%) of the 999,456 crashes analyzed that occurred on both arterials and freeways were categorized as WWD crashes. Stepwise regression modeling was used to identify statistically significant covariates at the 5% significance level. The study revealed that male drivers were found to be 1.3 times more prone to WWD crashes than female drivers. However, exposure was not considered in the analysis. Younger drivers, age 21-40 years, were found to be more likely to be involved in WWD crashes. Older drivers, age 80 and older, were also found to be prone to WWD crashes, especially on freeways. The likelihood of being involved in a WWD crash on arterials increased for non-Florida residents (i.e., tourists). Consistent with other WWD studies, the Ponnaluri (2018) study also found that WWD fatalities were higher for intoxicated drivers. Alcohol-related fatal WWD crashes were found to be more prominent on weekends, especially on Saturdays. As expected, WWD crashes were found to be more frequent between the hours of 6 PM to 6 AM, and predominately during night conditions. Adequate street lighting may help to potentially reduce WWD crashes at some locations.

While WWD crashes on freeways are usually more severe and attract more media attention, WWD crashes on non-limited access facilities are significantly more frequent. Nonetheless, WWD crashes on arterials have rarely been analyzed. Since arterial facilities often have multiple locations where a wrong-way driver may enter the roadway traveling the wrong way, analyzing WWD crash locations and determining specific WWD countermeasures can be challenging.

2.2 Wrong-way Driving Countermeasures

Table 2-1 describes possible factors that may contribute to a WWD incident. WWD crash contributing factors can be categorized into six categories: traffic violation, impaired judgment, inattention, insufficient knowledge, infrastructure deficiency, and others (Zhou et al., 2012). The following sections discuss traditional countermeasures and existing and emerging technologies that could be deployed to address the WWD issue. Several states, including Florida, have deployed Intelligent Transportation Systems (ITS) technologies and Transportation Systems Management & Operations (TSM&O) strategies at off-ramps and freeway mainlines to mitigate WWD incidents in real-time. However, very few strategies, if any, have been deployed along arterials. This section focuses on WWD mitigation strategies for limited access facilities.

Table 2-1: WWD Crash Contributing Factors (Zhou et al., 2012)

Category	Description
Traffic violation	• Driving under the influence (DUI) • Intentional reckless driving • Suicide • Test of courage • Escaping from a crime scene • Avoiding traffic congestion
Impaired judgment	• Older adult driver • Physical illness • Drivers with psychiatric problems
Inattention	• Careless, absent-mindedness, distraction • Falling asleep at the wheel • Inattention to informational signpost
Insufficient knowledge	• Unfamiliar with the roadway infrastructure • Lack of understanding of how to use the highway • Loss of bearings (i.e., lost, unsure which way to go)
Infrastructure deficiency	• Insufficient lighting • Heavy vegetation • Insufficient field of view
Others	• Inclement weather

2.2.1 Traditional Countermeasures

Several countermeasures have been deployed over the past few decades to mitigate WWD incidents. In many cases, S&PMs have traditionally been used to deter WWD events. In 1967, California took the initiative and started using cameras to detect WWD incidents (Tamburri, 1969). A few years later, in 1973, California began to lower the height of "Do Not Enter" and "Wrong Way" warning signs, and also began displaying both signs together on the same post. This strategy resulted in a significant reduction in the number of WWD incidents, decreasing from 50-60 per month to 2-6 WWD incidents per month in areas where the warning signs were installed (Leduc, 2008). In a later study, Campbell and Middlebrooks (1988) evaluated the effectiveness of lowering the "Wrong Way" signs posted near exit ramps in Atlanta, Georgia. The study found that many wrong-way drivers corrected before entering the freeway, and within a month, WWD maneuvers were reduced up to 97% (Campbell & Middlebrooks, 1988). North Texas Tollway Authority also evaluated the effectiveness of lower "Wrong Way" and "Do Not Enter" signs by installing them at a height of two feet above ground at 28 of 142 exit ramps in their jurisdiction (Finley et al., 2014). Based on findings from the study, Finley et al. (2014) stated that the effectiveness of the lower signs could be more accurately determined if the entire freeway corridor was equipped with the lower signs.

The Manual on Uniform Traffic Control Devices (MUTCD) recommend several countermeasures for addressing the WWD issue, such as pavement arrows for wrong-way, colored edge lines on exit ramps, red reflective raised pavement markers, etc., and these countermeasures have been widely used (Cooner et al., 2004). In addition, Texas and Virginia installed raised pavement markers at off-ramps (Athey Creek Consultants, 2016). Virginia Highway and Transportation Research Council evaluated the effectiveness of raised pavement markers in effectively correcting the wrong-way drivers' actions and found the markers to be effective in 94% of the cases (Shepard, 1976). Researchers from Texas A&M Transportation Institute (TTI) studied how traditional pavement markings and wrong-way signs affected intoxicated driver behavior. Although their research indicated that impaired drivers tend to look straight ahead at the pavement and less to the left and right, intoxicated drivers tend to not notice the lowered "Wrong Way" signs, and therefore, the warning signs are less effective (Finley et al., 2017). Capturing the attention of intoxicated drivers is difficult; however, some measures, such as enlarging the signs, incorporating flashing Light-emitting diode (LED) lights, and adding red retroreflective tape on signposts, can assist impaired drivers. One factor to be noted is that intoxicated drivers need to be closer to LED signs compared to traditional warning signs to read them clearly (Finley et al., 2014; Finley et al., 2017).

2.2.2 Existing and Emerging Technologies

Although often effective, traditional WWD countermeasures that recommend changes to roadway signage and pavement marking improvements, do not prevent all WWD incidents. More rigorous and active WWD detection and mitigation methods are required to: (a) alert wrong-way drivers as soon as they turn the wrong way; (b) warn right-way drivers of a possible wrong-way driver; and (c) inform law enforcement officials, Transportation management centers (TMCs), and first responders in real-time about wrong-way drivers.

In addition to traditional WWD countermeasures, several states, including Florida, have deployed ITS technologies and TSM&O strategies to mitigate WWD incidents. ITS technologies can alert wrong-way drivers in real-time using detection-triggered Wrong Way signs. Dynamic message signs (DMSs) and LED signs can also be used to alert right-way drivers (Finley et al., 2016). In some cases, multiple technologies are combined to prevent WWD incidents. For instance, the Washington State Department of Transportation (WSDOT) notifies wrong-way drivers using a combination of video cameras, LEDs, and flashers (Cooner et al., 2004; Finley et al., 2016). In Houston, Texas, a radar system was deployed in 2007 to detect WWD incidents. Over the next five years, 2008 to 2013, this countermeasure strategy resulted in a total of 94 wrong-way drivers correcting their driving path to avoid going in the wrong direction (Johnson & Harvey, 2013).

Advanced technology-based countermeasures, such as detection-triggered LEDs surrounding Wrong Way signs and red-Rectangular Rapid Flashing Beacons (red-RRFBs), etc., have played a crucial role in reducing WWD incidents. Many states, such as Florida, Wisconsin, and Texas, are currently using LED signs to alert wrong-way drivers (Finley et al., 2014; Sandt et al., 2015). Venglar and Fariello (2014) examined Wrong Way signs with LED border illumination in San Antonio, Texas. On roadway corridors installed with these countermeasures, a reduction of approximately 35% was observed in 911 calls per month related to WWD incidents (Venglar & Fariello, 2014). In Florida, Red-RRFB Wrong Way signs have been installed at several off-ramps across the state and found to be successful in detecting and alerting a wrong-way driver, thus, providing an opportunity for the driver to correct their driving path (Finley et al., 2014; Sandt et al., 2015).

The following sections discuss some of the ITS technologies that have been deployed to detect and respond to WWD incidents in real-time. These technologies are gaining in popularity as effective TSM&O strategies to improve safety on state highway systems.

Thermal Camera System

A thermal camera detection system is a promising technology that alerts wrong-way drivers when they enter a roadway. The Arizona Department of Transportation (ADOT) was the first in the nation to use this technology in combating wrong-way driving. The detection system is activated when it detects a wrong-way vehicle entering the roadway and then immediately alerts the wrong-way driver using red rectangular rapid flashing beacons (red-RRFBs). In addition, the system sends notifications to and alerts public safety officials. ADOT immediately processes the alert and broadcasts a warning to the road users via message boards. Currently, the system consists of 90 thermal cameras along 15 miles of I-17, a $4 Million investment by the state. According to ADOT, the thermal camera system has detected more than 45 WWD vehicles in the past one year and has also resulted in quicker response times by law enforcement and first responders (U.S. News, 2019). In late 2018, the Florida Department of Transportation (FDOT) has also added new software to the existing traffic cameras on the Howard Frankland bridge, a limited-access roadway, over Tampa Bay to detect WWD events (Trimble, 2018).

Radar Detection

A significant reduction in WWD incidents could be achieved with the deployment of early warning systems, such as radar detection. Wrong-way drivers can be proactively warned using accurate radar detectors and active warning systems. After the radar detects a WWD vehicle, alert systems, such as flashing beacons, audible alerts, or/and DMSs, can alert wrong-way drivers. This type of system can be used in combination with closed-circuit television (CCTV) cameras installed in both directions to visually verify WWD events.

In 2015, the Rhode Island Department of Transportation (RIDOT) deployed radar technology at 24 locations statewide to detect and warn wrong-way drivers, and caution right-way drivers by displaying messages on DMSs in real-time (RIDOT, 2015). A study in Florida by Ozkul and Lin (2017) found that about 66 of 78 (i.e., 85%) wrong-way drivers corrected their driving path after noticing the alert from the radar. Similarly, New Mexico developed a directional traffic sensor system to alert wrong-way drivers (Cooner et al., 2004; Finley et al., 2016).

Integrated On-road Detection, Tracking, and Notification System

An effective strategy to detect, alert, and mitigate WWD incidents in real-time includes a combination of technologies and active countermeasures. Several agencies have led the effort to develop, implement, and test an integrated on-road detection, tracking, and notification system to address WWD incidents. The United Civil Group Corporation, on behalf of ADOT, developed an integrated conceptual methodology to detect wrong-way drivers, alert the wrong-way driver, track the WWD vehicle, immediately inform ADOT and the law enforcement agencies, and warn right-way drivers. The study also generated a systematic deployment plan and guidelines to address WWD incidents (Simpson & Bruggeman, 2015).

More recently, the Texas Department of Transportation (TxDOT) conducted a study to create an integrated, comprehensive system to detect and alert wrong-way drivers. To create an integrated WWD mitigation system, the authors generated a conceptual step-by-step operation, designed functional requirements, and developed a system designed for a Connected Vehicle (CV) WWD management technique using vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication. The system was developed to identify WWD incidents, notify TxDOT and law enforcement agencies, and alert the right-way vehicles along the corridor. In concept, when a WWD vehicle is detected, a notification will be sent to the wrong-way vehicle using V2I communication, and a notification about the potential WWD incident will also be sent to the right-way vehicles using V2V and V2I communication. Prior to deploying the system, the authors recommended testing the concept at a test-bed outside of the actual roadway network as a proof-of-concept (Finley et al., 2016).

In-vehicle Systems and Sign Identification Systems

With the increasing advancement of V2V and V2I technologies, the potential for onboard vehicle systems to alert wrong-way drivers is increasing. In-vehicle systems can deliver audible and visual alerts to the driver when the vehicle moves in the wrong direction of travel using the on-board unit (OBU) installed in the vehicle. In addition, with CV technology, the right-way drivers will also be alerted as they approach a WWD vehicle.

Several automobile manufacturers are developing similar systems. For instance, Ford is planning to equip its vehicles with on-board traffic sign recognition technology. In addition, the vehicles will use Global Positioning System (GPS) data to check if the vehicle is on the right path. On-board cameras installed on the windshield will recognize the posted speed limit, as well as “Wrong Way” and “Do Not Enter” signs. When a vehicle enters a road with “No Entry” sign posted, the vehicle will sound an alarm to warn the driver. Ford tested this technology on its test track with “No Entry” signs in Belgium (Harman, 2018). Similar technology is being considered for adoption in the Mercedes-Benz S-Class and E-Class models (Szczesny, 2013). Toyota unveiled its reverse warning technology, which identifies “Wrong Way” signs, alerts drivers, and warns the driver to stop and turn back. However, the company has not announced when the technology will be available in its production cars (Archer, 2011).

Directional Rumble Strips

Zhou et al. (2018) evaluated the feasibility of using directional rumble strips in preventing wrong-way drivers from entering a roadway. This strategy involves a series of rumble strips specially designed to alert wrong-way drivers. Compared to conventional rumble strips, which provide the same amount of noise and vibration when a vehicle moves over them from either direction, directional rumble strips provide an elevated noise and vibration when a driver travels over them going in the wrong direction of travel. However, when a right-way driver drives over directional rumble strips, they experience noise and vibration similar to conventional rumble strips.

Several studies have been conducted to determine the performance baseline of directional rumble strips. Different designs of directional rumble strips have been identified by the national survey of transportation practitioners and vendors and through literature review and field tests (Roadway Safety Institute, 2018). Several researchers are conducting a series of experiments to determine and recommend the most suitable configuration of directional rumble strips which provide minimum noise and vibration to the right-way drivers, but alert wrong-way drivers with elevated noise and vibration (Roadway Safety Institute, 2018).

2.3 Summary

WWD crashes are often severe and generally result in more incapacitating injuries and fatalities than non-WWD crashes. Although previous research has identified that WWD crashes are more frequent on non-limited access roadways compared to limited access facilities, to date, the majority of studies have focused only on WWD crashes occurring on limited access roadways. This research focused on identifying strategies to mitigate WWD crashes on arterials.

This chapter primarily discussed previous WWD studies on arterials, as well as traditional and technology-based WWD countermeasures. In addition to the traditional countermeasures that include enhanced S&PM and “Wrong Way” and “Do Not Enter” warning signs, advanced technologies that are increasingly being deployed to detect, track, and respond to WWD incidents in real-time were also discussed. Strategies that incorporate a combination of multiple technologies, including the use of CV technologies and ITS infrastructure, were highlighted because many agencies are currently considering these countermeasures for adoption. Figures 2-1 through 2-6 illustrate several scenarios where multiple technologies could be used to mitigate WWD incidents on limited access facilities. Although these scenarios are more applicable to limited access facilities, they could be adapted, to an extent, to non-limited access facilities as well.

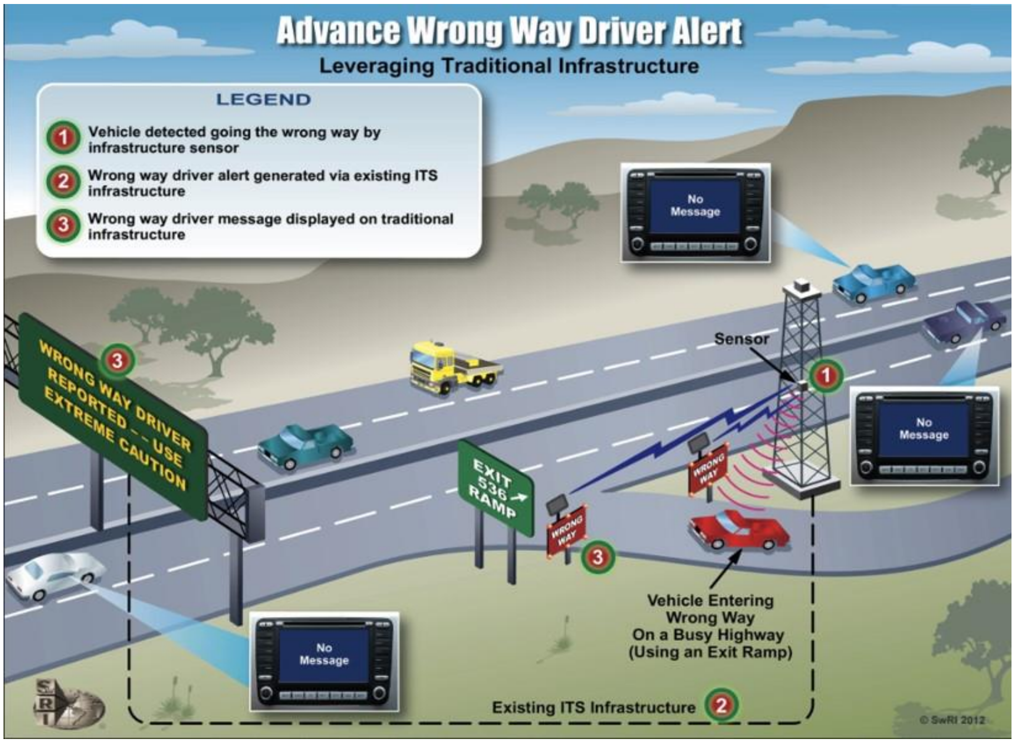

Figure 2-1: Advance Wrong-way Driver Alert – Leveraging Traditional Infrastructure (Randolph, 2014)

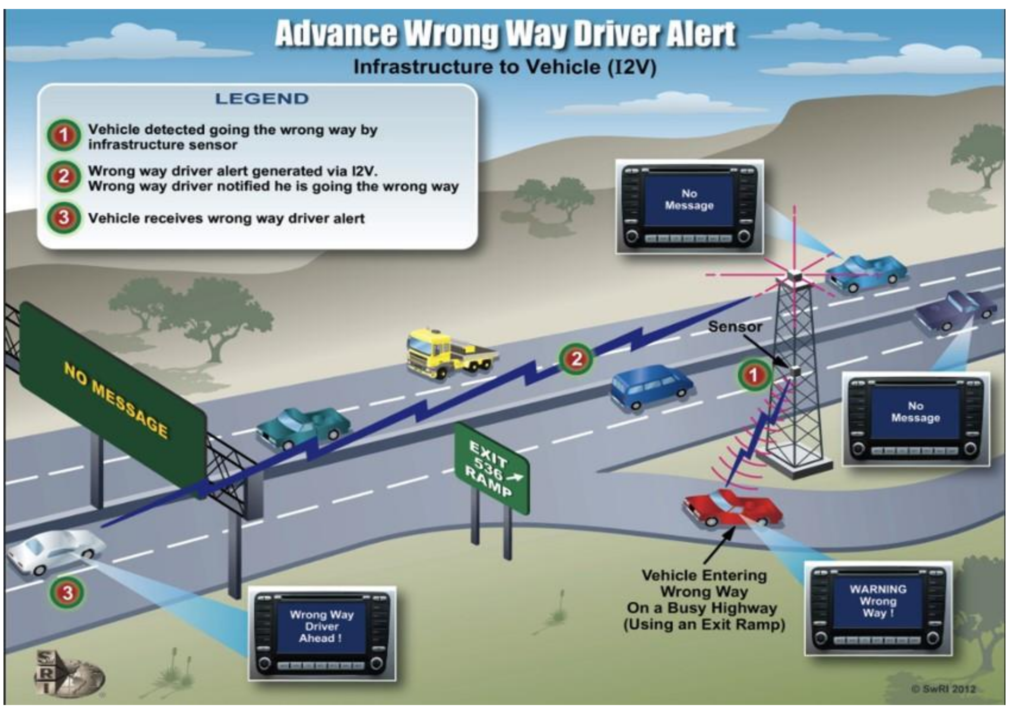

Figure 2-2: Advance Wrong-way Driver Alert – Infrastructure to Vehicle (Randolph, 2014)

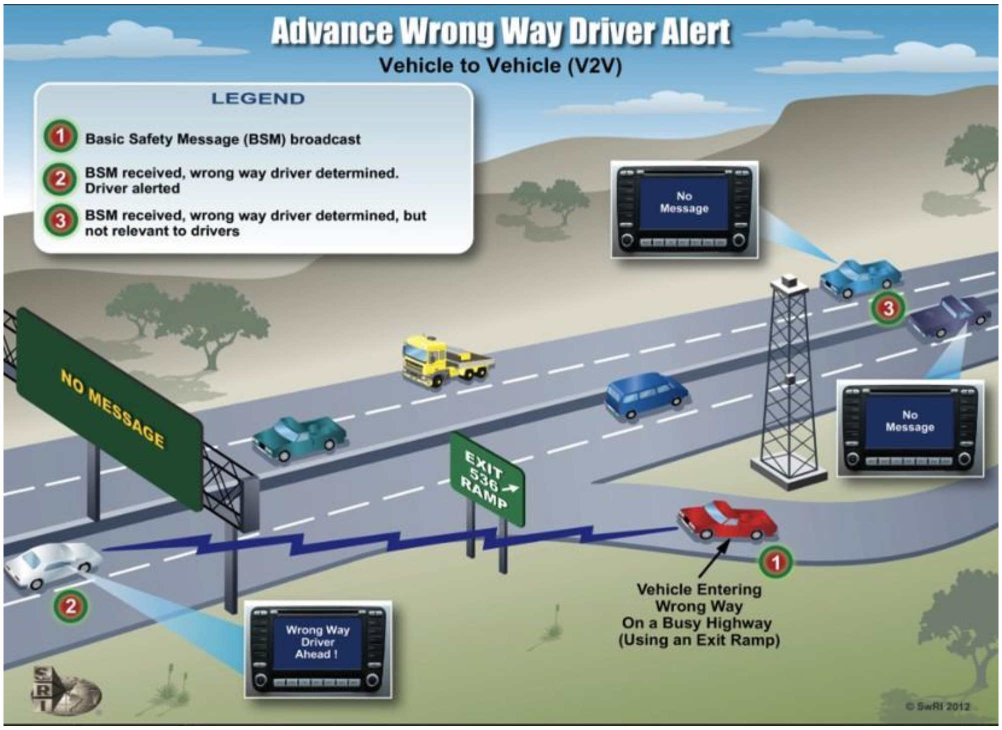

Figure 2-3: Advance Wrong-way Driver Alert – Vehicle to Vehicle (Randolph, 2014)

Figure 2-4: Advance Wrong-way Driver Alert – Intelligent Message Propagation (Randolph, 2014)

Figure 2-5: Advance Wrong-way Driver Alert – Local Wrong-way Driver in Disabled Vehicle (Randolph, 2014)

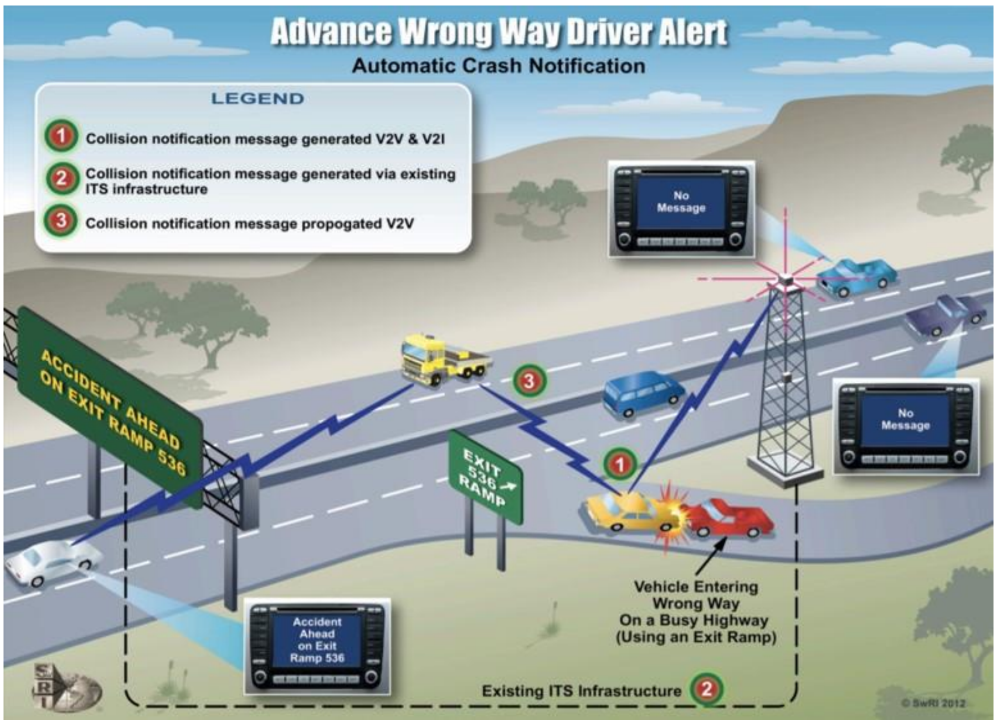

Figure 2-6: Advance Wrong-way Driver Alert – Automatic Crash Notification (Randolph, 2014)

CHAPTER 3
POTENTIAL OF CONDUCTING PUBLIC OUTREACH ACTIVITIES

This chapter explores the potential of conducting either a workshop or a series of public outreach activities on addressing the WWD issue on arterial roadways in Florida. Section 3.1 discusses the role of the 4 E's in mitigating WWD incidents and the collaborative nature of efforts required to successfully reduce the frequency and severity of WWD incidents. The Community Traffic Safety Team (CTST) members in each FDOT District were surveyed to better understand their perspective on addressing the WWD issue on arterials in Florida. Section 3.2 presents the approach used for the survey and the survey responses. Section 3.3 provides specific recommendations pertaining to conducting public outreach activities on WWD mitigation strategies.

3.1 The 4 E's of Traffic Safety

Traffic safety is a diverse and complex field. In an effort to reduce the frequency and severity of traffic crashes, transportation agencies have adopted several strategies that effectively engage diverse stakeholders. One approach is through the 4 E's of traffic safety:

1. Engineering
2. Education
3. Enforcement
4. Emergency Response

3.1.1 Engineering

The *Engineering* "*E*" of traffic safety typically refers to the agency engineering staff responsible for the design, operation, and maintenance of the physical transportation infrastructure. Their efforts generally are related to ensuring that the physical design of the transportation system meets the needs and expectations of road users. Engineers typically address road safety issues related to the roadway, roadside, and vehicle. *Engineering*-related countermeasures that could be implemented to mitigate WWD incidents on arterials include:

- **Signing**
    - Standard "WRONG WAY" sign package
    - Improved static signs
    - Redundant signs
    - Lowered sign height
    - Oversized signs
    - Multiple signs on the same post
    - Red retro-reflective tape on vertical posts

- **Pavement Markings**
    - Stop bar
    - Wrong-way arrow
    - Turn/through lane-only arrow
    - Raised pavement markers

    - Short dashed line to delineate the turning path

- **Geometric Improvements**
    - Raised curb median
    - Longitudinal channelizers

- **ITS Technologies**
    - LED-illuminated signs
    - Dynamic message signs to warn right-way drivers
    - Existing GPS navigation technologies to provide wrong-way movement alerts, especially on one-way streets

3.1.2 Education

The *Education* "*E*" of traffic safety refers to educational efforts that are intended to help road users understand what is expected from them and what they can expect from the transportation system. Oftentimes, when new traffic control devices or new roadway design features are introduced, an educational campaign will be undertaken to help road users understand the new features; how they work and what they mean. For example, when RRFBs or Pedestrian Hybrid Beacons are introduced in an area, it is helpful to explain what the various indications mean to both motorists and pedestrians. Educational activities are often conducted by engineering practitioners through public outreach efforts or by law enforcement officers through warnings issued prior to issuing citations.

Another purpose of *Education* in road safety is to change the behavior of road users (i.e., reduce unsafe behaviors and increase safe behaviors). Educational campaigns can be targeted to address specific unsafe actions, such as driving under the influence, texting while driving, not wearing a seatbelt, etc., or to address specific road user populations, such as teen drivers, motorcyclists, aging population, pedestrians, etc. *Education*–related countermeasures that could be implemented to mitigate WWD incidents include:

- Public awareness and understanding of the basics of road designs, interchange types, and proactive behaviors (i.e., witnessing a wrong-way driver)
- Focus groups involving older drivers, impaired drivers, and young drivers

3.1.3 Enforcement

The *Enforcement* "*E*" of traffic safety refers to the legal enforcement of the applicable traffic laws by law enforcement officers. This is often one of the most effective E's in improving traffic safety. Unfortunately, *Engineering* and *Education* efforts do not completely solve road safety issues. For example, an engineer can design a roadway and post a specific speed limit while an educational campaign explains the dangers of excessive speeds and driving under the influence. Despite these *Engineering* and *Education* efforts, some drivers may choose to exceed the posted speed limit and/or drive under the influence of alcohol. Therefore, *Enforcement* is needed to change the driver's behavior. Another safety-related task that falls on the enforcement team members is that of recording crash data on the crash reporting forms. This documentation provides the most useful and relevant data necessary for crash analyses to recommend appropriate countermeasures to reduce the frequency and severity of crash events. *Enforcement*–related countermeasures that could be implemented to mitigate WWD incidents on arterials include:

- Provide warnings and citations to wrong-way drivers
- Enforce DUI laws

3.1.4 Emergency Response

The *Emergency Response* "*E*" refers to the emergency responders who are responsible for rescuing victims from a crash, providing initial emergency care, and protecting other road users from further harm. Emergency responders include law enforcement, traffic engineers, fire and rescue, and emergency medical services (EMS). The first hour after a crash is often referred to as the "golden hour." What happens in that first 60 minutes after a crash has a very significant impact on whether the crash victims survive the crash or on the severity and extent of their injuries from the crash. Having well-trained EMS staff available to arrive quickly to a crash scene and begin their work greatly improves the survivability of crash victims by mitigating the severity of injuries. Furthermore, while emergency responders typically deal with post-crash issues, it is important for these professionals to have well-conceived incident management plans established before a crash occurs. Through effective incident management, these professionals can work in collaboration to mitigate the consequences of a crash for those involved, reduce the potential for further harm, and address traffic delay. *Emergency Response*-related countermeasures that could be implemented to mitigate WWD incidents on arterials include:

- Identify wrong-way vehicles as soon as possible.
- Develop a communication plan to inform all relevant agencies of a potential wrong-way incident.

Since a combined effort of the 4 E's of traffic safety is paramount in reaching the goal of "Toward Zero Deaths", Florida has established CTSTs in nearly every county in the state. Each CTST is comprised of people representing each category of the 4 E's, as well as other safety-interested partners, such as Mothers Against Drunk Driving (MADD), and other safety advocates. The CTST meetings typically feature members from FDOT, local, city, or county engineering, Florida Highway Patrol (FHP), local law enforcement, local fire-rescue personnel, and other interested members of the public.

3.2 Survey

3.2.1 Survey Administration

To explore the need to conduct public outreach activities on addressing the WWD issue in Florida, a survey was developed to seek feedback from across the spectrum of safety practitioners. Since CTSTs include representatives from all categories of the 4 E's and are people with a particular interest in traffic safety, CTST coordinators in each FDOT District were contacted and asked to answer the following questions:

1. Have you done any specific *enforcement*, *education*, or *engineering* efforts to mitigate wrong-way crashes on non-interstate roadways? If so, can you please describe?
2. Do you believe that additional *education*, *enforcement*, or *engineering* efforts should be undertaken to reduce WWD incidents on non-interstate roadways? If you have specific ideas that you think should be considered, please elaborate.
3. Do you believe that a workshop to encourage discussion on this topic would be helpful?
4. Do you believe that public outreach related to this topic would be helpful?

The following sections summarize the survey responses from the CTST members. Interestingly, the number of responses received was quite limited. This result may be due to a lack of focus on mitigating WWD crashes on arterials. Since the majority of past efforts to mitigate WWD crashes have concentrated on high-speed limited access roadways, as documented in Chapter 2, the research team believes that many people did not respond simply because they did not believe they had much to offer concerning arterial WWD.

3.2.2 Survey Responses

Specific Efforts Undertaken to Mitigate WWD Incidents

Q1: Have you done any specific enforcement, education, or engineering efforts to mitigate wrong-way crashes on non-interstate roadways? If so, can you please describe?

- Florida Highway Patrol (FHP) does various campaigns focused on different "hot topics" as they are identified by FDOT, Highway Safety and Motor Vehicles (HSMV), and FHP analysts. In Tampa, they had significant amounts of wrong-way crashes, and I believe that the enforcement focus was primarily on the interstate system, due to the high volume of devastating crashes. I do not know of any significant enforcement efforts that have occurred on non-interstate roadways directed specifically towards wrong-way drivers. However, with that being said, I am aware of significant enforcement that has focused on identifying and removing impaired drivers from our roadways. The majority of the wrong-way drivers I have encountered, both on and off the interstate, have been either drunk, drugged, or fatigued. Although, I once encountered an elderly woman who was confused about the construction in one area, and that resulted in her entering the interstate on the exit ramp. [response from FHP]
- No [response from local County government agency]
- This specific enforcement would most probably be "typical patrol type duties", as the occurrence of these cases is difficult to determine on specific locations. [response from the County Sheriff's office]
- Not from a systemic approach, but often at a spot location where wrong-way incidents had been reported. The most common locations/scenarios include one-way streets in tourist areas. We upped our use of pavement arrows at some locations:
    - St Petersburg has a number of one-way streets; they've used a lot of pavement arrows as well:
    - Unusual geometric locations; for example, I have personally seen three wrong-way movements from the northbound left-turn thinking the median was the far curb; there is no Keep Right sign here, just the yellow flex post.

- Any place drunk drivers go. A drunk driver hit another car head-on and killed three at this low speed location: [response from engineering consultant]

Key point: Unusual geometry (reversible lanes, one-way streets, wide roadways, etc.) coupled with either impaired or unfamiliar drivers seems to be problematic.

Perspective on Additional Efforts to Mitigate WWD Incidents

Q2: Do you believe that additional education, enforcement, or engineering efforts should be undertaken to reduce wrong-way driving on non-interstate roadways? If you have specific ideas that you think should be considered, please elaborate.

- I always believe that additional education is important. However, my question to you would be what kind of education are you looking to put out there? If we are looking to specifically target wrong-way drivers, we would need to pull data to determine the root cause for the wrong-way driving, whether it is on non-interstate roadways or not. If we have a large number of wrong-way drivers in one specific area with no signs of impairment, that is probably a roadway engineering issue that has people confused. In that case, instead of education, I would suggest a Road Safety Audit to determine exactly what is going wrong. If we have a large number of wrong-way drivers in a specific area with signs of impairment, I would be curious to see if there is a bar nearby or some type of location that is providing intoxicating substances to individuals. In this case, enforcement would be very important to deter, arrest, and prevent this behavior. Education on drunk and drugged driving is always important and we could increase that awareness in an area with a lot of wrong-way impairment crashes. Essentially, my thought process on wrong-way driving is that it is a symptom with a root cause. Exactly what that root cause is can be discovered through researching the crashes within certain areas and finding out what caused them. Once we know the root cause, we can develop educational programs, update roadways as necessary and make any additional changes to help mitigate these crashes. [response from FHP]
- Wrong-way driving incidents could be due to roadway engineering issues. For example, at a curve with an intersecting road - the driver can inadvertently turn into the wrong lane. Signage/lighting and possible changing the intersection to a perpendicular intersection may be the “step” considerations. [response from County government]
- Again, the occurrence of these crashes involves factors specific to the above listed driver’s actions/conditions. I do not see that any additional education, enforcement or engineering would help the overall occurrence of these factors; no more than the typical DUI education already does. In my opinion, it would not be feasible to think that re-engineering the roadway characteristics are a viable option. However, if these secondary roadways are at least a 4-lane, divided type roadway, center median barriers would tend to decrease accidental “cross-overs” by opposing vehicles. [response from County Sheriff’s office]
- Yes; recognizing the recurring locations is perhaps a key starting point…then working on specific countermeasures, either engineering or enforcement. Anti-DUI campaigns help as well. [response from engineering consultant]

Key point: Need to determine the root causes of wrong-way entries. Is it the geometrics, is it impairment, or a combination of these and other factors?

Perspective on Conducting a Workshop

Q3: Do you believe that a workshop to encourage discussion on this topic would be helpful?

- Potentially. Again, I suggest pulling data to find out the root causes of wrong-way driving in specific areas to determine what kind of topics should be explored in a workshop. Depending upon what is discovered in the data search, bringing in all stakeholders for, say, correction of an engineering issue, could be beneficial. [response from FHP]
- Not for our County [response from County government]
- Education is always helpful. However, again the human factors that overwhelmingly contribute to this situation cannot be solved through education in my opinion. [response from County Sheriff's office]
- Yes, perhaps part of a CTST Coalition conference where multi-discipline staff gathers. [response from engineering consultant]

Key points: First determine the root causes of WWD, then develop the workshop based on those causes. Some skepticism as to whether the workshop could be successful. One suggestion for when and where to do this workshop: as a part of one of the Statewide CTST Coalition meetings.

Perspective on Conducting Public Outreach Activities

Q4: Do you believe that public outreach related to this topic would be helpful?

- Yes, once the root cause is discovered. I don't think we can simply put out a [*Public Service Announcement*] PSA on "wrong way driving". I honestly don't think the vast majority of people go the wrong way. I think it is an impairment issue or, in rare cases, an engineering issue. [response from FHP]
- Not for our County [response from County government]
- No, I don't think WWD is a specific decision for drivers. However, a campaign to stay right at night might be good. [response from engineering consultant]

Key points: Discover the root cause, then see if it is something we can help through public outreach. Increased anti-DUI messages would be most beneficial.

3.2.3 Follow-up Survey Activities

Due to very limited responses to the initial survey administered to the CTST members, additional attempts were made to solicit input from District Traffic Operations Engineers (DTOEs), District Public Information Officers (PIOs), and other safety partners. Using the same questions asked of CTSTs (see Section 3.2.1), responses were received from two of the DTOE's contacted. The following information was gathered from this effort:

Q1. Have you done any specific enforcement, education, or engineering efforts to mitigate wrong-way crashes on non-interstate roadways? If so, can you please describe?
  - No
  - No

Q2. Do you believe that additional education, enforcement, or engineering efforts should be undertaken to reduce wrong-way driving on non-interstate roadways? If you have specific ideas that you think should be considered, please elaborate.
  - Yes. Gain an understanding of where such crashes are occurring and why then use that to develop Engineering, Enforcement and Education strategies; integrate into Transportation Systems Management & Operations (TSM&O)/active arterial management program; CTST
  - Yes. I am aware that the Arizona Department of Transportation is using the Forward-looking infrared (FLIR) camera to detect wrong-way movements on arterials. I think that could be looked into. Possibly incorporating internally illuminated raised pavement markers (IIRPMs)/additional pavement markings as well.

Q3. Do you believe that a workshop to encourage discussion on this topic would be helpful?
  - Yes
  - Yes

Q4. Do you believe that public outreach related to this topic would be helpful?
  - Yes, but after the Department gets a clear understanding of the problem (where and why such crashes are occurring)
  - Yes

In some of the other follow-up responses, the four questions posed to the CTSTs were not specifically addressed; however, useful input was received. These responses are listed below:

- I don't think anyone is tracking wrong ways on arterials, but I do think it is an important consideration and everyone would benefit from a wider conversation. I assume that alcohol, drugs, and mental illness are usually factors in wrong-way crashes. It's going to take more than just traffic folks to resolve or make any improvement to the crash rates.
- I'm the Healthy Communities Coordinator for DOH-Collier [*Department of Health, Collier County*]. My feedback and opinions are neutral, which is may be valuable in your decision process. Though my comment is professionally considered, I don't mean to speak on behalf of the whole department. I'm interested in improving the safety of our roadways and limiting fatalities. I haven't seen any efforts besides red reflectors and wrong way signs to mitigate wrong-way crashes. I am unsure of specific intervention possibilities, but I think engineering and design efforts would be the most effective way to reduce incidents. Educating that red reflectors mean you're going the wrong way could help. Though any incident is too often, their relative infrequency seems to indicate wrong-way crashes are a momentary hazard of lack of clarity or inattentive driving, with limited time for correction. At regions where age-reduced reaction times and vision play a role, I think increasing licensing test frequency may be a helpful preventive measure. I'm open to a workshop and discussion.

- I think education outreach campaigns are very positive to improve safety. The partnerships that we have developed on other campaigns such as *Anti-Aggressive Driving* and *Put It Down* are just two very positive examples of successful outreach campaigns.

3.3 Recommendations

Based on the results of the survey, it is apparent that the consensus of the respondents is that specific efforts to address WWD on arterial roadways is not something that has been done to date. One local law enforcement agency responded that WWD incidents are considered "typical patrol-type duties" and thus, not specifically flagged as unique or out of the ordinary. This point was highlighted in Chapter 2: that there is virtually no information available on arterial WWD crashes, and thus, it is difficult to identify any specific arterial WWD efforts or their success rates.

With respect to the second survey question on whether additional educational, enforcement or engineering efforts should be undertaken to address arterial WWD crashes, the consensus from the respondents is that they should be addressed, but only in a very targeted way. Several respondents indicated that we should first identify the underlying causes and contributing factors, and then focus the efforts towards those causes and factors.

The third question asked if the respondent thought that a workshop to encourage discussion on arterial WWD would be helpful. The majority of respondents indicated that they favored this type of workshop and thought it would be useful. It was suggested to include this topic in an upcoming Statewide CTST Coalition Meeting. The meeting would be an appropriate forum for a WWD discussion, since the CTST Coalition Meeting includes representatives from all of the 4 E's, and therefore, could have the desired effect of a truly multi-disciplinary approach to mitigating WWD incidents on arterials. However, based on the responses to question two, the discussion should occur only after a thorough analysis of arterial WWD crash reports to identify the underlying causes and contributing factors.

The fourth survey question asked if public outreach related to the topic of arterial WWD would be helpful. The majority of the respondents indicated that they did not believe that this would be particularly useful since they did not believe that WWD was a conscious choice that drivers typically make. However, one respondent suggested that additional educational efforts to remind drivers that if they see red reflectors (i.e., raised pavement markers), they are going the wrong way. This point may be a helpful addition to future PSAs on safe driving.

3.3.1 Presentation at the Statewide CTST Coalition Conference

Based on the responses to the survey, a presentation at the Statewide CTST Coalition Meeting would be a beneficial way to foster increased discussion on arterial WWD. However, this discussion should come after a thorough review of the WWD crash reports. It is anticipated that some information obtained from the WWD crash report review would enable the research team to identify some of the underlying causes or contributing factors to arterial WWD. This would then allow the research team to focus on strategies and countermeasures in locations where the impact may be maximized.

3.3.2 Statewide Showcase on Mitigating WWD Incidents

In addition to the Statewide CTST Coalition presentation described above, a statewide showcase on the mitigation of WWD incidents on freeways and arterials would help bring statewide attention to the WWD issue. This showcase would serve as a public outreach effort at the state level that brings together stakeholders from different sectors to discuss the recently completed, ongoing, and upcoming research and implementation efforts in mitigating WWD on both arterials and limited access facilities. This one-day showcase could primarily focus on the following topics:

- Background on WWD incidents
- The 4 E's of traffic safety in the context of mitigating WWD incidents
- Research and implementation efforts in addressing WWD issue in Florida
- Success stories and best practices from other states
- Experiences of FDOT districts, counties, and local agencies
- Strategies to address WWD issue from a policy perspective
- Strategies to address WWD issue from an enforcement perspective
- Next steps in mitigating WWD incidents

Some of the stakeholders to be included in the discussion would include the FHP, media personnel, District PIOs, CTSTs, DSEs, DTOEs, local Law Enforcement Organizations (LEOs), and safety advocates including AAA, MADD, etc. Figure 3-1 provides the draft preliminary agenda for this showcase.

STATEWIDE SHOWCASE ON MITIGATING WRONG-WAY DRIVING INCIDENTS

Tentative Agenda

8:00 AM – 8:30 AM	Registration
8:30 AM – 9:00 AM	Introductions
9:00 AM – 10:00 AM	Background on WWD Incidents
10:00 AM – 11:00 AM	The 4 E's of Traffic Safety in the Context of Mitigating WWD Incidents
11:00 AM – 12:00 PM	Completed and Ongoing Research in Addressing WWD Issue in Florida
12:00 PM – 1:00 PM	Lunch
1:00 PM – 2:00 PM	Success Stories and Best Practices from Other States
2:00 PM – 3:00 PM	Experiences of FDOT Districts, Counties, and Local Agencies
3:00 PM – 3:15 PM	BREAK
3:15 PM – 3:45 PM	Addressing WWD Issue from a Policy Perspective
3:45 PM – 4:15 PM	Addressing WWD Issue from an Enforcement Perspective
4:15 PM – 5:00 PM	Discussion on the Next Steps
5:00 PM	Wrap-up

Figure 3-1: Draft Preliminary Agenda for the Statewide Showcase on Mitigating WWD Incidents

CHAPTER 4
DESCRIPTIVE STATISTICS OF WRONG-WAY DRIVING CRASHES

This chapter discusses the data collection efforts that were undertaken to collect the WWD crash information. It also provides the descriptive statistics of WWD crashes on state-maintained non-limited access facilities in Florida. A comprehensive effort was made to review the police reports of all WWD crashes that occurred on the arterial network within the state highway system in Florida. Police reports of all the WWD crashes from 2012-2016 were extracted and reviewed in detail. The following information was collected from the police reports:

- The location where the wrong-way driver potentially turned the wrong way, if available,
- The exact location of the WWD crash,
- Any cues pertaining to the wrong-way incident, if present,
- Other roadway characteristics that may have contributed to WWD crashes (e.g., street lighting, pavement markings, one-way streets, etc.), and
- Information related to the crash, such as alcohol involvement, age of the wrong-way driver, the familiarity of the wrong-way driver with roadway network, etc.

In addition to reviewing the police reports, data related to roadway characteristics were also processed to identify characteristics, such as one-way streets, divided and undivided facilities, etc. Section 4.1 describes the police report review process undertaken in this research. Section 4.2 briefly describes the data processing efforts undertaken to retrieve certain roadway geometric characteristics from the All Roads Base Map (ARBM) and the FDOT's Roadway Characteristics Inventory (RCI). Sections 4.3 and 4.4 present the descriptive statistics of WWD crashes that occurred on arterials, based on the crash summary records and the police report review process, respectively. Section 4.5 presents the key findings of this effort.

4.1 Police Report Review

The analysis was based on available crash data for the years 2012-2016. Crash data shapefiles for the years 2012-2015 were retrieved from the FDOT Unified Basemap Repository (UBR). Since the scope of this research project was limited to state-maintained non-limited access facilities, only data pertaining to state roads in Florida were downloaded. The variable FL_WRNGWAY, a yes/no flag that indicates WWD involvement, was used to identify WWD crashes. At the time of this research, the FDOT State Safety Office had not yet finalized the 2016 crash data shapefiles. Therefore, WWD crashes for the year 2016 were identified from the FDOT's Crash Analysis Reporting System (CARS) database using the following code in the vehicle-driver-passenger extract file: Driver Action at Time of Crash = "21" (wrong side or wrong way). From 2012-2016, a total of 2,879 crashes were identified as potential WWD crashes. Police reports of these 2,879 crashes were obtained and reviewed in detail, and each report was manually reviewed to collect the following data:

1. *Is it a WWD crash?*
    - *Yes*
    - *No – passed over the median*
    - *No – reason* __________
    - *Unknown*

2. *Where did the WWD crash occur?*
   - *Middle of intersection*
   - *In very close proximity to an intersection*
   - *On major approach*
   - *On minor approach*
   - *On divided roadway*
   - *On undivided roadway*
   - *On Two-Way Left-Turn Lane*
   - *Other* __________________
   - *Not sure*

3. *Did the WWD crash occur on a one-way street?*
   - *Yes*
   - *No*
   - *Not Sure*

4. *If divided, the type of median*
   - *Paved*
   - *Raised Traffic Separator*
   - *Curb*
   - *Vegetation*
   - *Curb and vegetation*
   - *Other*

5. *Is there roadside lighting?*
   - *Yes*
   - *No*
   - *Not Sure*

6. *Is there a WWD Sign on the leg where the crash occurred?*
   - *Yes*
   - *No*
   - *Unsure*

7. *Where did the WWD possibly enter the wrong way?*
   - *At signalized intersection*
   - *At a four-way Stop sign*
   - *At a two-way Stop sign*
   - *From a driveway*
   - *Make a U-turn*
   - *Other* _________________
   - *Not sure*

8. *Did the police report state where the WWD possibly entered the wrong way?*
   - *Yes*

- *No*
- *Unsure*

9. *The coordinates where the WWD possibly entered the wrong way?*
   - *Lat:* ________________
   - *Lon:* ________________

10. *The blood alcohol concentration level of wrong-way driver:* __________________

In addition to the data collected from the police reports, the following variables were extracted from the FDOT's Crash Analysis Reporting System (CARS) database:

- Date and Time of Crash
- Day of Week of the Crash
- Crash Severity
- First Harmful Event
- Light Condition
- Alcohol Involvement
- Max Speed
- Driver's Age

Table 4-1 provides a summary of the WWD crash frequency statistics for crashes that occurred on state-maintained non-limited access roadways during the years 2012 through 2016. As indicated in Table 4-1, of the 2,879 potential WWD crashes on arterials, 1,890 crashes (i.e., 65.6%) were categorized as actual WWD crashes resulting from vehicles traveling the wrong way. A total of 945 crashes (i.e., 32.8%) were not considered to be WWD crashes. Of these 945 non-WWD crashes, a sizable number (353 crashes) were head-on crashes that occurred as a result of a driver crossing over the median. From these statistics, it can be inferred that head-on crashes on arterials are frequently and incorrectly flagged as WWD crashes.

Table 4-1: Descriptive Statistics of 2012-2016 Crash Data by Year

Year	WWD Crash	Not a WWD Crash	Not Sure	Total
2012	206	271	7	484
2013	309	255	6	570
2014	452	166	15	633
2015	491	121	6	618
2016	432	132	10	574
Total	**1,890**	**945**	**44**	**2,879**

4.2 Roadway Characteristics Data Preparation Efforts

This section discusses the data preparation efforts undertaken to extract roadway information for one-way streets and divided and undivided facilities in Florida.

4.2.1 One-Way Streets

FDOT maintains an *All Road Base Map (ARBM)* that was built on the NAVSTREETS™ base map from HERE (formerly known as NAVTEQ). To link this ARBM with its linear-referenced roadway and crash databases, FDOT added the linear references (i.e., roadway IDs and mileposts) to all road segments in the map. With the linear references, the state road portion of the map can be populated with roadway data from FDOT's RCI database. While the RCI is a comprehensive and well-maintained database, it is available for only state roads and a small portion of local roads. This leaves a majority of the local roads in the map, numbering over one million segments and growing, without the same data. FDOT has since added to the map some major variables, including functional class and roadside information, which are needed for safety analysis, among its other applications.

The following steps were undertaken to extract one-way streets from the FDOT's ARBM.

Step 1: Generate a one-way street layer based on the All Road Base Map.

The attribute "DIR_TRAVEL" of the ARBM shows the direction of travel, which is the legal travel direction for a navigable link. The definitions of the direction of travel are as follows:

- The direction of travel 'F' is applied when the direction of travel is one way from the reference node to the non-reference node.
- The direction of travel 'T' is applied when the direction of travel is one way to the reference node from the non-reference node.
- The direction of travel 'B' is applied when travel is allowed in both directions between the reference and the non-reference nodes.
- The direction of travel 'Not Applicable' is applied to non-navigable links.

The one-way street layer only includes the streets when the direction of travel is one way from the reference node to the non-reference node.

Step 2: Generate a one-way street layer without specific types of roads.

The attribute "FUNC_CLASS" in the ARBM defines a hierarchical network used to determine a logical and efficient route for a traveler. The definitions of functional class (NAVTEQ definition) are shown as follows:

- Functional Class '1' roads allow for high volume, maximum speed traffic movement between and through major metropolitan areas.
- Functional Class '2' roads are used to channel traffic to Functional Class '1' roads for travel between and through cities in the shortest amount of time.
- Functional Class '3' is applied to roads that interconnect Functional Class '2' roads and provide a high volume of traffic movement at a lower level of mobility than Functional Class '2' roads.

- Functional Class ‘4’ is applied to roads that provide for a high volume of traffic movement at moderate speeds between neighborhoods. These roads connect with higher functional class roads to collect and distribute traffic between neighborhoods.
- Functional Class ‘5’ is applied to roads whose volume and traffic movement are below the level of any functional class. In addition, walkways, truck-only roads, bus-only roads, and emergency vehicles only roads receive Functional Class ‘5’.

Since arterials and collectors are the focus of this research, the next step was to exclude freeways, major connectors, and local roads from the “one-way” database. Hence, all the one-way streets with Functional Class “1” and “2” were excluded from the dataset. The following specific types of roads were also excluded from the one-way street layer: ramps, tollways, bridges, tunnels, and private roads.

Step 3: Generate the final one-way streets layer.

Even when multiple rules are applied to extract the one-way streets, there may still be some small road segments (e.g., exclusive left-turn bays) that are not necessarily one-way streets. This issue was addressed by dissolving all road segments within the selected one-way street layer based on roadway ID. Finally, only the one-way segments that are longer than 0.25 miles are included in the dataset. Figure 4-1 shows the final one-way streets layer that was included in the analysis.

4.2.2 Divided Roads and Undivided Roads

Similar to the approach used to extract one-way streets, the selection of divided roads and undivided roads was also based on the ARBM. The RCI attribute “ROADSIDE” in the ARBM identifies the road segments as undivided (C) or divided (L or R). Obviously, the undivided roads layer includes records with “ROADSIDE” coded as “C”. Figure 4-2 shows the final undivided roads layer.

For extracting divided roadway sections, the following two rules were applied: (a) include only the records with “ROADSIDE” coded as “L” or “R”; and (b) exclude the records with “FUNCLASS” equal to “01”, “02”, “11” and “12”. Figure 4-3 shows the final divided roads layer that was included in the analysis.

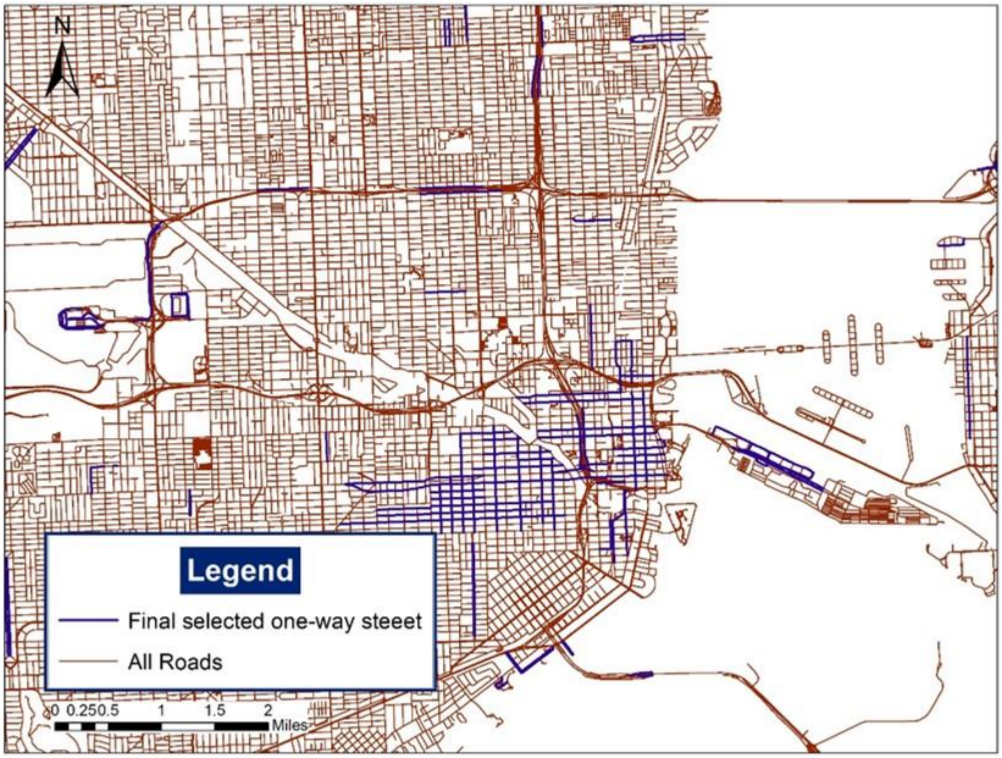

Figure 4-1: One-Way Streets Layer

Figure 4-2: Undivided Roads Layer

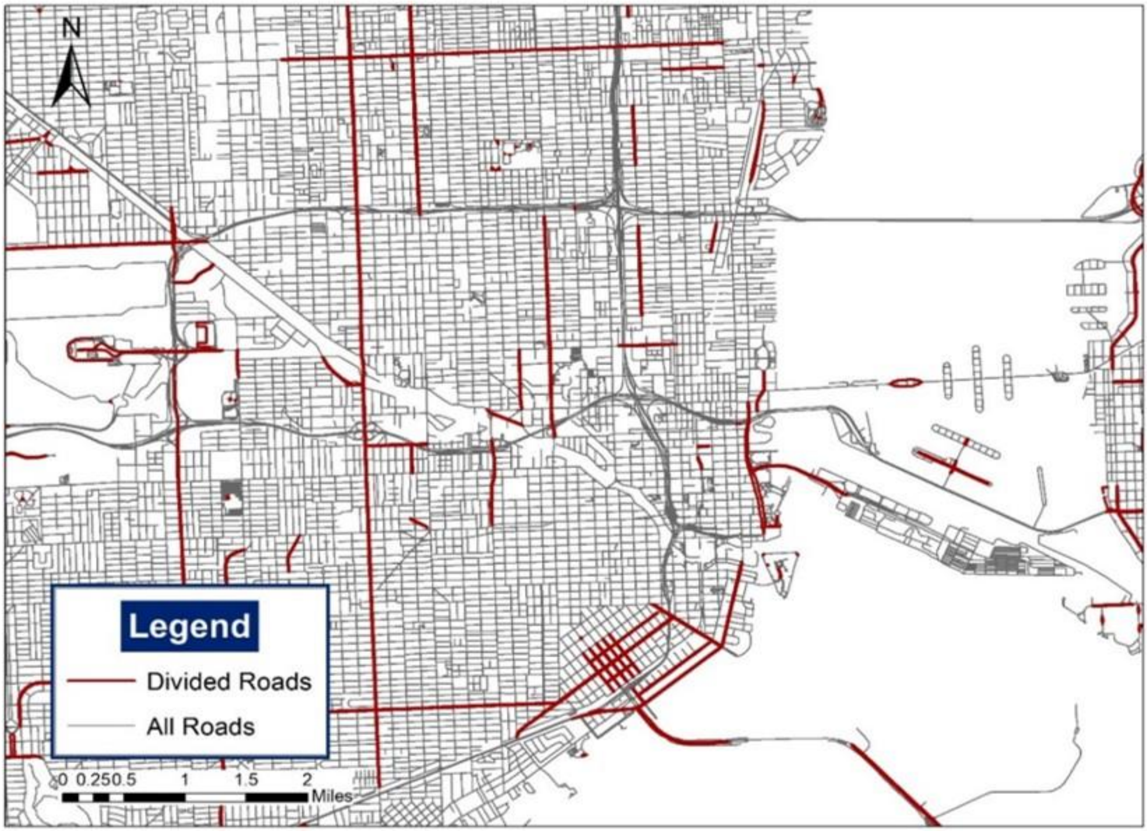

Figure 4-3: Divided Roads Layer

4.3 Descriptive Statistics Based on Crash Summary Records

This section provides descriptive statistics of WWD crashes based on information extracted from the crash summary records. Information analyzed included: crash severity, temporal characteristics, first harmful event, WWD driver vehicle speed, lighting conditions, and driver characteristics, such as age and if drugs or alcohol were a factor in the crash.

4.3.1 Crash Severity

Table 4-2 provides the WWD crash statistics by year and crash severity. On average, about 6.9% of all WWD crashes resulted in a fatality, while 52.5% of all WWD crashes resulted in an injury. Figure 4-4 provides the distribution of the 1,890 WWD crashes by crash severity.

Table 4-2: WWD Crash Statistics by Year and Crash Severity

Year	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
2012	14	6.8	121	58.7	71	34.5	206
2013	18	5.8	157	50.8	134	43.4	309
2014	37	8.2	237	52.4	178	39.4	452
2015	32	6.5	246	50.1	213	43.4	491
2016	29	6.7	231	53.5	172	39.8	432
Total	**130**	**6.9**	**992**	**52.5**	**768**	**40.6**	**1,890**

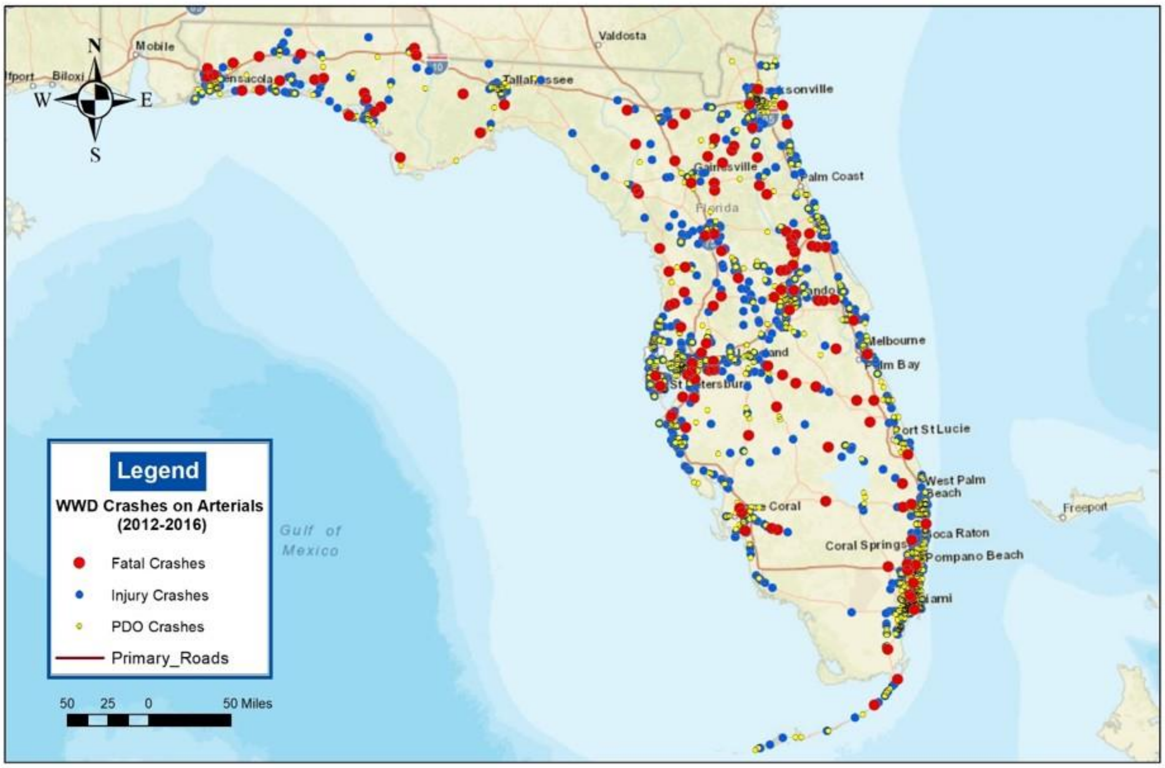

Figure 4-4: WWD Crashes on State-maintained Non-limited Access Facilities in Florida (2012-2016)

4.3.2 Temporal Characteristics

Table 4-3 provides WWD crashes by day of the week. The highest proportion of fatal WWD crashes (8.3%) occurred on Fridays, with a slightly lower proportion (7.0%) occurring on the remaining four weekdays (Monday to Thursday). Interestingly, the smallest proportion of fatal WWD crashes (6.0%) occurred on weekend days (Saturday and Sunday), when a higher number of motorists unfamiliar with the roadway network (i.e., tourists) are anticipated in Florida. For injury crashes, the highest percentage (56.2%) was observed for crashes that occurred during weekend days.

Table 4-3: WWD Crash Statistics by Day of Week and Crash Severity

Day of Week	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
Monday-Thursday	70	7.0	501	50.5	422	42.5	993
Friday	22	8.3	135	51.1	107	40.5	264
Weekend	38	6.0	356	56.2	239	37.8	633
Total	**130**	**6.9**	**992**	**52.5**	**768**	**40.6**	**1,890**

Table 4-4 gives the distribution of WWD crashes by crash severity and crash time. About 8.4% of the WWD crashes that occurred between 6 AM and noon resulted in fatalities. Similarly, 8.1% of those that occurred between midnight and 6 AM were fatal. In terms of both WWD crash frequency and crash severity, the most critical time was found to be from midnight to 6 AM, followed by 6 AM to noon. Figure 4-5 presents the hourly distribution of WWD crashes on arterials. WWD crashes were found to be more frequent from 6 PM to about 3 AM.

Table 4-4: WWD Crash Statistics by Crash Time and Crash Severity

Time	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
6 AM – Noon	47	8.4	290	51.7	224	39.9	561
Noon – 6 PM	25	5.3	253	53.2	198	41.6	476
6 PM – Midnight	15	4.7	171	53.6	133	41.7	319
Midnight – 6 AM	43	8.1	278	52.1	213	39.9	534
Total	**130**	**6.9**	**992**	**52.5**	**768**	**40.6**	**1,890**

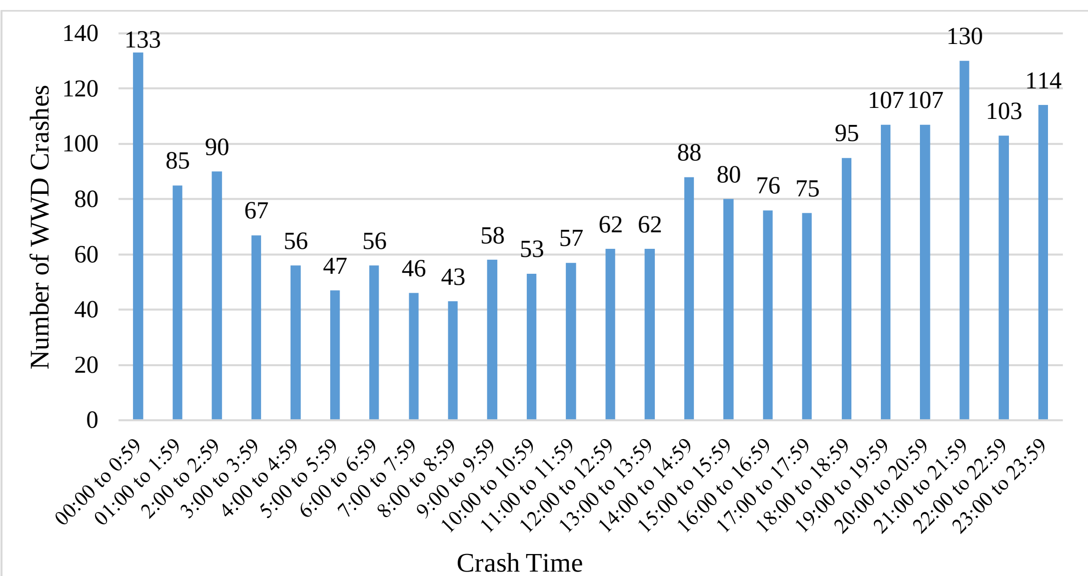

Figure 4-5: Hourly Distribution of WWD Crashes

4.3.3 First Harmful Event

Table 4-5 provides the WWD crash statistics by first harmful event and crash severity. As expected, the proportion of fatalities in WWD crashes that involved a collision with another motor vehicle (7.3%), often the result of head-on contact, was higher compared to other categories. Crashes with the first harmful event as a non-collision were those that involved mostly a single vehicle that overturned, rolled over, ran into water or canal, etc. Other crashes involved collisions with objects or other road users.

Table 4-5: WWD Crash Statistics by First Harmful Event and Crash Severity

First Harmful Event	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
Non-collision	2	5.0	23	57.5	15	37.5	40
Collision with Non-motorists	1	6.7	13	86.7	1	6.7	15
Collision with Motor Vehicle	123	7.3	900	53.4	664	39.4	1,687
Collision with Other Non-fixed Objects	0	0.0	3	50.0	3	50.0	6
Collision with Fixed Objects	4	2.8	57	40.1	81	57.0	142
Total	**130**	**6.9**	**992**	**52.5**	**768**	**40.6**	**1,890**

4.3.4 WWD Vehicle Speed

Table 4-6 gives the WWD crash statistics by the speed of the WWD vehicle and crash severity. A high proportion of WWD crashes involving vehicles traveling over 45 mph resulted in fatalities. Vehicle speed, as expected, was found to play a significant role in crash injuries.

Table 4-6: WWD Crash Statistics by Vehicle Speed and Crash Severity

Speed	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
15 – 30 mph	1	0.6	68	42.8	90	56.6	159
35 – 45 mph	31	3.3	483	51.3	427	45.4	941
> 45 mph	96	21.0	246	53.8	115	25.2	457
Unknown	2	0.6	195	58.6	136	40.8	333
Total	**130**	**6.9**	**992**	**52.5**	**768**	**40.6**	**1,890**

4.3.5 Lighting Condition

Table 4-7 provides the WWD crash statistics by lighting condition and crash severity. Over 55% of all WWD crashes occurred during dark conditions; over 64% of all fatal WWD crashes occurred during dark conditions. Moreover, 19% of all WWD crashes that resulted in fatalities occurred during dark conditions with no lighting. On the contrary, only 4.9% of all WWD crashes occurred during daylight conditions.

Table 4-7: WWD Crash Statistics by Lighting Condition and Crash Severity

Lighting Condition	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
Daylight	38	4.9	414	53.6	320	41.5	772
Dusk	4	9.8	23	56.1	14	34.1	41
Dawn	4	13.8	16	55.2	9	31.0	29
Dark Lighted	21	3.0	355	50.3	330	46.7	706
Dark Not lighted	63	19.0	181	54.5	88	26.5	332
Dark Unknown	0	0.0	3	37.5	5	62.5	8
Other	0	0.0	0	0.0	2	100.0	2
Total	**130**	**6.9**	**992**	**52.5**	**768**	**40.6**	**1,890**

4.3.6 Driver Characteristics: Alcohol and Drug-Related Crashes

Table 4-8 provides the WWD crash statistics by alcohol and drug involvement and crash severity. Of the 1,890 WWD crashes, 680 crashes (36%) involved intoxicated drivers. Based on the statistics shown in Table 4-8, drugs were found to result in more fatalities compared to when only alcohol was a factor. About 30.5% of WWD crashes that were drug- and alcohol-related resulted in fatalities, and 24.6% of WWD crashes that involved only drugs led to fatalities. Approximately 6.2% of WWD crashes that were alcohol-related resulted in fatalities. When the driver was not impaired, only 4.0% of WWD crashes were fatal.

Table 4-8: WWD Crash Statistics by Alcohol and Drug Involvement and Crash Severity

Alcohol & Drug Involvement	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
None	48	4.0	638	52.7	524	43.3	1,210
Alcohol	31	6.2	271	54.1	199	39.7	501
Drugs	15	24.6	24	39.3	22	36.1	61
Alcohol & Drugs	36	30.5	59	50.0	23	19.5	118
Total	**130**	**6.9**	**992**	**52.5**	**768**	**40.6**	**1,890**

Driver Age

Table 4-9 provides the WWD crash statistics by driver age and crash severity. Approximately 8.8% of WWD crashes involving a driver age 35 to 64 were fatal, and 7.6% of WWD crashes involving a driver age 65 and older resulted in a fatality.

Table 4-9: WWD Crash Statistics by Driver Age and Crash Severity

Age	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
≤ 20 years	6	2.8	107	49.8	102	47.4	215
21 - 34 years	37	5.8	355	55.7	245	38.5	637
35 - 64 years	64	8.8	361	49.5	305	41.8	730
≥ 65 years	23	7.6	166	55.0	113	37.4	302
Unknown	0	0.0	3	50.0	3	50.0	6
Total	**130**	**6.9**	**992**	**52.5**	**768**	**40.6**	**1,890**

4.4 Descriptive Statistics Based on Police Report Review

Police reports of WWD crashes were reviewed in detail. The following sections provide descriptive statistics based on the information collected.

4.4.1 WWD Crash Location

Six categories were established to define the location where the WWD crashes occurred: in close proximity to an intersection, middle of an intersection, on a divided roadway, on an undivided roadway, on a two-way left-turn lane (TWLTL), and other. Table 4-10 provides the WWD crash statistics by crash location and crash severity. Over 50% of WWD crashes (i.e., 986 out of 1,890) occurred at or near an intersection, and the majority of these crashes did not result in a fatality. Divided facilities experienced a high number of WWD crashes (764 out of 1,890) or 40.4%, and over 11% resulted in a fatality. WWD crashes on undivided facilities, although relatively rare, also resulted in a high proportion of fatalities (12%). The "Other" category, which represents WWD crashes that occurred at locations other than the aforementioned locations (e.g., bridges), had the highest proportion of fatalities (18.2%).

Table 4-10: WWD Crash Statistics by WWD Crash Location and Crash Severity

Location of WWD	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
In Close Proximity to an Intersection	23	4.0%	286	49.1%	273	46.9%	582
Middle of an Intersection	5	1.2%	216	53.5%	183	45.3%	404
On Divided Roadway	86	11.3%	413	54.1%	265	34.7%	764
On Two-way Left-turn Lane	1	4.8%	15	71.4%	5	23.8%	21
On Undivided Roadway	13	12.0%	57	52.8%	38	35.2%	108
Other	2	18.2%	5	45.5%	4	36.4%	11
Total	**130**	**6.9%**	**992**	**52.5%**	**768**	**40.6%**	**1,890**

Note: The "Other" category includes the WWD crash locations that are not listed in the table and those that could not be determined from the police reports.

The police report for each WWD crash was carefully reviewed to determine the precise location where the wrong-way driver might have entered the wrong way. Table 4-11 provides the WWD crash statistics by the location where the wrong-way driver had potentially entered the wrong way. As can be observed from Table 4-11, the largest proportion of the wrong-way drivers (718 out of 1,890; 38%) turned the wrong way at a signalized intersection, while 154 drivers turned the wrong way at a stop sign. About 17.8% of wrong-way drivers were found to have entered the roadway going the wrong way from a driveway.

The location where the WWD may have potentially entered the wrong way was identified for about 85% of the WWD crashes reviewed. This information was used to estimate the distance between the points where the wrong-way drivers possibly entered the wrong way and the points where the WWD crashes occurred. The actual path that the driver traveled could not be determined based on the information available in the police reports; therefore, the shortest distance between the two points was calculated. Over 95% of the time, WWD crashes were found to occur within 450 ft from where the drivers potentially entered the wrong way. Figure 4-6 presents the cumulative probability curve of the distance between the WWD entrance location and the WWD crash location. It can thus be inferred that wrong-way drivers, especially on arterials, do not travel far prior to getting involved in a crash. It could also be possible that the drivers traveling the wrong way on an arterial may quickly recognize their error and turn around. Thus, there would be less exposure to longer distances. Based on the curve in Figure 4-6, the probability reaches 1 at around 600 feet, implying that the wrong-way driver has either crashed or turned around within 600 feet after entering the roadway going the wrong way.

Table 4-11: WWD Crash Statistics by Entering Location of the Wrong-way Driver

Entering Location of the Wrong-way Driver	Number of WWD Crashes
At a Stop Sign	154
At a Signalized Intersection	718
From a Driveway	338
Made a U-turn	26
Other	654
Total	**1,890**

Note: The "Other" category includes the WWD entry locations that are not listed in the table and those that could not be determined from the police reports.

Of the 1,890 WWD crashes, the entering location of the wrong-way driver was mentioned in the police report for 1,068 crashes (i.e., 56.5%). The entering location of 737 WWD crashes (39.0%) was deduced from illustrations and crash diagrams included in the reports, and this information was unavailable for the remaining 85 WWD crashes.

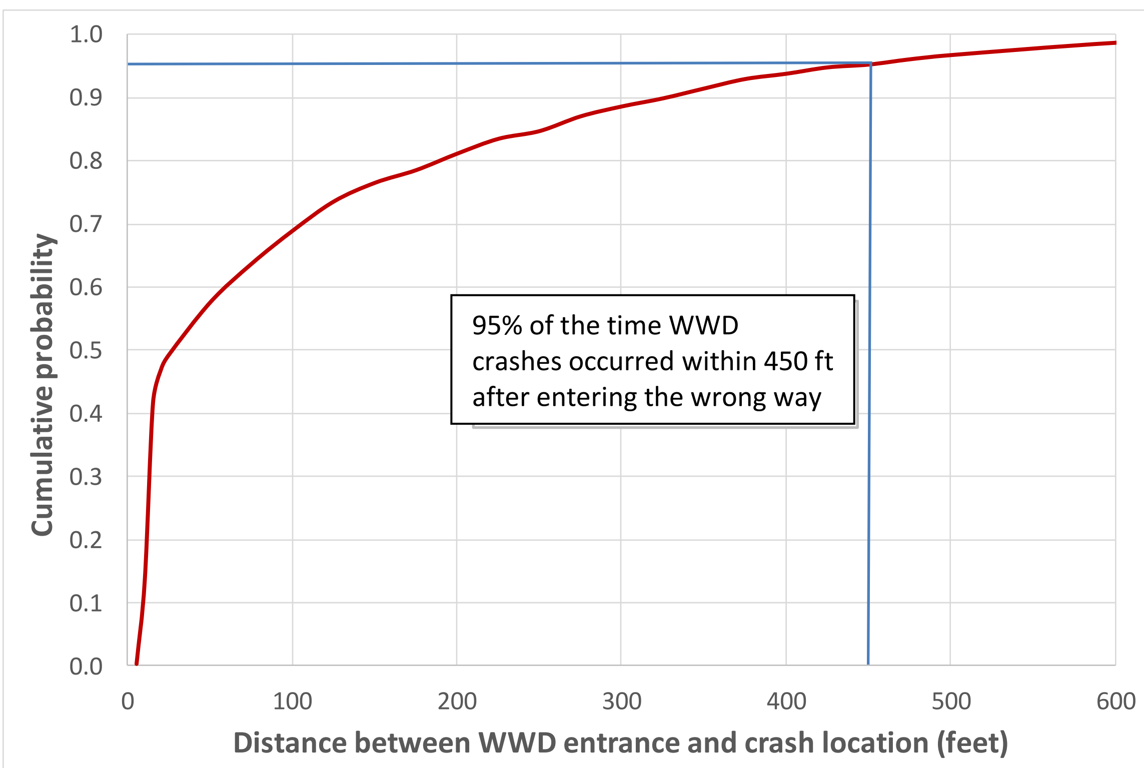

Figure 4-6: Cumulative Probability Curve: Distance between WWD Entrance Location and WWD Crash Location

4.4.2 Roadway Cross-Section

Table 4-12 provides the WWD crash statistics by roadway cross-section and crash severity. Of the 1,890 WWD crashes analyzed, 13.5% were found to occur on one-way streets, and these crashes were relatively less severe. Only about 2.4% of crashes that occurred on one-way streets resulted in a fatality, while the proportion was 7.5% for crashes that occurred on two-way streets.

Table 4-12: WWD Crash Statistics by Roadway Cross-Section and Crash Severity

Cross-Section	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
Two-way Street	120	7.5	863	53.8	621	38.7	1,604
One-way Street	6	2.4	118	46.3	131	51.4	255
Unknown	4	12.9	11	35.5	16	51.6	31
Total	**130**	**6.9%**	**992**	**52.5%**	**768**	**40.6%**	**1,890**

Note: The police reports of a few WWD crashes do not have enough information to accurately determine the WWD crash location and are therefore categorized as "Unknown".

4.4.3 Blood Alcohol Concentration

The CARS database has a column to identify if the driver was intoxicated at the time of the crash. However, the actual blood alcohol concentration (BAC) level of the driver is not available in the crash summary records. Therefore, this information was extracted from the police reports, where law enforcement officers enter the BAC level of suspected intoxicated drivers. In some cases, the BAC level may not be available at the crash scene, requiring the police reports to be updated after the crash summary records are populated. For example, in a fatal crash, it may take a few days before the BAC level becomes available. Also, when the driver refuses to take the BAC test in the field, it may take a few days to receive the test results from the laboratory.

Table 4-13 presents the WWD crash statistics considering the BAC level of wrong-way drivers and crash severity. This information was only available for 60.7% (i.e., 1,148 of 1,890) of all WWD crashes. Based on available information, the majority of WWD crashes involved non-impaired drivers (i.e., BAC = 0), and a low percentage (6.1%) of these crashes were fatal. When WWD crashes involving intoxicated drivers were considered, almost 60% of all WWD crashes involving drivers with a BAC < 0.08 were fatal, while about 14.5% of WWD crashes involving drivers with a BAC > 0.08 were fatal. These statistics are counterintuitive. Although no empirical evidence exists, the following insights attempt to explain these statistics:

- If an impaired driver has a BAC under 0.08, the driver may not realize the degree of impairment, so the driver may be less cautious when driving. On the other hand, if an impaired driver has a BAC that is over 0.08, the driver may recognize that they are intoxicated, and therefore, drive slower and more cautiously to avoid a potential DUI violation. This behavior can significantly reduce the risk of a fatal crash. Impaired drivers over the 0.08 BAC limit may be involved in more crashes; however, since they are driving at lower speeds, crashes may result in more injuries and fewer fatalities.

- The most likely explanation of this apparent anomaly is that the sample size of WWD crashes involving impaired drivers with a BAC < 0.08 is very small, with only 22 crashes reported in this category. Alternatively, the number of WWD crashes involving impaired drivers with a BAC > 0.08, was greater (235 crashes). Therefore, the comparison of the percentages is biased.

Table 4-13: WWD Crash Statistics by Driver BAC Level and Crash Severity

Blood Alcohol Concentration	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
None	54	6.1	480	53.9	357	40.1	891
Below 0.08	13	59.1	7	31.8	2	9.1	22
Over 0.08	34	14.5	110	46.8	91	38.7	235
Unknown	29	3.9	395	53.2	318	42.9	742
Total	**130**	**6.9%**	**992**	**52.5%**	**768**	**40.6%**	**1,890**

4.4.4 WWD Warning Signs

Table 4-14 presents the WWD crash statistics comparing the presence of WWD warning signs and crash severity. WWD warning signs present at WWD crash locations include: DO NOT ENTER, KEEP RIGHT/LEFT, and ONE WAY. As shown in Table 4-14, only 309 of 1,890 (16.3%) WWD crashes occurred at locations where WWD warning signs were installed. WWD crashes at these locations were found to be relatively less severe compared to the WWD crashes at locations with no WWD warning signs.

Table 4-14: WWD Crash Statistics by Presence of WWD Warning Signs and Crash Severity

Presence of WWD Warning Signs	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
Yes	10	3.2	146	47.2	153	49.5	309
No	104	8.0	685	52.8	508	39.2	1,297
Unknown	16	5.6	161	56.7	107	37.7	284
Total	**130**	**6.9%**	**992**	**52.5%**	**768**	**40.6%**	**1,890**

Yes – WWD signs present were DO NOT ENTER, KEEP RIGHT/LEFT, and/or ONE WAY

Table 4-15 shows that over 60% of WWD crashes that occurred on one-way streets happened at locations where WWD warning signs were present. On the other hand, only 9.2% of WWD crashes that occurred on two-way roadways happened at locations where WWD warning signs were present. A higher proportion of WWD crashes (76.7%) on two-way roadways occurred at locations with no WWD warning signs. As expected, since one-way streets usually have WWD warning signs, fewer WWD crashes were observed on one-way streets with no WWD warning signs.

Table 4-15: WWD Crash Statistics by Presence of WWD Warning Signs and Cross-Section

Presence of WWD Warning Signs	Roadway Cross-Section						
	Two-way		One-way		Unknown		Total
	No.	%	No.	%	No.	%	
Yes	147	9.2%	157	61.6%	5	16.1%	309
No	1,231	76.7%	53	20.8%	13	41.9%	1,297
Unknown	226	14.1%	45	17.6%	13	41.9%	284
Total	**1,604**	100.0%	**255**	100.0%	**31**	100.0%	**1,890**

4.4.5 Presence of Roadside Lighting

Corridors with adequate street lighting may experience fewer and/or less severe crashes, especially at night. Table 4-16 presents the WWD crash statistics comparing the presence of roadside lighting and crash severity. WWD crashes that occurred along the corridors with no street lighting were found to be relatively more severe compared to the crashes that occurred along the corridors with street lighting.

Table 4-16: WWD Crash Statistics by Presence of Roadside Lighting and Crash Severity

Presence of Roadside lighting	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
No	89	15.1	327	55.4	174	29.5	590
Yes	39	3.1	647	51.2	578	45.7	1,264
Unknown	2	5.6	18	50.0	16	44.4	36
Total	**130**	**6.9%**	**992**	**52.5%**	**768**	**40.6%**	**1,890**

4.5 Summary

This chapter discussed the data collection efforts that were undertaken to collect information about WWD crashes on arterials. Police reports of 2,879 WWD crashes that occurred on state-maintained non-limited access facilities for the years 2012 to 2016 were reviewed to understand the underlying crash patterns and contributing causes. Key observations from the analysis include:

- On average, nearly 7% of all WWD crashes on state-maintained non-limited access facilities resulted in a fatality, and 52.5% resulted in an injury.
- The proportion of fatal WWD crashes on Fridays was higher than the proportion of fatal WWD crashes on typical weekdays (Monday to Thursday) and on weekends.
- In terms of both WWD crash frequency and crash severity, the most critical time was found to be from midnight to 6 AM and from 6 AM to noon.
- A high proportion of WWD crashes involving vehicles traveling over 45 mph resulted in fatalities.
- Over 55% of all WWD crashes occurred during dark conditions; over 64% of all fatal WWD crashes occurred during dark conditions.
- Of the 1,890 WWD crashes analyzed, 680 crashes (36%) involved intoxicated (either alcohol, or drugs, or both) drivers. Of the 130 fatal WWD crashes, 82 crashes (63.1%) involved intoxicated drivers.
- Over 50% of WWD crashes occurred at or near intersections.
- Divided facilities experienced a high number of WWD crashes, and a high proportion of fatal WWD crashes.
- WWD crashes on undivided facilities, although relatively rare, resulted in a high proportion of fatalities.
- A large proportion of the wrong-way drivers (38%) turned the wrong way at a signalized intersection, while 11.2% of the wrong-way drivers turned the wrong way at a stop sign. About 17.8% of wrong-way drivers were found to enter the wrong way from a driveway.
- Over 95% of the time, WWD crashes were found to occur within 450 ft from where the drivers potentially entered the wrong way.

- About 13.5% of all WWD crashes were found to occur on one-way streets, and also, these crashes were relatively less severe.
- WWD crashes at locations with WWD warning signs were found to be relatively less severe compared to the WWD crashes at corridors where no warning signs were present.
- WWD crashes that occurred along the corridors with no street lighting were found to be relatively more severe compared to the crashes that occurred along the corridors with street lighting.

In addition to providing the descriptive statistics of WWD crashes on arterials, this chapter also discussed the data preparation efforts undertaken to extract information about one-way streets and divided and undivided facilities in Florida. Table 4-17 provides the number of miles of one-way streets and the divided and undivided facilities in Florida.

Table 4-17: Total Miles of One-Way, Divided, and Undivided Streets in Florida

	One-way Streets	Divided Streets	Undivided Streets
State Roads	147.59 miles	4,862.35 miles	4,961.08 miles
All Public Roads	1,211.46 miles	12,728.95 miles	167,032.05 miles

CHAPTER 5
WRONG-WAY DRIVING CRASH HOTSPOTS ON ARTERIALS

This chapter focuses on identifying the WWD crash hotspots on state-maintained non-limited access facilities in Florida. The analysis was based on five years of WWD crashes on non-limited access facilities from 2012-2016. Geographic Information System (GIS)-based spatial clustering analysis was used to identify the top WWD crash hotspots in each FDOT District.

5.1 Wrong-way Driving Crash Data

Five years of WWD crash data (2012-2016) was used in the analysis. As discussed in Chapter 4, police reports of 2,879 potential WWD crashes were reviewed, and 1,890 crashes (i.e., 65.6%) were categorized as WWD crashes that occurred as a result of vehicles traveling the wrong way. Figure 5-1 provides the WWD crash frequency on arterials during the years 2012 through 2016. WWD crashes on arterials were on an increasing trend from 2012 through 2015, and then slightly reduced in 2016. The year 2015 experienced the highest number of WWD crashes, with more than double the number of occurrences in 2012.

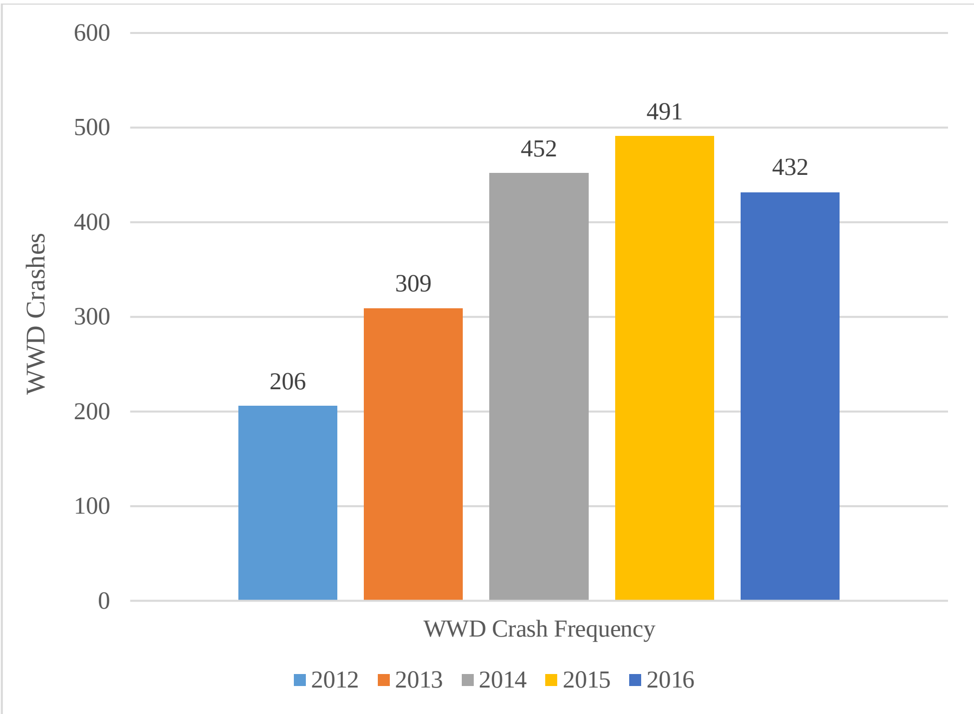

Figure 5-1: WWD Crashes on Arterials from 2012-2016

Figure 5-2 shows the spatial distribution of WWD crashes on arterials. Note that the purple lines in the figure are state roads. WWD crashes on arterials are not evenly distributed across Florida, rather are clustered more in urban areas, particularly in Tampa Bay and South Florida (from West Palm Beach to Miami) regions. Orlando and Jacksonville downtown areas also experienced a higher density of WWD crashes. Smaller clusters of WWD crashes were observed in the Fort Myers and Pensacola regions.

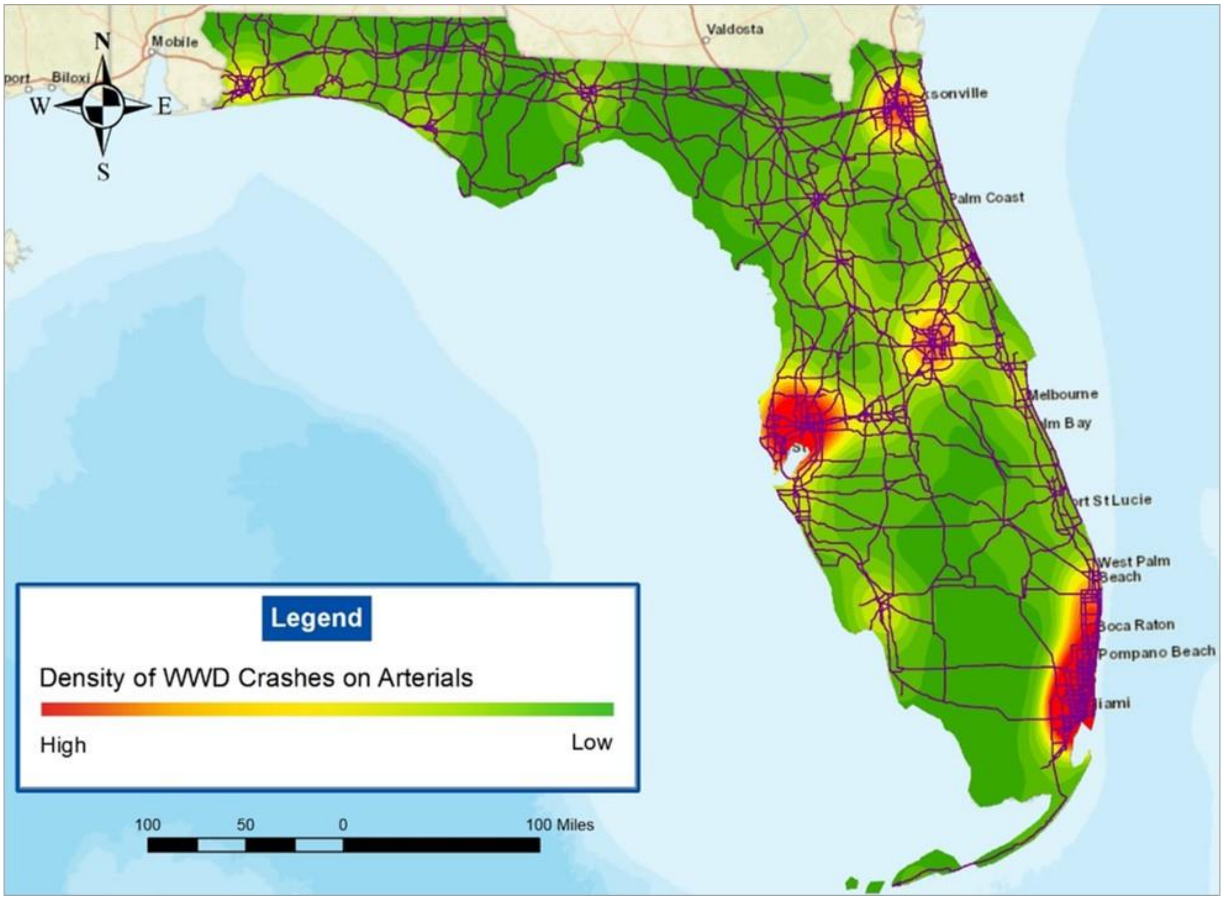

Figure 5-2: Density Map of WWD Crashes on Arterials in Florida (2012-2016)

5.2 Analysis Framework to Identify Crash Hotspots

A GIS-based spatial clustering analysis was used to identify WWD crash hotspots. Figure 5-3 illustrates the concept, where the *X*- and *Y*-axis represent the spatial terrain of the region. The *Z*-axis represents the number of WWD crashes. This approach creates a service area (along the road network) for each WWD crash and then merges the overlapping service areas. Depending on the density of the WWD crashes, each of the overlapping service areas will cover a varying number of WWD crashes. The nearby service areas within a certain step length (i.e., within a certain distance) are then identified and grouped together. These grouped service areas are then ranked based on the total number of WWD crashes identified within these areas and their equivalent property damage only (EPDO) scores.

The following steps constitute the framework adopted to identify the WWD crash hotspots on arterials in each FDOT District in Florida:

1. Develop Arterials Network
2. Identify Service Area for Each Crash
3. Merge Overlapping Service Area
4. Group Nearby Service Areas
5. Identify Candidate Hotspots

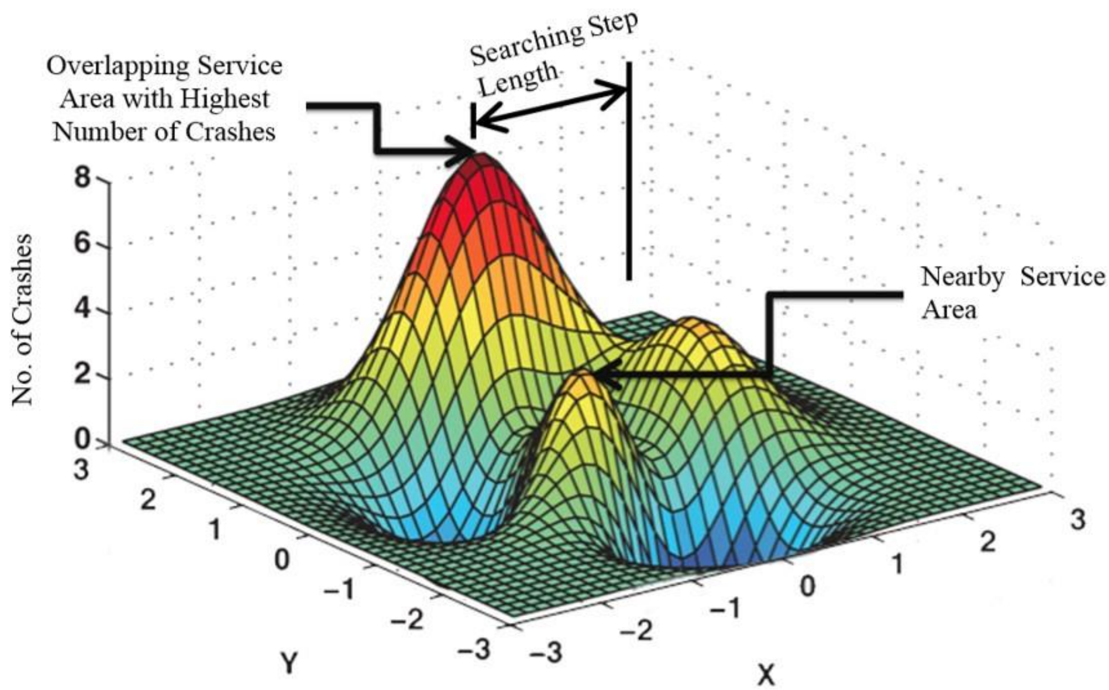

Figure 5-3: Concept to Identify Hotspots

Step 1: Develop Arterials Network

The network dataset was developed based on the 2015 Florida Street Network extracted from the NAVTEQ NAVSTREETS layer. The 2015 Florida Street Network includes 18,053,775 street records, which covers the entire public road network in Florida. Since this project focused only on WWD crashes on state-maintained non-limited access facilities, all limited-access facilities were excluded from the network dataset. Figure 5-4 shows one service area of a WWD crash located near I-95 in Miami. Note that the streets included within the service area did not constitute freeway segments.

Step 2: Identify the Service Area for Each Crash

The WWD crash service area was identified based on a default radius. The *radius of the WWD crash service area* helps determine the total number of WWD crashes that occurred within the core area. The radius will affect the number of crashes within the overlapping service area. The larger the radius, the higher the number of crashes, and the larger the service area.

Since the WWD crashes are not evenly distributed across Florida, setting the appropriate values for all districts was extremely crucial. If the values are too big, the hotspot region will cover a very large area (such as District 6 downtown), and if the values are too small, the hotspot region will be too small, especially in rural areas. Based on a trial-and-error method, the radius of 0.25 miles was selected and used in this analysis. Figure 5-5 shows an example of two service areas near Bayonet Point in District 7. Note that these two service areas are not over-lapping, and hence are treated as two separate service areas.

Figure 5-4: Arterial Streets within a WWD Crash Service Area

Figure 5-5: Example of Two Service Areas near Bayonet Point in FDOT District 7

Service areas were identified for each of the 1,890 WWD crashes using the 0.25-mile radius. This step helps identify the impact area of each WWD crash. Figure 5-6 shows an example of service areas for each of the 12 WWD crashes that occurred near Bayonet Point at FDOT District 7. Note that the service area of each crash was identified using a different color.

Figure 5-6: Preliminary Service Areas of Each WWD Crash

Step 3: Merge Overlapping Service Areas

Once the service areas for each WWD crash were identified, the next step was to merge the overlapping service areas and determine the total number of WWD crashes that occurred within the core area. As can be observed from Figure 5-7, the overlapped service areas of the 12 WWD crashes (i.e., 12 independent service areas) near Bayonet Point in FDOT District 7 were merged, and these 12 areas were aggregated into seven areas. The areas shown in red and dark blue colors experienced three WWD crashes each.

Once the overlapping service areas were merged, the next step was to check if the number of crashes within the overlapping service area was appropriate for additional network-space analysis. To better balance the uneven distribution of WWD crashes with each FDOT District, the highest number of crashes within the overlapping service area within each district was limited to approximately 10-60 WWD crashes. The smallest service area was found to have 9 crashes (in FDOT District 5) while the largest service area was found to have 70 crashes (in FDOT District 6).

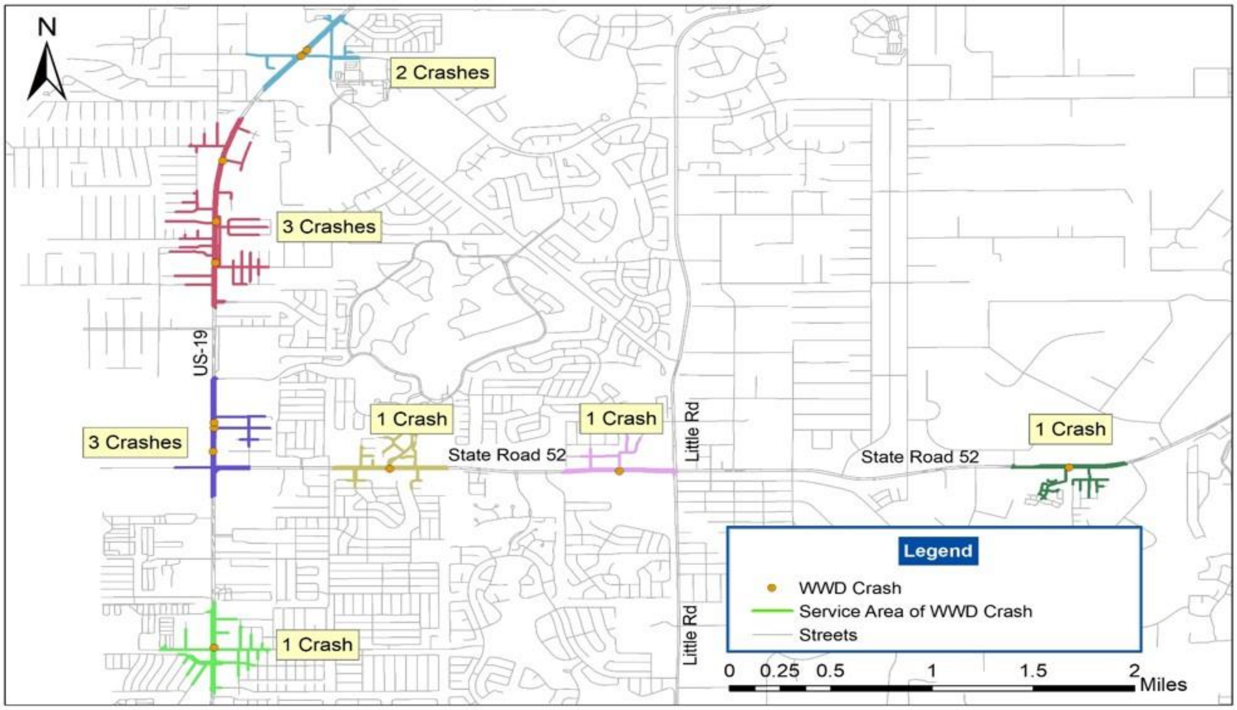

Figure 5-7: Merging Overlapped Service Areas

Step 4: Group Nearby Service Areas

Once the overlapping service areas were merged, the next step was to identify nearby service areas that could be grouped together. All the service areas within 0.75 miles of each other, known as the step length, were grouped together. Note that the most suitable step length (i.e., 0.75 miles) was selected on a trial-and-error basis.

For example, as can be observed from Figure 5-7, a total of six service areas are within 0.75 miles of each other. These six service areas, identified in green in Figure 5-8, are grouped into one large service area. Note that one service area shown in purple in Figure 5-8 is not grouped with the others since it is farther than 0.75 miles (i.e., searching step length) from the other service areas.

Once the nearby service areas are grouped together, the size of the grouped service areas was checked to determine if it was suitable for additional network-space analysis. To better balance the uneven distribution of WWD crashes in each FDOT District, the length of the grouped service area was limited to approximately 5 miles. The maximum length of the grouped service area was found to be 5.3 miles in District 6, and was considered to be acceptable.

Figure 5-8: Grouping Nearby Service Areas

Step 5: Identify Candidate Hotspots

This step focuses on selecting WWD crash hotspots within each FDOT District based on the number of crashes and the EPDO weighting method. The EPDO weighting method was used to calculate the EPDO score of candidate crash hotspots based on injury weighting. Note that the EPDO score considers the severity breakdown of crashes, providing greater weight to fatal and injury crashes over PDO crashes. Table 5-1 provides the EPDO weighting scores for different injury severity levels based on the High Crash Analysis Report Section of CAR Online. Fatal and serious injury crashes were assigned an EPDO weight of 234.69. This was calculated as the ratio of fatal and serious injury crash costs to the PDO crash cost. Similarly, other injury crashes were assigned an EPDO weight of 15.72, which was calculated as the ratio of other injury crash costs to the PDO crash cost. Finally, the PDO crashes were assigned a weight of 1.0.

Table 5-1: EPDO Weighting Scores for Different Injury Severity Levels

Injury Severity	Crash Count	Crash Cost – Total	Cost Per Crash	Weight
PDO	567,140	$4,310,264,000	$7,600.00	1.00
Minor Injury	378,337	$45,195,589,720	$119,458.55	15.72
Fatal + Serious Injury	60,041	$107,093,696,640	$1,783,676.09	234.69

Note: Values are based on 2013 cost estimates.

5.3 WWD Crash Hotspots

Table 5-2 lists the top 10 WWD crash hotspots in each FDOT District based on the EPDO scores and Figures 5-9 through 5-15 map the WWD hotspots in each District. Supplemental documents provided with this report include a Google Earth file (kmz) with the spatial locations of these hotspots. The analysis of each of these hotspots to identify the most predominant factor(s) that could potentially affect the occurrence of WWD incidents along these corridors is discussed in Chapter 6.

Table 5-2: Top WWD Crash Hotspots in Each FDOT District

District	Rank	Location	Total Crashes	Fatal/ Severe Crashes	Minor Injury Crashes	PDO Crashes	EPDO Score
1	1	Fowler St, Fort Myers	14	4	5	5	1,022.37
1	2	S Tamiami Trail, Memphis	7	3	2	2	737.52
1	3	Bartow Rd, Lakeland	5	1	3	1	282.85
1	4	SR 82, Gateway	3	1	2	0	266.13
1	4	US 41, Gulf Gates Estates	3	1	2	0	266.13
1	6	Tamiami Trail, Fort Myers	6	1	1	4	254.41
1	7	SR 82, Lehigh Acres	3	1	1	1	251.41
1	8	Magnolia Ave, Auburndale	4	1	0	3	237.69
1	9	Sikes Blvd, Lakeland	6	0	5	1	79.59
1	10	Manatee Ave, Bradenton	4	0	2	2	33.44
2	1	University Blvd, Jacksonville	13	2	4	7	539.26
2	2	W Union St, Jacksonville	30	1	14	15	469.75
2	3	Charles Memorial Hwy, St Augustine	5	1	3	1	282.85
2	4	Beach Blvd, Jacksonville Beach	4	1	1	2	252.41
2	5	Kingsley Ave, Orange Park	3	1	1	1	251.41
2	5	Cassat Ave, Jacksonville	3	1	1	1	251.41
2	7	Williston Rd, Gainesville	3	1	0	2	236.69
2	7	Blanding Blvd, Orange Park	3	1	0	2	236.69
2	9	Main St, Brentwood	6	0	2	4	35.44
2	10	Dixie Hwy, St. Augustine	4	0	1	3	18.72
3	1	Dr MLK Jr Dr, Pensacola	15	2	7	6	585.42
3	2	Lillian Hwy, West Pensacola	6	2	3	1	517.54
3	3	Woodville Hwy, Tallahassee	5	2	1	2	487.11
3	4	S Hwy 29, Gonzalez	4	2	1	1	486.11
3	5	US Hwy 98, Fort Walton Beach	3	2	0	1	470.39
3	6	Pennell St, Panama Beach City	5	1	3	1	282.85
3	6	Perdido Key Dr, Perdido Key	5	1	3	1	282.85
3	8	Martin Luther King Blvd, Panama City	7	1	2	4	270.13
3	9	Beal Pkwy NE, Fort Walton Beach	6	1	2	3	269.13
3	10	S Monroe St, Tallahassee	9	0	5	4	82.59
4	1	Hollywood Blvd, Hollywood	15	3	2	10	745.52
4	2	SR 80, Royal Palm Beach	8	3	1	4	723.80
4	3	N Dixie Hwy, Oakland Park	13	2	8	3	598.13
4	4	Dixie Hwy, Lake Worth	13	2	7	4	583.42
4	5	Lake Worth Rd, Greenacres	7	2	3	2	518.54
4	6	S Flamingo Rd, Southwest Ranches	6	2	3	1	517.54
4	7	20th St, Vero Beach	7	2	2	3	503.82
4	8	W Hillsboro Blvd, Deerfield Beach	12	1	7	4	348.72
4	9	S Federal Hwy, Delray Beach	15	1	6	8	337.00
4	10	W Broward Blvd, Fort Lauderdale	11	1	4	6	303.57

Table 5-2 (Cont'd): Top WWD Crash Hotspots in Each FDOT District

District	Rank	Location	Total Crashes	Fatal/ Severe Crashes	Minor Injury Crashes	PDO Crashes	EPDO Score
5	1	Woodland Blvd, North De Land	7	4	3	0	985.93
5	2	N Dixie Hwy, Melbourne	5	3	1	1	720.80
5	3	SR 46, Sorrento	4	3	1	0	719.80
5	3	E Colonial Dr, Bithlo	4	3	1	0	719.80
5	5	S Orange Ave, Pine Castle	9	2	2	5	505.82
5	6	Orange Blossom Trail. Orlando	7	1	4	2	299.57
5	7	W King St, Cocoa West	7	1	3	3	284.85
5	8	Citrus Blvd, Fruitland Park	5	1	3	1	282.85
5	9	Washington St, Orlando	6	1	2	3	269.13
5	10	South St, Titusville	5	1	2	2	268.13
5	10	John Young Pkwy, Orlando	5	1	2	2	268.13
6	1	SW 1st St, Miami	70	6	20	44	1,766.53
6	2	NE 125th St, North Miami	43	3	17	23	994.29
6	3	E 21st St, Hialeah	16	1	3	12	293.85
6	4	W Palm Dr, Florida City	5	1	0	4	238.69
6	5	Biscayne Blvd, Miami	18	0	6	12	106.31
6	6	Dixie Hwy, Palmetto Bay	14	0	4	10	72.87
6	7	Dixie Hwy, Coral Gables	7	0	4	3	65.87
6	8	5th St, Miami Beach	12	0	3	9	56.15
6	9	Hwy A1A, North Beach	6	0	3	3	50.15
6	10	S 57th Ave, West Miami	10	0	2	8	39.44
7	1	N Tampa St, Tampa	56	4	32	20	1,461.76
7	2	US 19, Holiday	14	4	4	6	1,007.65
7	3	4th St N, Pinellas Park	14	3	9	2	847.55
7	4	SR 54, Trinity	6	3	2	1	736.52
7	5	US 19, Hudson	11	2	6	3	566.70
7	6	4th Ave N, St. Petersburg	18	1	8	9	369.44
7	7	W Baker St, Plant City	5	1	3	1	282.85
7	8	US 41, Thonotosassa	4	1	3	0	281.85
7	9	Main St, Dunedin	4	1	2	1	267.13
7	9	5th Ave, Zephyrhills West	4	1	2	1	267.13

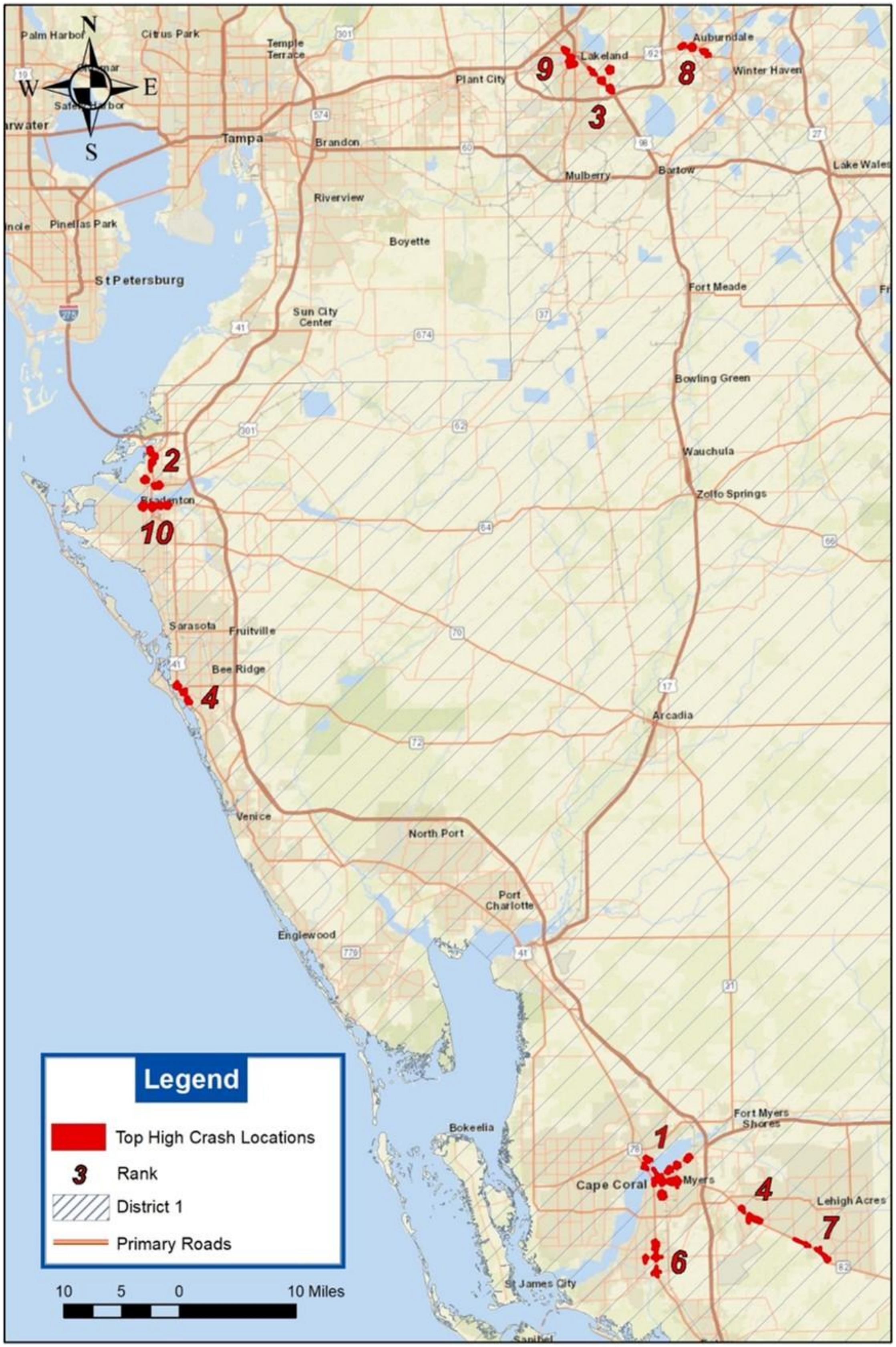

Figure 5-9: FDOT District 1: Top 10 WWD Crash Hotspots

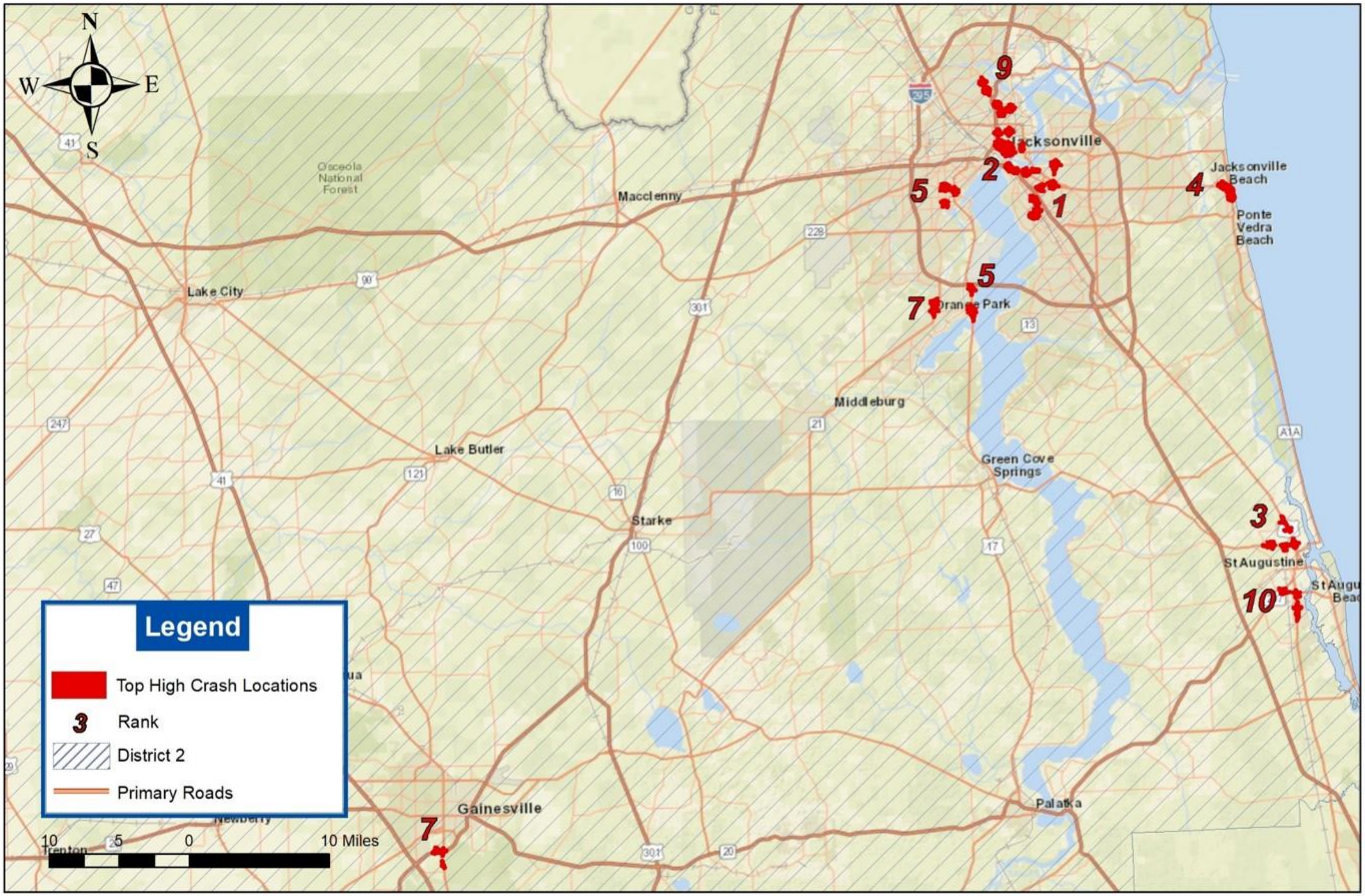

Figure 5-10: FDOT District 2: Top 10 WWD Crash Hotspots

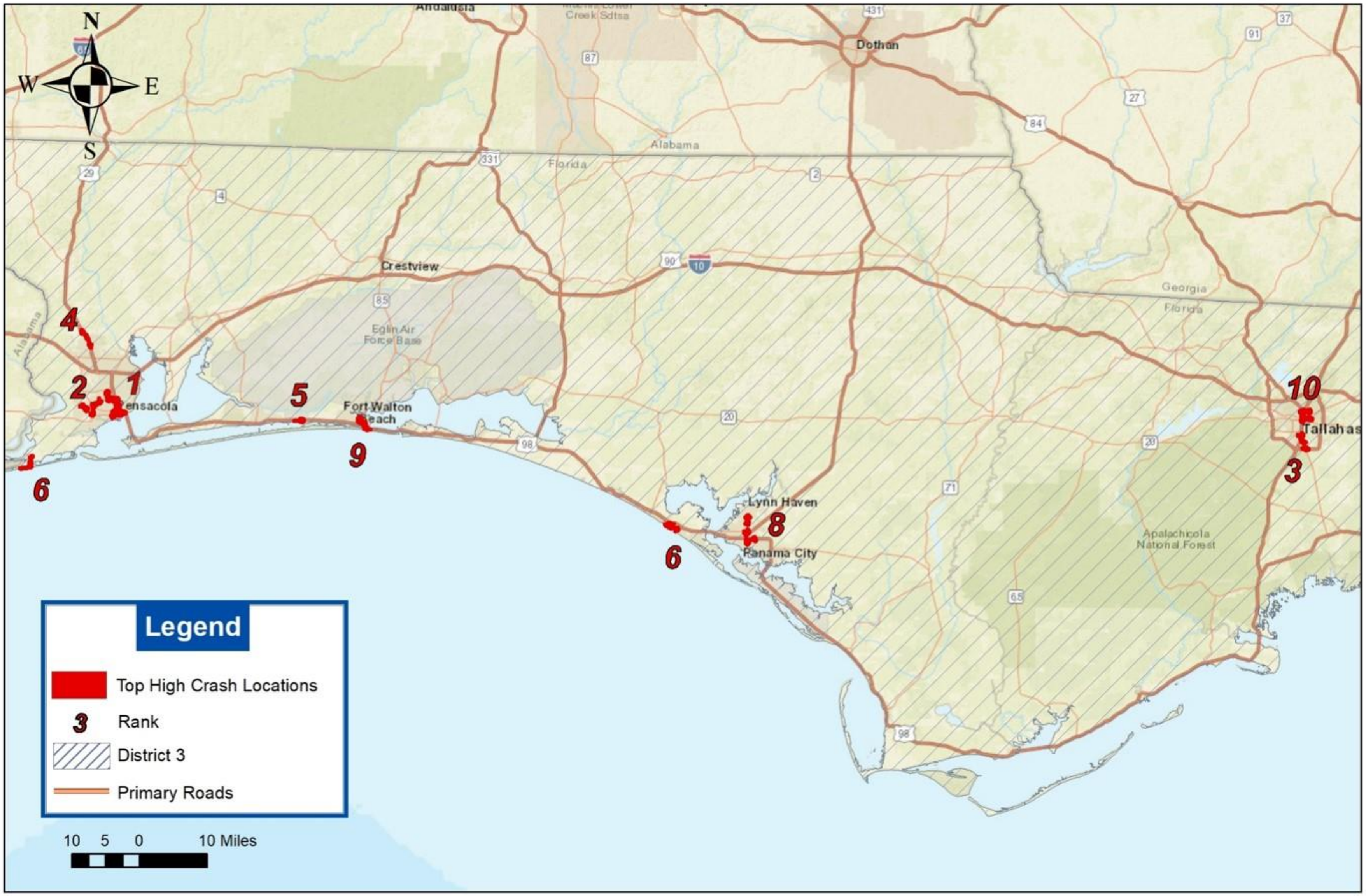

Figure 5-11: FDOT District 3: Top 10 WWD Crash Hotspots

Figure 5-12: FDOT District 4: Top 10 WWD Crash Hotspots

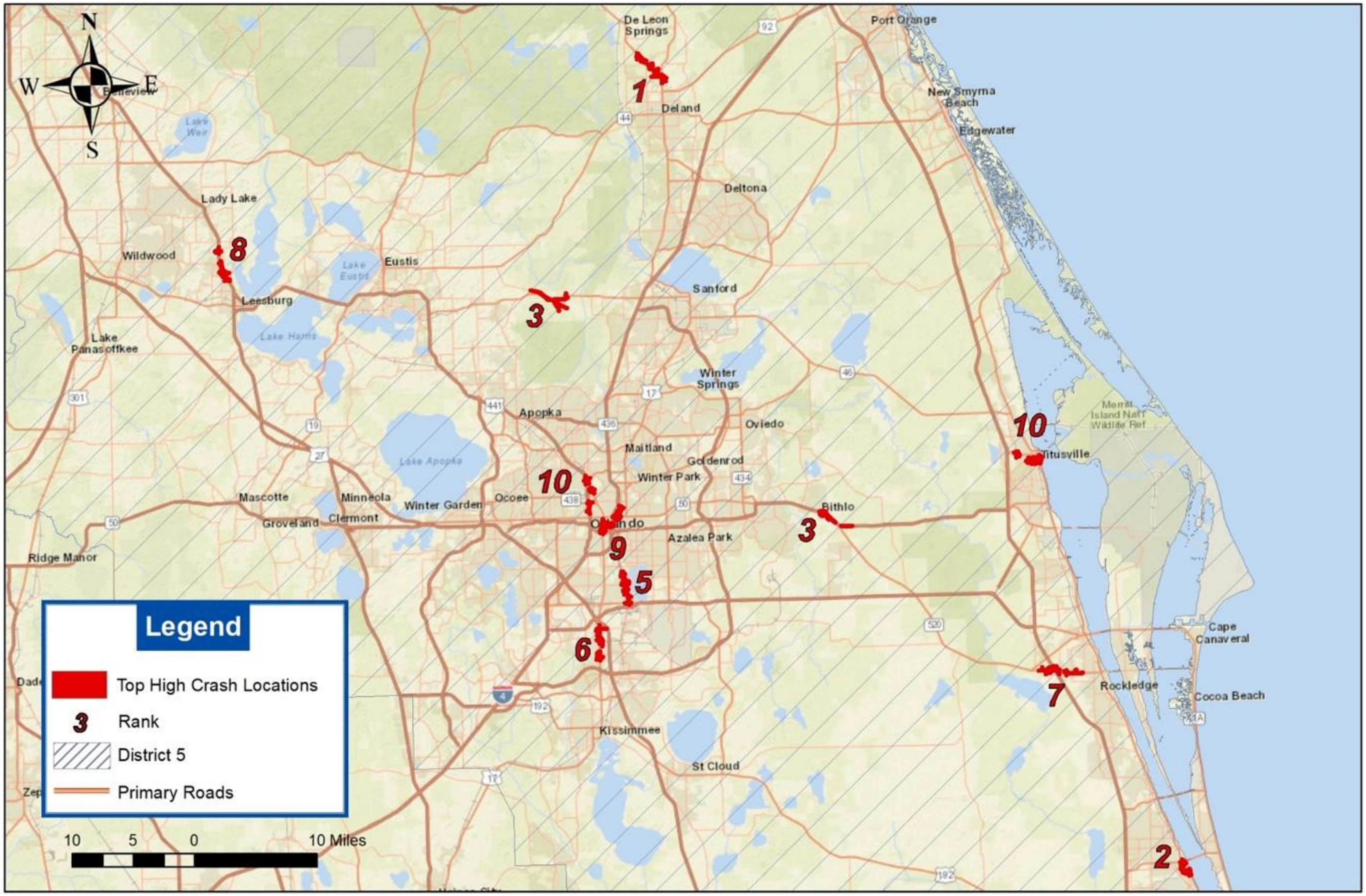

Figure 5-13: FDOT District 5: Top 10 WWD Crash Hotspots

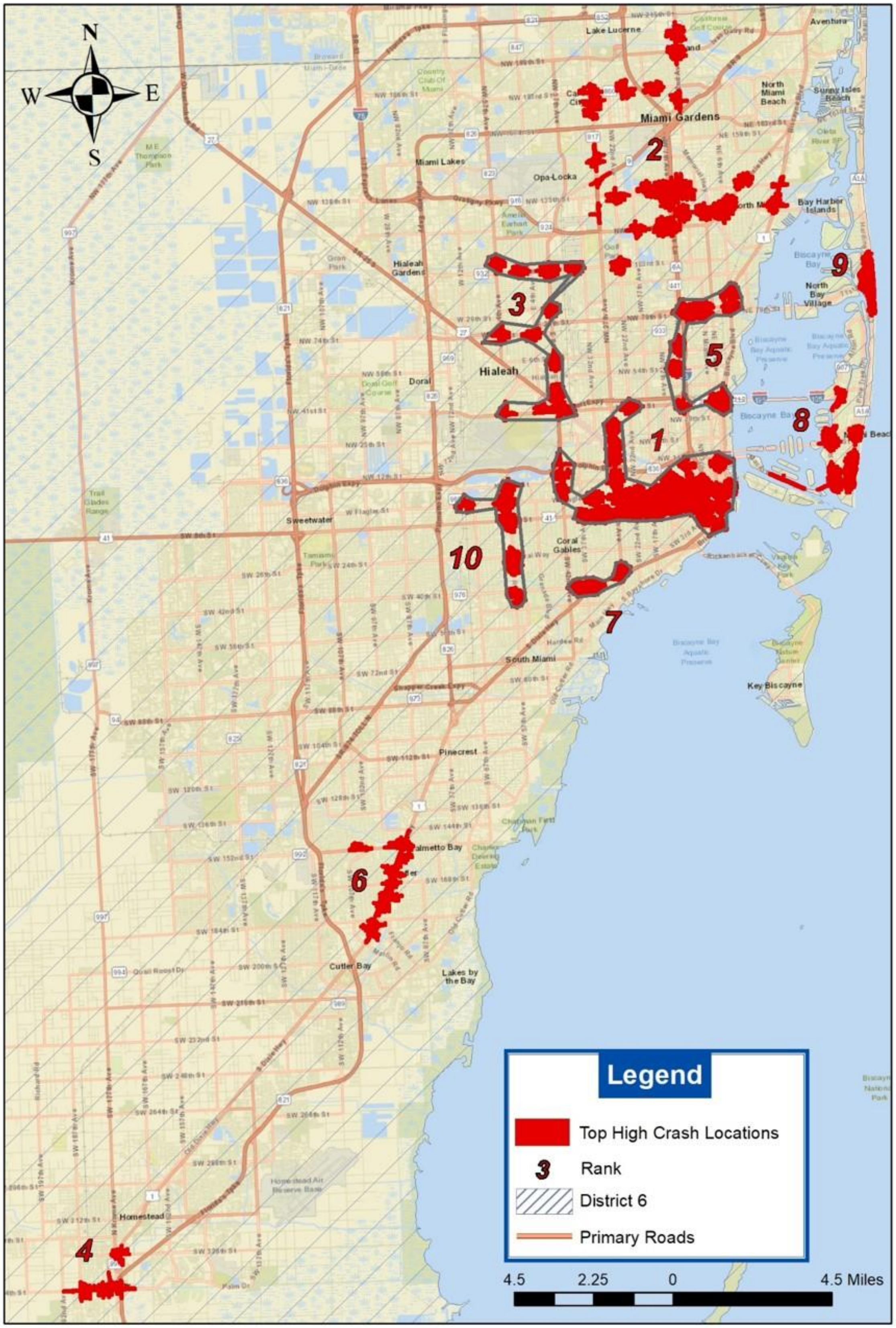

Figure 5-14: FDOT District 6: Top 10 WWD Crash Hotspots

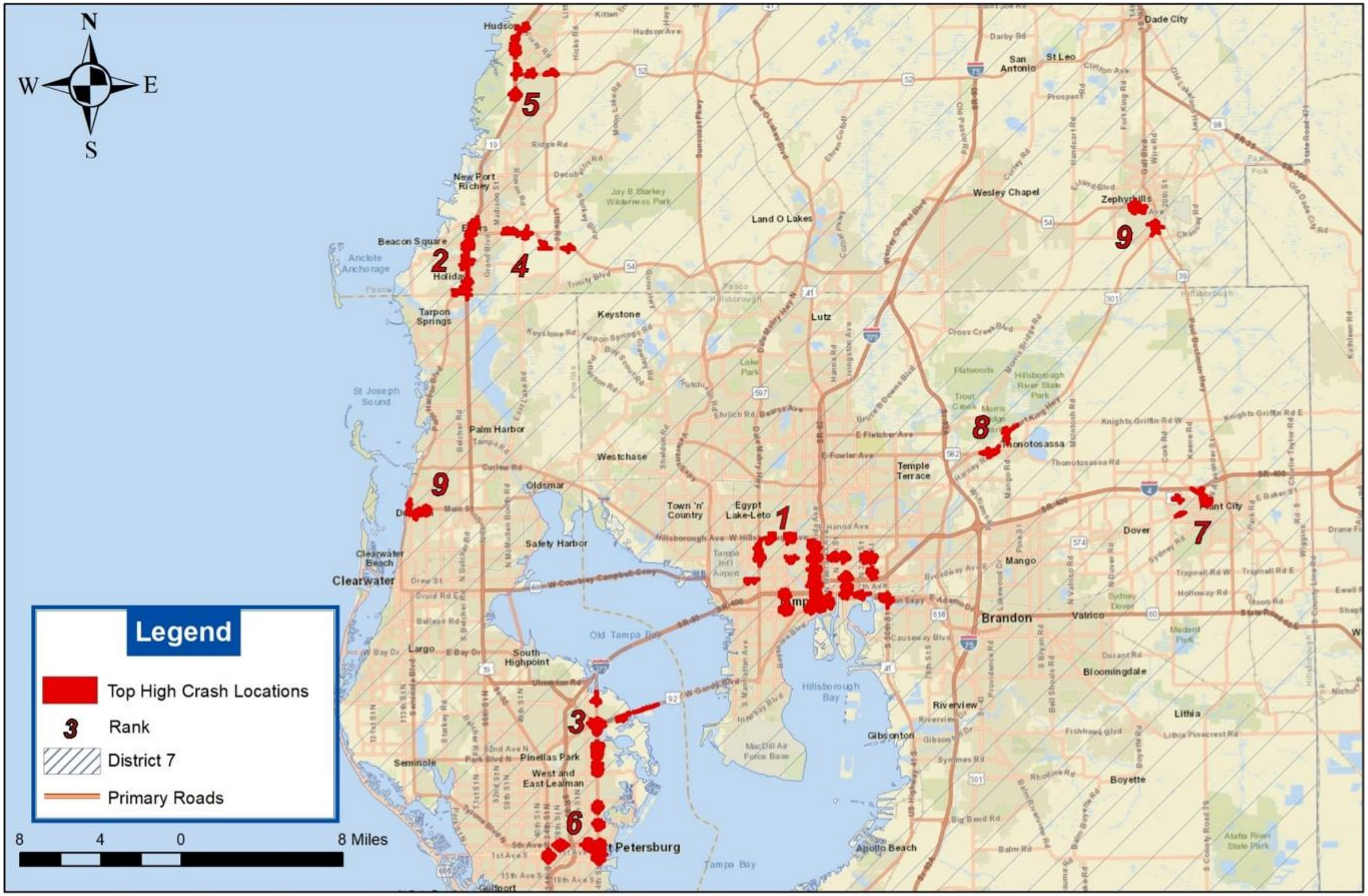

Figure 5-15: FDOT District 7: Top 10 WWD Crash Hotspots

CHAPTER 6
ANALYSIS OF WRONG-WAY DRIVING CRASH CORRIDORS OF INTEREST

This chapter discusses the analysis of the top 10 WWD crash hotspots identified in each FDOT District based on the EPDO scores. The approach adopted to identify these hotspots was discussed in Chapter 5. Section 6.1 provides the descriptive statistics of WWD crashes within hotspots, based on the top 10 hotspots identified in each district. Section 6.2 focuses on the analysis of WWD crashes based on crash location. Section 6.3 discusses the study results based on the data collected from the police reports, and Section 6.4 provides a summary of this research effort.

6.1 Analysis of WWD Crashes within Hotspots

Table 6-1 provides the statistics of WWD crashes within the top 10 crash hotspots by crash severity in each FDOT District. From 2012 to 2016, 702 WWD crashes (i.e., 37.1% of 1,890 WWD crashes) were found to have occurred within the hotspots. At these hotspots, nearly 3% of WWD crashes resulted in a fatality, while 52.1% resulted in an injury. Among the FDOT Districts, District 6 was found to have the highest number of WWD crashes. However, only 1.5% of the WWD crashes within District 6 hotspots resulted in a fatality, which is lower compared to the average (across the other districts) of 2.7%. Districts 4 and 7 also displayed similar trends. On the other hand, the districts with relatively fewer WWD crashes (District 1, 2, 3, and 5) were found to have a greater proportion of fatal crashes.

Table 6-1: Hotspot WWD Crash Statistics by District and Crash Severity

District	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
1	3	5.5%	33	60.0%	19	34.5%	55
2	3	4.1%	33	44.6%	38	51.4%	74
3	3	4.6%	38	58.5%	24	36.9%	65
4	2	1.9%	60	56.1%	45	42.1%	107
5	4	6.3%	41	64.1%	19	29.7%	64
6	3	1.5%	70	34.8%	128	63.7%	201
7	1	0.7%	91	66.9%	44	32.4%	136
Total	**19**	**2.7%**	**366**	**52.1%**	**317**	**45.2%**	**702**

6.2 Analysis of WWD Crash Locations

This section provides descriptive statistics of WWD crashes based on crash location, the location where the wrong-way driver potentially may have entered the wrong way, and the estimated distance traveled by the wrong-way driver prior to being involved in the crash. In Figure 6-1, the red nodes represent WWD crash locations. This information was extracted from the FDOT's CARS database. The blue nodes represent the location where the wrong-way driver potentially entered the roadway. This information was inferred from reviewing the police reports and was available for about 85% of all WWD crashes. The pink lines linking the red and blue nodes show the estimated travel path of the wrong-way driver.

Based on initial analyses discussed in Chapter 4, over 95% of the time, WWD crashes were found to occur within 450 ft from where the drivers potentially entered the wrong way. Note that Euclidian distance (the pink line between nodes) was used to calculate the estimated distance traveled by the wrong-way driver. From the police reports, it appears that most wrong-way drivers did not make a second turn after turning onto the road in the wrong direction.

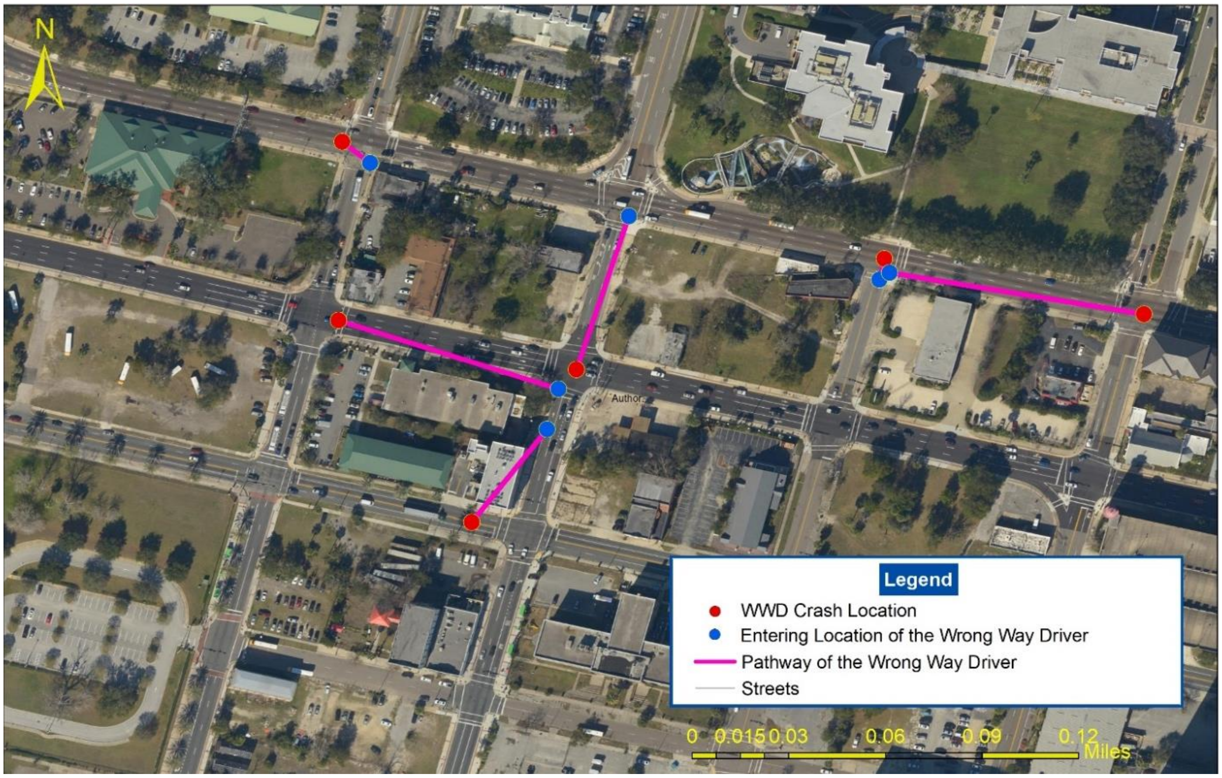

Figure 6-1: Analysis of WWD Crash Locations

6.2.1 WWD Crash Locations within Hotspots

The location where the WWD crashes occurred were divided into the following five categories:

- at or near an intersection,
- on a divided roadway,
- on an undivided roadway,
- on a two-way left-turn lane (TWLTL), and
- other.

Table 6-2 provides the WWD crash statistics by crash location and FDOT District. Over 65% (i.e., 457 out of 702) of WWD crashes within hotspots occurred at or near an intersection. Compared to the 1,890 WWD crashes on arterials initially analyzed, over 52% (i.e., 986 out of 1,890) occurred at or near an intersection (see Section 4.3.1). Therefore, it can be inferred that WWD crash hotspots tend to be concentrated in urban areas with higher intersection density.

Nearly one-third (28.2%) of WWD crashes within hotspots occurred on divided highways. This proportion is lower than the 40.4% of the 1,890 statewide WWD crashes on arterials initially analyzed.

Table 6-2: Hotspot WWD Crash Statistics by Crash Location and FDOT District

District	Intersection	On Divided Roadway	On Undivided Roadway	On TWLTL	Other	Total
1	32	18	5	0	0	55
2	54	18	2	0	0	74
3	33	30	1	1	0	65
4	74	28	5	0	0	107
5	31	28	2	2	1	64
6	145	40	15	0	1	201
7	88	36	8	4	0	136
Total	**457**	**198**	**38**	**7**	**2**	**702**
%	**65.1%**	**28.2%**	**5.4%**	**1.0%**	**0.3%**	**100%**

Figure 6-2 shows a comparison of the proportion of WWD crashes at different locations across FDOT Districts. Compared to the districts in relatively rural regions, predominately urban districts (Districts 2, 4, 6, and 7) were found to experience a higher proportion of WWD crashes at or near intersections. The percentages were found to be relatively lower in the other districts. Districts 1, 3, and 5 were found to experience a higher proportion of WWD crashes on divided facilities.

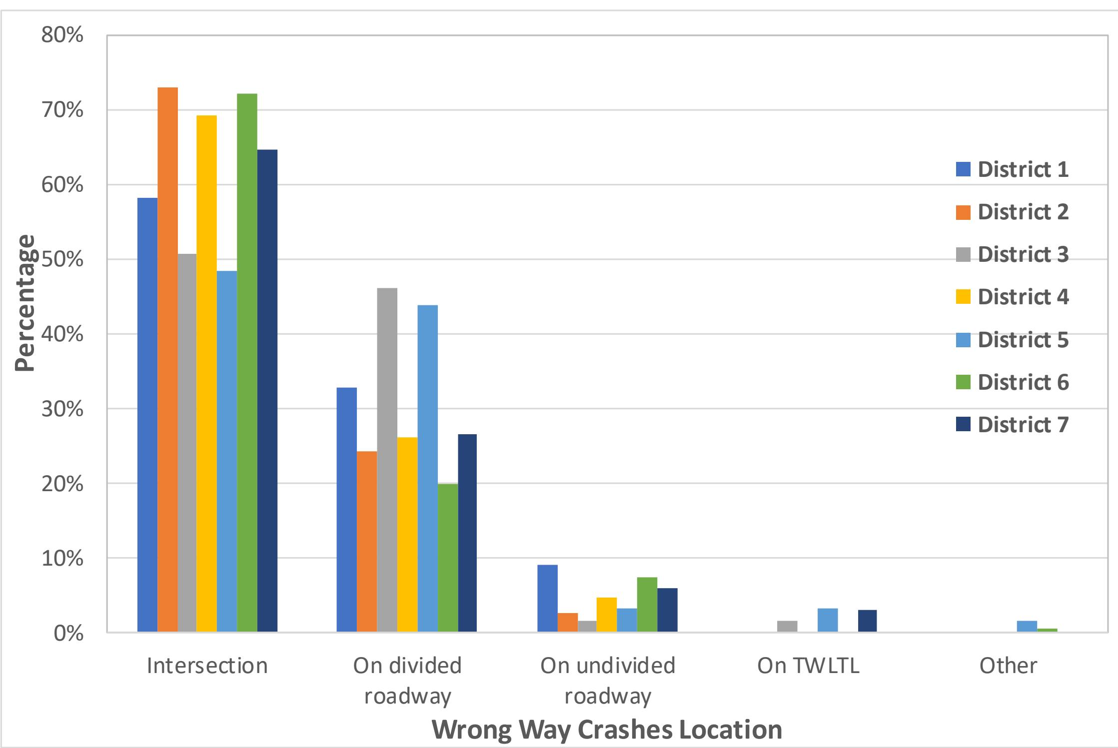

Figure 6-2: Proportion of WWD Crashes by Crash Location in Each District

Table 6-3 provides the WWD crash statistics by crash location and crash severity. Although over 65% of all WWD crashes within hotspots occurred at or near intersections, only 1.5% of the intersection crashes resulted in a fatality. On the contrary, over 6% of WWD crashes that occurred on divided facilities were fatal.

Table 6-3: WWD Crash Statistics by WWD Crash Location and Crash Severity

Location of WWD	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
At or Near Intersection	7	1.5%	229	50.1%	221	48.4%	457
On Divided Roadway	12	6.1%	112	56.6%	74	37.4%	198
On Undivided Roadway	0	0.0%	18	47.4%	20	52.6%	38
On Two-way Left-turn Lane	0	0.0%	6	85.7%	1	14.3%	7
Other	0	0.0%	1	50.0%	1	50.0%	2
Total	**19**	**2.7%**	**366**	**52.1%**	**317**	**45.2%**	**702**

6.2.2 Potential Entry Location of Wrong-way Driver

The police report of each WWD crash was carefully reviewed to determine the precise location where the wrong-way driver may have entered the wrong way. Table 6-4 presents these results. As expected, a relatively high proportion of the wrong-way drivers (305 out of 702; 43%) turned the wrong way at a signalized intersection. A considerable proportion of wrong-way drivers (approximately 20%) were also found to turn the wrong way from a driveway.

Table 6-4: WWD Crash Statistics by Entering Location of the Wrong-Way Driver

Potential Entry Location of Wrong-way Driver	Number of WWD Crashes	Percentage
At a Stop Sign	84	12.0%
At a Signalized Intersection	305	43.4%
From a Driveway	137	19.5%
Made a U-turn	8	1.1%
Other	168	23.9%
Total	**702**	**100%**

Table 6-5 provides the WWD crash statistics based on different entry locations by wrong-way drivers for each FDOT District, and Figure 6-3 shows the comparison of the proportion of WWD crashes at different entry locations across FDOT Districts. Similar to the results of WWD crash locations presented in Figure 6-2, a significant proportion of WWD crashes in relatively urban districts (Districts 2, 4, 6, and 7) resulted from the wrong-way driver entering the facility the wrong way at a signalized intersection. These percentages were found to be relatively lower for the other districts (Districts 1, 3, and 5). The percentages of drivers turning the wrong way at a stop sign or from a driveway were found to be very similar across the districts.

Table 6-5: WWD Crash Statistics by Wrong-Way Driver Entry Location and FDOT District

District	At a Stop Sign	At Signalized Intersection	From a Driveway	Made a U-turn	Not Sure /Other	Total
1	11	19	11	1	13	55
2	7	41	13	0	13	74
3	9	20	12	0	24	65
4	12	52	19	1	23	107
5	8	20	17	1	18	64
6	19	100	40	1	41	201
7	18	53	25	4	36	136
Total No.	**84**	**305**	**137**	**8**	**168**	**702**
Total %	**12.0%**	**43.4%**	**19.5%**	**1.1%**	**23.9%**	**100%**

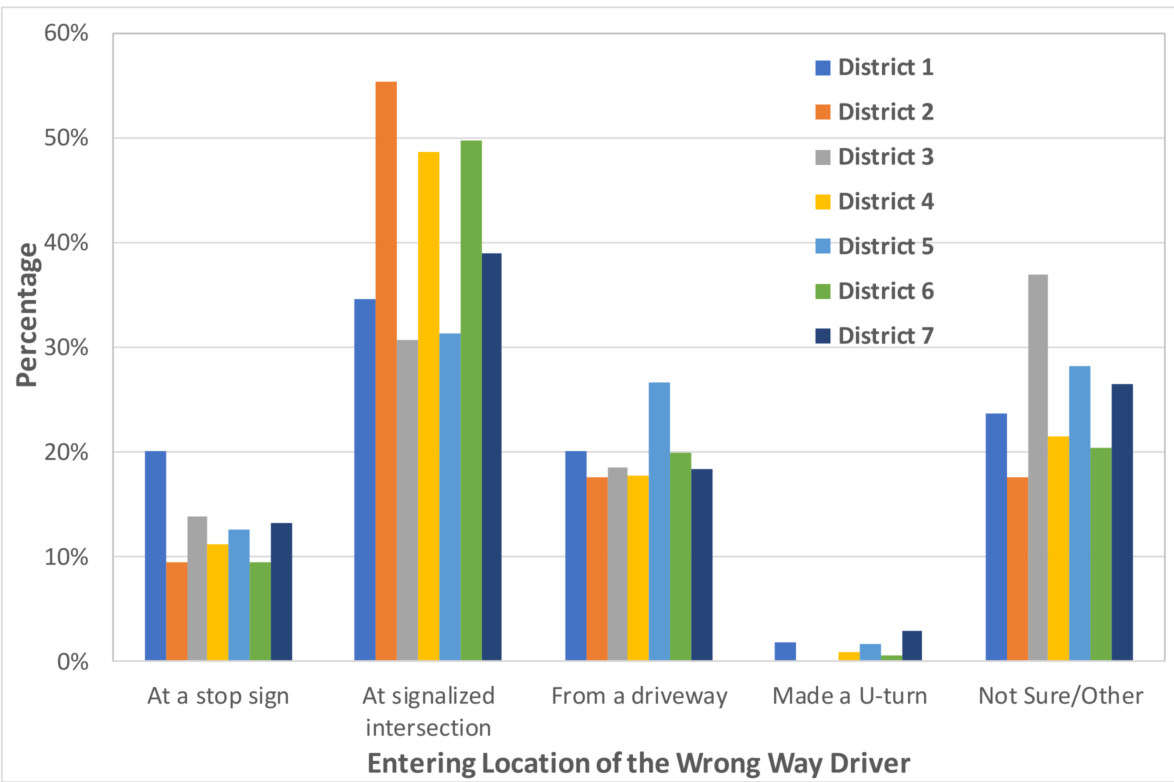

Figure 6-3: Percentage of WWD Crash by Crash Location in Each District

6.2.3 Distance Between Wrong-way Driver Entry Location and WWD Crash Location

Table 6-6 provides the statistics based on the wrong-way driver entry location and WWD crash location. The table also includes the average distance traveled by the wrong-way driver after turning the wrong way prior to the crash. The most frequent scenario involved a wrong-way driver entering the facility the wrong way at a signalized intersection, resulting in a crash at or near the intersection. The average estimated distance traveled by the wrong-way driver in this scenario was found to be relatively low (approximately 150 ft), implying that the crashes often occurred at the same intersection where the wrong-way driver turned the wrong way. Since the wrong-way driver in these scenarios usually traveled at low speeds, these crashes typically resulted in a PDO or an injury.

Table 6-6: Statistics Based on Wrong-way Driver Entry Location and WWD Crash Location

Wrong-way Driver Entry Location	WWD Crash Location	Crash Severity	# of WWD Crashes	Average Distance Traveled (ft)
At a Stop Sign	Intersection	PDO	23	154
		Injury	20	148
		Fatal	0	Not Applicable
At a Stop Sign	On Divided Roadway	PDO	10	141
		Injury	20	150
		Fatal	1	11
At a Signalized Intersection	Intersection	PDO	126	132
		Injury	126	119
		Fatal	3	10
At a Signalized Intersection	On Divided Roadway	PDO	16	129
		Injury	19	357
		Fatal	2	544
From a Driveway	Intersection	PDO	44	178
		Injury	46	240
		Fatal	2	241
From a Driveway	On Divided Roadway	PDO	14	287
		Injury	17	212
		Fatal	2	664

Figure 6-4 shows the average distances traveled by the wrong-way driver prior to the crash for the three crash severity categories (PDO, injury, and fatality), and for the following scenarios:

- The wrong-way driver entered the wrong way at a stop sign and resulted in a crash at an intersection.
- The wrong-way driver entered the wrong way at a stop sign and resulted in a crash on a divided highway.
- The wrong-way driver entered the wrong way at a signalized intersection and resulted in a crash at the intersection.
- The wrong-way driver entered the wrong way at a signalized intersection and resulted in a crash on a divided highway.
- The wrong-way driver entered the wrong way from a driveway and resulted in a crash at an intersection.
- The wrong-way driver entered the wrong way from a driveway and resulted in a crash on a divided highway.

Wrong-way drivers were found to travel for relatively longer distances on divided facilities, and these crashes often resulted in fatalities and injuries. It can also be inferred from Figure 6-4 that PDO crashes are associated with shorter travel distances. Moreover, in general, fatal WWD crashes were found to be associated with longer travel distances, which are about three to four times longer than the travel distances associated with PDO crashes.

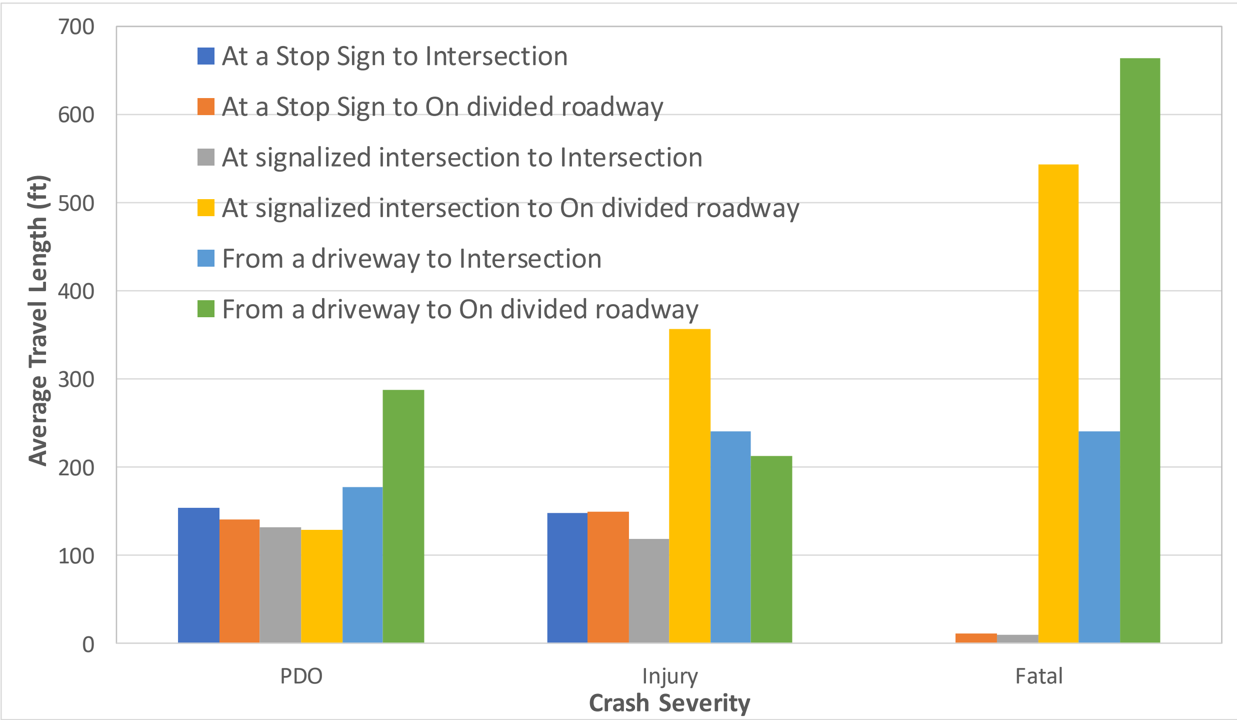

Figure 6-4: Average Distance between Wrong-way Driver Entry Location and WWD Crash Location

6.3 Analysis Based on Data Collected from Police Reports and Google Street View

This section presents descriptive statistics of WWD crashes within hotspots based on the data collected from police reports and Google Street View.

6.3.1 One-Way Streets

One-way streets within the WWD crash hotspots were extracted from the ARBM (NAVSTREETS^{TM} base map from HERE). These data were also verified from the information obtained from the police reports. Table 6-7 lists the WWD crash statistics by District and operation way (i.e., two-way street vs. one-way street). Approximately 26% of WWD crashes within hotspots were found to have occurred on one-way streets. Districts 2, 6, and 7 had the highest percentage of WWD crashes on one-way streets, followed by Districts 1, 3, and 4 (around 30% and 20%, respectively). Only 12.5% of WWD crashes in District 5 were found to have occurred on one-way streets.

Table 6-7: WWD Crash Statistics by District and Operation Way

District	Two-way Street		One-way Street	
	No.	%	No.	%
1	43	78.2%	12	21.8%
2	51	68.9%	23	31.1%
3	52	80.0%	13	20.0%
4	85	79.4%	22	20.6%
5	56	87.5%	8	12.5%
6	138	68.7%	63	31.3%
7	94	69.1%	42	30.9%
Total	**519**	**73.9%**	**183**	**26.1%**

Table 6-8 provides the WWD crash statistics by operation way (i.e., two-way street vs. one-way street) and crash severity. About 1.1% of WWD crashes that occurred on one-way streets resulted in a fatality, while the proportion was 3.3% for crashes that occurred on two-way streets.

Table 6-8: WWD Crash Statistics by Operation Way and Crash Severity

Cross-Section	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
Two-way Street	17	3.3%	283	54.5%	219	42.2%	519
One-way Street	2	1.1%	83	45.4%	98	53.6%	183
Total	**19**	**2.7%**	**366**	**52.1%**	**317**	**45.2%**	**702**

6.3.2 WWD Warning Signs

Information about the existence of WWD warning signs at the WWD crash location was collected from the police reports. These data were later verified using the Google Street View. Table 6-9 lists the WWD crash statistics by the presence (or absence) of WWD warning signs and crash severity. Overall, WWD warning signs were absent in the vicinity of 412 (i.e., 58.7%) WWD crashes. WWD crashes along the corridors with WWD warning signs were found to be relatively less severe compared to the WWD crashes along the corridors with no WWD warning signs.

Table 6-9: WWD Crash Statistics by Presence of WWD Warning Signs and Crash Severity

Presence of WWD Warning Signs	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
Yes	1	0.5%	91	46.4%	104	53.1%	196
No	16	3.9%	217	52.7%	179	43.4%	412
Unknown	2	2.1%	58	61.7%	34	36.2%	94
Total	**19**	**3.1%**	**366**	**52.4%**	**317**	**45.3%**	**702**

Yes – One or more of the following signs were present in the vicinity of the WWD crash location: DO NOT ENTER, WRONG WAY, KEEP RIGHT/LEFT, or ONE WAY.

6.3.3 Roadside Lighting

Information on the presence or absence of roadside lighting in the vicinity of WWD crashes was collected from the police reports and later verified using Google Street View. Corridors with adequate street lighting were found to experience less severe crashes, especially at night. Table 6-10 presents the WWD crash statistics by the presence of roadside lighting and crash severity. As expected, WWD crashes that occurred along the corridors with no street lighting were found to be relatively more severe (6.2% fatal) compared to the crashes that occurred along the corridors with street lighting (2.0% fatal).

Table 6-10: WWD Crash Statistics by Presence of Roadside Lighting and Crash Severity

Presence of Roadside lighting	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
Yes	11	2.0%	281	50.5%	264	47.5%	556
No	8	6.2%	78	60.5%	43	33.3%	129
Unknown	0	0.0%	7	41.2%	10	58.8%	17
Total	**19**	**2.7%**	**366**	**52.1%**	**317**	**45.2%**	**702**

6.3.4 Drivers' Attributes

Table 6-11 presents the WWD crash statistics by alcohol involvement and Districts. Overall, 27.5% of all WWD crashes within the hotspots were found to be DUI-related. District 6 had the lowest percentage of WWD crashes involving impaired drivers, while the highest percentage occurred in District 3 (46.2%).

Table 6-11: WWD Crash Statistics by Impairment and District

District	DUI-related		Non-DUI-related		Total
	No.	%	No.	%	
1	17	30.9%	38	69.1%	55
2	26	35.1%	48	64.9%	74
3	30	46.2%	35	53.8%	65
4	31	29.0%	76	71.0%	107
5	25	39.1%	39	60.9%	64
6	23	11.4%	178	88.6%	201
7	41	30.1%	95	69.9%	136
Total	**193**	**27.5%**	**509**	**72.5%**	**702**

Table 6-12 presents the WWD crash statistics by alcohol involvement and crash severity. As expected, WWD crashes involving impaired drivers were found to be more severe. About 5.7% of all DUI-related WWD crashes were fatal while only 1.6% of all non-DUI-related WWD crashes were fatal.

Table 6-12: WWD Crash Statistics by Impairment and Crash Severity

Impairment	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
DUI-related	11	5.7%	112	58.0%	70	36.3%	193
Non-DUI-related	8	1.6%	254	49.9%	247	48.5%	509
Total	**19**	**2.7%**	**366**	**52.1%**	**317**	**45.2%**	**702**

Table 6-13 presents the WWD crash statistics by driver age (driver age 65 and older versus other age groups) and crash severity. As expected, WWD crashes involving drivers age 65 and older were found to be more severe. About 4.1% of all WWD crashes involving drivers age 65 and older were fatal, while only 2.5% of WWD crashes involving younger drivers (less than age 65) were fatal.

Table 6-13: WWD Crash Statistics by Involving Drivers Age 65 and Older and Crash Severity

Driver Age	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
65 Years and Older	4	4.1%	59	60.8%	34	35.1%	97
Younger Than 65 Years	15	2.5%	307	50.7%	283	46.8%	605
Total	**19**	**2.7%**	**366**	**52.1%**	**317**	**45.2%**	**702**

Tourists and visitors are often unfamiliar with the roadway network and, hence, are considered to have a greater probability of driving the wrong way. The zip code of each wrong-way driver and the crash location were compared to identify crashes involving tourists. The following rules were adopted to identify crashes involving tourists: (a) crashes involving drivers with zip codes within the county where the crash occurred were considered as those involving the local population (i.e., not tourists); (b) crashes involving drivers with zip codes within the counties surrounding the county where the crash occurred were also considered as those involving local people (i.e., not tourists); (c) crashes involving drivers with all the remaining zip codes were considered as crashes involving tourists.

Of the 702 WWD crashes that occurred within the WWD crash hotspots, only 30 crashes were found to have involved a tourist driver. Moreover, as can be observed from Table 6-14, the familiarity of the roadway network did not affect the WWD crash severity.

Table 6-14: WWD Crash Statistics by Driver Familiarity with Road Network and Crash Severity

Category	Fatal		Injury		PDO		Total
	No.	%	No.	%	No.	%	
Local	15	2.6%	308	53.0%	258	44.4%	581
Tourist	0	0.0%	16	53.3%	14	46.7%	30
Unknown	4	4.4%	42	46.2%	45	49.5%	91
Total	**19**	**2.7%**	**366**	**52.1%**	**317**	**45.2%**	**702**

6.4 WWD Crash Contributing Factors

Once the WWD crash hotspots along non-limited access facilities in each FDOT District were identified, these hotspots were analyzed to identify potential WWD crash contributing factors. The WWD crash summary records, police reports of the WWD crashes, and the existing roadway geometric characteristics of the WWD crash locations were analyzed to identify if any of the following factors had contributed to WWD crashes along each of the crash hotspots: one-way streets, signalized intersections, stop-controlled intersections, lack of WWD warning signs, impaired drivers, and/or drivers age 65 years and older. Table 6-15 provides the specific criteria used to identify WWD crash contributing factors at each of the hotspots. Table 6-16 lists the WWD crash contributing factors at each of the WWD crash hotspots in each FDOT District.

Table 6-15: Criteria Used to Identify WWD Crash Contributing Factors

Potential Contributing Factor	Criteria Used
One-way streets	At least one WWD crash occurred on a one-way street.
Signalized intersections	At least two WWD crashes occurred where the wrong-way driver entered the facility at signalized intersections.
Stop-controlled intersections	At least two WWD crashes occurred where the wrong-way driver entered the facility at stop-controlled intersections.
Lack of WWD signs	A majority of the State Roads within the WWD crash hotspots are missing WWD warning signs such as DO NOT ENTER, ONE WAY, WRONG WAY, etc.
Impaired drivers	At least two WWD crashes involved impaired drivers.
Drivers age 65 years and older	At least two WWD crashes involved drivers age 65 and older.

Table 6-16: WWD Crash Contributing Factors at WWD Crash Hotspots

Dist.	Rank	Location	Roadway Geometric Characteristics Contributing to WWD Crashes				Demographics of Wrong-way Driver	
			One-way Street	Signalized Int.	Stop Int.	Lack of WWD Signs	Impaired Drivers	Drivers Aged 65+
1	1	Fowler St, Fort Myers	Yes	Yes	No	Yes	Yes	Yes
1	2	S Tamiami Trail, Memphis	Yes	Yes	Yes	Yes	Yes	Yes
1	3	Bartow Rd, Lakeland	No	Yes	No	Yes	Yes	No
1	4	SR 82, Gateway	Yes	No	Yes	Yes	No	No
1	4	US 41, Gulf Gates Estates	No	No	No	Yes	No	No
1	6	Tamiami Trail, Fort Myers	No	Yes	No	Yes	Yes	Yes
1	7	SR 82, Lehigh Acres	No	No	No	Yes	No	No
1	8	Magnolia Ave, Auburndale	Yes	No	No	Yes	Yes	No
1	9	Sikes Blvd, Lakeland	No	Yes	No	Yes	Yes	No
1	10	Manatee Ave, Bradenton	Yes	Yes	Yes	Yes	No	No
2	1	University Blvd, Jacksonville	No	Yes	Yes	Yes	Yes	Yes
2	2	W Union St, Jacksonville	Yes	Yes	No	Yes	Yes	Yes
2	3	Charles Memorial Hwy, St Augustine	No	Yes	No	Yes	No	No
2	4	Beach Blvd, Jacksonville Beach	No	No	Yes	Yes	Yes	No
2	5	Kingsley Ave, Orange Park	Yes	No	No	Yes	Yes	No
2	5	Cassat Ave, Jacksonville	No	Yes	No	Yes	No	No
2	7	Williston Rd, Gainesville	No	No	No	Yes	Yes	No
2	7	Blanding Blvd, Orange Park	No	Yes	No	Yes	Yes	No
2	9	Main St, Brentwood	No	Yes	No	Yes	No	Yes
2	10	Dixie Hwy, St. Augustine	No	Yes	No	Yes	No	No
3	1	Dr MLK Jr Dr, Pensacola	Yes	Yes	Yes	Yes	Yes	No
3	2	Lillian Hwy, West Pensacola	No	No	No	Yes	Yes	No
3	3	Woodville Hwy, Tallahassee	No	No	No	No	Yes	Yes
3	4	S Hwy 29, Gonzalez	No	No	Yes	Yes	Yes	Yes
3	5	US Hwy 98, Fort Walton Beach	No	No	No	Yes	No	No
3	6	Pennell St, Panama Beach City	No	No	No	No	Yes	No
3	6	Perdido Key Dr, Perdido Key	No	No	No	Yes	No	No
3	8	Martin Luther King Blvd, Panama City	No	Yes	No	Yes	Yes	No
3	9	Beal Pkwy NE, Fort Walton Beach	No	Yes	No	Yes	Yes	No
3	10	S Monroe St, Tallahassee	Yes	Yes	No	Yes	Yes	No

Table 6-16 (Cont'd): WWD Crash Contributing Factors at WWD Crash Hotspots

Dist.	Rank	Location	Roadway Geometric Characteristics Contributing to WWD Crashes				Demographics of Wrong-way Driver	
			One-way Street	Signalized Int.	Stop Int.	Lack of WWD Signs	Impaired Drivers	Drivers Aged 65+
4	1	Hollywood Blvd, Hollywood	Yes	Yes	Yes	Yes	Yes	Yes
4	2	SR 80, Royal Palm Beach	No	Yes	No	Yes	Yes	Yes
4	3	N Dixie Hwy, Oakland Park	Yes	Yes	No	Yes	No	Yes
4	4	Dixie Hwy, Lake Worth	Yes	Yes	Yes	Yes	Yes	No
4	5	Lake Worth Rd, Greenacres	No	Yes	No	Yes	Yes	No
4	6	S Flamingo Rd, Southwest Ranches	No	Yes	No	Yes	No	No
4	7	20th St, Vero Beach	Yes	Yes	No	Yes	Yes	Yes
4	8	W Hillsboro Blvd, Deerfield Beach	No	Yes	No	Yes	Yes	No
4	9	S Federal Hwy, Delray Beach	Yes	Yes	Yes	Yes	Yes	Yes
4	10	W Broward Blvd, Fort Lauderdale	No	Yes	No	Yes	Yes	No
5	1	Woodland Blvd, North De Land	Yes	No	No	Yes	Yes	Yes
5	2	N Dixie Hwy, Melbourne	No	No	No	Yes	Yes	No
5	3	SR 46, Sorrento	No	No	No	Yes	Yes	No
5	3	E Colonial Dr, Bithlo	No	No	No	Yes	No	No
5	5	S Orange Ave, Pine Castle	Yes	Yes	No	Yes	Yes	No
5	6	Orange Blossom Trail. Orlando	No	Yes	No	Yes	No	No
5	7	W King St, Cocoa West	No	No	Yes	Yes	Yes	No
5	8	Citrus Blvd, Fruitland Park	No	Yes	No	Yes	No	No
5	9	Washington St, Orlando	Yes	Yes	No	Yes	Yes	No
5	10	South St, Titusville	Yes	Yes	No	Yes	No	No
5	10	John Young Pkwy, Orlando	No	Yes	No	Yes	Yes	No
6	1	SW 1st St, Miami	Yes	Yes	Yes	Yes	Yes	Yes
6	2	NE 125th St, North Miami	Yes	Yes	Yes	No	Yes	Yes
6	3	E 21st St, Hialeah	No	Yes	No	Yes	No	Yes
6	4	W Palm Dr, Florida City	No	Yes	No	Yes	No	No
6	5	Biscayne Blvd, Miami	Yes	Yes	Yes	Yes	Yes	Yes
6	6	Dixie Hwy, Palmetto Bay	Yes	Yes	No	No	Yes	No
6	7	Dixie Hwy, Coral Gables	No	Yes	No	No	No	No
6	8	5th St, Miami Beach	Yes	Yes	No	Yes	No	No
6	9	Hwy A1A, North Beach	Yes	Yes	Yes	No	No	No
6	10	S 57th Ave, West Miami	Yes	Yes	No	Yes	Yes	Yes
7	1	N Tampa St, Tampa	Yes	Yes	Yes	Yes	Yes	Yes
7	2	US 19, Holiday	No	Yes	No	Yes	Yes	Yes
7	3	4th St N, Pinellas Park	Yes	Yes	Yes	Yes	Yes	Yes
7	4	SR 54, Trinity	No	Yes	No	Yes	No	No
7	5	US 19, Hudson	No	Yes	Yes	Yes	No	Yes
7	6	4th Ave N, St. Petersburg	Yes	Yes	Yes	Yes	Yes	Yes
7	7	W Baker St, Plant City	Yes	No	No	No	No	No
7	8	US 41, Thonotosassa	No	No	No	Yes	Yes	No
7	9	Main St, Dunedin	No	Yes	No	Yes	No	Yes
7	9	5th Ave, Zephyrhills West	No	No	Yes	Yes	No	No

6.5 Summary

Ten WWD crash hotspots within each FDOT District were identified based on spatial analysis in ArcGIS. A total of 702 WWD crashes were found to occur within these hotspots. These crashes along with the roadway geometric characteristics of the crash hotspots were analyzed. Key factors of this analysis include:

- Over 90% of WWD crashes within hotspots were found to have occurred at (or near) intersections or on divided roadways.
- Only 1.5% of WWD crashes within hotspots that occurred at or near intersections resulted in a fatality, while over 6% of WWD crashes that occurred on divided facilities were fatal.
- About 43% of the wrong-way drivers turned the wrong way at a signalized intersection. Approximately 20% of the wrong-way drivers were found to turn the wrong way from a driveway.
- The most frequent scenario involved a wrong-way driver entering the facility the wrong way at a signalized intersection, resulting in a crash at or near an intersection. Moreover, these crashes were found to have occurred most often at the same intersection where the wrong-way driver turned the wrong way.
- Wrong-way drivers were found to travel for relatively longer distances on divided facilities, and these crashes often resulted in fatalities and injuries.
- Approximately 26% of WWD crashes within hotspots were found to have occurred on one-way streets.
- About 1.1% of WWD crashes that occurred on one-way streets resulted in a fatality, while the proportion was 3.3% for crashes that occurred on two-way streets.
- WWD crashes along the corridors with WWD warning signs were found to be relatively less severe compared to the WWD crashes along the corridors with no WWD warning signs.
- WWD crashes that occurred along corridors with no street lighting were found to be relatively more severe compared to the WWD crashes that occurred along corridors with street lighting.
- Overall, 27.5% of all WWD crashes within the hotspots were found to be DUI-related. About 5.7% of all DUI-related WWD crashes were fatal while only 1.6% of all non-DUI-related WWD crashes were fatal.
- WWD crashes involving drivers age 65 and older were found to be more severe.
- Very few tourists were found to be involved in WWD crashes on arterials. Moreover, the familiarity of the roadway network did not affect the WWD crash severity.

The supplemental documents provided with this report include an Excel file with a detailed discussion about the roadway geometric and demographic factors contributing to WWD crashes at the WWD crash hotspots on non-limited access roadways in each FDOT District. The Excel file includes the following worksheets:

- Contributing Factors: For each of the WWD crash hotspot in each district, one or more of the following roadway geometric and demographic factors that contributed to WWD crashes were identified:
    - One-way streets
    - Signalized intersections
    - Stop-controlled intersections
    - Absence of WWD warning signs
    - Impaired drivers
    - Drivers age 65 and older

- WWD Crash Hotspots: All state roads (along with begin and end locations) in each of the WWD crash hotspots in each district were identified.

- Signalized Intersections: The latitude and longitudes of critical signalized intersections within the WWD crash hotspots were included. Signalized intersections were identified as critical if a wrong-way driver was found to enter the facility the wrong way from the intersection. A total of 279 signalized intersections were included in this worksheet.

- Stop-controlled Intersections: The latitude and longitudes of critical Stop-controlled intersections within the WWD crash hotspots were included. Intersections were identified as critical if a wrong-way driver was found to enter the facility the wrong way from the intersection. A total of 83 stop-controlled intersections were included in this worksheet.

CHAPTER 7
SUMMARY AND CONCLUSIONS

A wrong-way driving (WWD) incident involves a vehicle traveling opposite to the legal flow of traffic on a direction-separated highway, freeway or arterial, or access ramp (NTSB, 2012). Although crashes involving wrong-way drivers are relatively few, they often lead to severe head-on collisions. As such, the fatality rate in WWD incidents is much higher compared to other crashes (Zhou et al., 2012). The majority of previous studies concerning WWD crashes have focused on freeways. This could be potentially because they draw more media attention, involve more vehicles, cause extended freeway closures, and result in more fatalities per crash. Although WWD on limited access facilities receives more attention, WWD crashes are more frequent on arterial streets compared to freeways.

Mitigating WWD crashes on arterials is complicated because there are multiple access points along arterial facilities. In other words, there are many possible locations where a driver may enter the facility the wrong way, and it is difficult to have some type of WWD countermeasure(s) at each of these access points. Analyzing WWD crashes to identify factors that affect their frequency and severity is crucial in selecting the most suitable countermeasure(s) for deployment.

The goal of this research effort was to identify strategies to mitigate WWD incidents on arterials in Florida by developing a scenario-based WWD crash mitigation approach to address two specific needs: *which arterial corridors are prone to WWD incidents*, and *which WWD incident category needs addressing on these corridors.*

7.1 WWD Mitigation Strategies

To date, there has been considerable research addressing WWD on freeways, while there are very few studies that have analyzed WWD incidents on non-limited access facilities. Several states, including Florida, have deployed ITS technologies and TSM&O strategies at off-ramps and freeway mainline to mitigate WWD incidents in real-time. However, very few strategies, if any, have been deployed along arterials. New and emerging technologies, including thermal camera systems, radar detection, integrated on-road detection, tracking, and notification systems, in-vehicle systems, and sign identification systems, etc., are proving to be successful in preventing WWD crashes on freeways. These applications, though more readily applicable to limited access facilities, could be adapted to an extent, to non-limited access facilities as well.

7.1.1 The 4 E's of Traffic Safety

The frequency and severity of traffic crashes could be reduced through the 4 E's of traffic safety: *Engineering*, *Education*, *Enforcement*, and *Emergency Response*. Countermeasures that could be implemented to mitigate WWD incidents on arterials include:

Engineering:

- Signing
  - Standard "WRONG-WAY" sign package
  - Improved static signs

    - Redundant signs
    - Lowered sign height
    - Oversized signs
    - Multiple signs on the same post
    - Red retro-reflective tape on vertical posts

- Pavement Markings
    - Stop bar
    - Wrong-way arrow
    - Turn/through lane-only arrow
    - Raised pavement markers
    - Short dashed line to delineate turning path

- Geometric Improvements
    - Raised curb median
    - Longitudinal channelizers

- ITS Technologies
    - LED-illuminated signs
    - DMSs to warn right-way drivers
    - Existing GPS navigation technologies to provide wrong-way movement alerts, especially on one-way streets

Education:

- Public awareness and understanding of the basics of road designs and interchange types and proactive behaviors (witnessing a wrong-way driver)
- Focus groups involving older drivers, impaired drivers, and young drivers

Enforcement:

- Provide warnings and citations to wrong-way drivers
- Enforce DUI laws
- Warn right-way drivers using DMSs

Emergency Response:

- Identify the wrong-way vehicles as soon as possible.
- Develop a communication plan to inform all the relevant agencies of a potential wrong-way incident.

7.1.2 Perception of the CTSTs

To explore the need to conduct public outreach activities on addressing the WWD issue in Florida, CTST coordinators in each FDOT District were contacted and asked about the specific efforts they have undertaken to mitigate WWD incidents, their perspective on additional efforts to mitigate WWD incidents, and their perspective on conducting a workshop and/or public outreach activities.

Based on the survey responses, it can be inferred that the CTSTs have not, to date, specifically addressed WWD on arterial roadways. The respondents noted that unusual geometry (reversible lanes, one-way streets, wide roadways, etc.) coupled with either impaired or unfamiliar drivers seems to be problematic. Also, there is a need to determine the root causes of wrong-way entries. A workshop, offered at the Statewide CTST Coalition Meeting, could potentially be useful once the root causes for WWD incidents on arterials are determined.

7.1.2 Statewide Showcase on Mitigating WWD Incidents

Since *Engineering* countermeasures do not completely mitigate WWD incidents, it is crucial to consider *Education* and *Enforcement* strategies to effectively address the WWD issue. As such, a statewide showcase on mitigating WWD incidents is recommended. Stakeholders to be included in the discussion would include the FHP, media personnel, District PIOs, CTSTs, DSEs, DTOEs, local LEOs, and safety advocates, including AAA, MADD, etc. This one-day showcase could primarily focus on the following topics:

- Background on WWD incidents
- The 4 E's of traffic safety in the context of mitigating WWD incidents
- Research and implementation efforts in addressing WWD issue in Florida
- Success stories and best practices from other states
- Experiences of FDOT districts, counties, and local agencies
- Strategies to address WWD issue from a policy perspective
- Strategies to address WWD issue from an enforcement perspective
- Next steps in mitigating WWD incidents

7.2 WWD Crashes on Arterials

The WWD crash data analysis was based on five years of crash data from 2012-2016. During the analysis period, a total of 2,879 crashes were identified as potential WWD crashes. Police reports of these 2,879 crashes were obtained and reviewed in detail. Each police report was manually reviewed, and the following information was collected:

- The location where the wrong-way driver potentially turned the wrong way, if available.
- The exact location of the WWD crash.
- Any cues pertaining to the Wrong Way incident, if present.
- Other roadway characteristics that may have contributed to WWD crashes (e.g., street lighting, pavement markings, one-way streets, etc.)
- Information related to the crash, such as alcohol involvement, age of the wrong-way driver, the familiarity of the wrong-way driver with the roadway network, etc.

Of the total of 2,879 potential WWD crashes on arterial statewide from 2012-2016, only 1,890 crashes (i.e., 65.6%) were categorized as actual WWD crashes resulting from vehicles traveling the wrong way. The WWD arterial crashes were analyzed to determine the crash frequency, crash severity, crash location, and potential contributing factors, such as roadway characteristics, lighting condition, driver age, driver impairment, and presence of WWD warning signs.

On average, nearly 7% of all WWD crashes on arterials resulted in a fatality, and 52.5% resulted in an injury. Over 95% of WWD crashes occurred within 450 ft from where the drivers potentially entered the wrong way. A considerable number of WWD crashes (over 50%) occurred at or near intersections, and a large proportion of the wrong-way drivers (38%) turned the wrong way at a signalized intersection. Divided facilities also experienced a high number of WWD crashes, and a high proportion of fatal WWD crashes. WWD crashes on undivided facilities, although relatively rare, resulted in a high proportion of fatalities.

About 13.5% of all arterial WWD crashes occurred on one-way streets, while 84.9% occurred on two-way streets. Note that the crash locations of about 1.6% of arterial WWD crashes were unknown. The fatality rate for WWD crashes on two-way streets (7.5%) was over three times greater than for one-way streets (2.4%). Based on the review of the police reports, WWD warning signs, such as DO NOT ENTER, KEEP RIGHT/LEFT, and ONE WAY were found to be present at fewer than 51% of the one-way streets where WWD crashes occurred. Nearly 95% of two-way streets where WWD crashes occurred had no WWD warning signs .

The highest number of WWD crashes (38.6%) involved drivers age 35 to 64, with nearly 9% of these crashes resulting in a fatality. Although drivers age 65 and older were involved in only 16% of the 1,890 crashes analyzed, 7.6% of these WWD crashes were fatal. Nearly 36% (680 of 1,890 crashes) of WWD crashes involved intoxicated (either alcohol, or drugs, or both) drivers. Of the 130 fatal WWD crashes, 82 crashes (63.1%) involved intoxicated drivers.

In terms of both WWD crash frequency and crash severity, the most critical time was found to be from midnight to 6 AM and from 6 AM to noon. WWD crashes that occurred along the corridors with no street lighting were found to be relatively more severe compared to the crashes that occurred along the corridors with street lighting. Over 55% of all WWD crashes occurred during dark conditions, and over 64% of all fatal WWD crashes occurred during dark conditions.

7.3 WWD Crash Hotspots on Arterials

A GIS-based spatial clustering analysis was used to identify 10 WWD crash hotspots within each FDOT District, based on the number of WWD crashes and the EPDO scores. Between the years 2012 to 2016, a total of 702 WWD crashes occurred at the identified hotspots, constituting 37.1% of the total 1,890 WWD crashes on arterials in Florida during the same analysis period. These crashes along with the roadway geometric characteristics of the crash hotspots were analyzed.

Over 90% of WWD crashes within hotspots occurred at (or near) intersections or on divided roadways. Only 1.5% of WWD crashes within hotspots that occurred at or near intersections resulted in a fatality, while over 6% of WWD crashes that occurred on divided facilities were fatal. Approximately 43% of the wrong-way drivers turned the wrong way at a signalized intersection, which most often resulted in a crash at the same intersection. Approximately 20% of the wrong-way drivers were found to have turned the wrong way from a driveway.

Approximately 26% of WWD crashes within hotspots occurred on one-way streets. Only 1.1% of these crashes resulted in a fatality, while the proportion was 3.3% for crashes that occurred on two-way streets. Wrong-way drivers were found to travel for relatively longer distances on divided facilities, and these crashes often resulted in fatalities and injuries.

WWD crashes along the corridors with WWD warning signs were found to be relatively less severe compared to the WWD crashes along the corridors with no WWD warning signs. The absence of street lighting resulted in WWD crashes with greater severity, compared to the WWD crashes that occurred along corridors with street lighting.

Overall, 27.5% of all WWD crashes within the hotspots were found to be DUI-related. Nearly 6% of all DUI-related WWD crashes were fatal while only 1.6% of all non-DUI-related WWD crashes were fatal. WWD crashes involving drivers age 65 and older were found to be more severe.

7.4 WWD Countermeasure Implementation Plan for Arterials

The supplemental documents provided with this report include an Excel file with a detailed discussion about the roadway geometric and demographic factors contributing to WWD crashes at the WWD crash hotspots on arterials in each FDOT District. The Excel file includes the following worksheets:

- Contributing Factors: For each of the WWD crash hotspot in each district, one or more of the following roadway geometric and demographic factors that contributed to WWD crashes were identified:
    - One-way streets
    - Signalized intersections
    - Stop intersections
    - Absence of WWD warning signs
    - Impaired drivers
    - Drivers age 65 years and older

- WWD Crash Hotspots: All state roads (along with begin and end locations) in each of the WWD crash hotspots in each district were identified.

- Signalized Intersections: The latitude and longitudes of all critical signalized intersections within the WWD crash hotspots were included. Signalized intersections were identified as critical if a wrong-way driver was found to enter the facility the wrong way from the intersection. A total of 279 signalized intersections were included in the worksheet.

- Stop-controlled Intersections: The latitude and longitudes of all critical stop-controlled intersections within the WWD crash hotspots were included. Intersections were identified as critical if a wrong-way driver was found to enter the facility the wrong way from the intersection. A total of 83 stop-controlled intersections were included in the worksheet.

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