Final Report

Submitted to

Florida Department of Transportation (FDOT)

BDV24-977-37

STUDY OF OPERATIONAL AND SAFETY IMPACTS OF DISABLED AND ABANDONED VEHICLES ON FDOT ROADWAYS

Principal Investigator:	Haitham Al-Deek, Ph.D., P.E. University of Central Florida (UCF) Civil, Environmental, and Construction Engineering Dept. 12800 Pegasus Drive, Suite 211 Orlando, FL 32816 Email: Haitham.Al-Deek@ucf.edu Phone: (321) 695-7664
DSR Administrative Contact:	Stephanie Rodriguez-Makhlouf Manager, Sponsored Programs University of Central Florida (UCF) Office of Research and Commercialization 12201 Research Parkway, Suite 501 Orlando, FL 32826 Email: Stephanie.R.Makhlouf@ucf.edu Phone: (407) 823-0263
Project Managers:	Eric Gordin, P.E. Assistant Traffic Operations Engineer Florida's Turnpike Enterprise (FTE) Mile Post 263, Turkey Lake Service Plaza, Bldg. 5315 Ocoee, FL 34761 Email: Eric.Gordin@dot.state.fl.us Phone: (407) 264-3316
	Jeff Frost Traffic Incident Management / Commercial Vehicle Operations Program Manager Florida Department of Transportation (FDOT) 605 Suwannee St. Tallahassee, FL 32399 Email: Jeff.Frost@dot.state.fl.us Phone: (850) 410-5607

Submitted in September 2022

Disclaimer Page

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

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Study of Operational and Safety Impacts of Disabled and Abandoned Vehicles on FDOT Roadways		5. Report Date September 2022
		6. Performing Organization Code
7. Author(s) Haitham Al-Deek, Adrian Sandt, John McCombs, Grady Carrick, Erik Cornelison, Eric Ginsberg, Angel Lopez Sanchez, Daniel Dollman, Vishay Chudgar		8. Performing Organization Report No.
9. Performing Organization Name and Address Civil, Environmental, and Construction Engineering Department University of Central Florida (UCF) 12800 Pegasus Drive, Suite 211 Orlando, FL 32816-2450		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. BDV24-977-37
12. Sponsoring Agency Name and Address Florida Department of Transportation 605 Suwannee Street, MS 30 Tallahassee, FL 32399		13. Type of Report and Period Covered Final Report January 2021 – September 2022
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Disabled and abandoned vehicles (DAVs) are a common occurrence on Florida roadways. This research focused on evaluating the operational and safety impacts of DAVs and identifying and evaluating methods to reduce these impacts. A comprehensive literature review showed that previous studies focused on DAV response (including the use of innovative towing programs), but not DAV impacts. The responses to a developed national survey on DAVs indicated that abandoned vehicles are more common in other states than in Florida and that improving towing procedures and equipment could reduce the impacts of these events. Over 1,250 DAV crashes, 1.5 million non-crash SunGuide events, and 10.2 million Waze alerts were analyzed. The DAV crashes resulted in 53 fatalities, 976 injuries, and $966 million in comprehensive fatality and injury costs. Compared to DAV crashes, the non-crash events were less likely to be lane-blocking and more common during daytime hours. About 47% of SunGuide events had an associated Waze alert preceding the SunGuide event, indicating that utilization of DAV Waze alerts in SunGuide could improve DAV detection. Benefit-cost evaluations of utilizing these Waze alerts on SR-91 in D4 and I-4 in D5 resulted in benefit-cost ratios of 18.4 and 59.7, respectively, when considering only congestion savings. An instant dispatch tow program could also provide significant benefits, especially in urban areas, while expanding the hours of Road Ranger patrols would not be as cost effective. Therefore, it is recommended to explore the potential of utilizing DAV Waze alerts and implementing instant dispatch tow in Florida.

17. Key Word	18. Distribution Statement
Disabled vehicle, abandoned vehicle, traffic incident management, safety service patrol, agency survey, benefit-cost analysis	No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.	255	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Executive Summary

Disabled and abandoned vehicles (DAVs) are a common occurrence on Florida roadways. In fiscal year 2017-2018, Florida Road Rangers responded to approximately 285,000 events involving a disabled vehicle or an abandoned vehicle, comprising about 68% of all roadway events (Florida Department of Transportation [FDOT] Commercial Vehicle Operations [CVO] and Traffic Incident Management [TIM] Program, 2018). These DAVs can create many impacts to traffic operations and pose a risk to motorist and responder safety. This project studied and evaluated the frequency and impacts of DAVs on Florida limited access roadways to better understand these events and identify potential improvements to existing response practices. Benefit-cost evaluations were conducted for select improvements to make recommendations on methods for FDOT to investigate further. The results of this research can help enhance traffic operations and increase safety on FDOT roadways by improving the detection of and response to DAVs, reducing congestion and crashes caused by these events.

To help understand the existing DAV response policies, procedures, and programs used in Florida and other states, a comprehensive literature review was conducted and a national stakeholder survey was developed and sent to state departments of transportation (DOTs), turnpike/toll road authorities, state and local law enforcement agencies, and safety service patrols (SSPs) across the United States. The literature review showed that Florida has many policies and programs in place to handle DAVs, including the Open Roads Policy (ORP) and Road Ranger Service Patrol Program. FDOT's ORP has helped keep roadway clearance times to an average of 33 minutes and incident clearance times to an average of 64 minutes, while Road Rangers help clear crashes and assist motorists with vehicle issues. These have been effective, but improvements to towing practices (such as instant dispatch tow or similar programs used in other states) could improve DAV response even more.

The national stakeholder survey developed in this project was completed by 60 respondents (27 state DOTs, four turnpike/toll road authorities, 12 state law enforcement agencies, 13 state SSPs, and four FDOT districts). Most of the state DOT and turnpike/toll road respondents reported that they experienced 10 to 50 disabled vehicle events and 11 to 25 abandoned vehicles per day on average, mainly during daytime hours. Clearing DAV events in urban and suburban areas was of high priority, but this priority was reduced if the DAV was not lane-blocking or an immediate hazard. Typically, disabled vehicles were generally moved to the shoulder within 30 minutes. The main suggestions for reducing DAV impacts were to improve interagency coordination to clear vehicles, reduce detection and response times, expand existing SSPs, and better track DAV events and manage their associated data. Some innovative programs were also mentioned as effective means to reduce clearance times and positively impact traffic operations and safety. These innovative programs included a way to more quickly clear abandoned vehicles, clearing DAVs from construction zones, and allowing SSP vehicles to remove DAVs without waiting for a tow truck. Over two-thirds of law enforcement and SSP respondents stated that an officer or responder from their agency had been struck by another vehicle while responding to a DAV event, indicating the importance for responder safety procedures. These respondents also indicated that improved tracking and monitoring of DAVs, as well as expansion of SSP patrols, could help improve DAV response.

Multiple DAV data sources for Florida limited access roadways were analyzed to thoroughly understand the impacts of DAVs in Florida. DAV crash reports were collected from Signal 4 Analytics. The identified 1,256 DAV crashes from 2015 through 2020 resulted in 53 fatalities, 976 injuries, $17.3 million in property and vehicle damages, and $966 million in comprehensive fatality and injury costs due to DAV crashes (average yearly cost of about $163.9 million). These DAV crashes lasted an average of 130 minutes each. Over 34% of DAV crashes blocked at least one travel lane, emphasizing the need for quick response to reduce operational impacts. Approximately 10% of DAV crashes occurred on exit or entrance ramps. Distraction was also found to be a common contributing factor of DAV crashes, as 15% of all DAV crashes were due to distracted driving. Interstates in urban counties had the highest frequency of DAV crashes, suggesting that improving detection and subsequent response in these areas would lead to the most benefits in terms of reducing crashes and their associated fatalities and injuries.

In addition to these DAV crashes, approximately 1.6 million SunGuide non-crash DAV events from January 2018 through December 2021 were collected and analyzed. About 90% of these were disabled vehicle events, with the remaining 10% being abandoned vehicle events. These events were less common than DAV crashes during nighttime hours, with about 22% of disabled vehicle SunGuide events occurred from 9 PM to 7 AM, compared to 45% of disabled vehicle crashes occurring in this timeframe. This suggests that clear visibility and conspicuity plays an important role in reducing crashes. Only about 4% of DAV SunGuide events blocked a travel lane in some capacity, with over 50% blocking at least one shoulder (usually the right shoulder) and only 0.8% partially or completely blocking an exit or entrance ramp. Disabled vehicle SunGuide events lasted about half the time as DAV crash events, but abandoned vehicle SunGuide events lasted over 13 hours on average before being fully cleared from the scene.

DAV Waze alerts from April 2019 through December 2021 were also collected and analyzed (a total of approximately 10.3 million alerts). These alerts were compared to the DAV SunGuide events. About 70% of the DAV SunGuide events have at least one overlapping Waze alert (using a 30-minute buffer and approximately 1-mile radius), with 47% having at least one Waze alert before the SunGuide event. Waze-SunGuide overlap was more present during daytime hours than nighttime hours and was more common in urban areas and on high-volume roadways. Analyzing the SunGuide events which had a Waze alert before the SunGuide event was reported showed that the earliest Waze alert occurred, on average, about 16 minutes before the SunGuide event. This suggests that incorporating DAV Waze alerts into SunGuide system could help traffic management center (TMC) operators identify DAVs earlier, which could reduce the congestion and potential for crashes to occur. Additional research is needed to understand how to best utilize these Waze alerts to obtain the most benefits without overwhelming TMC operators.

Based on the literature review, survey responses, and data analysis, three potential methods to reduce the impacts of DAVs were evaluated: expanding Road Ranger patrol hours, implementing instant dispatch tow, and utilizing Waze alerts for earlier detection of DAV events. To evaluate these methods, a methodology was developed to estimate the congestion savings for lane-blocking and shoulder-blocking DAV events due to the implementation of these methods on select roadways. Using the developed methodology, congestion costs were estimated for the roadway in each FDOT district with the most DAV crashes and SunGuide events in 2019. The

13,882 applicable capacity-reducing DAV incidents on these roadways (13,859 DAV SunGuide events and 23 DAV crashes) resulted in over 79,500 hours of congestion, 11 million vehicle-hours of delay, congestion costs of nearly $336 million, and comprehensive crash costs of almost $36 million. These estimates do not include congestion due to incidents where congestion was present before the DAV incident occurred or incidents which occurred on entrance or exit ramps, so the actual congestion costs are likely much higher.

Evaluations of the three potential methods to improve DAV detection and response showed that Road Ranger expansions could be slightly cost-effective (benefit-cost ratios of 4.33 for I-295 in D2 and 1.95 for I-10 in D3). However, the evaluations of instant dispatch tow and utilization of DAV Waze alerts provided more promising results. While the exact costs of implementing instant dispatch tow are not clear, the estimated annual benefits due to congestion savings ranged from $1,274,637 (I-10 in D3) to $7,413,816 (SR-91 in D5) compared to $1,404,587 for Road Ranger expansion on I-295 in D2 and $447,980 for Road Ranger expansion on I-10 in D3. The utilization of Waze alerts to detect DAV events also had more benefits and higher benefit-cost ratios than the Road Ranger expansions, with annual congestion savings of $3,518,402 and a benefit-cost ratio of 18.39 for SR-91 in D4 and annual congestion savings of $8,471,581 and a benefit-cost ratio of 59.65 for I-4 in D5. Additionally, it is possible that the earlier detection provided by the Waze alerts could have allowed responders to get to three DAVs before a crash occurred, potentially preventing these crashes and their associated costs of $4,327,000 (not considered in the calculated benefit-cost ratios).

This project shows the significant impacts of DAV events in Florida and potential methods that could effectively reduce these impacts. It is recommended that FDOT continues to investigate the potential of reporting Waze alerts for lane-blocking DAV events to the TMC, including the development of appropriate filtering protocols for different roadways, locations, and times of day to best utilize these data for the lowest cost. It is also recommended to consider implementing an instant dispatch tow or similar program in D5 or other urban areas to help improve DAV response. The findings and conclusions form this project can help FDOT make informed decisions regarding DAV policies and programs in the future to ensure the continued improvement of traffic operations and safety on their roadways.

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

AAA	American Automobile Association
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
ALERT	Arizona Local Emergency Response Team
ATMS	Advanced Traffic Management System
CAF	Capacity Adjustment Factor
CFX	Central Florida Expressway Authority
CHART	Coordinated Highways Action Response Team
CRV	Custom Response Vehicle
CTSO	Committee on Transportation Systems Operations
CVO	Commercial Vehicle Operations
DAV	Disabled and Abandoned Vehicle
DMS	Dynamic Message Sign
DOT	Department of Transportation
EEI	Enforcement Engineering, Inc.
ETP	Emergency Traffic Patrol
F.S.	Florida Statute
FDOT	Florida Department of Transportation
FFS	Free-flow speed
FHP	Florida Highway Patrol
FHWA	Federal Highway Administration
FIRST	Freeway Incident Response Safety Team
FSP	Freeway Service Patrol
FSPE	Freeway Service Patrol Evaluation
FTE	Florida’s Turnpike Enterprise
GDOT	Georgia Department of Transportation
GIS	Geographic Information System
HCM6E	Highway Capacity Manual, Sixth Edition
IBTTA	International Bridge, Tunnel and Turnpike Association
ICT	Incident Clearance Time
INDOT	Indiana Department of Transportation
IRU	Incident Response Unit
ITS	Intelligent Transportation Systems
MnDOT	Minnesota Department of Transportation
ORP	Open Roads Policy
PDO	Property Damage Only
PHF	Peak Hour Factor
PHP	PHP: Hypertext Preprocessor
RCT	Roadway Clearance Time

List of Abbreviations and Acronyms

RISC	Rapid Incident Scene Clearance
RTMC	Regional Traffic Management Center
S4A	Signal 4 Analytics
SIRV	Severe Incident Response Vehicle
SQL	Structured Query Language
SR	State Road
SSP	Safety Service Patrol
STARR	Specialty Towing and Roadside Repair
TIM	Traffic Incident Management
TIME	Traffic Incident Management Enhancement
TMC	Traffic Management Center
TOC	Traffic Operations Center
TRB	Transportation Research Board
TRIP	Towing and Recovery Incentive Program
UCF	University of Central Florida
VDOT	Virginia Department of Transportation

Chapter 1: Introduction

1.1 Problem Description

Disabled and abandoned vehicles (DAVs) are a common occurrence on Florida roadways. According to the Florida Department of Transportation (FDOT) Commercial Vehicle Operations (CVO) and Traffic Incident Management (TIM) program (2018), Florida Road Rangers responded to approximately 285,000 events involving a disabled vehicle or abandoned vehicle, comprising about 68% of all roadway events for the 2017-2018 fiscal year. These DAVs can create many impacts to traffic operations and pose a risk to motorist and responder safety. Since these events are the most common events handled by Road Rangers, it is important to study them further to better understand their impacts and how these impacts could be reduced.

The impact of DAVs on traffic operations is one of the most visible aspects of these events. The Federal Highway Administration (FHWA, 2021) notes that incidents involving DAVs can cause non-recurring congestion, which comprises about 50% of all congestion on freeways. Incident durations play an important role in traffic operations, especially if they involve lane-blocking vehicles. An evaluation of DAVs in Tennessee from 2004 to 2010 found that 78% of all freeway incidents involved a disabled vehicle or abandoned vehicle with an average incident duration of 57 minutes (Chimba et al., 2013). While 90% of the DAV events in this Tennessee study were cleared from the roadway within 30 minutes, their impacts on traffic can linger after they are cleared from the roadway. Finding ways to minimize the impact of DAVs on traffic operations can help save money by reducing vehicle delay and the time spent by operators monitoring the incident.

Events involving DAVs can also pose a significant safety hazard to motorists and responders. Other drivers can strike a vehicle that is disabled or abandoned, injuring people located in or near the vehicle. On average, 566 people are killed and 14,371 are injured in disabled vehicle-related events each year in the United States (Spicer et al., 2021). The authors specify that these are mostly due to moving vehicles striking a disabled vehicle that is not moving; some of these fatalities and injuries also involve pedestrians, usually motorists who have exited their disabled vehicle or responders who are providing assistance to motorists at the scene. Moreover, an average of 18% of pedestrian fatalities on limited access facilities each year are related to disabled vehicles (Wang & Cincchino, 2020). These risks are not just limited to disabled vehicle crashes. In North Carolina, a five-year study of abandoned vehicle crash data found that there were 47 fatalities and over 500 injuries because of abandoned vehicles being left on the roadway (I-95 Corridor Coalition, 2007). These DAV-related crashes can still prove dangerous for drivers who do remain in their vehicles as well. A review of Signal 4 Analytics crash data from 2017 to 2019 in FDOT Districts 4, 5, 6, and 8 identified 901 DAV-related crashes, resulting in 25 fatalities and 325 injuries, along with over 500 property damage only (PDO) crashes, as shown in **Figure 1-1** (The GeoPlan Center, 2020).

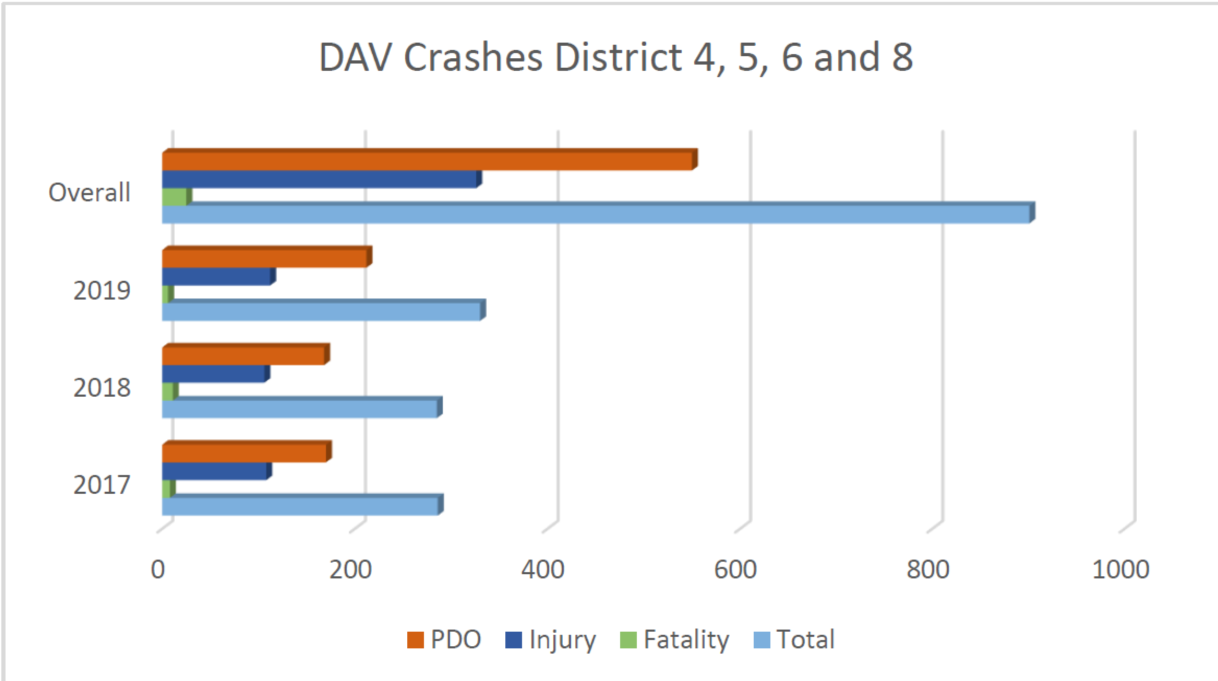

Figure 1-1: DAV Crashes in FDOT Districts 4, 5, 6, and 8 (2017-2019)
(The GeoPlan Center, 2020)

1.2 Research Goal, Objectives, and Tasks

The main goal of this research is to enhance and improve traffic operations and safety on FDOT roadways by evaluating the operational and safety impacts of DAVs on FDOT limited access roadways, identifying and evaluating methods to reduce these impacts, and estimating the benefits and costs of these methods. Impacts include injuries and fatalities of travelers due to crashes associated with these vehicles; congestion-related delays impacting commerce, productivity, and quality of life; and time spent by traffic management centers (TMCs) and responders handling disabled and abandoned vehicles. Various strategies to reduce the frequency of DAVs and their impacts will be studied and evaluated, including improvements to existing notification methods and response procedures, as well as new methods that could improve the handling of DAV events.

The following objectives need to be met to achieve the above goal:

- Review and evaluate existing practices, policies, procedures, and training methods used by FDOT and responding agencies such as Florida Highway Patrol (FHP) and Road Rangers to handle DAVs.
- Survey other states on their agency practices for dealing with DAVs to identify potential improvements or innovative methods that could be implemented by FDOT.
- Analyze historical SunGuide and Waze data to determine the frequency and potential impacts of DAVs on FDOT limited access roadways and shoulders.
- Study historical traffic crash data to understand the nature and frequency of hazards associated with DAVs stopped or parked on limited access roadways, including potential explanatory and mitigating factors.

- Estimate the costs of DAVs on limited access roadways. These costs include crash costs (injury/fatality costs, vehicle and property damage, etc.) and traveler delay to passenger and commercial vehicles due to congestion caused by DAVs.
- Recommend potential improved or alternative ways of dealing with DAVs, such as new response procedures or methods to more quickly detect DAVs.
- Conduct benefit-cost evaluations to show how the recommended improvements or new methods could reduce the frequency or impacts of DAVs and save money by reducing congestion and decreasing crashes and their associated injuries and fatalities.

The tasks used to achieve these objectives, including their methodologies and results, are discussed in the remainder of this report. Chapter 2 discusses the thorough literature review on the state of the practice in handling DAVs both in the state of Florida and nationally as well as methods to quantify their impacts. Chapter 3 discusses the design, implementation, and results of a national survey of stakeholders to better understand the operational and safety impacts of DAVs around the country and how agencies respond to these events. Chapter 4 discusses the data collection and analysis of DAV crash reports, non-crash SunGuide events, and Waze alerts to understand the nature and frequency of these events as well as their impacts to operations and safety. Chapter 5 discusses the developed congestion cost methodology used to quantify the congestion impacts of DAVs, three potential methods to improve the response to and handling of DAVs, and benefit-cost analyses of implementing these potential methods. Lastly, Chapter 6 discusses the overall conclusions of this project, including the operational and safety impacts of DAVs and recommended ways to reduce these impacts and improve response.

Chapter 2: Literature Review

To understand the operational and safety impacts of DAVs on FDOT roadways, an extensive literature review was conducted to understand the state of the practice both in Florida and nationally. Section 2.1 discusses the procedures various Florida agencies use to respond to DAV events and the results of these procedures while Section 2.2 discusses the DAV response procedures used by other states and their accompanying results. Section 2.3 discusses various benefit-cost analyses conducted on traffic incident response programs used for DAVs and other roadway incidents in previous research as well as the methods for conducting these and other similar benefit-cost analyses. Finally, Section 2.4 discusses the gaps in the previous research and how the results and findings from previous research can be used to bolster the current research and help understand the operational and safety impacts of DAVs on Florida roadways.

2.1 Florida Procedures for DAV Response

This section discusses TIM procedures for responding to DAV events in Florida as well as guiding procedures and laws that help facilitate these procedures. There are two common time-based measurements used to evaluate DAV response: roadway clearance time (RCT) and incident clearance time (ICT), as shown in **Figure 2-1**. RCT refers to the amount of time between the incident being reported and all travel lanes being open, while ICT refers to the amount of time between the incident being reported and all responders leaving the scene. Since 2002, FDOT and FHP have agreed to an Open Roads Policy (ORP) that is designed to expedite the removal of an incident from the roadway to restore traffic capacity after an incident (FDOT, 2014). This policy sets a goal of RCT within 90 minutes of the arrival of the first responding officer. Current programs and procedures meet this goal, as the average RCT for freeways was 33 minutes from July 1, 2019, to June 30, 2020 (FDOT, n.d.-b). In this same period, the average ICT for freeways was 64 minutes.

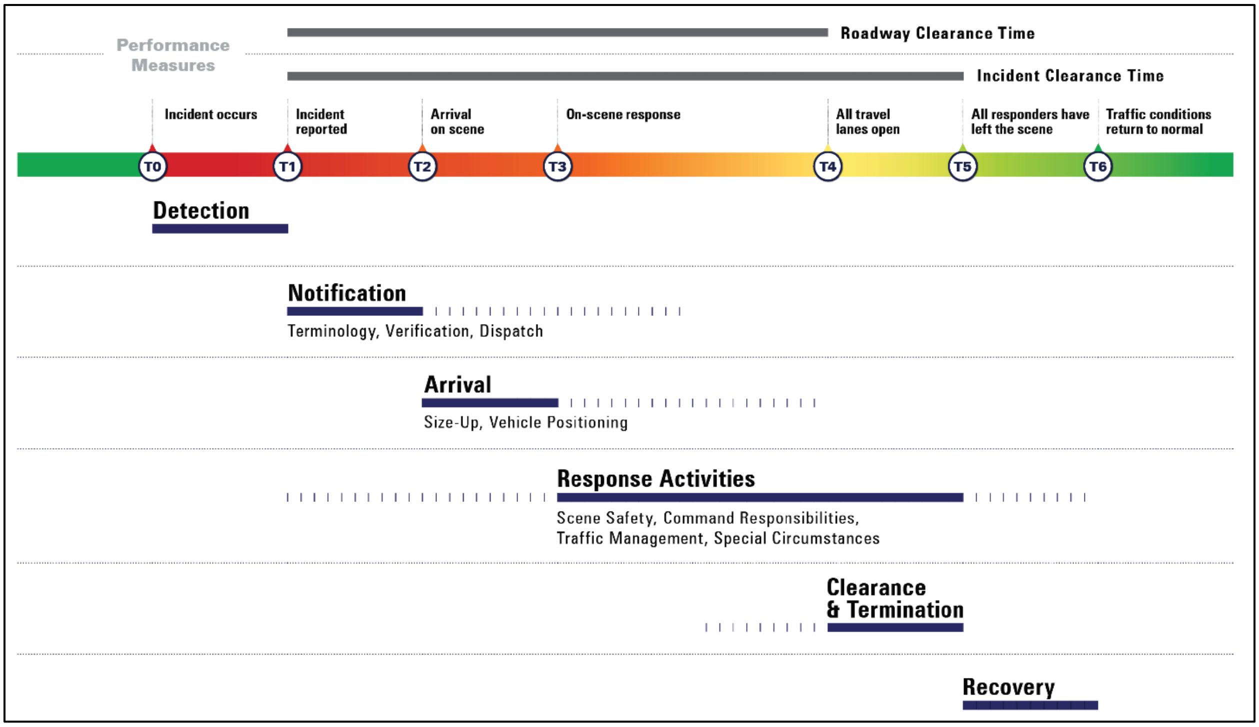

Figure 2-1: TIM incident duration timeline
(FHWA, 2019)

2.1.1 Traffic Incident Management in Florida

In the state of Florida, TIM is made up of many organizations at the state and local levels alongside partnerships with law enforcement, tow truck operators, emergency medical services, and similar agencies. At the state level, FDOT has a division for TIM and CVO which handles TIM programs for the state and coordinates with local TIM teams. TIM teams are active in all seven FDOT Districts as well as Florida's Turnpike Enterprise (FTE), with a total of 25 teams representing 43 counties. **Figure 2-2** shows the specific counties with TIM teams. These teams focus on improving response and clearance times, preventing secondary crashes, decreasing vehicle idling times and their associated pollutants, and improving safety.

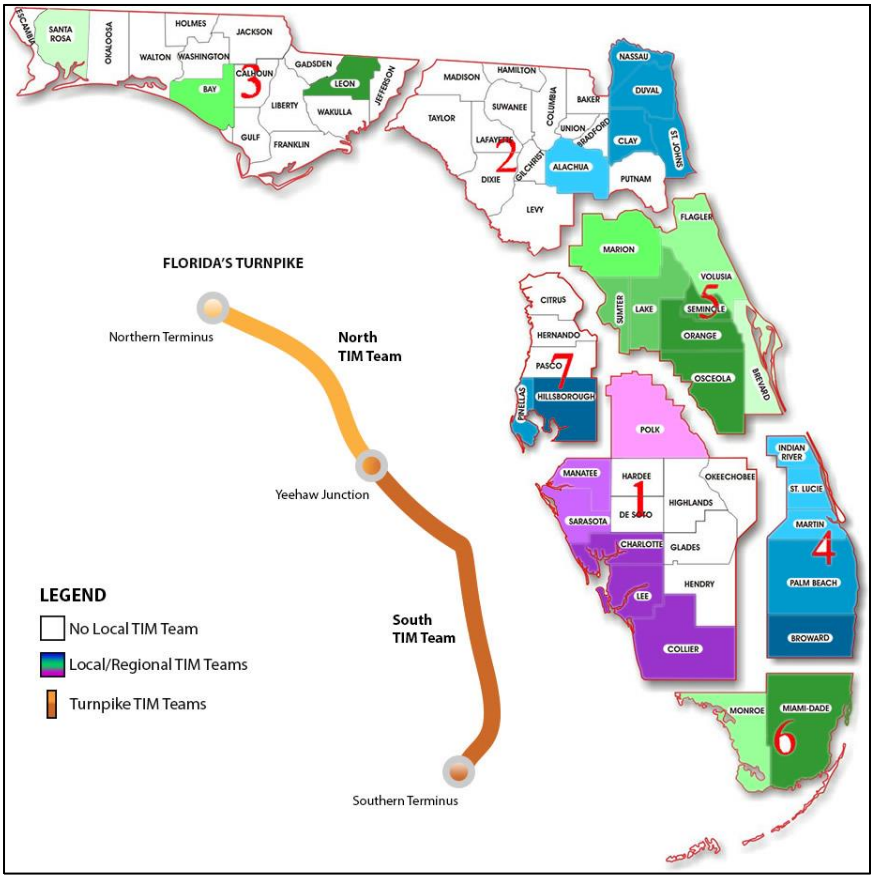

Figure 2-2: TIM team distribution in Florida
(FDOT, 2017)

An integral part of Florida TIM is data. There are two primary data sources used by TIM: SunGuide and FHP. These data are used to quantify TIM performance, demonstrate TIM effectiveness, and improve the planning process (FDOT, 2019). Intelligent transportation systems (ITS) collect data from a network of detectors and cameras across the state and transfer it to regional traffic management centers (RTMCs) to incorporate into SunGuide, which aggregates incident data for Florida limited access facilities. FHP computer-aided dispatch (CAD) data is integrated into SunGuide as well (FDOT, 2019). FHP dispatchers and RTMC operators often work together to quickly identify traffic incidents and work to clear them in an appropriate manner. By leveraging ITS infrastructure like Florida 511 and dynamic message signs (DMS) over roadways, drivers receive real-time information about roadway conditions, travel times, and downstream crashes.

Florida TIM involves many aspects that contribute to its operations, including public awareness and education. Campaigns can often make drivers aware of laws and procedures that they should follow when driving on Florida roads. There are two prevalent laws that involve TIM and help bolster the incident response and clearance procedures. The first of these is the Move Over law, which is outlined in Florida Statute (F.S.) 316.126 (*Operation of Vehicles and Actions of Pedestrians*, 2020). The Move Over law requires that drivers should move over a lane for stopped incident response vehicles, such as law enforcement or tow trucks. If a driver is unable to move over (such as when there are few lanes), they should reduce their speed to 20 miles per hour below the speed limit or to five miles per hour if the speed limit is 20 miles per hour or less. The second law is the Move It law, which is outlined in F.S. 316.071 (*Disabled Vehicles Obstructing Traffic*, 2020). The Move It law requires that when a vehicle is disabled and obstructing traffic, the driver should take actions to move the vehicle out of the travel lanes to allow the regular flow of traffic to resume. If they are unable to do so alone, they should seek assistance to move it, such as using the Road Ranger Service Patrol program.

2.1.2 Road Ranger Service Patrol Program

The most prominent and widely used program by Florida motorists is the Road Ranger Service Patrol program (known more commonly as Road Rangers), a free service offered by FDOT that patrols more than 1,500 centerline miles of limited access facilities throughout the state. Since the program's inception in December 1999, Road Rangers have provided more than 5.3 million assists across the state to both incident responders and motorists (FDOT CVO and TIM Program, 2017c).

While the Road Ranger program is statewide, it is managed on a district level in each of the seven districts and FTE. Each district determines the service hours, roadways patrolled, and contracting involved in the program as well as managing the program budget (FDOT CVO and TIM Program, 2018). Usage of the Road Ranger program varies by district and is reflective of district size and other factors, such as the cost of the contracting company and the number of vehicles in the fleet. **Figure 2-3** shows the number of Road Ranger events by district for the 2017-2018 fiscal year. The district with the most assists was FTE, followed by District 4. Most events across the state occur during the period of 6AM to 6PM, with about 21% of all events occurring from 3PM to 6PM (FDOT CVO and TIM Program, 2018).

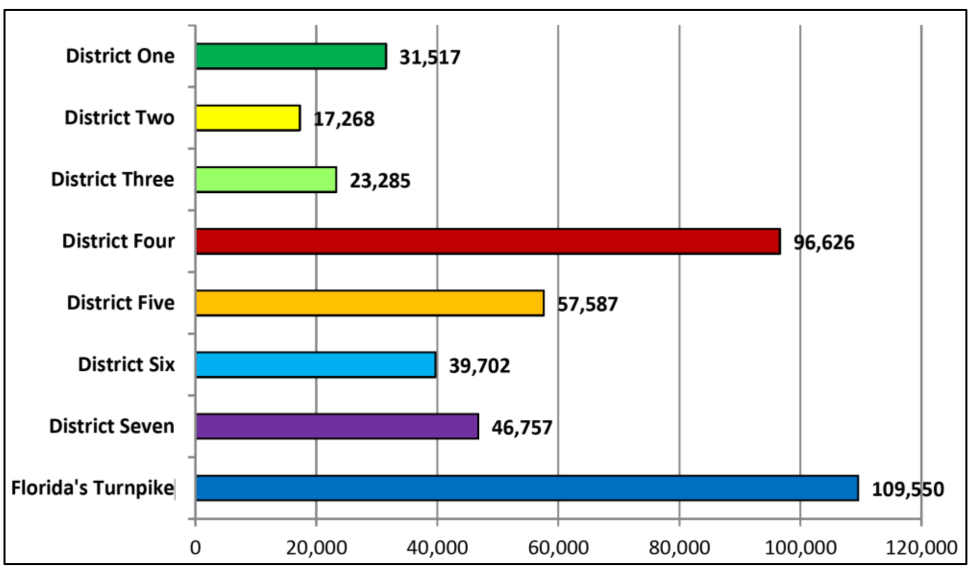

Figure 2-3: Road Ranger assists by district for the 2017-2018 fiscal year (FDOT CVO and TIM Program, 2018)

Road Rangers primarily provide two major services, the first of which is working alongside FHP and other responders to quickly clear incidents from the travel lanes. In a survey of 176 incident responders (such as FHP and towing services), Road Rangers were found to have arrived on scene within 30 minutes about 88% of the time (FDOT CVO and TIM Program, 2017c). The most common reason for incident responders to request a Road Ranger was to provide maintenance of traffic assistance while responding to an event. While most respondents were extremely satisfied with the competency, professionalism, respectfulness, and helpfulness of the individual Road Rangers they work with, they did offer some suggestions for improving the program as a whole. The most common suggestion was a more direct communication method between the Road Rangers and on-scene incident responders. Other common suggestions included extending service hours and increasing the towing capabilities of the vehicles to clear an incident more quickly.

The second main service provided by Road Rangers is assisting individual motorists whose vehicles are disabled due to having a flat tire, no gasoline, or other minor vehicle issues. Each year, most of the assists Road Rangers provide to motorists involve a disabled vehicle. During the period of July 1, 2017, to June 30, 2018, Florida Road Rangers responded to approximately 259,000 events involving a disabled vehicle, comprising about 62% of all roadway events for that fiscal year (FDOT CVO and TIM Program, 2018). During the 2016-2017 fiscal year, 8,416 motorists left feedback on their experience with Road Rangers. These responses come from all the districts excluding FTE and a part of District 4. About 50% of respondents stated that the reason they needed a Road Ranger was for a tire change (FDOT CVO and TIM Program, 2017b). This report also showed that about 88% of the time, a Road Ranger arrived within 15 minutes of the event occurring. Additionally, most motorists who utilized Road Rangers were extremely satisfied with their assistance (FDOT CVO and TIM Program, 2017b). Road Rangers are also able to keep other motorists safe by utilizing digital alert technology that pushes alerts to navigation providers to help warn drivers of roadside incidents. These alerts help keep Road Rangers, the vehicles they are assisting, and other drivers safe by increasing awareness of the incident.

While the Road Ranger program is well-received by both incident responders and motorists, there are some issues affecting the success of the program. Even though the Road Ranger program is an FDOT-backed safety program available to all Florida travelers, having sponsorships with other entities (such as the insurance company State Farm) has led to driver confusion about who is eligible to use the program. This potential confusion reduces the number of drivers utilizing the program as these drivers may not realize it is a free service provided by FDOT and not part of another company's services (FDOT, 2019). Another commonly mentioned issue with the Road Ranger program is the need for vehicle improvements, such as having more vehicles capable of towing or removing a vehicle and better lighting and signage on the vehicles to tell drivers to move over and avoid the scene (FDOT, 2019). Lastly, Road Rangers can help FHP tag abandoned vehicles for removal in some locations, but this capability is not available statewide. Increasing the number of Road Rangers that are able to tag abandoned vehicles could help to mitigate the potential safety hazards posed by these vehicles (FDOT, 2019).

2.1.3 Rapid Incident Scene Clearance Program

Florida's TIM program includes some programs targeted to specialized events that a Road Ranger would not be able to address. A statewide program known as the Rapid Incident Scene Clearance (RISC) program is an incentive-based incident clearance program designed to handle major highway incidents involving specific vehicles, such as tractor-trailers, motor homes, and buses. Addressing incidents that involve these kinds of heavy vehicles requires specialized equipment that is not standard on other tow trucks or service patrol vehicles, such as a 50-ton capacity wrecker. The RISC program covers approximately 1,590 centerline miles of limited access roadways in Florida, of which 460 are on the FTE system (FDOT CVO and TIM Program, 2017a). Vendors that are part of the RISC program receive bonus incentive payments based on how quickly they can clear an incident from the roadway. **Figure 2-4** shows the RISC incident timeline and bonus incentive payment structure. During the 2016-2017 fiscal year, RISC was activated 233 times and paid out $577,700 to vendors for meeting clearance incentives (FDOT CVO and TIM Program, 2017a). RISC was activated the most on the FTE system with 43% of all RISC activations occurring on its roads. This specialized response has been noted as a best practice in other research, with other states utilizing similar programs in their TIM procedures (Dougald et al., 2016).

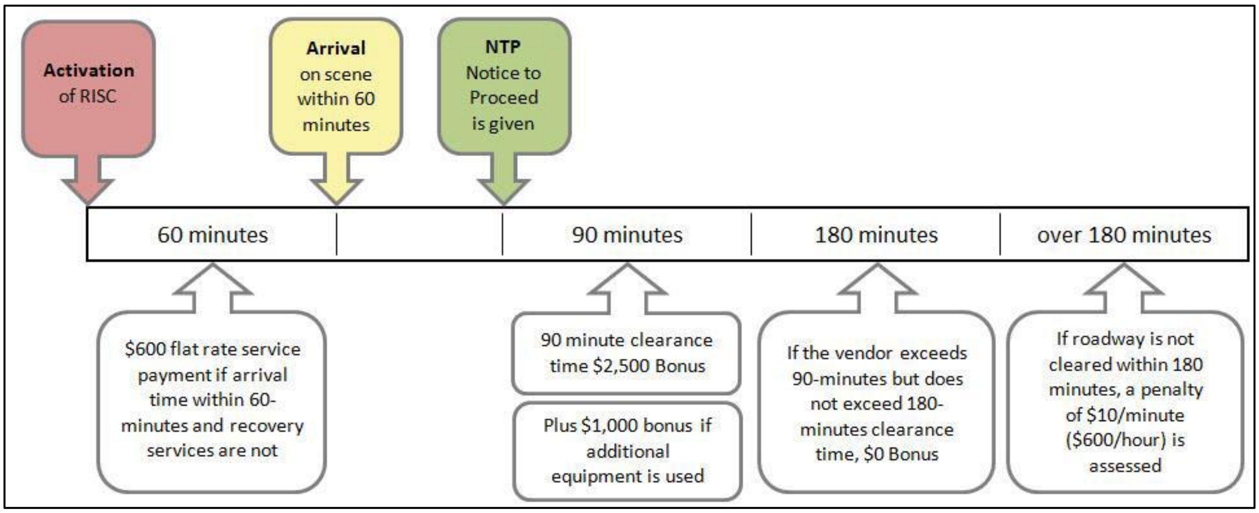

Figure 2-4: The RISC incident timeline and bonus incentive payment structure (FDOT CVO and TIM Program, 2017a)

2.1.4 Severe Incident Response Vehicle Program

While Road Rangers typically assist disabled vehicles or abandoned vehicles, dispatching a Severe Incident Response Vehicle (SIRV) is another option for those in Southeast Florida involved in a more serious incident. Since the program was created in 2005, a SIRV is dispatched for an incident that involves a full highway closure, fatalities, overturned commercial trucks, or other events that could last longer than two hours (FDOT District Four ITS, 2013). Currently, the SIRV program only operates in District 4. While similar to the RISC program in that it focuses on major incidents, SIRVs do not require the kind of special equipment that RISC vendors need, such as a heavy wrecker. However, SIRVs do carry some specialized equipment, including more than 700 pounds of spill absorbent materials. The SIRV program is designed to mitigate the delays caused by severe incidents by providing a safer work zone for emergency responders and subsequently assisting in debris removal and other incident support tasks (FDOT, 2020). Based on the success of the SIRV program on limited access facilities, the program has been expanded to arterial roadways in District 4 since 2019.

2.1.5 Towing Programs

The last major element of TIM in Florida is the various towing programs used in smaller capacities around the state. One of these programs is instant dispatch tow, which involves dispatching a tow truck and FHP officer simultaneously to quickly clear a roadway of an event. Due to the language of F.S. 321.051(4) (*Florida Highway Patrol Wrecker Operator System*, 2020), which relates to who can request towing services for a crash or disabled vehicle, FHP officers typically wait to dispatch a tow truck to clear an event until they talk with the driver and confirm they do not have their own preferred towing arrangements. Since few drivers request their own tow truck and most rely on FHP to arrange a tow to move the vehicle, this practice ultimately increases clearance time (FDOT, 2019).

Two other towing programs are the staged towing and safe tow. Staged towing refers to having tow trucks waiting in strategic locations to help quickly clear vehicles. Currently, this program is only used for tow trucks on the Howard Franklin Bridge in Tampa and on the I-95 Express Lanes in Miami (FDOT, 2019). The safe tow program involves relocating a disabled vehicle from the event location to a safer location that does not impede traffic or put the driver at a safety risk. Currently, District 2 utilizes a safe tow program and FTE uses a similar program known as Specialty Towing and Roadside Repair (STARR). Unlike the free Road Rangers program, STARR charges for its services, which include towing, changing a flat tire, and others (FTE, n.d.).

2.2 Elements of DAV Analysis and Response from Other States

The programs in a TIM strategy can vary greatly from state to state, as well as between jurisdictions within a state. This section discusses some elements of TIM programs from other states and how other states handle DAVs, in addition to analyses of the characteristics of DAV events. These include laws and policies, data sources, identified characteristics of DAV events, and specific services and programs.

2.2.1 Laws and Policies

There are many laws and policies that affect DAV response procedures. While each state or jurisdiction has their own laws with specific wording, there are common types of laws and policies that many states use. These include “Move Over” laws, driver removal laws (“Move It” laws), authority removal laws, and others. The most widespread law is the “Move Over” law, with some form of this law present in all fifty states (American Automobile Association [AAA], n.d.). The Florida version of this law is discussed in Section 2.1. These laws are focused on having drivers move over a lane (if possible) or slowing down to a certain speed when in the vicinity of emergency vehicles to give the responders room to manage the incident. Carson (2008) notes that most of these laws include tow trucks as emergency vehicles as well, but not all states include them. A common issue with many “Move Over” laws is that they may not encompass as many responder types as they need to, such as some states not including safety service patrol responders (Carson, 2008). Another issue with “Move Over” laws discussed by Spicer et al. (2021) is that they only apply when responders are on the scene of an incident. If a vehicle is disabled on the side of the road and the driver does not seek assistance from event responders, “Move Over” laws do not require other drivers to move over (Spicer et al., 2021). As such, drivers whose vehicles have become disabled can be at an increased risk of being struck compared to when responders are on the scene and other motorists are legally required to move over.

Driver removal laws, also known as “Move It,” “Clear It,” or “Fender Bender” laws, require that motorists involved in minor traffic incidents should remove their vehicle from the travel lanes until the drivers can exchange information or law enforcement arrives (FHWA, 2019). This type of law is present in Florida, as discussed in Section 2.1. Typically, drivers are encouraged to move their vehicles to at least the shoulder of the roadway, but any safe area out of the travel lanes is acceptable. The primary goal of this law is to enhance safety, as leaving motorists and their disabled vehicles in the travel lanes can pose a risk to themselves and other drivers. It also creates a risk for any responders (such as safety service patrols or law enforcement officers) who are on the scene of the incident. According to Carson (2008), driver removal laws can be difficult to enforce, and their success relies on the cooperation of the motoring public. When drivers follow these laws and consistently remove their vehicles from the travel lanes after a disablement, there can be significant benefits. A 2007 study of South Carolina’s driver removal law found that it helped reduce delay by 11% and saved an average of $1,682 per lane-blocking incident, which can add up to substantial savings when considering how many minor incidents occur (Hamlin et al., 2007). Carson (2008) notes that another issue that driver removal laws face is that they can suggest that vehicles on the shoulder are not a hazard. While being removed from the travel lanes reduces the risks of injury to motorists and responders, the shoulder is still not completely free of risk. Legislations encouraging drivers to move their vehicles as far from the travel lanes as reasonable can help minimize any shoulder risks involved (Carson, 2008).

Authority removal laws, sometimes called “Hold Harmless” laws, give certain public agencies the ability to remove disabled vehicles from the roadway if they pose a hazard (FHWA, 2019). Specific wording varies by state, but these laws often allow an agency to remove vehicles from the travel lanes or other right-of-way without needing to rely on the driver to do so. These agencies are typically not held liable for any damage to the vehicle when moving it, which is typically included as part of a “Hold Harmless” clause. Authority removal laws share a similar goal with driver removal laws in that they seek to expedite the removal of vehicles from travel lanes to minimize congestion and potential safety risks (Carson, 2008). These laws can be particularly useful for the removal of abandoned vehicles on roadways if legislation permits it. Carson (2008) also specifies that legislation surrounding abandoned vehicles vary by state but abandoned vehicles can typically be left on the roadway for 24 to 72 hours. After this point, law enforcement or another agency as defined in the authority removal law can remove the vehicle from the right-of-way. Often, the question about who can tow an abandoned vehicle and who pays for the tow can impede quick removal from the scene. Tow companies can be reluctant to move abandoned vehicles since they typically must bear all the costs with no one to pay them back (I-95 Corridor Coalition, 2007). However, not all states allow for invoking the authority removal law when removing abandoned vehicles (Carson, 2008). Having these laws apply to both disabled and abandoned vehicles, rather than just disabled vehicles, can give agencies more power to remove abandoned vehicles.

The last major policy that some states utilize is the Open Roads Policy (ORP). Although the name of the policy can vary state to state, ORPs are focused on quickly and urgently removing vehicles or other debris from the roadway to restore traffic conditions. This is achieved with interagency agreements, typically between law enforcement and the agency managing the roadway (such as the state department of transportation [DOT]). Currently, eight states have ORPs: Florida, Georgia, Maryland, Minnesota, New Hampshire, Nevada, Tennessee, and Washington (Kinney, 2020). Most of these ORPs have goals of having incident traffic control at the scene within 30 minutes of being notified of the incident during working hours and within 60 minutes after hours or during the weekend, along with a roadway clearance goal of 90 minutes. As discussed in Section 2.1, FDOT meets and exceeds this roadway clearance goal.

2.2.2 Identification of DAV Characteristics and Data Sources

Understanding the characteristics of DAV events is important to determine the methods which can most effectively reduce these events. To obtain this understanding, a variety of DAV-related data are needed. These data are used to understand the nature of DAV events, where they occur, how frequently they occur, and many other aspects. One of the most important aspects surrounding DAV events is incident duration. Many of the laws, policies, and programs that other states utilize are geared towards reducing incident duration. Reducing incident duration serves to keep both responders and motorists safe, as responder risk exposure and the number of secondary crashes are both reduced with quick clearance (FHWA, 2019). A common way of visualizing the incident duration timeline is shown in **Figure 2-1** in Section 2.1. The times associated with each stage of the timeline can be obtained from a variety of sources, including RTMC monitoring, roadway cameras, safety service patrols, law enforcement and any of their associated event reports, and data from motorists (such as 911 call data and Waze data). As mentioned in Section 2.1, RCT and ICT are two common time-based measurements of DAV response. Another common measurement is the number of secondary crashes. However, it can sometimes be difficult to determine what is a secondary crash and what is not, so this measurement can require human judgment (Souleyrette et al., 2018).

Depending on the project scope and goal, various data sources can be leveraged to understand the nature of traffic events, including DAVs. In a report for the Kentucky Transportation Cabinet (KTC), Souleyrette et al. (2018) used four different data sources to determine baseline performance measures for RCT, ICT, and secondary crashes. These four datasets were Kentucky State Police crash data, incident records from the Louisville metropolitan area containing both crash and non-crash data, Waze data, and probe vehicle speed data. The crash and incident datasets were used to determine RCT and ICT along with any secondary crashes while the Waze and speed datasets were used to identify event start and event detection times (Souleyrette et al., 2018). According to the authors, the speed data provided from Waze along with the probe vehicle speed data can help to identify events, as sudden speed drops across multiple sources can suggest an event has occurred. After evaluating all sources, the crash reports became the primary source of data while the other sources helped to supplement the crash data (Souleyrette et al., 2018). The authors concluded that all the evaluated data sources provided important information for various aspects of incident event response, so leveraging all of them can be useful for agencies trying to understand the nature of roadway events in their jurisdictions.

One of the data sources used by Souleyrette et al. (2018) which has seen more use in recent years is Waze, the smartphone application that allows drivers to report traffic conditions in real time. Using Waze, drivers can report many events in traffic, including disabled vehicles. The use of crowdsourced data from Waze can help to bolster existing data sources (such as RTMC monitoring data) and assist with timely incident management, such as how Souleyrette et al. (2018) used Waze data in conjunction with other datasets. Amin-Naseri et al. (2018) compared a year of user-reported Waze data with data from Iowa's advanced traffic management system (ATMS) to understand how reliable the Waze data was and what kind of value it could provide to traffic managers. They found that Waze data often overlapped with the ATMS data, with about 43.2% of reports being present in both. Moreover, they found that the user-reported events in Waze reported incidents about 9.8 minutes earlier than their existing probe-based alternatives. However, due to the crowdsourced nature of Waze, data was most sparse and unreliable during nighttime hours between 12AM and 6AM when fewer drivers are on the road (Amin-Naseri et al., 2018). The authors conclude that Waze is an important addition to traffic data, especially for incident detection.

Goodall and Lee (2019) also evaluated Waze data, but looked specifically at disabled vehicle events. The authors evaluated Waze data over a 36-day period in Virginia and compared it with data from the traffic operations center (TOC), including video images from traffic cameras. There were 560 disabled vehicle reports in Waze during this study period (Goodall & Lee, 2019). About 22% of the reported disabled vehicles were verified by the TOC as valid reports, but about 50% were unable to be confirmed either due to poor video quality or being outside the range of a camera (Goodall & Lee, 2019). The authors also found that 23% of Waze reports were false reports, as the video images obtained by the TOC operators did not indicate a DAV event. Goodall and Lee (2019) note that the study area was an urban area with dense camera coverage and that rural areas with less camera coverage may see more benefits from Waze reports (since Waze alerts could notify operators of events they otherwise would not have detected due to the lack of camera coverage). Regardless of area type, the authors recommend that Waze data should only be used to verify events due to the presence of false reports.

2.2.3 Safety Service Patrol Programs

Practically every state uses safety service patrols (SSPs) in some capacity to address disabled vehicles and, to a lesser extent, abandoned vehicles. These service patrols often focus on reducing roadway or incident clearance times by providing helpful services to motorists in disabled vehicles, although the scope and procedures of these patrols can vary by state. SSPs can be operated on a state, regional, agency, or metropolitan area level. DAV event statistics and handling procedures for some of the SSPs in the United States are discussed in this section.

In Minnesota, the Twin Cities area (the combined metropolitan area of Minneapolis and Saint Paul) utilizes the Freeway Incident Response Safety Team (FIRST) program to help minimize congestion and assist disabled vehicles. According to the Minnesota Department of Transportation (MnDOT, 2013), FIRST trucks patrol 382 miles of freeways from 3:30 AM to 9:00 PM on weekdays with some limited coverage on weekends. In 2011, FIRST responded to nearly 26,000 incidents, primarily stalled vehicles (71% of incidents), crashes (18% of incidents), and debris (5% of incidents) (MnDOT, 2013). MnDOT also specifies that about 55% of these incidents are first found by FIRST trucks that patrol the freeways, with other detections coming from RTMC cameras and 911 calls to the Minnesota State Patrol. FIRST trucks are equipped to clear traffic lanes blocked by disabled vehicles or debris, provide maintenance of traffic for incidents they cannot move on their own, assist motorists who need minor services (such as a battery jump start or tire change), and remove abandoned vehicles from the roadway shoulder (MnDOT, 2013). According to MnDOT (2013), this program cost $1,592,425 in 2011 and had a calculated benefit-cost ratio of 15:1 in 2004.

The Indiana Department of Transportation (INDOT) uses a similar program known as Hoosier Helpers. The Hoosier Helpers cover 177 miles of interstates in central, northwest, and southern Indiana (INDOT, n.d.). According to INDOT (n.d.), the program has helped over 350,000 motorists since 1991 by changing flat tires, fixing minor mechanical problems, providing small amounts of fuel, providing emergency medical assistance, and removing debris from the roadway. Latoski et al. (1998) found that operating the program 24 hours a day, 7 days a week, had a benefit-cost ratio of 13.28:1 compared to a benefit-cost ratio of 4.71:1 if it was just operated in the daytime. These results suggest that some of the greatest benefits of SSPs come from nighttime operations.

Some SSP programs utilize several types of response vehicles, such as the Maryland Emergency Traffic Patrols (ETP) program. The ETP program is a part of the Maryland Coordinated Highways Action Response Team (CHART) and operates 24 hours a day, 7 days a week, in the Baltimore and Washington, D.C. areas and from 5:00 AM to 9:00 PM in other areas of Maryland (Maryland DOT CHART, n.d.). Statistics on the Maryland CHART website note that the program assists around 37,400 motorists each year and has helped to reduce incident duration by up to 50%. A part of this success is from the three types of specialized vehicles used by the program: heavy-duty utility body trucks, tow trucks, and custom response vehicles (CRVs) (Maryland DOT CHART, n.d.). Although each vehicle has similar equipment on board, such as warning devices, arrow boards, and vehicle relocation equipment, each vehicle is deployed for specific incidents. For example, CRVs are deployed when directions are needed to instruct other drivers approaching the incident due to it being the only vehicle with message board capabilities (Maryland DOT CHART, n.d.). They also come equipped with a generator and floodlights, making them the ideal vehicle for nighttime incidents. **Figure 2-5** shows a typical CRV and its equipment (Maryland DOT CHART, n.d.).

Figure 2-5: A CRV used as part of the Maryland ETP program
(Maryland DOT CHART, n.d.)

Other patrol programs have been created more recently, such as the Incident Response Unit (IRU) used by the Arizona Department of Transportation (ADOT). Started in October of 2019, this team primarily provides traffic control and assistance at crash scenes but also assists motorists and performs minor roadway maintenance (ADOT, n.d.). In its first year, it responded to more than 10,000 incidents and was praised by many motorists in the Phoenix area (Larson, 2020). This team replaced the Arizona Local Emergency Response Team (ALERT) which was staffed by highway maintenance workers who would only respond to incidents when called upon, which could take time as they were not actively prepared for an incident and rather responded to incidents as a secondary activity. With the IRU, the responders are focused on traffic incident management and perform other duties when there are no active calls. This shift in priority is intended to reduce response times by half (ADOT, n.d.).

In recent years, the insurance company State Farm has sponsored many SSPs as part of their Assist Patrol program. This program is a partnership between State Farm and state agencies to locate accidents, clear roadway debris, and assist motorists with disabled vehicles. In many cases, the name of the patrol is simply "State Farm Service Patrol" or another similar name. In other cases, the program operates under its own name but is merely sponsored by State Farm. Some of the state programs that fall into this category include Indiana with its Hoosier Helper program, Maryland with its ETP program, Arizona with its IRU program, and Florida with its Road Ranger program (State Farm Assist Patrol, n.d.).

2.2.4 Towing Programs

Many agencies use a towing program to help move disabled vehicles out of the right-of-way to minimize delays and improve roadway clearance time. These programs are typically in the form of a public-private partnership where the agency works with private towing companies to tow vehicles. One such towing program is the Houston Tow and Go program, formerly known as the SafeClear program, which provides many towing related services to motorists on freeways. These include free towing off the freeway to a nearby safe location within one mile of the incident location, free towing to a storage lot where the vehicle can be left for 48 hours before accruing fees, and a flat fee for a tow to any location within 20 miles of the incident location (City of Houston, n.d.). However, the City of Houston specifies that if the vehicle is abandoned, involved in a crash, or involved in an incident with law enforcement, the tow would not be free, and the owner would have to pay any fines associated with the tow. The program has a goal of having at least 90% of responses within six minutes of the incident occurring. This goal is often exceeded, with about 98% of all responses being within six minutes of the incident occurring (Lomax & Stein, 2014).

Another towing program that has seen success is instant dispatch tow. The Virginia Department of Transportation (VDOT) piloted an instant tow program that simultaneously dispatched a tow truck and a Virginia State Police trooper to lane blocking incidents to reduce clearance time (Dougald et al., 2016). According to the authors, a trooper would need to arrive on the scene and verify if the incident needed a tow truck to remove the vehicle prior to starting the instant dispatch tow program. Under this program, tow truck operators would be reimbursed by VDOT for any instances where they arrived on the scene but a tow truck was not needed. VDOT estimated that only 5% of dispatches would result in the tow truck not being needed, costing around $2,000 a month in reimbursements to operators (Dougald et al., 2016). Washington state used a similar instant dispatch tow program and found that it reduced incident clearance time by an average of 15 minutes due to the elimination of the trooper verification step (Nee & Hallenbeck, 2003).

While many towing programs focus on lighter vehicles, such as passenger vehicles, some are focused on major incidents or heavier vehicles that may require specialized equipment. One such program is the Towing and Recovery Incentive Program (TRIP) utilized by the Georgia Department of Transportation (GDOT) in the greater Atlanta area. The program, which is managed by the Georgia Traffic Incident Management Enhancement (TIME) Task Force, is focused on quickly clearing large commercial vehicle incidents by providing a monetary incentive to tow truck operators with specialized equipment (Georgia TIME Task Force, 2020). These types of incidents include truck tractor semi-trailer combinations, motor homes, buses, and any complex or extended incident where specialized equipment would be needed. A benefit-cost analysis of the TRIP program found that it resulted in a cost savings of $456,396 per incident with an overall benefit-cost ratio of 10.96:1 (PBSJ & Serco, 2011). Even with conservative estimates of the benefits, the determined benefit-cost ratio was 5.35:1, suggesting the program was a good return on investment.

2.3 Evaluations and Benefit-Cost Analyses of Incident Response Programs

To determine the performance of incident response methods and programs used to handle DAVs and other traffic incidents, their benefits (reductions in RCT, ICT, traveler delay, etc.) and costs can be compared. This section focuses on the benefit-cost analyses of response and TIM programs both in Florida and other states. It is important to note that most previous research has not evaluated the impact of DAVs, instead focusing on the response to DAVs in the form of TIM programs. As such, this section primarily focuses on SSPs that work extensively with DAVs. However, DAVs are not the only incidents SSPs respond to, so it is important to bear in mind that the benefits and costs of these programs will differ from the benefits and costs of programs that only address DAVs. The benefits and costs of some programs were already discussed in the previous sections. It is important to note that many benefit-cost evaluations have been performed for various SSPs since the 1990s. Many of these evaluations were similar in approach and structure, with the only differences being the location and program being evaluated. To avoid excessive repetition, this section focuses on major evaluations and ones with notable results or novel approaches.

2.3.1 Benefit-Cost Evaluation Methods and Approaches

After a response program has been launched, it is important to evaluate it to understand if it is meeting performance goals and is cost-effective. Response programs generally work to meet at least three primary goals (reductions of RCT, ICT, and secondary crashes), but other goals can be created based on the program and its scope (FHWA, 2019). Zhang et al. (2020) developed a TIM dashboard that utilizes these three primary performance measures along with the number of responders struck by crashes (where first responders are hit by a vehicle while responding to an event) and the number of commercial vehicle crashes. Due to data issues, Zhang et al. (2020) used responder vehicle crashes as a substitute measure for responders struck by crashes. Using these kinds of performance measures can give agencies insights into how effective their response programs are on a year-by-year basis.

These performance measures can also be useful when trying to evaluate the benefits and costs of a response program, as improving these performance measures (i.e., reducing event time and number of secondary crashes) leads to monetary benefits. When developing a benefit-cost analysis, it is important to quantify the benefits and costs as thoroughly as possible. While there are no benefits to a DAV event occurring, there are many associated costs. These costs include increased congestion and delays for other motorists on the road, increased fuel consumption, and increased risk of injury from a secondary crash. Congestion and its associated fuel costs are one of the greatest costs financially for other drivers on the roadway. Schrank et al. (2019) found that in a 2017 evaluation of mobility across the United States, drivers lost about $179 billion to delay and fuel costs due to waiting in traffic. About 54% of this loss comes from travel delays on freeways, which includes non-recurring congestion in the form of disabled vehicle events along with other unexpected events (Schrank et al., 2019). Developing response programs that work to reduce these impacts on a local level can help reduce these costs and provide benefits to travelers. Beyond reductions in congestion-related travel delay and its associated fuel consumption, there are other benefits to response programs; these benefits include a reduced number of secondary crashes; reduced responder risk of injury while working an incident; improved response times; reduced emissions; and improved motorist satisfaction.

Quantifying some of these elements can be straightforward, but others can be more involved or may not be able to be measured precisely. One of the major impacts of DAVs is the delay associated with these events. There are three primary approaches to estimating delay: deterministic queueing and shockwaves, simulations, and regression models and statistical approaches (Margiotta et al., 2012). Each have their own data requirements, benefits, and shortcomings. Deterministic queueing and shockwaves are the easiest to work with and typically require the least amount of data. However, Margiotta et al. (2012) note that this approach can oversimplify some problems due to its underlying assumptions. For example, shockwaves tend to report shorter recovery time as they only calculate queue dissipation time, which does not necessarily equal the time to return to pre-incident traffic flow conditions (Margiotta et al., 2012). Simulations typically require the most data but give the most accurate results. However, a simulation is only as accurate as the data and methods used to construct it, and many TIM teams may not have people with the necessary data, skills, and time to create a simulation specific to their region of focus (Margiotta et al., 2012). Simulation software can be adapted from other published simulation packages, but the issue of result validity becomes more relevant as the simulation is modified and adapted to the region of focus (Margiotta et al., 2012). The final approach is using regression models or other statistical approaches to model delay. Data requirements can vary based on what type of model is being used, but more data is generally better. With these models, it can be difficult to make site-specific determinations of delay impacts since regression models tend to be generalized (Margiotta et al., 2012). Moreover, the explanatory power of the model may be poor based on the kind of data used. As such, each prevailing delay calculation method has its own drawbacks when used independently. Similar issues arise when determining other elements needed for a benefit-cost analysis, such as congestion costs and environmental impacts.

Due to the many possible elements that can be included in a benefit-cost analysis and potential uncertainty in the validity of the results, some agencies may be hesitant to conduct their own analyses. To help ease these concerns, the FHWA's Turner-Fairbank Highway Research Center developed a free web-based TIM benefit-cost analysis tool called TIM-BC. This tool uses standardized methodologies that can be universally employed to evaluate eight different TIM programs (Ma et al., 2016). These eight programs are SSP, driver removal laws, authority removal laws, shared quick-clearance goals, pre-established towing service agreements, dispatch colocation, TIM task forces, and Second Strategic Highway Research Program training. The TIM-BC tool is user-friendly and less data-intensive than other methods due to leveraging regression models, microscopic simulation data, and real-world data, ultimately requiring users to not need as much data compared to other tools (Ma et al., 2016). This makes the tool suitable for agencies that may not have adequate or relevant data to conduct an analysis using other means. The TIM-BC tool is also able to estimate travel delay, fuel consumption, emissions, and secondary incidents. Of particular note is the tool's ability to evaluate the impact of various laws related to TIM, which is often overlooked in other analyses.

2.3.2 Safety Service Patrol Evaluations

The most common benefit-cost evaluations performed by transportation agencies focus on their SSP programs. SSPs can help to quickly identify disabled vehicles, provide preliminary assistance to the vehicles, and potentially resolve the event in a short amount of time. Moreover, some SSPs can assist in identifying and tagging potentially abandoned vehicles for later removal. The ability of SSPs to identify events and respond accordingly in a timely manner make them one of the easiest and most direct ways to mitigate the impact of DAV events. Their efforts in reducing DAV event durations are often one of the biggest benefits of the program, but evaluation methodologies can vary depending on the jobs and responsibilities of a given SSP. Typically, evaluations of SSP programs use annual operating costs as a part of the considered expenses, so benefit-cost evaluations for a single year are adequate rather than conducting a life-cycle cost evaluation (Pecheux et al., 2016). Benefit-cost evaluations can vary greatly based on the input data used, so direct comparisons between programs and their benefit-cost ratios are not recommended (Pecheux et al., 2016).

States have been evaluating SSP programs since the 1990s, with one of the earliest examples being the work performed by Skabardonis et al. (1995) on the California Freeway Service Patrol (FSP). In their research, the authors collected data before and after the implementation of the FSP along a nine-mile section of I-880 in 1993 to understand program effectiveness in reducing the impacts of incidents. This section was selected due to high data availability, little to no roadway shoulders, high event frequency, no ongoing construction activities, and a lack of existing tow truck services (Skabardonis et al., 1995). The authors found that the program greatly improved response times due to the frequent patrols of FSP trucks, leading to a 38% reduction in incident response time. The program was also cost-effective with a benefit-cost ratio of 3.35:1 (Skabardonis et al., 1995). The authors used reductions in travel delay, fuel consumption, and fuel emissions as the primary benefits of the program, but they noted that there are other benefits (such as the value of motorist satisfaction) that can be harder to quantify. Most of the program costs came from contracting tow companies, but other included costs were operational costs, administrative costs, and capital costs (Skabardonis et al., 1995). Later research by Skabardonis et al. (1998) evaluated an eight-mile stretch of I-10 using a similar approach as Skabardonis et al. (1995), which found a benefit-cost ratio of 5.6:1. These two studies led to the development of the Freeway Service Patrol Evaluation (FSPE) model, which incorporates data about FSP assists along with geometric and traffic characteristics of the patrol area (Mauch & Skabardonis, 2016). The FSPE model has been used extensively in California and has also been applied to SSPs in other states, such as by Lin et al. (2012) in Florida as part of an evaluation of the Road Rangers.

The Road Rangers are Florida's SSP program, and Lin et al. (2012) conducted a benefit-cost evaluation of the program. The authors compiled data from each district in Florida for the year 2010 to conduct analyses for each district as well as the entire state. These data were sourced from district Road Ranger managers, SunGuide, and FDOT files about design and traffic characteristics (Lin et al., 2012). As mentioned previously, the evaluation used the FSPE model developed by the University of California, Berkeley. The authors calibrated this model to adapt it to Florida conditions as much as possible. The benefits considered in this study were reduced travel delay, reduced fuel consumption, and reduced fuel emissions while the contracting cost of the Road Ranger fleets was the only cost (Lin et al., 2012). Overall, the program was found to be cost effective in each district as well as the entire state, with District 7 (Tampa Bay area) having the highest benefit-cost ratio (11.09:1) and FTE having the smallest benefit-cost ratio (3.28:1) (Lin et al., 2012). The overall state benefit-cost ratio was 6.68:1 based on about $134 million in benefits and about $20 million in costs. While the evaluation suggests the program is cost-effective, the results may not be fully accurate. The model used by the authors was developed for California and not Florida, leading to various limitations in their study. Particularly, the emissions lookup tables were not specific to Florida and are based on California emission rates instead. Moreover, the model is based on capacity reduction factors, but events that do not affect capacity can still create impacts in other ways. As such, developing a model that is specific to Florida that considers more event types could give more accurate results.

The state of Iowa has also evaluated their SSP program. Known as the Highway Helpers, this SSP program provides travelers in the greater Des Moines area with assistance including battery jump starts and tire changes (Khalilzadeh, 2020). Beyond assisting motorists, they also assist emergency responders by providing maintenance of traffic and cleaning incident debris.

The evaluation by Khalilzadeh (2020) focused on the benefits of the program and did not discuss any costs of the program. The evaluated benefits were reduced travel delay, reduced fuel consumption, reduced fuel emissions, reduction in the number of secondary crashes, and motorist satisfaction. This motorist satisfaction consideration is relatively unique in program evaluations as it can be hard to quantify this aspect. Khalilzadeh (2020) used motorist satisfaction values from a 2002 survey of Atlanta motorists administered by Guin et al. (2007) that placed motorist satisfaction at $60.25/assist. To evaluate these benefits, the author used a k-nearest neighbors approach to calculate delay from speed data from 2017 to 2019. Overall, Khalilzadeh (2020) found the total benefits to be over $1.35 million. Despite the author determining these benefits, there are several shortcomings with the evaluation, most notably its lack of costs that would give the ability to compute a benefit-cost ratio. Moreover, the incident data was noted to be incomplete and not encompassing all events, which can greatly affect results.

One of the largest benefit-cost ratios found in the literature comes from an evaluation of the Motorist Assist program in the St. Louis, Missouri area by Sun et al. (2010). The Motorist Assist program focuses on helping motorists whose vehicles have become disabled by providing simple repairs or services, but program responders also aid with maintenance of traffic and incident debris cleanup (Sun et al., 2010). Using data from 2000 to 2008, the authors focused their benefits on just travel delay reductions and reductions in the number of secondary crashes. Based on this, the authors determined the program had a benefit-cost ratio of 38.25:1, with most of the benefits coming from the reduction in secondary crashes. In particular, the authors determined that the Motorist Assist program reduced 1,082 secondary crashes each year, giving annual benefits of about $78 million. The calculation of the monetary value of secondary crash reduction was based on secondary crash data available in the same period that contained monetary information. By leveraging this data, the authors were able to estimate the financial impacts of having fewer secondary crashes. Congestion costs for the same period were found to only be about $1.13 million per year (Sun et al., 2010). However, it is important to note that the data used in this study suggests that there are nearly as many, if not more, secondary crashes than primary crashes. Depending on how the authors defined and/or determined secondary crashes and how lenient they were with this definition and/or their determination method, more secondary crashes could have been included than is reasonable.

The state of Georgia has done evaluations for not only its motorist assistance program, but also a specialty program that deals with heavy vehicles. Guin et al. (2007) used 12 months of data from 2003 to 2004 to evaluate the motorist assistance program's benefits with respect to travel delay, fuel consumption, fuel emissions, customer satisfaction, and number of secondary crashes reduced. Most of the benefits came from a reduction of incident duration coupled with travel delay savings; about $152 million of the $187 million total benefits were attributed to these mobility benefits (Guin et al., 2007). The authors determined costs based on the annual operating costs to manage the TMC facilities, ITS design costs, and ITS deployment costs, which were used for monitoring the roadway system. After determining these costs, the final benefit-cost ratio was 4.4:1, making the motorist assistance program cost-effective (Guin et al., 2007). A specialty towing program operated in Georgia known as TRIP was also found to be cost effective by PBSJ and Serco (2011). This program is designed for clearing large commercial vehicle incidents that a typical SSP cannot. Using data from 2008 and 2009, the authors found that incidents where TRIP responded to had a 71% decrease in costs compared to similar incidents where TRIP did not respond to. These costs were based on delay, fuel consumption, and fuel emissions. Overall, the program saved over $9 million through the end of 2009, leading to a benefit-cost ratio of 10.96:1 (PBSJ & Serco, 2011). Even with conservative estimates, the authors found the benefit-cost ratio to be 5.35:1, which suggests it is still a cost-effective program.

To summarize and compare the previous evaluations of SSP and towing programs discussed in this chapter, **Table 2-1** contains information on the reviewed evaluations, including the elements considered and the resulting benefit-cost ratio. For these evaluations, decreases in travel delay, fuel use, fuel emissions, and number of secondary crashes are considered benefits, as is an increase in motorist satisfaction. All of these evaluations resulted in benefit-cost ratios greater than 3.0, with a maximum of 38.25, indicating that these programs are cost-effective.

Table 2-1: Summary of Reviewed Benefit-Cost Evaluations on Incident Response Programs

Reference	State	Evaluation Period	Elements Considered					Benefit-Cost Ratio
			Travel Delay	Fuel Use	Fuel Emissions	Secondary Crashes	Motorist Satisfaction	
Skabardonis et al. (1995)	California	1993	✓	✓	✓			3.35
Latoski et al. (1998)	Indiana	1995-1996	✓			✓		13.28
Skabardonis et al. (1998)	California	1996	✓	✓	✓			5.6
Guin et al. (2007)	Georgia	2003-2004	✓	✓	✓	✓	✓	4.4
MnDOT (2013)	Minnesota	2004	✓		✓	✓		15.0
Sun et al. (2010)	Missouri	2000-2008	✓			✓		38.25
PBSJ and Serco (2011)	Georgia[a]	2008-2009	✓	✓	✓			10.96
Lin et al. (2012)	Florida	2010	✓	✓	✓			6.68
Khalilzadeh (2020)	Iowa	2017-2019	✓	✓	✓	✓	✓	N/A[b]

[a] *This program was a specialty towing program; all other response program evaluations in this table are for safety service patrols.*
[b] *N/A stands for "not applicable".*

2.4 Summary and Applications of Literature Review Findings to FDOT

The research discussed in this chapter helps to show the elements of DAV response programs, and TIM programs in general, in Florida and other states. In Florida, a combination of laws and policies, response programs, and towing programs guide DAV response. Other states often utilize similar elements, but the scale of these elements may differ based on geographic or budgetary constraints. Evaluations and analyses of these programs are often similar as well, as they tend to focus on just program statistics (such as number of events responded to in a year or motorist satisfaction) and benefit-cost evaluations of programs. However, previous research has focused on the response to DAVs instead of quantifying the impacts of DAVs. Moreover, much of the focus is on disabled vehicles with little mention of abandoned vehicles. If abandoned vehicles are discussed, the discussion is very short and does not look deeper into problems surrounding abandoned vehicles, such as towing authority to remove these vehicles. This FDOT-UCF project is among the first to investigate abandoned vehicles and their impacts in-depth rather than as just an afterthought. Moreover, understanding the way other states handle abandoned vehicles via a national survey will help show the state of the practice and provide insights into how Florida can better handle disabled and abandoned vehicle events.

Having sufficient and accurate data is a crucial part of evaluating DAV events. Most of the previous literature has primarily used data from TMCs to understand the nature of incidents in their jurisdiction, but there are other sources of data as well. A recent and notable source is the use of Waze data to supplement other data sources. User-reported data from Waze can give greater insight into the frequency and location of disabled vehicle events, as not every disabled vehicle needs assistance from Road Rangers or other source of assistance. For example, some drivers may be able to fix their own flat tire by replacing it with a spare tire. Capturing these kinds of disabled vehicle events with Waze data can help to show more of these underreported disablements. However, it is important to keep in mind that there can be either duplicate reports (multiple users reporting the same event) or false reports (users inputting incorrect information) in the Waze data, so the Waze data might not be completely accurate and representative of disabled vehicle frequency.

Florida’s TIM practices are handled at the state level through laws and policies and at the district level through specific response programs. The Open Roads Policy agreement between FDOT and FHP helps ensure quick roadway clearance times, while the Move Over and Move It laws help improve responder safety and reduce congestion due to vehicles blocking travel lanes. At the district level, the Road Rangers program provides one of the most widespread and effective DAV response programs for motorists. Covering more than 1,500 centerline miles across the state's limited access facilities, the Road Rangers frequently handle disabled vehicles (62% of all events) and occasionally handle abandoned vehicles (7% of all events) (FDOT CVO and TIM Program, 2018). Road Rangers help to clear incidents from travel lanes and assist motorists with minor vehicle issues. Some improvements could be made to the Road Ranger program to increase its effectiveness; these improvements include clarification of program sponsorships so motorists know it is a free FDOT service, inclusion of a more direct line of communication with other responders, and addition of more towing capabilities and better lighting and signage. Other specialized response programs are used throughout Florida, including the RISC program for major highway incidents involving large vehicles, the SIRV program for severe incidents which cause full highway closures (in FDOT District 4), staged towing on select roadways in Tampa and Miami, and safe tow in FDOT District 2 and on FTE roadways.

Similar laws, policies, and programs are present in other states, but the characteristics can vary. Additionally, some states have innovative practices which could be useful methods to deploy in Florida, most notably towing programs. Virginia uses an instant dispatch tow system that deploys a trooper and a tow truck simultaneously to clear lane-blocking events in a timely manner. This program reimburses tow trucks if they are deployed but ultimately not needed, but this only occurs about 5% of the time (Dougald et al., 2016). When Washington state used a similar instant dispatch tow program, they found it reduced ICT by about 15 minutes due to the elimination of the trooper verification step (Nee & Hallenbeck, 2003). A similar towing program in Houston, Texas for minor vehicle disablements uses a safe tow approach that provides free tows off the facility to nearby areas to clear the scene and keep both the driver and responders safe (City of Houston, n.d.). Removing the motorists and responders from the facility greatly minimizes the safety risks while improving motorist satisfaction due to receiving a free tow to a nearby location. By having several tow trucks ready, 98% of responses to incidents on Houston freeways are within six minutes of the incident occurring (Lomax and Stein, 2014). Having similar towing programs deployed in a larger capacity in Florida could help improve RCT and ICT goals while reducing the number of secondary crashes and number of responders struck by crashes. Benefit-cost evaluations of DAV response programs (SSP and towing programs) have generally shown significant benefits of these programs compared to their costs.

Overall, DAV response and the TIM program in Florida is mature and contains many elements used by other agencies. Analyzing DAV events along Florida limited access facilities will give FDOT insight into the extent of the problem as well as common attributes of these events. Deploying a national survey of agencies to understand how agencies deal with DAV events can show the state of the practice throughout the nation and reveal innovative practices and methods used by other states. These practices and methods can inspire new programs in Florida, helping to solidify its position as a national leader in TIM. Conducting benefit-cost evaluations on methods to improve DAV detection and response can help identify cost-effective methods to reduce the financial impacts of these events in ways not considered previously in the literature. Ultimately, conducting these analyses will help cost-effectively improve traffic operations on Florida limited access facilities and increase the safety of motorists and responders who use these facilities by recommending data-driven suggestions for program improvements and additions.

Chapter 3: Survey of State Practices Regarding Handling of DAVs and DAV Characteristics

This chapter describes the design, implementation, and results of a national survey of stakeholders to better understand the operational and safety impacts of DAVs around the country and how agencies respond to these events. The survey was developed by the UCF research team with input from the FDOT project management team, and jointly distributed to state DOTs, select law enforcement agencies, SSP representatives, and toll road agencies throughout the United States. These agencies are actively engaged in detecting, responding to, and clearing DAVs. The survey was designed to understand the characteristics of DAVs and how agencies handle them, with the promise of potentially applying that knowledge to Florida. Understanding what methods, both well-established and newly piloted, work well in other states can provide FDOT and FTE with valuable ideas for improving DAV response programs in Florida. This chapter discusses the survey design, implementation methods, and collected responses for each question, along with a summary of the important findings. Supplementary material is also provided in two appendices. Appendix A shows the final survey design with all questions and programming instructions for the third-party vendor who hosted the survey. Appendix B shows summary tables for all the multiple-choice and ranking questions, along with figures for select questions.

3.1 Survey Design and Implementation

The handling of DAVs and DAV characteristics survey was developed by the UCF research team with input from FTE and FDOT. Appendix A contains the final version of the survey which was approved by FTE and FDOT. The survey contained 68 multiple-choice, ranking, and open-ended questions in branching paths. The exact path taken by each respondent depended on the answers selected for certain questions. Due to this branching nature, no respondent answered all 68 questions. **Figure 3-1** shows the various survey paths possible depending on the answer choices selected for certain questions. As shown in this figure, there are three primary paths in the survey (each has its own color in this figure): one path for respondents from state DOTs or turnpike/toll road authorities (path 1); one path for respondents from state or local law enforcement agencies (path 2); and one path from respondents who represent SSPs (path 3). Respondents were split into the appropriate path based on their answer to Q2. Excluding the participation question, the longest possible survey path was path 1 (maximum length of 34 questions) while the shortest possible survey path was path 3 (maximum length of 16 questions).

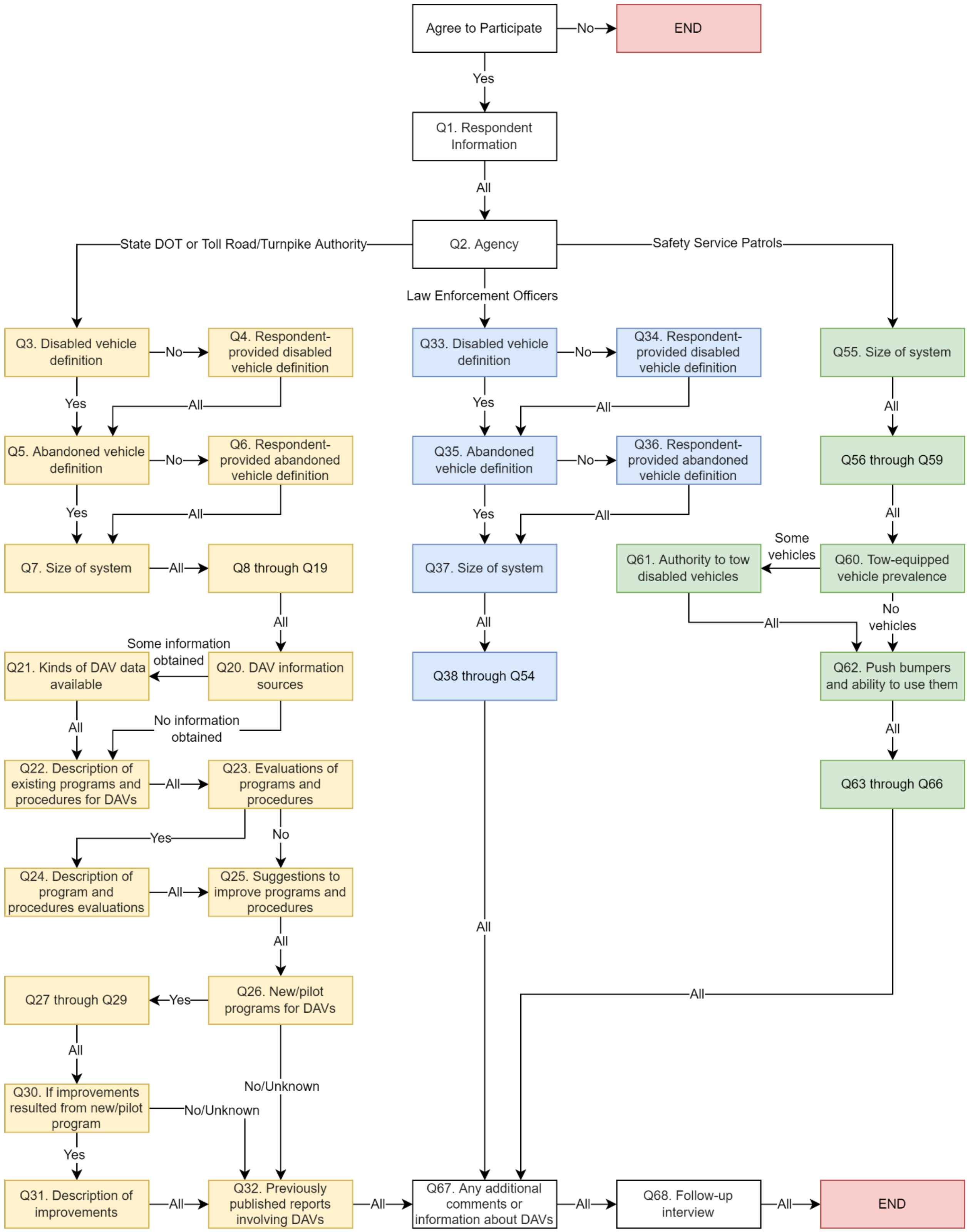

Figure 3-1: Diagram of Various Survey Paths

Multiple iterations of the survey questions and paths were developed based on feedback from the FTE and FDOT management team before settling on this final version. After being approved by the management team, the survey was sent to a third-party vendor who made the survey available online to potential respondents via a provided link and hosted the results of the survey. The online survey was thoroughly tested by UCF, FTE, and FDOT (with any identified issues being fixed by the third-party vendor) before the survey was officially launched on September 3, 2021. Once launched, a link to the survey and message describing the survey and overall project were emailed to various contacts from several potential respondent pools. **Table 3-1** shows the respondent pools emailed, the source of the email contacts, the method of contacting the respondents, and the intended path(s) to be taken. The emails were tailored to each potential respondent pool and provided instructions on what response to select for Q2 to ensure the intended survey path was taken. Additionally, the emails requested that the survey link and message be forwarded to another individual in their agency if the original recipient was not the appropriate person to answer the survey questions.

Table 3-1: Contacted Pools of Respondents for Taking the Survey

Pool	Contact Source	Method of Contact	Intended Path(s)
American Association of State Highway and Transportation Officials (AASHTO) Committee on Transportation System Operations (CTSO)	Public list of members on CTSO website and an existing list provided to the UCF research team by FTE.	FTE sent the original email to the contacts in the list they provided; UCF research team sent the original email to the list from the CTSO website and sent follow up emails to both lists.	Path 1 (State DOTs)
Operations Academy	Operations Academy listserv obtained by FTE.	FTE sent the original and follow up emails to the listserv.	All paths, but mainly path 1
International Bridge, Tunnel and Turnpike Association (IBTTA)	IBTTA listserv obtained by FTE.	FTE sent the original email to the listserv. No follow up emails were sent.	Path 1 (Turnpike/Toll Road Authorities)
National Incident Management (Law Enforcement)	Existing list compiled by Enforcement Engineering, Inc.*	Enforcement Engineering, Inc.* sent the original and follow up emails to the National Incident Management (Law Enforcement) contacts.	Path 2 (State and Local Law Enforcement)
State TIM Contacts	Existing list compiled by Enforcement Engineering, Inc.*	UCF research team sent all original and follow up emails.	Path 3 (SSP Representatives)
Florida District TIM Team Managers	Existing list compiled by Enforcement Engineering, Inc.*	Enforcement Engineering, Inc.* sent all original and follow up emails.	Path 3 (SSP Representatives)

* Enforcement Engineering, Inc. is an approved UCF vendor.

3.2 Survey Results

As of May 31, 2022, the survey received a total of 60 responses split across the three main survey paths. Section 3.2.1 discusses the questions asked to the state DOTs and turnpike/toll road authorities (path 1, which consists of Q3 through Q32 as shown in **Figure 3-1**), section 3.2.2 discusses the questions asked to state and local law enforcement agencies (path 2, which consists of Q33 through Q54), and section 3.2.3 discusses the questions asked to SSP representatives (path 3, which consists of Q55 through Q66). Each section also discusses how respondents in each respective path answered Q67, which was asked to all respondents. Section 3.2.4 contains additional analyses for questions which were common to multiple paths. Appendix B provides more information for all the multiple-choice and ranking questions, including counts and percentages for each answer.

3.2.1 Questions for DOTs and Turnpike/Toll Road Authorities (Path 1)

This survey path received a total of 31 responses, with 27 responses from state DOTs and four responses from turnpike/toll road authorities (Georgia State Road & Tollway Authority, Kansas Turnpike Authority, Oklahoma Turnpike Authority, and Virginia Elizabeth River Crossings). Responses were received from the following state DOTs (shown in **Figure 3-2**):

- Northeast: Connecticut, Massachusetts, Rhode Island
- Midwest: Illinois, Iowa, Michigan, Minnesota, Missouri, North Dakota, Ohio, South Dakota
- South: Alabama, Delaware, Florida, Georgia, North Carolina, Texas, Virginia, West Virginia
- West: California, Colorado, Montana, Nevada, Oregon, Utah, Washington, Wyoming

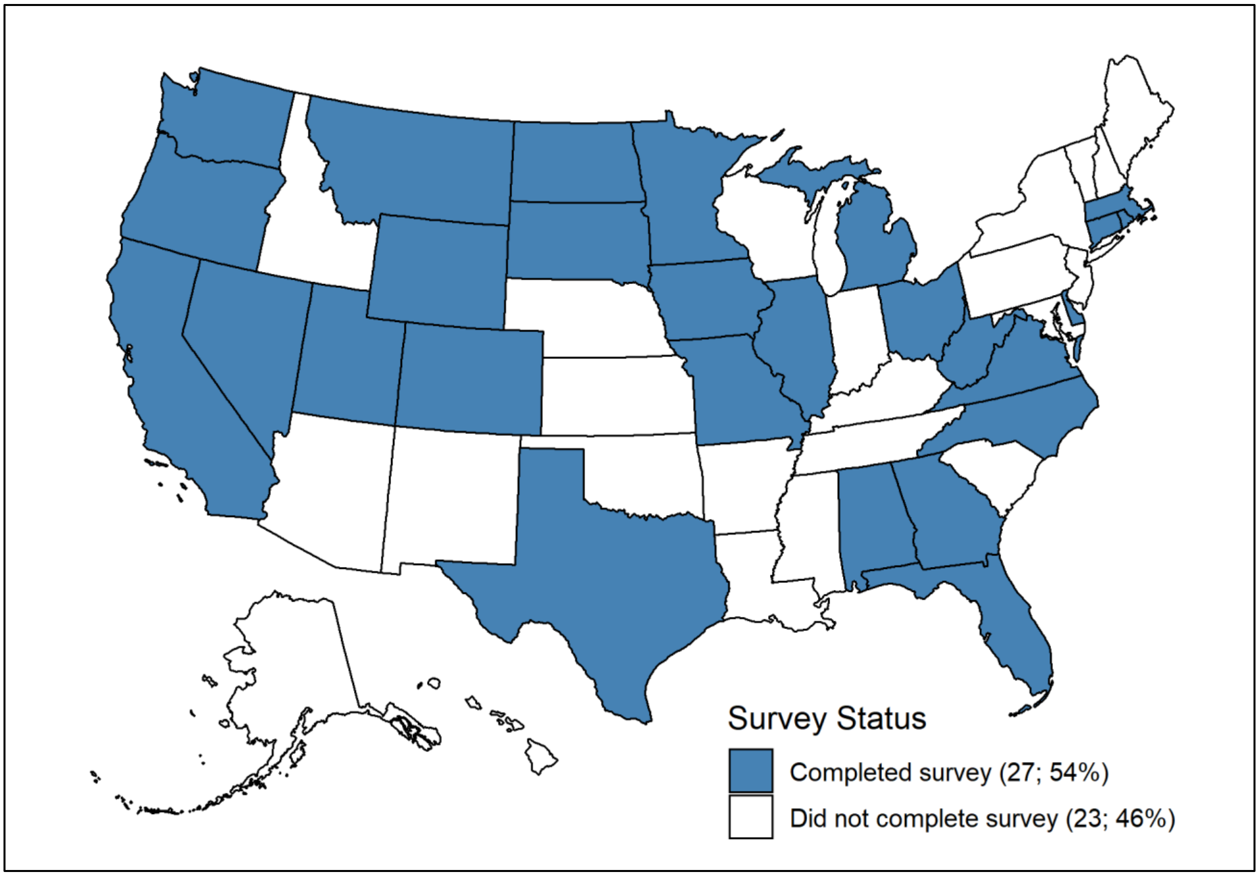

Figure 3-2: State DOTs that Responded to the DAV Survey

The first four questions of this section of the survey (Q3 through Q6) pertain to how the agency defines DAVs. Separate sample definitions were provided for disabled and abandoned vehicles and respondents were asked to specify if their agency's definitions aligned with the provided ones. The provided sample definition for a disabled vehicle was "a vehicle that is unable to operate under its own motive power or is unsafe to operate", while the provided sample definition of an abandoned vehicle was "a vehicle that is unattended, unaccompanied, or unoccupied on a public right-of-way for any amount of time". If respondents indicated that their agency defined disabled and/or abandoned vehicle differently, the respondents were able to specify how their agency defined DAVs. All 31 respondents said the provided definitions aligned with how their agency defined DAVs. Next, agencies specified how large (in centerline miles) their limited access roadway network was (Q7). Of the 31 respondents, 20 (65%) specified their agency maintained more than 1000 miles of limited access roadway networks, which is reflective of how most of the respondents were state DOTs.

The next two questions (Q8 and Q9) asked how many disabled events and abandoned events occurred on their network per day, respectively. These results are shown in **Table 3-2** and **Table 3-3**. Of the 31 respondents, 25 (81%) had no more than 100 disabled vehicle events per day, and 27 (87%) had no more than 25 abandoned vehicle events per day. Most agencies had between 10 to 50 disabled vehicle events (12 respondents, or 39%) and 11 to 25 abandoned vehicle events (10 respondents, or 32%) per day. These results differ from the Florida data analyzed in Chapter 4, which show that there are approximately 9 times more disabled vehicle events than abandoned vehicle events based on Florida SunGuide reports. This suggests that abandoned vehicles are more frequent in other states. The respondent from Texas indicated that their network (which has over 1000 miles of limited access roadways) typically experiences over 500 disabled vehicle events and over 50 abandoned vehicle events per day, which reflects how larger states with longer networks could experience more DAV events. However, this is not always the case, as discussed later in Section 3.2.4.

Table 3-2: Frequency of Disabled Vehicle Events per Day (Path 1)

Response	Count	Percentage
Less than 10 disabled vehicle events per day	6	19%
10 to 50 disabled vehicle events per day	12	39%
51 to 100 disabled vehicle events per day	7	23%
101 to 250 disabled vehicle events per day	5	16%
251 to 500 disabled vehicle events per day	0	0%
More than 500 disabled vehicle events per day	1	3%
Total	**31**	**100%**

Table 3-3: Frequency of Abandoned Vehicle Events per Day (Path 1)

Response	Count	Percentage
Less than 1 abandoned vehicle event per day	4	13%
1 to 5 abandoned vehicle events per day	6	19%
6 to 10 abandoned vehicle events per day	7	23%
11 to 25 abandoned vehicle events per day	10	32%
26 to 50 abandoned vehicle events per day	1	3%
More than 50 abandoned vehicle events per day	3	10%
Total	**31**	**100%**

Q10 asked each respondent to rate how serious of a problem DAV events are in their jurisdiction for urban, suburban, and rural areas on a scale of 1 to 5, with 1 indicating that they are not a problem at all and 5 indicating they are a very serious problem. **Table 3-4** shows the responses to this question. DAV events in urban areas were identified as the most serious, with 17 respondents (55%) scoring DAV events in urban areas as either 4 or 5 and an average score of 3.42. DAV events in suburban areas are somewhat of a problem, but were not scored as highly as DAV events in urban areas, with 18 respondents (58%) scoring them as 3 or 4 and an average score of 2.55. DAV events in rural areas were not typically seen as a problem, with 22 respondents (71%) selecting a score of 1 or 2 and an average score of 2.03.

Table 3-4: Severity of DAV Problem in Urban, Suburban, and Rural Areas

Response	Urban		Suburban		Rural	
	Count	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
1 – Not a problem at all	2	6%	7	23%	13	42%
2	7	23%	6	19%	9	29%
3	5	16%	12	39%	5	16%
4	10	32%	6	19%	3	10%
5 – Very serious problem	7	23%	0	0%	1	3%
Total	**31**	**100%**	**31**	**100%**	**31**	**100%**

Q11 had a similar rating scale, but asked respondents how high of a priority it is to respond to DAV events that are not lane-blocking or immediate safety hazards, with 1 indicating that it is not a priority and 5 indicating it is an essential priority. As shown in **Table 3-5**, 14 of the 31 respondents (45%) ranked the response priority 1 or 2, indicating that it is a low priority for their agency. Only 3 respondents (10%) indicated that responding to these types of events is an essential priority (score of 5). The average score was 2.71.

Table 3-5: Response Priority for Non-Lane-Blocking DAV Events (Path 1)

Response	Count	Percentage
1 – Not a priority	5	16%
2	9	29%
3	10	32%
4	4	13%
5 – Essential priority	3	10%
Total	**31**	**100%**

The next question (Q12) asked what time of day DAV events most frequently occurred. Most respondents (24, or 77%) indicated that these events are most frequent between 6:00 AM and 6:00 PM, which are daytime hours. The results of Q10, Q11, and Q12 suggest that clearing DAV events in urban and suburban areas is of high importance, but these events might not be as urgent to clear if they are not lane-blocking or immediate hazards. Moreover, focusing efforts to clear daytime DAV events would likely result in the most benefits since more events occur during the daytime.

Next, agencies were asked to indicate how they notify other drivers on the road when a disabled vehicle is reported (Q13). Respondents were able to select multiple options, including an option to write in a method not provided in the answer choices. The responses are summarized in **Table 3-6**, with the percentages indicating the percentage of the total 31 respondents who chose each answer choice. Since each respondent could select multiple answers, these percentages add up to more than 100%. The most selected method was using traveler information systems (such as 511 or a phone app), with 16 respondents (52%) indicating their agency uses a similar method to inform other drivers of a disabled vehicle. The next most common method was the use of highway message signs, with 14 respondents (45%) selecting this method. However, the next most common response was that the respondent's agency did not notify other drivers of disabled vehicle events, with nine (29%) respondents indicating this. Furthermore, the two respondents who selected "Other" and indicated their own method specified that their agency only notify other drivers if the disabled vehicle event is lane-blocking but did not specify how they are notified. These results indicate how there is no one approach to notifying drivers of disabled vehicles, and that some agencies might not notify drivers of DAVs at all or only notify them for certain types of disabled vehicles.

Table 3-6: Methods Used to Notify Drivers of DAVs

Response	Count	Percentage
Highway message signs (VMS, CMS, DMS)	14	45%
Highway advisory radio (HAR)	0	0%
Traveler information systems (511 or phone app developed for your state or jurisdiction)	16	52%
Navigation providers (Waze, Google Maps, GPS units, etc.)	8	26%
Posting to social media (Facebook, Twitter, etc.)	2	6%
Other	2	6%
My agency does not notify other drivers of disabled vehicle events.	9	29%

The next two questions (Q14 and Q15) asked about the average time it takes to clear disabled vehicles from either the travel lanes or the roadway, respectively. These responses are summarized in **Table 3-7** and **Table 3-8**. In **Table 3-7** (and some other tables throughout the chapter), even though the rounded percentages shown in the table add up to slightly less or slightly more than 100%, the unrounded percentages sum to 100% exactly. Most respondents (24, or 77%) indicated that when a disabled vehicle is reported in the travel lanes, it is moved to the shoulder within 30 minutes. Once on the shoulder, responses varied for how long it took to clear the disabled vehicle fully from the facility. The most common answer was that it took four hours or more, with 10 respondents (32%) selecting this answer, but 13 respondents (42%) indicated that it was typically cleared from the facility within an hour. This variability is reflective of how different agencies prioritize the removal of events that are not lane-blocking, as indicated in the responses to Q11.

Table 3-7: Time to Clear Disabled Vehicles from Travel Lanes (Path 1)

Response	Count	Percentage
Less than 15 minutes	6	19%
15 minutes to less than 30 minutes	15	48%
30 minutes to less than 45 minutes	6	19%
45 minutes to less than 1 hour	1	3%
1 hour to less than 2 hours	2	6%
2 hours or more	1	3%
Total	**31**	**100%**

Table 3-8: Time to Clear Disabled Vehicles from the Roadway (Path 1)

Response	Count	Percentage
Less than 30 minutes	5	16%
30 minutes to less than 1 hour	8	26%
1 hour to less than 2 hours	4	13%
2 hours to less than 4 hours	4	13%
4 hours or more	10	32%
Total	**31**	**100%**

Q16 asked about the average time to clear abandoned vehicles from the facility. As shown in **Table 3-9**, most respondents (20, or 65%) indicated that abandoned vehicles are cleared from the facility within 24 to 72 hours, while many of the remaining respondents (9, or 29%) indicated that the clearance time for abandoned vehicles was less than 24 hours. These differences could be due to variations in state legislation related to the length of time abandoned vehicles can remain on roadways.

Table 3-9: Time to Clear Abandoned Vehicles from the Roadway (Path 1)

Response	Count	Percentage
Less than 6 hours	4	13%
6 hours to less than 12 hours	1	3%
12 hours to less than 24 hours	4	13%
24 hours to less than 48 hours	11	35%
48 hours to less than 72 hours	9	29%
72 hours or more	2	6%
Total	**31**	**100%**

Q17 and Q18 asked about who has the authority to remove or tow DAVs that are not lane-blocking. Respondents were able to select multiple responses for both questions, with the response summaries for these two questions shown in **Table 3-10**. Law enforcement was the most common response for both disabled and abandoned vehicle removal (27 respondents, or 87%). In general, fewer entities were authorized to remove abandoned vehicles compared to disabled vehicles.

Table 3-10: Authorized Entities to Remove Non-Lane-Blocking DAVs

	Disabled Vehicle Removal		**Abandoned Vehicle Removal**	
Response	**Count**	**Percentage**	**Count**	**Percentage**
State DOT contracted vendor	11	35%	9	29%
Law enforcement	27	87%	27	87%
Private entity	17	55%	13	42%
Other	4	13%	3	10%

Q19 asked if there were any legal time limits regarding how long an abandoned vehicle could be left on the shoulder or side of a roadway before being towed. Of the 31 respondents, 23 (74%) indicated that their state did have some legal time limit involving abandoned vehicles. Most respondents indicated that this time limit was anywhere from 24 to 72 hours, but it varied depending on the type of roadway (interstate, toll road, etc.), the area classification (urban or rural), and the abandoned vehicle's specific location on the roadway (shoulder, off the shoulder in the grass, etc.). A period of 24 to 48 hours was most common before an abandoned vehicle was towed from the facility.

The next two questions (Q20 and Q21) asked about sources of information available to agencies and the kinds of information contained within them. For both questions, respondents could select multiple responses. These responses are summarized in **Table 3-11** and **Table 3-12**. The three most common sources of information were 911 calls/computer aided dispatch data (25 respondents, or 81%), traffic management center reports (25 respondents, or 81%), and safety service patrols (21 respondents, or 68%). The least commonly used source of information from the provided options was citation data, which only four agencies (13%) used to obtain DAV event data. Two respondents specified that they did not obtain information about DAV events, so they were not asked Q21 about the kinds of information collected from the available information sources. For this question, the most common kinds of information available were about the event location as both the general location and detailed location options were selected by 21 of the 29 respondents (72%). Other common kinds of available information included traffic impacts (18 respondents, or 62%), event duration (16 respondents, or 55%), and response details (13 respondents, or 45%). No agencies had access to towing costs, likely due to how towing was typically handled by law enforcement or private entities. The two respondents who selected "Other" indicated they had access to event logs.

Table 3-11: DAV Event Information Sources

Response	Count	Percentage
911 calls/computer aided dispatch (CAD) data	25	81%
Citation data	4	13%
Crash reports	11	35%
Secondary crash information	6	19%
Traffic management center (TMC) reports	25	81%
Crowdsourced data (such as Waze)	6	19%
Safety service patrols	21	68%
Other (please specify)	3	10%
No information obtained	2	6%

Table 3-12: Available DAV Event Information

Response	Count	Percentage
Event general location (such as roadway)	21	72%
Event detailed location (such as lane or shoulder location)	21	72%
Event duration	16	55%
Event cause	10	34%
Severity level (for crashes)	13	45%
Secondary crashes involving disabled or abandoned vehicles	6	21%
Traffic impacts (lane closures, delays)	18	62%
Property damage costs	2	7%
Towing costs	0	0%
Response details (responding agency, response time, removal time, etc.)	13	45%
Other (please specify)	2	7%

The remaining questions in path 1 (Q22 through Q32 and Q67) focused on existing programs and procedures used by the agency in responding to DAV events. Q22 asked respondents what their current existing programs or procedures are for removing DAVs from limited access facilities. This question was open-ended and allowed respondents to type their response. Many agencies specified that their agency did not handle DAVs and instead deferred them to law enforcement or the state highway patrol. As such, these agencies did not have any programs or procedures for DAV events. When an agency did have such programs or procedures, it was typically within the context of a greater TIM program. Agencies often rely on SSPs to help drivers of disabled vehicles, with services ranging from providing simple repairs (such as tire inflation) to giving drivers references to towing companies in the area that can help move the vehicle. Some states utilized more specialty programs, such as Ohio DOT utilizing what they call the "Mini TRIP" program for clearing small vehicles from construction zones. This is similar to TRIP which specializes in timely clearance of larger commercial vehicles. North Carolina DOT has a comprehensive framework for responding to DAV events, with responses varying depending on the severity of the event and its location on the roadway. For disabled vehicle events that are lane-blocking and do not have any injuries, their SSP is allowed to clear the vehicle from the travel lane. If injuries or fatalities are present, the state highway patrol handles the event and calls a towing company to remove the vehicle from the travel lane. Abandoned vehicles can be tagged by either law enforcement or SSP for removal after 24 hours.

The following questions (Q23 and Q24) asked respondents if their agency had performed any evaluations of the procedures described in Q22, and if so, what those results were. Only 11 respondents (35%) indicated that their agency had performed evaluations. Most respondents indicated that their agency tracked clearance times and other performance measures to identify areas for potential improvement. One unique example was from Nevada DOT, where the project manager of the SSP program occasionally rides along with responders to inspect the program's efficiency from an "on the ground" perspective and evaluate its performance. In general, these evaluations found that DAV removal programs often reduce the time vehicles are on the system, freeing up time for law enforcement to handle other issues. Secondary crashes are also reduced due to timely clearance.

Q25 asked respondents how their existing programs and procedures can be improved. Responses generally fell into one of four categories: improving interagency coordination and establishing a greater sense of urgency to clear vehicles; improving the detection and response times to get law enforcement, SSPs, or tow truck operators on the scene faster; establishing an SSP (if the agency did not already have one) or expanding an existing SSP with more equipment, people, and vehicles; and having a better way to track events and manage the data involved in identifying and responding to DAV events. At their core, these four main means of improving the existing programs and procedures can be placed within a greater TIM context. One of the main goals of a TIM program is improving interagency coordination for the timely clearance of events, and this improved coordination involves many different entities, including agencies, law enforcement, and responders (such as SSPs or tow truck operators). Improving the communication between these agencies can allow for the faster exchange of information to start the process of event removal sooner, thereby improving response times and allowing for more timely clearance of DAV events. Improving detection, monitoring, and data management capabilities could also reduce DAV response times, while expanding SSPs (especially when and where DAVs are most common) could reduce the impacts of these vehicles.

The final set of questions (Q26 through Q31) asked respondents about any pilot programs utilizing innovative methods for responding to DAV events. Only 6 respondents (19%) indicated that their agency was piloting such a program. Most of these programs involved utilizing towing programs to clear vehicles in more ways. These generally focused on clearing abandoned vehicles sooner, clearing vehicles from construction zones, and upgrading or equipping existing vehicles in their SSP fleet with tow capabilities to remove DAVs on their own without waiting for a tow truck. The most advanced innovative program among the respondents was being used by Nevada DOT, which is using an artificial intelligence-based system to detect incidents in a timely manner. Five of the six agencies using these new programs have implemented them more than a year ago, and four of them have seen improvements in safety and operations thanks to these programs. These all relate to improving clearance times and the subsequent reductions in secondary crashes congestion. With Nevada DOT, the ability to quickly detect events has allowed them to push information to other drivers sooner, thereby reducing some congestion and the risk of secondary crashes.

The final questions asked to respondents in this path (Q32 and Q67) asked for any relevant published reports involving DAV events and any additional comments or information they would like to share about DAV events, respectively. Most respondents did not have anything additional to share, but some did have additional notes. North Carolina DOT mentioned their focus on improving communication between agencies to ensure that programs and procedures are implemented consistently across the state. South Dakota DOT noted that due to the rural nature of the state, DAV events were not a significant issue and did not commonly occur. It is possible that similar statements can be said for other rural areas which might not experience frequent DAV events.

3.2.2 Questions for State and Local Law Enforcement (Path 2)

This survey path received a total of 12 responses, with all 12 from state law enforcement and none from local law enforcement. Responses were received from the following state law enforcement agencies (shown in **Figure 3-3**):

- Northeast: None
- Midwest: Iowa, Nebraska, South Dakota
- South: Alabama, Florida, Georgia, Oklahoma, South Carolina
- West: Colorado, Nevada, Utah, Wyoming

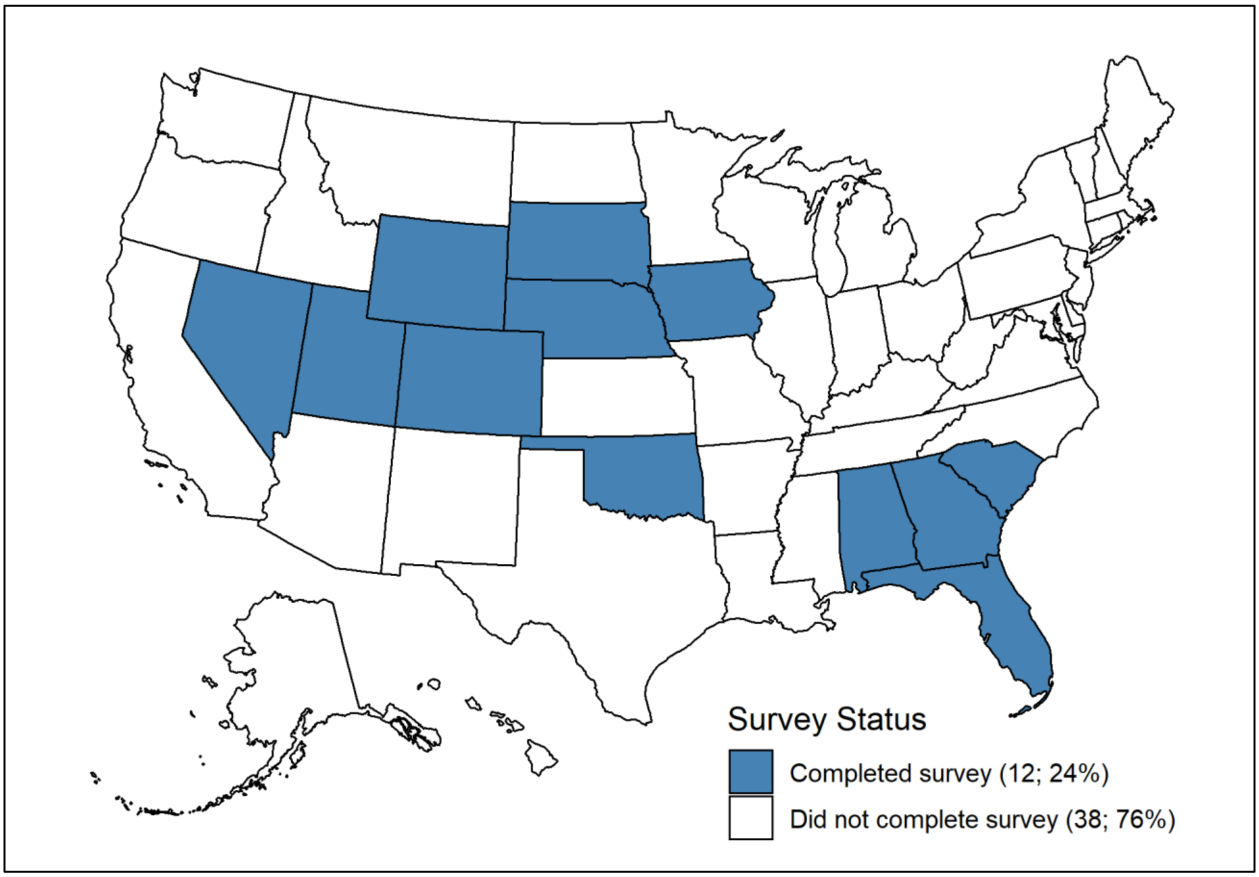

Figure 3-3: State Law Enforcement Agencies that Responded to the DAV Survey

Some of the questions in this path were very similar to questions in path 1, but there were some questions focused on response activities and procedures which were not in path 1. Like path 1, the first four questions of path 2 (Q33 through Q36) pertain to how the agency defines DAVs. The same sample definitions for disabled and abandoned vehicles were provided and respondents were asked if their agency's definition aligned with these provided ones. All 12 respondents said the provided definitions aligned with how their agency defined DAVs (same as path 1 where all 31 respondents said these definitions agreed with their agency's definitions). Next, the law enforcement respondents specified how large (in centerline miles) the limited access roadway network they patrol was (Q37). Of the 12 respondents, seven (58%) specified their agency patrolled more than 1000 miles of limited access roadway networks, and all respondents indicated their patrol networks were at least 200 miles or more, which is reflective of how all respondents are state law enforcement.

The next two questions asked respondents how many disabled vehicle events (Q38) and abandoned vehicle events (Q39) occurred in their patrol area per day, with the results shown in **Table 3-13** and **Table 3-14** for disabled vehicle events and abandoned vehicle events, respectively. Most respondents indicated that no more than 100 disabled vehicle events and 50 abandoned vehicle events occurred per day, with the most common answers being from 10 to 50 disabled vehicle events (six respondents, or 50%) and 1 to 10 abandoned vehicle events (eight respondents, or 67%) per day. Since these questions were also asked in path 1 (Q8 and Q9), it is possible to compare the law enforcement responses to the DOT and toll road agency responses; these comparisons are discussed in section 3.2.4, along with comparisons for other similar questions between paths and cross-tabulations to compare answer choices for related questions.

Table 3-13: Frequency of Disabled Vehicle Events per Day (Path 2)

Response	Count	Percentage
Less than 10 disabled vehicle events per day	2	17%
10 to 50 disabled vehicle events per day	6	50%
51 to 100 disabled vehicle events per day	2	17%
101 to 250 disabled vehicle events per day	1	8%
251 to 500 disabled vehicle events per day	0	0%
More than 500 disabled vehicle events per day	1	8%
Total	**12**	**100%**

Table 3-14: Frequency of Abandoned Vehicle Events per Day (Path 2)

Response	Count	Percentage
Less than 1 abandoned vehicle event per day	0	0%
1 to 5 abandoned vehicle events per day	4	33%
6 to 10 abandoned vehicle events per day	4	33%
11 to 25 abandoned vehicle events per day	0	0%
26 to 50 abandoned vehicle events per day	2	17%
More than 50 abandoned vehicle events per day	2	17%
Total	**12**	**100%**

Q40 asked each respondent to rate how serious of a problem DAV events are in their patrol area on a scale of 1 to 5, with 1 indicating that they are not a problem at all and 5 indicating they are a very serious problem. As shown in **Table 3-15**, 10 of 12 respondents (83%) scored DAV events as either 2 or 3, indicating they are not a particularly serious problem. The average score for this question was 2.9. Q41 asked respondents how high of a priority it is to respond to DAV events that are not lane-blocking or immediate safety hazards, with 1 indicating that it is not a priority and 5 indicating it is an essential priority. Similar to Q40, 10 of 12 respondents (83%) ranked the priority 2 or 3, indicating that they are of moderate priority (**Table 3-16**). The average score for this question was 2.6.

Table 3-15: Seriousness of DAV Problem (Path 2)

Response	Count	Percentage
1 – Not a problem at all	0	0%
2	4	33%
3	6	50%
4	1	8%
5 – Very serious problem	1	8%
Total	**12**	**100%***

* Unrounded percentages sum to 100%.

Table 3-16: Response Priority for Non-Lane-Blocking DAV Events (Path 2)

Response	Count	Percentage
1 – Not a priority	1	8%
2	5	42%
3	5	42%
4	0	0%
5 – Essential priority	1	8%
Total	**12**	**100%**

The next three questions asked about the average time it takes to clear disabled vehicles from the travel lanes (Q42), clear disabled vehicles from the roadway (Q43), and clear abandoned vehicles from the roadway (Q44). **Table 3-17**, **Table 3-18**, and **Table 3-19** show the response summaries for these questions, respectively. All 12 respondents indicated that when a disabled vehicle is reported in the travel lanes, it is moved to the shoulder within one hour. Once on the shoulder, responses varied for how long it took to fully clear the disabled vehicle from the facility. The most common answer was that it took four hours or more (six respondents, or 50%), but four respondents (33%) indicated that it could be cleared from the facility within an hour. Most respondents (10, or 83%) indicated that abandoned vehicles are cleared from the facility within 24 to 72 hours.

Table 3-17: Time to Clear Disabled Vehicles from Travel Lanes (Path 2)

Response	Count	Percentage
Less than 15 minutes	3	25%
15 minutes to less than 30 minutes	4	33%
30 minutes to less than 45 minutes	4	33%
45 minutes to less than 1 hour	1	8%
1 hour to less than 2 hours	0	0%
2 hours or more	0	0%
Total	**12**	**100%***

* Unrounded percentages sum to 100%.

Table 3-18: Time to Clear Disabled Vehicles from the Roadway (Path 2)

Response	Count	Percentage
Less than 30 minutes	0	0%
30 minutes to less than 1 hour	4	33%
1 hour to less than 2 hours	2	17%
2 hours to less than 4 hours	0	0%
4 hours or more	6	50%
Total	**12**	**100%**

Table 3-19: Time to Clear Abandoned Vehicles from the Roadway (Path 2)

Response	Count	Percentage
Less than 6 hours	0	0%
6 hours to less than 12 hours	0	0%
12 hours to less than 24 hours	1	8%
24 hours to less than 48 hours	6	50%
48 hours to less than 72 hours	4	33%
72 hours or more	1	8%
Total	**12**	**100%***

* Unrounded percentages sum to 100%.

Q45 and Q46 asked if the respondent's agency has the authority to remove or tow DAVs off the facility. All 12 respondents indicated that their agency has the authority to remove or tow disabled vehicles (Q45) and abandoned vehicles (Q46) off the facility. Q47 asked if there were any legal time limits regarding how long an abandoned vehicle could be left on the shoulder or side of a roadway before being towed. Eleven respondents (92%) indicated that their state did have some legal time limit involving abandoned vehicles. Ten respondents indicated that this time limit is either 24 or 48 hours, which is consistent with what was reported in the path 1 (Q19). Among these 10 respondents, the respondent from Nebraska indicated that the time limit is 12 hours for interstates and 24 hours for other state highways while the respondent from Georgia indicated that the time limit is 8 hours for interstates and 24 hours for other state highways.

The next question (Q48) asked if the agency's vehicles were equipped with push bumpers and, if so, whether officers could use them to move DAVs out of the travel lanes. All respondents indicated that their vehicles had push bumpers, but only 11 of the 12 respondents (92%) said their agency could use these vehicles to push DAVs out of the travel lanes. The following three questions (Q49 through Q51) asked officers how they approach the response to DAV events and their safety during these events. All 12 respondents indicated that they are trained to use a non-traffic side approach when responding to DAV events (Q49). Ten respondents (83%) indicated that an officer in their agency had been struck while responding to a disabled vehicle (Q50).

Table 3-20 shows how concerned officers in the respondent's agency are for their safety when responding to disabled vehicles. All 12 respondents indicated that officers in their agency are at least somewhat concerned for their safety when responding to disabled vehicles, with four respondents (33%) indicating that officers are moderately concerned for their safety and two respondents (17%) indicating that officers are very concerned. The responses to these three questions reinforce that DAV response can be very dangerous to first responders and highlight the importance of quickly clearing these events to keep law enforcement officers safe.

Table 3-20: Safety Concern When Responding to Disabled Vehicle Events (Path 2)

Response	Count	Percentage
Not concerned at all	0	0%
Slightly concerned	0	0%
Somewhat concerned	6	50%
Moderately concerned	4	33%
Very concerned	2	17%
Total	**12**	**100%**

Q52 asked respondents to rank common reasons for vehicles to become disabled or abandoned. Four options were provided and each respondent had to rank each of these options from 1 to 4, with 1 indicating the most common reason and 4 indicating the least common reason. **Table 3-21** shows the rankings given to each option, along with an average score based on these rankings and an overall rank (option with the lowest average ranked 1). Overall, the most common reason was that the vehicle had a mechanical issue but was not involved in a crash (average score of 1.58), followed by the vehicle being involved in a crash (average score of

2.08), then the vehicle being involved in an extreme weather-related event (average score of 2.83), and last being due to the driver's condition, such as being fatigued or impaired (average score of 3.50). Understanding these common causes could help agencies like FDOT take measures to clear these events more quickly (such as making sure responders have tools to fix common mechanical issues).

Table 3-21: Ranking of Common Reasons for DAVs (Path 2)

Response	Ranking Counts				Average Score	Overall Rank
	1	2	3	4		
Vehicle was involved in a crash	5	2	4	1	2.08	2
Mechanical issue with the vehicle (not involved in a crash)	7	4	0	1	1.58	1
Extreme weather-related events	0	6	2	4	2.83	3
Driver condition	0	0	6	6	3.50	4

The next question (Q53) asked respondents if their agency provided any leniency to the driver or vehicle owner of an abandoned vehicle owner to remove the vehicle, to which all 12 respondents indicating that their agencies do provide such leniency. The final questions for path 2 respondents (Q54 and Q67) asked for any suggestions to improve the response process when handling DAV events and any additional comments or information they would like to share about DAV events, respectively. Most respondents did not have any suggested improvements, but the respondent from Nebraska suggested that improving the tracking of these events would be beneficial to understand the timeline associated with a particular vehicle. As removal is typically contingent on the duration the vehicle has been disabled or abandoned, having a better sense of timestamps associated with different stages of the event are important. This sentiment was echoed in the additional comments by some other respondents. Additionally, the respondent from South Carolina indicated that due to increased driver inattention, any time stopped on the shoulder is inherently dangerous for all parties involved (the driver, other motorists, and responders). Encouraging drivers to remain focused on the road can help keep both them and others safe by reducing the likelihood of hitting a responding officer or crashing into a DAV. The respondent from Georgia suggested that there be greater coordination between state and local law enforcement for addressing events on interstates. Interagency coordination is key to the prompt response to DAV events, so bolstering coordination efforts between state and local agencies can help to reduce the time to respond to events. Lastly, the respondent from Florida suggested that staged towing services be provided on limited access facilities. This approach to towing can be useful to help reduce the time it takes for a tow truck to reach a DAV and tow it.

3.2.3 Questions for Safety Service Patrols (Path 3)

This survey path received a total of 17 responses, with 13 responses from state SSPs and four responses from FDOT TIM team managers representing District 2 (D2), District 3 (D3), District 7 (D7), and FTE. Responses were received from the following state SSPs (shown in **Figure 3-4**):

- Northeast: New Hampshire, New York
- Midwest: Minnesota, Wisconsin
- South: Alabama, Florida, Georgia, Maryland, North Carolina, Texas, Virginia
- West: Hawaii, Montana

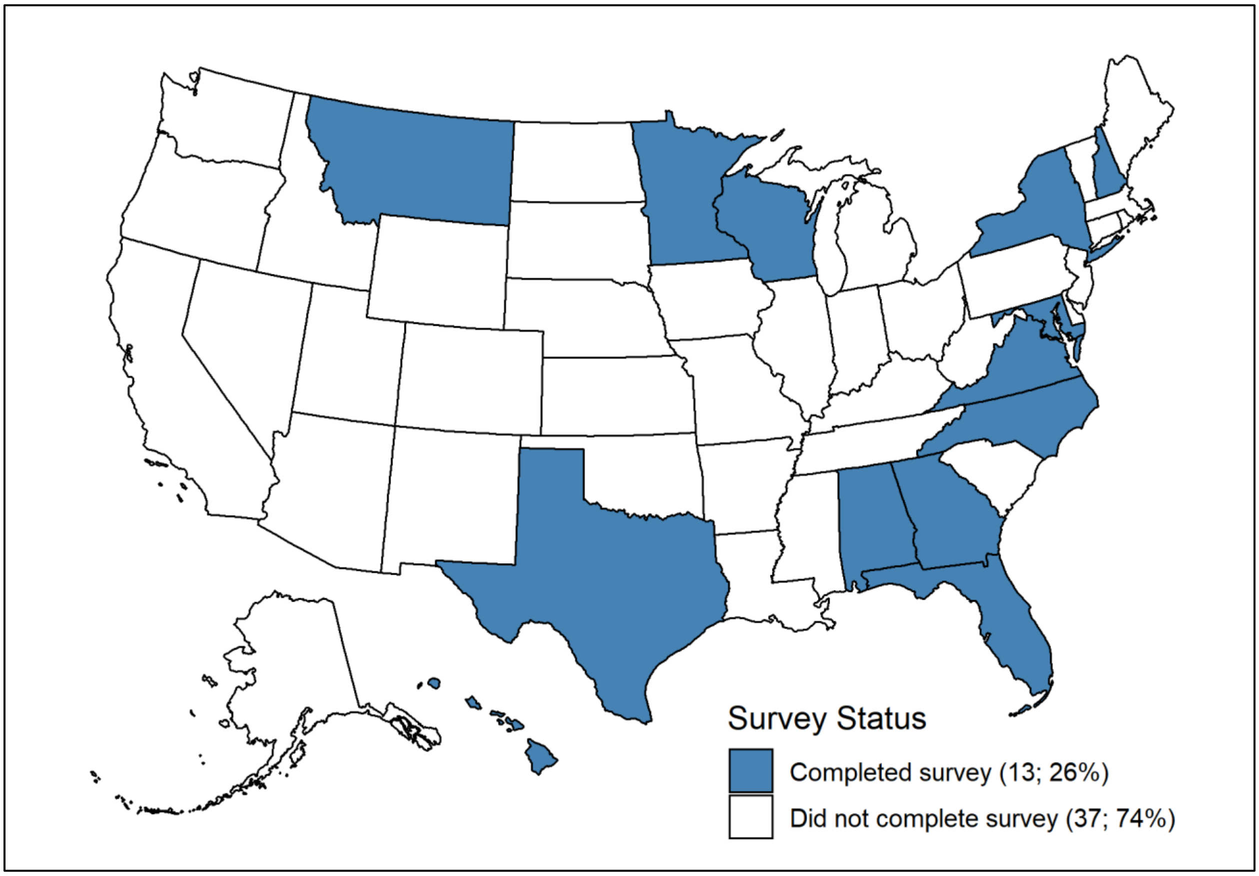

Figure 3-4: State SSPs that Responded to the DAV Survey

All of the questions on this path of the survey were common to one or both of the other main paths, with some being modified slightly to focus on SSPs. Comparisons of these questions between the different paths are discussed in section 3.2.4. The first question (Q55) asked how large (in miles) the limited access roadway network patrolled by the SSP was. Responses to this question varied, with the most common response being 201 to 500 miles (six respondents, or 35%). The four FDOT district respondents indicated their patrol areas range from 101 to 500 miles. The next two questions asked how many disabled vehicle events (Q56) and abandoned vehicle events (Q57) occurred on limited access facilities with the SSP's patrol area per day. These results are shown in **Table 3-22** and **Table 3-23**. Most respondents indicated that no more than 250 disabled vehicle events and 50 abandoned vehicle events occurred per day. Respondents mostly reported anywhere from 10 to 50 disabled vehicle events (nine respondents, or 53%) and 1 to 5 abandoned vehicle events (seven respondents, or 41%) per day. The four FDOT district respondents indicated that 51 to 250 disabled vehicle events and 6 to 50 abandoned vehicle events occur each day on their networks. These responses indicate that FDOT districts tend to have more DAV events compared to other SSPs nationally.

Table 3-22: Frequency of Disabled Vehicle Events per Day (Path 3)

Response	Count	Percentage
Less than 10 disabled vehicle events per day	0	0%
10 to 50 disabled vehicle events per day	9	53%
51 to 100 disabled vehicle events per day	4	24%
101 to 250 disabled vehicle events per day	3	18%
251 to 500 disabled vehicle events per day	0	0%
More than 500 disabled vehicle events per day	1	6%
Total	**17**	**100%***

* Unrounded percentages sum to 100%.

Table 3-23: Frequency of Abandoned Vehicle Events per Day (Path 3)

Response	Count	Percentage
Less than 1 abandoned vehicle event per day	0	0%
1 to 5 abandoned vehicle events per day	7	41%
6 to 10 abandoned vehicle events per day	3	18%
11 to 25 abandoned vehicle events per day	4	24%
26 to 50 abandoned vehicle events per day	2	12%
More than 50 abandoned vehicle events per day	1	6%
Total	**17**	**100%***

* Unrounded percentages sum to 100%.

Q58 asked respondents to rank common reasons for vehicles to become disabled or abandoned, with the same options and ranking system as Q52. As shown in **Table 3-24**, the most common reason for a vehicle becoming disabled was a non-crash related mechanical issue, followed by a vehicle being involved in a crash, then driver-related issues (such as being fatigued), and finally extreme weather-related events. Results from the four FDOT respondents are consistent with these results as well.

Table 3-24: Ranking of Common Reasons for DAVs (Path 3)

Response	Ranking Counts				Average Score	Overall Rank
	1	2	3	4		
Vehicle was involved in a crash	1	11	3	2	2.35	2
Mechanical issue with the vehicle (not involved in a crash)	15	1	0	1	1.24	1
Extreme weather-related events	1	2	4	10	3.35	4
Driver condition	0	3	10	4	3.06	3

The next question (Q59) asked each respondent to rate how serious of a problem DAV events are in their service area on a scale of 1 to 5, with 1 indicating that they are not a problem at all and 5 indicating they are a very serious problem. As **Table 3-25** shows, the responses were spread across all scores, with the most common rating being 3 (seven respondents, or 41%) and the average score being 3.12. All four FDOT respondents rated the DAV problem at least 3. This suggests that DAV events are a more serious problem in Florida compared to other states, which ranked the problem lower.

Table 3-25: Seriousness of DAV Problem (Path 3)

Response	Count	Percentage
1 – Not a problem at all	2	12%
2	2	12%
3	7	41%
4	4	24%
5 – Very serious problem	2	12%
Total	**17**	**100%***

* Unrounded percentages sum to 100%.

The next three questions (Q60 through Q62) asked respondents about towing and removal practices involving DAVs. Q60 asked how many vehicles were tow-capable, and most respondents (9, or 53%) indicated that no vehicles in their fleet were tow-capable. Three of the four FDOT respondents indicated that vehicles in their fleet were tow-capable; the FDOT respondent from D3 indicated they did not have any tow-capable vehicles in their fleet. Of the remaining eight respondents with at least some tow-capable vehicles in their fleet, all indicated in Q61 that they were allowed to tow disabled vehicles. The most common place disabled vehicles could be moved to is the shoulder or side slope of the facility, with five of the eight respondents (62%) selecting this response. The next question (Q62) asked if the agency's vehicles were equipped with push bumpers and, if so, whether responders could use them to move DAVs out of the travel lanes. Fifteen of the 17 respondents (88%) indicated that their vehicles had push bumpers and that they could use them to move DAVs out of the travel lanes. The remaining two respondents indicated that their vehicles were not equipped with push bumpers. All four FDOT respondents indicated their vehicles were equipped with push bumpers and that they can be used.

The following three questions (Q63 through Q65) asked responders about how they approach the response to DAV events and their safety to these events. From Q63, 15 of 17 respondents (88%) stated that their agency trains them to use a non-traffic side approach when responding to DAV events. All four FDOT respondents indicated their responders are trained to use a non-traffic side approach. Ten respondents (59%) stated that a responder in their agency had been struck while responding to a disabled vehicle (Q64). Three of the four FDOT respondents stated that a responder in their agency had been struck while responding to a disabled vehicle; the FDOT respondent from D3 indicated that no one in their agency had been struck while responding to a disabled vehicle. When asked how concerned responders are for their safety when responding to disabled vehicles (Q65), most respondents (12, or 71%) indicated that responders were very concerned for their safety (**Table 3-26**). All four FDOT district respondents stated that responders were very concerned for their safety.

Table 3-26: Safety Concern When Responding to Disabled Vehicle Events (Path 3)

Response	Count	Percentage
Not concerned at all	1	6%
Slightly concerned	0	0%
Somewhat concerned	1	6%
Moderately concerned	3	18%
Very concerned	12	71%
Total	**17**	**100%***

* Unrounded percentages sum to 100%.

The final questions for path 3 respondents (Q66 and Q67) asked for any suggestions to improve the response process when handling DAV events and any additional comments or information they would like to share about DAV events, respectively. The respondent from North Carolina recommended that if a disabled vehicle cannot be immediately repaired and sent on its way, it should be immediately removed from the facility to maximize the safety of those on the road. Two respondents from Florida (one from D3, representing Florida's panhandle, and one from FTE) offered suggestions as well, namely increasing funding to have more patrolling vehicles and allowing Road Rangers (the Florida SSP) to clear abandoned vehicles from the travel lane without needing to wait for law enforcement first. Several respondents specified that while DAVs can be tagged by SSPs, they must often wait for law enforcement to remove the vehicles. Often, DAVs are not moved unless they present a hazard, leading to the vehicle remaining on the facility for an extended period. This is especially common with abandoned vehicles, and several respondents suggested a timelier response to removing abandoned vehicles would be beneficial.

3.2.4 Additional Analyses of Questions Common to Multiple Paths

The previous sections in this chapter discussed the responses for each individual path based on the respondents' answers to Q2. Since several questions were common to multiple paths, the responses for these questions were combined and analyzed. This section discusses the combined results for some of these shared questions (and comparisons between their responses for different paths), along with cross comparisons between related questions. Three questions were common to all three paths: network size (Q7, Q37, and Q55), frequency of disabled vehicles (Q8, Q38, and Q56), and frequency of abandoned vehicles (Q9, Q39, and Q57). The results of the combined responses to these questions are shown in **Table 3-27**, **Table 3-28**, and **Table 3-29**, respectively. Most respondents (51, or 85%) indicated that their agency maintains or patrols networks that are over 200 miles long. In general, SSP respondents indicated that they patrolled a smaller area than those of the law enforcement respondents. Across the paths, the most selected frequencies for DAV events were 10 to 50 disabled vehicle events per day and 1 to 5 abandoned vehicle events per day. The frequency of disabled vehicle events was consistent among all three paths, but law enforcement and SSP respondents indicated fewer abandoned vehicle events per day compared to the DOT and toll road agency respondents.

Table 3-27: Network Size (All Paths)

Response	Count	Percentage
Less than 50 miles	3	5%
50 to 100 miles	2	3%
101 to 200 miles	4	7%
201 to 500 miles	11	18%
501 to 1000 miles	8	13%
More than 1000 miles	32	53%
Total	**60**	**100%***

* Unrounded percentages sum to 100%.

Table 3-28: Frequency of Disabled Vehicle Events per Day (All Paths)

Response	Count	Percentage
Less than 10 disabled vehicle events per day	8	13%
10 to 50 disabled vehicle events per day	27	45%
51 to 100 disabled vehicle events per day	13	22%
101 to 250 disabled vehicle events per day	9	15%
251 to 500 disabled vehicle events per day	0	0%
More than 500 disabled vehicle events per day	3	5%
Total	**60**	**100%**

Table 3-29: Frequency of Abandoned Vehicle Events per Day (All Paths)

Response	Count	Percentage
Less than 1 abandoned vehicle event per day	4	7%
1 to 5 abandoned vehicle events per day	17	28%
6 to 10 abandoned vehicle events per day	14	23%
11 to 25 abandoned vehicle events per day	14	23%
26 to 50 abandoned vehicle events per day	5	8%
More than 50 abandoned vehicle events per day	6	10%
Total	**60**	**100%***

* Unrounded percentages sum to 100%.

Although it is expected that agencies with larger networks would have a greater frequency of DAV events, this may only be true to a certain extent. **Table 3-30** and **Table 3-31** show the relationships between network size and disabled vehicle events and network size and abandoned vehicle events, respectively. These tables show that as the network size increases, the number of DAV events does not change much (especially for disabled vehicles). This could be reflective of how some agencies might have more rural networks or lower traffic volumes, resulting in a low number of DAV events despite having a large network. **Table 3-32** shows the relationship between disabled vehicle events and abandoned vehicle events. In looking at the survey results, respondents who indicated a higher number of disabled vehicle events typically had a higher number of abandoned vehicle events as well. No respondent indicated that there were more abandoned vehicle events than disabled vehicle events in their network. In general, the results indicate that abandoned vehicles are more frequent in other states compared to Florida, as most respondents indicated disabled vehicles were one to 10 times more frequent than abandoned vehicles while Florida has approximately nine times more disabled vehicles than abandoned vehicles.

Table 3-30: Relationship Between Network Size and Disabled Vehicle Frequency (All Paths)

Network Size (miles)	Frequency of Disabled Vehicles per Day						
	< 10	10 – 50	51 – 100	101 – 250	251 – 500	> 500	**Total**
< 50	1 (2%)	2 (3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	**3 (5%)**
50 – 100	1 (2%)	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	**2 (3%)**
101 – 200	0 (0%)	3 (5%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	**4 (7%)**
201 – 500	0 (0%)	5 (8%)	4 (7%)	2 (3%)	0 (0%)	0 (0%)	**11 (18%)**
501 – 1000	3 (5%)	3 (5%)	2 (3%)	0 (0%)	0 (0%)	0 (0%)	**8 (13%)**
> 1000	3 (5%)	14 (23%)	7 (12%)	5 (8%)	0 (0%)	3 (5%)	**32 (53%)**
Total	**8 (13%)**	**27 (45%)**	**13 (22%)**	**9 (15%)**	**0 (0%)**	**3 (5%)**	**60 (100%)**

Table 3-31: Relationship Between Network Size and Abandoned Vehicle Frequency (All Paths)

Network Size (miles)	Frequency of Abandoned Vehicles per Day						
	< 1	1 – 5	6 – 10	11 – 25	26 – 50	> 50	**Total**
< 50	1 (2%)	2 (3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	**3 (5%)**
50 – 100	1 (2%)	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	**2 (3%)**
101 – 200	0 (0%)	2 (3%)	1 (2%)	1 (2%)	0 (0%)	0 (0%)	**4 (7%)**
201 – 500	0 (0%)	1 (2%)	3 (5%)	5 (8%)	2 (3%)	0 (0%)	**11 (18%)**
501 – 1000	1 (2%)	4 (7%)	1 (2%)	0 (0%)	2 (3%)	0 (0%)	**8 (13%)**
> 1000	1 (2%)	8 (13%)	9 (15%)	7 (12%)	1 (2%)	6 (10%)	**32 (53%)**
Total	**4 (7%)**	**17 (28%)**	**14 (23%)**	**14 (23%)**	**5 (8%)**	**6 (10%)**	**60 (100%)**

Table 3-32: Relationship Between Disabled Vehicle and Abandoned Vehicle Frequency (All Paths)

Frequency of Disabled Vehicles per Day	Frequency of Abandoned Vehicles per Day						
	< 1	1 – 5	6 – 10	11 – 25	26 – 50	> 50	Total
< 10	4 (7%)	3 (5%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	**8 (13%)**
10 – 50	0 (0%)	14 (23%)	9 (15%)	2 (3%)	2 (3%)	0 (0%)	**27 (45%)**
51 – 100	0 (0%)	0 (0%)	4 (7%)	6 (10%)	2 (3%)	1 (2%)	**13 (22%)**
101 – 250	0 (0%)	0 (0%)	0 (0%)	6 (10%)	1 (2%)	2 (3%)	**9 (15%)**
251 – 500	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	**0 (0%)**
> 500	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (5%)	**3 (5%)**
Total	**4 (7%)**	**17 (28%)**	**14 (23%)**	**14 (23%)**	**5 (8%)**	**6 (10%)**	**60 (100%)**

In addition to the previous questions which were common to all three survey questions, several questions were common to two paths of the survey. The first of these questions asked respondents of paths 1 and 2 about their agency's priority level for removing DAV events that were not lane-blocking or immediate safety hazards (Q11 and Q41). The combined results of these questions are shown in **Table 3-33**. For many agencies, clearing DAV events that are not lane-blocking or immediate hazards is not a very high priority, as 29 respondents (67%) ranked the priority either 2 or 3. Clearing DAV events are of only moderate importance to law enforcement compared to the greater importance indicated by state DOTs and turnpike/toll road authorities.

Table 3-33: Response Priority for Non-Lane-Blocking DAV Events (Paths 1 and 2)

Response	Count	Percentage
1 – Not a priority	6	14%
2	14	33%
3	15	35%
4	4	9%
5 – Essential priority	4	9%
Total	**43**	**100%**

Three pairs of questions asked respondents of paths 1 and 2 how long it takes to clear DAV events from either the travel lanes or shoulder (Q14 and Q42 for removal of disabled vehicles from travel lanes, Q15 and Q43 for removal of disabled vehicles from the shoulder, and Q16 and Q44 for removal of abandoned vehicles from the shoulder). The combined results of these questions are shown in **Table 3-34**, **Table 3-35**, and **Table 3-36**, respectively. Most respondents (38, or 88%) indicated that disabled vehicles are cleared from the travel lanes within 45 minutes, suggesting that agencies have a very consistent response to this type of event. However, when the disabled vehicle is on the shoulder, clearing these events can take considerably longer, and the response is not as consistent across agencies. Over a third of respondents indicated that once a disabled vehicle is on the shoulder, it can take four hours or more to clear it fully from the roadway. **Table 3-37** shows the relationship between an agency's priority for clearing DAV events that are not lane-blocking or immediate hazards and the average time it takes to clear a disabled vehicle from the shoulder. In general, agencies who indicated clearing these types of events is a low priority for their agency also indicated that it takes more than four hours to clear disabled vehicles from the shoulder. However, the variability in responses to these questions is reflective of how different agencies prioritize the removal of events that are not lane-blocking. Lastly, over two-thirds of respondents indicated that abandoned vehicles are cleared from the roadway anywhere from 24 to 72 hours after the event is reported.

Table 3-34: Time to Clear Disabled Vehicles from Travel Lanes (Paths 1 and 2)

Response	Count	Percentage
Less than 15 minutes	9	21%
15 minutes to less than 30 minutes	19	44%
30 minutes to less than 45 minutes	10	23%
45 minutes to less than 1 hour	2	5%
1 hour to less than 2 hours	2	5%
2 hours or more	1	2%
Total	**43**	**100%**

Table 3-35: Time to Clear Disabled Vehicles from the Roadway (Paths 1 and 2)

Response	Count	Percentage
Less than 30 minutes	5	12%
30 minutes to less than 1 hour	12	28%
1 hour to less than 2 hours	6	14%
2 hours to less than 4 hours	4	9%
4 hours or more	16	37%
Total	**43**	**100%**

Table 3-36: Time to Clear Abandoned Vehicles from the Roadway (Paths 1 and 2)

Response	Count	Percentage
Less than 6 hours	4	9%
6 hours to less than 12 hours	1	2%
12 hours to less than 24 hours	5	12%
24 hours to less than 48 hours	17	40%
48 hours to less than 72 hours	13	30%
72 hours or more	3	7%
Total	**43**	**100%**

Table 3-37: Relationship Between Response Priority and Full Clearance Time for Disabled Vehicles (Paths 1 and 2)

Response Priority for Non-Lane-Blocking DAV Events	Average Time to Clear Disabled Vehicles from the Roadway					
	< 30 min.	30 min. to < 1 hr.	1 hr. to < 2 hrs.	2 hrs. to < 4 hrs.	> 4 hrs.	Total*
1 – Not a priority	1 (2%)	0 (0%)	0 (0%)	0 (0%)	5 (12%)	**6 (14%)**
2	2 (5%)	3 (7%)	2 (5%)	1 (2%)	6 (14%)	**14 (33%)**
3	0 (0%)	6 (14%)	3 (7%)	2 (5%)	4 (9%)	**15 (35%)**
4	1 (2%)	1 (2%)	0 (0%)	1 (2%)	1 (2%)	**4 (9%)**
5 – Essential priority	1 (2%)	2 (5%)	1 (2%)	0 (0%)	0 (0%)	**4 (9%)**
Total	**5 (12%)**	**12 (28%)**	**6 (14%)**	**4 (9%)**	**16 (37%)**	**43 (100%)**

The remaining shared questions were asked to respondents of paths 2 and 3. The first of these asked respondents to identify the problem severity of DAV events in their patrol or service area (Q40 and Q59). The combined results of these questions are shown in **Table 3-38** and suggest that the problem is of moderate severity, as the most common response of 3 was selected by 13 respondents (45%). The next shared question asked respondents if any officers or responders in their agency had been struck while responding to a disabled vehicle (Q50 and Q64). The results shown in **Table 3-39** indicate that many agencies have had an officer or responder struck, with 20 respondents (69%) indicating that someone in their agency had been struck. Q51 and Q65 asked respondents how concerned officers or responders in their agency were for their safety when responding to disabled vehicles. The results in **Table 3-40** show that 21 respondents (72%) indicated officers or responders in their agencies are moderately or very concerned for their safety. This consistency of responses between the paths shows how responding to these events can be very dangerous to first responders, whether law enforcement or SSPs.

Table 3-38: Seriousness of DAV Problem (Paths 2 and 3)

Response	Count	Percentage
1 – Not a problem at all	2	7%
2	6	21%
3	13	45%
4	5	17%
5 – Very serious problem	3	10%
Total	**29**	**100%**

Table 3-39: Respondent Agency has had Officer/Responder Struck while Responding to Disabled Vehicle Events (Paths 2 and 3)

Response	Count	Percentage
Yes	20	69%
No	9	31%
Total	**29**	**100%**

Table 3-40: Safety Concern When Responding to Disabled Vehicle Events (Paths 2 and 3)

Response	Count	Percentage
Not concerned at all	1	3%
Slightly concerned	0	0%
Somewhat concerned	7	24%
Moderately concerned	7	24%
Very concerned	14	48%
Total	**29**	**100%***

* Unrounded percentages sum to 100%.

The final question in common with both paths 2 and 3 asked respondents to rank the common reasons for DAVs in their patrol or service area (Q52 and Q58). **Table 3-41** shows that the most common reason for a vehicle to become disabled or abandoned was that it had a non-crash related mechanical issue, followed by a vehicle being involved in a crash, then extreme weather-related events, and finally driver-related issues (such as being fatigued). These results are consistent with the ranking from the law enforcement path; the SSP path respondents ranked the final two options in the opposite order. This could possibly be due to how, when extreme weather is occurring, drivers would be more likely to request the help of law enforcement rather than an SSP, making SSP response to these kinds of events less common.

Table 3-41: Ranking of Common Reasons for DAVs (Paths 2 and 3)

Response	Ranking Counts				Average Score	Overall Rank
	1	**2**	**3**	**4**		
Vehicle was involved in a crash	6	13	7	3	2.24	2
Mechanical issue with the vehicle (not involved in a crash)	22	5	0	2	1.38	1
Extreme weather-related events	1	8	6	14	3.14	3
Driver condition	0	3	16	10	3.24	4

3.3 Summary and Conclusions of Survey Results

The DAV stakeholder survey described in this chapter is an important tool for understanding the characteristics of DAV events and their subsequent handling by various agencies across the United States. The results from this survey can help FDOT and FTE understand the state of the practice and identify new possible approaches to handling DAVs that have been successful in other states. Understanding the state of the practice and advancing new methods of handling DAVs can help Florida be a leader in DAV response and TIM as a whole.

The online survey was developed and tested by the UCF research team FTE and FDOT. This survey was sent to state DOTs, turnpike/toll road authorities, state and local law enforcement, and SSPs across the United States. By May 31, 2022, 60 respondents completed the survey. Among these 60 respondents, the most completed survey path was for state DOT and turnpike/toll road authorities (path 1), which received a total of 31 responses (27 state DOTs and 4 turnpike/toll road authorities). This was followed by the SSP path (path 3), which received responses from 13 state SSPs and 4 FDOT districts. The law enforcement path (path 2) received 12 responses from state law enforcement agencies. Responses from each of these paths were analyzed separately, with additional analyses on the combined responses for similar questions between paths and cross-tabulations for related questions.

Path 1, which contained the most questions, was focused on the characteristics of DAVs and the response programs used by DOTs and toll road agencies. Most of the path 1 respondents reported 10 to 50 disabled vehicle events and 11 to 25 abandoned vehicles per day on average, with most of these events occurring during daytime hours. These respondents indicated that clearing DAV events in urban and suburban areas is of high importance, but DAV clearance might not be as high priority if the DAV is not lane-blocking or an immediate hazard. Agencies that notified other drivers of DAV events tended to most commonly use traveler information systems (such as 511 or a phone app) or highway message signs, but 29% of agencies did not notify other drivers of any DAV. With respect to clearance, disabled vehicles are generally moved to the shoulder within 30 minutes but can take longer to be fully cleared. Similarly, abandoned vehicles are typically cleared anywhere from 24 to 72 hours after being reported.

These time frames can be reflective of how, for many of these agencies, events that are not lane-blocking or an immediate hazard are relatively low priority.

Many of the path 1 respondents also reported that their agency does not directly work with DAVs, either having law enforcement handle them directly or coordinating with a TIM program or SSP. As such, most of these DAV events are cleared by law enforcement. North Carolina DOT has policies that allow for SSPs to clear lane-blocking events that do not involve injuries, reducing the event's impact on traffic operations and safety and saving time for law enforcement to focus on other tasks. Moreover, SSPs in North Carolina can tag abandoned vehicles alongside law enforcement, which can expedite the clearance timeline of these events.

In terms of improving response, these respondents had four main suggestions: improving interagency coordination and establishing a greater sense of urgency to clear vehicles; improving the detection and response times; establishing an SSP (if the agency did not already have one) or expanding an existing SSP ; and having a better way to track events and manage the data involved in identifying and responding to DAV events. All these elements are essential to TIM programs, so ensuring that a state has a robust TIM program is crucial to the timely clearance of DAV events. FDOT has a strong TIM program, but improvements can always be made.

This DOT/toll agency path also asked about any innovative methods or pilot programs that state DOTs or toll road agencies use to handle DAV events. Most of the described programs focused on clearing abandoned vehicles sooner, clearing vehicles from construction zones, and upgrading or equipping existing vehicles in the SSP fleet with tow capabilities to remove DAVs on their own without waiting for a tow truck. The agencies piloting these programs indicated that they have reduced clearance times and have had positive effects on traffic operations and safety. The most advanced innovative program among the respondents is being used by Nevada DOT; this program is an artificial intelligence-based system to detect incidents in a timely manner. Using this system, Nevada DOT can alert other drivers more quickly and manage the DAV event better, improving both operations and safety.

Respondents of the law enforcement path (path 2) had several questions in common with path 1, but were also asked more specific questions related to DAV response. Most of the path 2 respondents indicated that an average of 10 to 50 disabled vehicle events and 1 to 10 abandoned vehicle events happen each day. These respondents also indicated that clearing DAV events which are not lane-blocking or immediate hazards are low priority. Disabled vehicles are usually moved to the shoulder within 45 minutes but can take longer to fully clear from the roadway, and abandoned vehicles are usually cleared within 24 to 72 hours. Most respondents indicated that their state has legal time limits regarding abandoned vehicles, often 24 to 48 hours. However, respondents also indicated that they provide leniency to the drivers or vehicle owners of abandoned vehicles, granting them extra time to handle the vehicle. This leniency can explain why some agencies can take up to 72 hours to clear abandoned vehicles.

All path 2 respondents indicated that vehicles in their agency's fleet are equipped with push bumpers, and most can use them to move DAVs from the travel lanes. Eighty-three percent of respondents indicated that an officer in their agency had been struck by a vehicle while responding to a disabled vehicle; accordingly, all respondents were at least somewhat concerned for the safety of officers in their agency. These responses reinforce that responding to these events can be very dangerous to first responders, highlighting the importance of quickly clearing these events to keep law enforcement officers safe. When asked for ways to improve the response process, respondents indicated that improving the tracking of DAVs would be beneficial as time is crucial in the removal process. Identifying vehicles earlier can help to expedite their eventual removal. The respondent from South Carolina indicated that due to increased driver inattention, any time stopped on the shoulder is inherently dangerous for all parties involved (the driver, other motorists, and responders), so prompt removal of inoperable vehicles would be the safest response route.

As with the law enforcement path, respondents of the SSP path (path 3) had many shared questions with the DOT/toll agency path, along with several questions which were shared with law enforcement. Path 3 respondents indicated that 10 to 50 disabled vehicle events and 1 to 5 abandoned vehicle events are typical on a given day. Over half of the respondents' agencies did not have vehicles that were tow capable. Of those with tow capable vehicles in their fleet, all were allowed to relocate the vehicle, typically to the shoulder or side slope of the road. Most fleet vehicles had push bumpers that could move vehicles out of the travel lanes. Nearly two-thirds of respondents indicated that someone in their agency had been struck while responding to a disabled vehicle, and most indicated that responders in their agency were very concerned for their safety. Respondents suggested expanding SSP programs (larger fleets, more funding, additional responders) might assist with the prompt removal of DAVs. The four respondents from the FDOT districts indicated that their districts had a high number of DAV events, suggesting that these districts have more DAVs compared to other SSPs nationally. These four respondents also ranked DAVs as a more serious problem than respondents from other states, reinforcing that these districts have many DAVs compared to other states. All four FDOT district respondents also indicated that responders in their agency are very concerned for their safety, highlighting the importance for FDOT to find ways which can keep responders safe when responding to DAVs.

Some questions were common to all three survey paths, including questions about DAV frequency. The frequency of disabled vehicles was fairly consistent across the paths, but law enforcement and SSP respondents stated they had fewer abandoned vehicles compared to respondents from DOT/toll agencies. This difference might be attributed to a heightened surveillance of the issue among transportation agencies. Despite respondents having different network sizes, the reported event frequencies were consistent across the different sizes. This indicates that other factors, such as location or traffic volumes, could be more impactful on DAV frequency than network size. These factors could be the reason why other states tend to report fewer DAVs overall (but a higher proportion of abandoned vehicles) than Florida despite having large roadway networks. Comparing the stated frequency of disabled vehicles with the stated frequency of abandoned vehicles suggests that abandoned vehicles might be more frequent in other states than they are in Florida.

Several questions were common to the DOT/toll agency and law enforcement paths, primarily focusing on event response. Based on the combined results from these questions, clearing DAVs that are not lane-blocking or immediate hazards are of only moderate importance to law enforcement, but are more important to state DOTs and turnpike/toll road authorities. The response time for disabled vehicles that block travel lanes is consistent among states, but these response times grow less consistent once the disabled vehicle is on the shoulder. Respondents who specified their agency places a lower priority on removing disabled vehicles that are not lane-blocking or immediate hazards tended to take longer to clear disabled vehicles from the shoulder, often taking four hours or more to do so.

Questions common to the law enforcement and SSP paths focused on event response and responder safety. With regards to safety, over two-thirds of respondents from these paths specified that an officer or responder in their agency had been struck while assisting a disabled vehicle. Consequently, 72% of respondents stated that officers or responders in their agency are moderately or very concerned for their safety. These results reinforce that responding to DAV events can be very dangerous to first responders.

Chapter 4: Data Analysis and Quantification of DAV Impacts

To quantify the impacts of DAVs on Florida's limited access roadways, accurate and reliable data are needed. This chapter discusses the collection and analysis of three main sources of DAV event data: crash data, SunGuide event data, and Waze event data. First, each data source is discussed in detail to establish the scope of the data and what information is available in each data source. A database developed by the research team to help identify overlap between the SunGuide and Waze data is also discussed. Next, each data source is analyzed individually and in conjunction with another data source as applicable. The quantified impacts of DAVs on Florida's limited access roadways based on the results of these analyses are then discussed, with a more detailed discussion of congestion impacts for select roadways in Chapter 5. Lastly, recommendations are made on ways to potentially improve the detection of and response to DAV events on FDOT and FTE roadways.

4.1 DAV Data Collection

This section discusses the collection and attributes of the three main sources of data used in this task. These three sources are DAV crash data, DAV SunGuide event data, and DAV Waze event data (discussed in Sections 4.1.1 through 4.1.3, respectively). SunGuide is the ATMS utilized by TMCs around the state of Florida. It allows for TMC operators to monitor traffic conditions in real time and create logs of events as they occur (FDOT Traffic Engineering and Operations Office, 2021). Waze is a mobile app that allows users to report and receive traffic conditions and incidents in real-time. With over 140 million global users, Waze's crowdsourced data provides a large and robust pool of data on roadway conditions, including DAVs (Waze, n.d.). FDOT currently collects data from Waze and imports these alerts into SunGuide (FHWA Center for Accelerating Innovation, 2021). However, only Waze alerts reporting crashes and other severe incidents are imported into SunGuide due to the high volume of Waze alerts. This means that Waze alerts associated with DAV events are currently not reported in SunGuide. To understand how the Waze data compares to SunGuide data and identify potential benefits of including DAV Waze alerts in SunGuide, a database of SunGuide and Waze data was built, as discussed in Section 4.1.4.

4.1.1 DAV Crash Data

DAV crash data were obtained by the UCF research team from Signal Four Analytics (S4A), an online crash report repository for Florida (The GeoPlan Center, 2021). Crash data were obtained for six calendar years (2015-2020) for Florida limited access roadways. S4A provides a spreadsheet containing many of the fields from the crash report along with scanned copies of the crash reports, allowing for the ability to read crash narratives and view crash diagrams. The fields in the generated spreadsheet include spatiotemporal information (such as roadway, county, and time and date of the crash), environmental details (such as lighting and weather conditions), crash characteristics (such as collision manner and crash severity), and other miscellaneous fields.

While there are a variety of filters available in S4A, the presence of a disabled or abandoned vehicle is not one of these filters. Since the S4A crash data do not contain a field explicitly identifying if the crash involved a DAV, the research team used the three queries shown below to obtain potential DAV crashes via the S4A filtering system:

1. Participants > Vehicle Type > Parked Motor Vehicle
2. Circumstances > Crash Type > Detailed > Parked Vehicle
3. Circumstances > First Harmful Event > Parked Motor Vehicle

These three queries led to a combined total of 8,199 crash reports, which included overlap between the three queries. Once all duplicate crash reports were excluded, there were 5,090 unique crash reports remaining. To determine how many of these reports were actually DAV crashes, each report was manually reviewed. Since each crash report was manually created by a law enforcement officer, some reports were missing some important information or were misclassified in S4A. All crash reports that contained inaccurate information (such as crashes erroneously being categorized as occurring on interstates when they occurred on residential streets), were missing essential information to confirm if they involved a DAV (such as a narrative or crash diagram), or were outside the scope of this project (such as crashes that only involved roadway debris) were excluded. After this manual review of each crash report, 1,051 were identified as disabled vehicle crashes and 205 were identified as abandoned vehicle crashes. Each crash report was classified as either a disabled vehicle crash, an abandoned vehicle crash, or neither based on its details and description. For example, a vehicle that was disabled and subsequently abandoned was classified as an abandoned vehicle for the purposes of this research. As noted previously, vehicles can also be abandoned without being disabled. The defining element of abandoned vehicles is that they are left unattended on a public right-of-way, regardless of whether they are disabled or not. This distinction was made to ensure that the two sets of crashes are independent and do not contain any overlap.

While the spreadsheet from S4A contains much of the information from the crash reports, this spreadsheet only included the time of the crash and no other times related to crash response. Since these times are important to determine various crash-related timeframes, four additional fields were manually obtained from the crash reports: time the crash was reported, time officers were dispatched, time officers arrived on the scene, and time the crash was cleared. Using these additional times, the detection, notification, arrival, and response durations were calculated to identify areas for potential improvement.

4.1.2 DAV SunGuide Event Data

SunGuide data for DAV events on Florida limited access roadways were provided to the research team by Enforcement Engineering, Inc. (EEI), and the Central Florida Expressway Authority (CFX). The SunGuide data provided by EEI contained data for all Florida limited access facilities in 2018 and all Florida limited access facilities except for the CFX network from January 2019 through December 2021. All FTE and FDOT operated roadways were included in the EEI provided data. The data from EEI were provided in three batches. The first batch contained data from January 2018 through December 2020, the second batch contained data from January 2021 through June 2021, and the third batch contained data from July 2021 through December 2021. Since the SunGuide data provided by EEI did not contain data on CFX roadways starting in 2019 (as CFX SunGuide data was managed by CFX's own TMC rather than through FDOT District 5), the CFX SunGuide data for 2019 through 2021 were requested from and provided by the CFX TMC. These data were provided in two batches, with the first batch containing data from January 2019 through December 2020 and the second batch containing data from January 2021 to December 2021.

The data provided by EEI and CFX contained the same fields and used the same attributes. These data were obtained for roadways labeled as limited access with an event type of either “Disabled Vehicle” or “Abandoned Vehicle”. The data contained the following fields: created_date (date and time of event start), closed_date (date and time of event end), event_type (either “Disabled Vehicle” or “Abandoned Vehicle”), roadway, direction, county, location (a text string describing the location of the event), latitude, longitude, worst_blockage (a text string describing the most lanes blocked by the event), and district. Using these fields, two additional fields were created: year and event_duration (found by subtracting created_date from closed_date). The SunGuide data did not contain information about queues formed due to the DAV, making it difficult to accurately estimate the exact impact each DAV event had on traffic operations. The closest approximation to this was captured by the worst_blockage. Moreover, there was no information about who reported the event, who was the first to respond, or how long different parties (such as law enforcement, Road Ranger, etc.) stayed on the scene to address the event.

After combining the five batches of data (January 2018 through December 2020 from EEI, January 2021 through June 2021 from EEI, July 2021 through December 2021 from EEI, January 2019 through December 2020 from CFX, and January 2021 through December 2021 from CFX), the dataset contained 1,599,335 DAV events. It is important to note that these are only non-crash DAV events. If a DAV became involved in a crash, the SunGuide event type was changed from either “Disabled Vehicle” or “Abandoned Vehicle” to “Crash” by the TMC operators. Since only events with event_type of “Disabled Vehicle” or “Abandoned Vehicle” were collected, these crashes are not part of the collected DAV SunGuide data. This means that there is no overlap between the provided DAV SunGuide data and the crash data, so it is not possible to determine how many DAV events became DAV crashes using the information in the provided data. If the SunGuide reports for events that were initially DAVs, then became crashes were obtained in the future, it would be possible to identify how many DAVs result in crashes. Some data cleaning was performed to ensure consistency amongst roadway labels before conducting analyses. This made sure that different labels which corresponded to the same roadway (such as “I4”, “I-4”, and “SR-400” all corresponding to Interstate 4) were counted correctly. During this data cleaning, some events were identified as not occurring on a limited access facility. Additionally, the calculated event durations for some events were negative, which is infeasible. Filtering out these misclassified or erroneous events resulted in 1,591,508 DAV SunGuide events on Florida limited access facilities from January 2018 through December 2021.

4.1.3 DAV Waze Event Data

Waze data for DAVs were provided to the research team by EEI. These data were provided in four batches. Batch 1 contained Waze data from 1/1/2020 through 12/31/2020, batch 2 contained Waze data from 1/1/2021 through 6/30/2021, batch 3 contained Waze data from 4/22/2019 through 12/31/2019, and batch 4 contained Waze data from 7/1/2021 through

12/31/2021. Batch 1 and 2 only contained Waze alerts that were type = WEATHERHAZARD, subtype = HAZARD_ON_SHOULDER_CAR_STOPPED, and roadType = Freeway. These batches contained the following data fields: datePublished (date and time of alert), location_x (longitude), location_y (latitude), city, street, roadwayName, dirOfTravel (direction), and county. Batches 3 and 4 contained all types of Waze alerts on freeways (no Waze data available before 4/22/2019), so these data had to be filtered using the same type and subtype as batches 1 and 2 to only include DAV events. Additionally, the times in the datePublished (or "ts") field had to be converted to Eastern Daylight Time or Eastern Standard Time as appropriate. Overall, there were 10,319,417 DAV Waze alerts (3,217,663 records in batch 1; 2,287,985 records in batch 2; 2,291,877 records in batch 3; and 2,521,892 records in batch 4). A DAV SunGuide and Waze database was developed to filter and analyze this vast quantity of data and compare them, as discussed in the next section.

4.1.4 Development of DAV SunGuide and Waze Database

A MySQL (SQL stands for Structured Query Language) database was created to hold Waze and SunGuide data and queries were developed to process and filter the date, time, latitude, longitude, and roadway from the raw data sets. The collected Waze and SunGuide raw data were imported to the database, columns were verified and modified as needed to ensure compatibility between the imported data sets, then erroneous data (e.g., latitude of 0) were removed before combining and partitioning the database. The following queries were then applied to the data to identify overlap between the SunGuide and Waze data (note that the longitude variable was named "looong" in these queries and all subsequent queries because "long" and "longitude" are common keywords in programming and are therefore not suitable for variable names):

```
CREATE TABLE wazePeriod
SELECT created_date, closed_date, lat, looong, event_type, roadway, county, district FROM
sunguide WHERE
DATE(created_date) BETWEEN "20190422" AND "20211231" AND DATE(created_date)
NOT IN
("20191014","20191015","20191016","20200425","20200426","20200427","20200428",
"20200429","20200430","20200623","20200624","20200625","20200626","20200627",
"20200628","20200629","20200630","20200720","20200721","20200722","20200723",
"20200724","20200725","20200726","20211231");

CREATE TABLE wazeOverlap
SELECT s.created_date, s.closed_date, s.lat sg_lat, s.looong sg_looong, s.event_type, s.roadway,
s.county, s.district, COUNT(w.datez) AS counter, MIN(w.datez) as earliest_ping,
TIMESTAMPDIFF(MINUTE,(MIN(w.datez) - INTERVAL 59 SECOND),s.created_date) AS
time_before_minutes
        FROM wazePeriod s
JOIN
        (SELECT datez, lat, looong FROM waze) w
WHERE (s.created_date - INTERVAL 30 minute<=w.datez AND w.datez<=s.closed_date)
        AND (s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015)
        AND (s.looong-0.017<=w.looong AND w.looong<=s.looong+0.017)
```

```
group by s.created_date, s.closed_date, s.lat, s.looong;

CREATE TABLE wazeBefore
SELECT * FROM wazeOverlap
WHERE earliest_ping < created_date;

SELECT time_before_minutes, COUNT(time_before_minutes)
FROM wazeBefore
GROUP BY time_before_minutes
ORDER BY time_before_minutes
```

Waze data were missing or incomplete for some days, so these days were excluded from both the Waze and SunGuide data sets in these queries. The excluded days were 10/14/2019 through 10/16/2019, 4/25/2020 through 4/30/2020, 6/23/2020 through 6/30/2020, 7/20/2020 through 7/26/2020, and 12/31/2021. These queries identified SunGuide events and the number of overlapping Waze alerts, the associated SunGuide events for each Waze alert, and the time before the SunGuide created_date when the associated Waze alert(s) occurred. The search was limited by specified temporal and spatial buffers. The temporal buffer used was 30 minutes (30 minutes before the SunGuide created_date to the SunGuide closed_date) and the spatial buffers were ±0.015 latitude and ±0.017 longitude (resulting in a box with approximately 2-mile-long edges centered on the event). These buffers were selected after testing numerous values on one week of data from 2/9/2020 through 2/15/2020.

The results of these queries were all SunGuide events with at least one overlapping Waze alert, the number of overlapping Waze alerts for each of these SunGuide events, a binary column to determine the SunGuide events which had at least one Waze alert occur within the 30-minute buffer period before the SunGuide event was created, and the number of these SunGuide events for each minute of time difference (0 to 1 minute, 1 to 2 minutes, up to 29 to 30 minutes). These queries were run three times: once for all DAV events, once for disabled vehicle events only, and once for abandoned vehicle events only. A one-week sample of data from 2/9/2020 through 2/15/2020 was extracted from the database and compared with the same data processed in Excel to validate the database and test the developed MySQL queries.

4.2 DAV Data Analysis

This section discusses the data analyses performed on the three datasets described in Section 4.1. The crash data and SunGuide data were analyzed independently due to the large number of variables contained in each; these analyses are discussed in Sections 4.2.1 and 4.2.2, respectively. Limited analyses were conducted on the Waze dataset due to its lack of variables, but multiple analyses were conducted on the overlap between the Waze and SunGuide data. All of the analyses involving the Waze data (individually and overlap with SunGuide) are discussed in Section 4.2.3. Only analyses regarding characteristics and trends of these data are discussed in this section; analyses involving impacts of these events (such as crash costs, crash severities, and event durations) are discussed in Section 4.3.

4.2.1 DAV Crash Data Analysis

As stated earlier, S4A had no explicit filter to identify DAV crashes, so three queries were used to locate potential DAV crashes (as shown in Section 4.1.1). There were 1,256 independent non-overlapping DAV crashes on Florida limited access facilities from 2015 through 2020 obtained from these queries after manual review. **Table 4-1** shows a summary of how many DAV crashes were identified by each query or combination of queries. Query 2 yielded the most DAV crashes, identifying 962 of the 1,256 DAV crashes (77%) when considering all combinations that include this query. Query 1 yielded the least DAV crashes, only identifying 510 of the 1,256 DAV crashes (41%). Nonetheless, there is value is leveraging all three queries to locate DAV crashes in S4A as about half of all identified DAV crashes (614 out of 1256) came from one of the three queries alone and would not have been detected by the other two queries.

Table 4-1: Summary of DAV Crash Queries from S4A

	Disabled Vehicle Crashes		**Abandoned Vehicle Crashes**		**DAV Crashes**	
Query	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
Query 1 Only	138	13%	11	5%	149	12%
Query 2 Only	335	32%	37	18%	372	30%
Query 3 Only	83	8%	10	5%	93	7%
Query 1 & Query 2	114	11%	35	17%	149	12%
Query 1 & Query 3	44	4%	8	4%	52	4%
Query 2 & Query 3	227	22%	54	26%	281	22%
All 3 Queries	110	10%	50	24%	160	13%
Total	**1,051**	**100%**	**205**	**100%**	**1,256**	**100%**

The number of DAV crashes varies by year as shown in **Table 4-2**. These variations could be due to changes in roadway conditions (traffic volumes, roadway design, etc.), how crash reports are categorized, and reporting requirements. For example, the increase in the number of crashes from 2016 to 2017 could be partially reflective of a shift in how DAVs were encoded in the crash reports. There have been more DAV crashes per year from 2017 onward, with a peak of 239 DAV crashes in 2018. Even with the COVID-19 pandemic in 2020 reducing traffic volumes, there were still more DAV crashes in 2020 than in 2019. Most of the DAV crashes were due to disabled vehicles, ranging from 79.1% in 2019 to 87.4% in 2018.

Table 4-2: Summary of DAV Crashes by Year

Year	Disabled Vehicle Crashes	Abandoned Vehicle Crashes	DAV Crashes
2015	148	29	177
2016	141	34	175
2017	199	34	233
2018	209	30	239
2019	163	43	206
2020	191	35	226
Total	**1,051**	**205**	**1,256**

Table 4-3 and **Figure 4-1** show the number of DAV crashes per month. The number of disabled vehicle crashes is lowest in January through April then increases starting in May and peaks in August before decreasing in later months. This increase in crashes in the summer months could be due to increased traffic volumes from people traveling around Florida, tourists visiting Florida, and/or inclement weather and environmental conditions (such as high temperatures, humidity, and frequent heavy storms) during Florida's long summer months. The abandoned vehicle crashes remain relatively stable over the year, with June having the most abandoned vehicle crashes (24) and May having the fewest (11).

Table 4-3: Summary of DAV Crashes by Month

Month	Disabled Vehicle Crashes	Abandoned Vehicle Crashes	DAV Crashes
January	76	16	92
February	71	12	83
March	72	17	89
April	73	15	88
May	91	11	102
June	101	24	125
July	107	19	126
August	108	18	126
September	83	22	105
October	98	17	115
November	85	12	97
December	86	22	108
Total	**1,051**	**205**	**1,256**

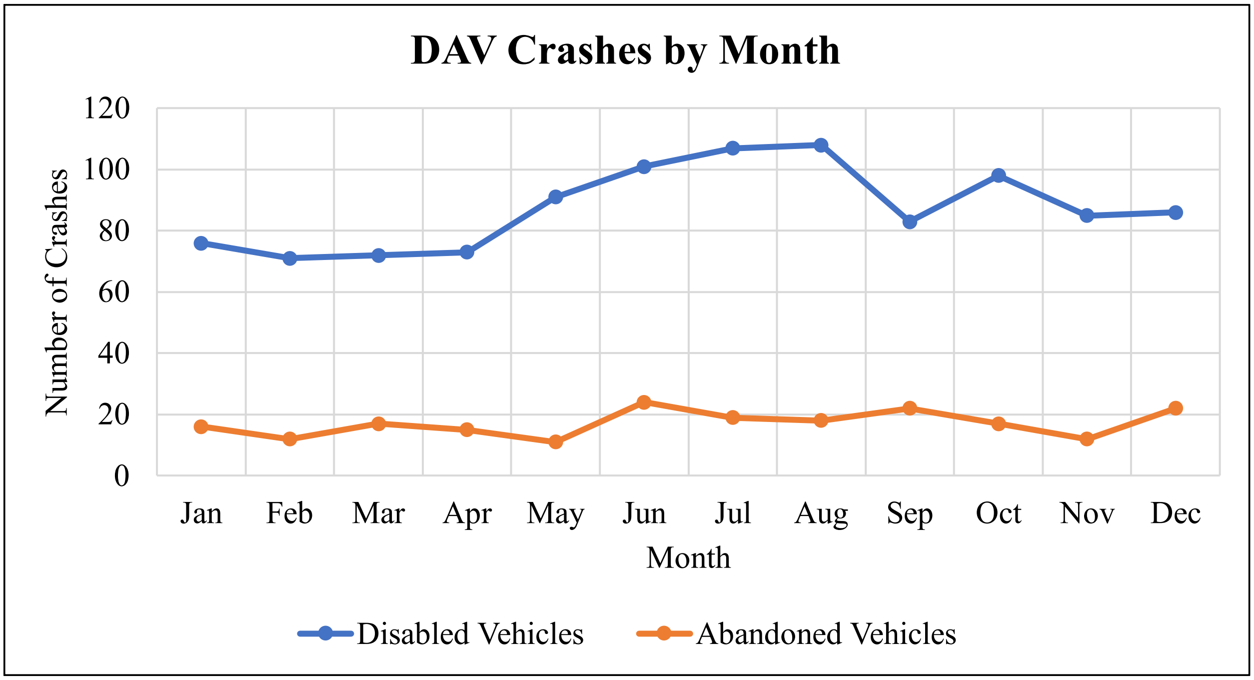

Figure 4-1: DAV Crashes by Month

Analyzing the number of DAV crashes with respect to the time of day showed some interesting trends. **Table 4-4** and **Figure 4-2** show the frequency of DAV crashes by hour of the day, with the table also showing the percentage of total disabled vehicle, abandoned vehicle, or DAV crashes occurring in each hour. For this figure and all subsequent figures in this chapter showing analyses by hour of the day, hour 0 corresponds to 12 AM, hour 1 corresponds to 1 AM, and so on. Disabled vehicle crashes had several peaks, with the highest being at 6 AM followed by 12 AM and 8 PM. In general, the number of disabled vehicle crashes during nighttime hours (especially from 7 PM until 1 AM) was higher than during daylight hours, suggesting that the visibility of disabled vehicles could play an important role in the chances of a crash. The trend for abandoned vehicle crashes was slightly different, as these crashes peaked at 4 AM and were highest from the hours of 12 AM until 7 AM. Since there are fewer vehicles on the road in these nighttime hours, this further supports the idea that DAV visibility is a key factor affecting the probability of them being struck by another vehicle. Vehicle visibility could be improved by educating the public about the importance of ensuring their disabled vehicles are visible to other drivers at night by using their flashing hazard lights. Additional nighttime patrols from law enforcement or Road Rangers, both of which have vehicles with emergency lights that increase visibility, could also aid in preventing crashes. For this to be effective, DAVs would need to be quickly identified and responded to so crash risks are minimized.

Table 4-4: Summary of DAV Crashes by Hour

	Disabled Vehicle Crashes		Abandoned Vehicle Crashes		DAV Crashes	
Hour	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
12 AM	58	5.5%	14	6.8%	72	5.7%
1 AM	36	3.4%	14	6.8%	50	4.0%
2 AM	40	3.8%	12	5.9%	52	4.1%
3 AM	35	3.3%	13	6.3%	48	3.8%
4 AM	39	3.7%	16	7.8%	55	4.4%
5 AM	50	4.8%	14	6.8%	64	5.1%
6 AM	60	5.7%	11	5.4%	71	5.7%
7 AM	33	3.1%	4	2.0%	37	2.9%
8 AM	32	3.0%	6	2.9%	38	3.0%
9 AM	31	2.9%	6	2.9%	37	2.9%
10 AM	35	3.3%	10	4.9%	45	3.6%
11 AM	36	3.4%	4	2.0%	40	3.2%
12 PM	43	4.1%	4	2.0%	47	3.7%
1 PM	41	3.9%	4	2.0%	45	3.6%
2 PM	49	4.7%	8	3.9%	57	4.5%
3 PM	55	5.2%	2	1.0%	57	4.5%
4 PM	33	3.1%	9	4.4%	42	3.3%
5 PM	40	3.8%	9	4.4%	49	3.9%
6 PM	41	3.9%	10	4.9%	51	4.1%
7 PM	54	5.1%	6	2.9%	60	4.8%
8 PM	57	5.4%	7	3.4%	64	5.1%
9 PM	51	4.9%	10	4.9%	61	4.9%
10 PM	51	4.9%	6	2.9%	57	4.5%
11 PM	51	4.9%	6	2.9%	57	4.5%
Total	**1,051**	**100%**	**205**	**100%**	**1,256**	**100%**

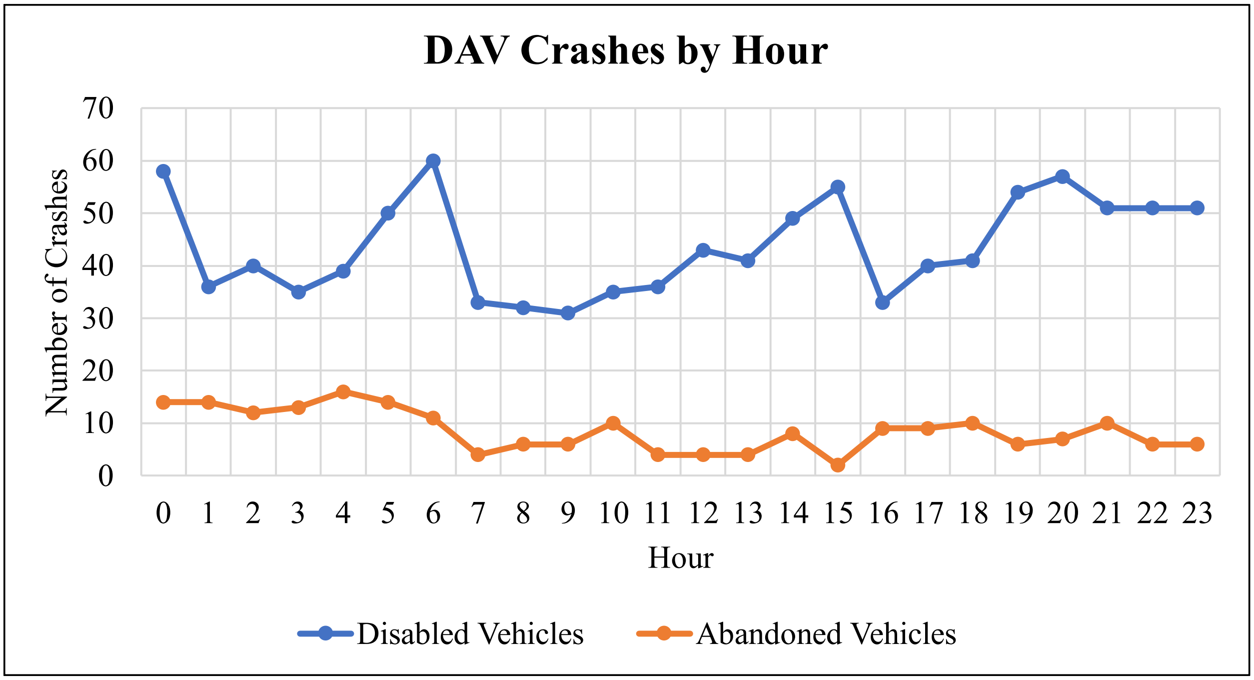

Figure 4-2: Frequency of DAV Crashes by Hour

Table 4-5 and **Figure 4-3** show the breakdown of DAV crashes by county. The frequency of DAV crashes varies by county, with more populous counties generally having more DAV crashes. Broward had the highest number of DAV crashes (189). Counties with large urban cities, such as Broward, Duval, Miami-Dade, and Hillsborough, had the most DAV crashes. This is likely due to these counties having more drivers on the roads compared to rural counties. Some rural counties, such as Holmes and Suwannee, had only one or two DAV crashes over the entire six-year period. Over 20% of the abandoned vehicle crashes occurred in Duval County, suggesting that efforts are needed to reduce the frequency of abandoned vehicles there.

Table 4-5: Summary of DAV Crashes by County

County	Disabled Vehicle Crashes		Abandoned Vehicle Crashes		DAV Crashes	
	Count	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
Broward	169	16.1%	20	9.8%	189	15.0%
Duval	131	12.5%	45	22.0%	176	14.0%
Hillsborough	112	10.7%	33	16.1%	145	11.5%
Miami-Dade	114	10.8%	6	2.9%	120	9.6%
Palm Beach	98	9.3%	17	8.3%	115	9.2%
Orange	69	6.6%	13	6.3%	82	6.5%
Brevard	30	2.9%	10	4.9%	40	3.2%
Volusia	26	2.5%	3	1.5%	29	2.3%
Marion	20	1.9%	4	2.0%	24	1.9%
Pinellas	17	1.6%	7	3.4%	24	1.9%
Seminole	18	1.7%	3	1.5%	21	1.7%
Alachua	16	1.5%	4	2.0%	20	1.6%
Polk	14	1.3%	6	2.9%	20	1.6%
St Lucie	15	1.4%	4	2.0%	19	1.5%
St Johns	16	1.5%	2	1.0%	18	1.4%
Osceola	15	1.4%	3	1.5%	18	1.4%
Manatee	12	1.1%	1	0.5%	13	1.0%
Sarasota	11	1.0%	2	1.0%	13	1.0%
Martin	10	1.0%	2	1.0%	12	1.0%
Pasco	11	1.0%	0	0.0%	11	0.9%
Escambia	8	0.8%	3	1.5%	11	0.9%
Lee	10	1.0%	0	0.0%	10	0.8%
Hamilton	8	0.8%	2	1.0%	10	0.8%
Collier	9	0.9%	0	0.0%	9	0.7%
Columbia	8	0.8%	1	0.5%	9	0.7%
Jackson	7	0.7%	1	0.5%	8	0.6%

Table 4-5: Summary of DAV Crashes by County

	Disabled Vehicle Crashes		Abandoned Vehicle Crashes		DAV Crashes	
County	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
Flagler	6	0.6%	2	1.0%	8	0.6%
Nassau	6	0.6%	2	1.0%	8	0.6%
Charlotte	6	0.6%	1	0.5%	7	0.6%
Santa Rosa	6	0.6%	1	0.5%	7	0.6%
Sumter	6	0.6%	1	0.5%	7	0.6%
Leon	5	0.5%	2	1.0%	7	0.6%
Indian River	6	0.6%	0	0.0%	6	0.5%
Lake	6	0.6%	0	0.0%	6	0.5%
Gadsden	5	0.5%	1	0.5%	6	0.5%
Walton	4	0.4%	0	0.0%	4	0.3%
Jefferson	3	0.3%	1	0.5%	4	0.3%
Okaloosa	3	0.3%	1	0.5%	4	0.3%
Washington	3	0.3%	1	0.5%	4	0.3%
Baker	3	0.3%	0	0.0%	3	0.2%
Hernando	3	0.3%	0	0.0%	3	0.2%
Madison	2	0.2%	0	0.0%	2	0.2%
Okeechobee	2	0.2%	0	0.0%	2	0.2%
Holmes	1	0.1%	0	0.0%	1	0.1%
Suwannee	1	0.1%	0	0.0%	1	0.1%
Total	**1,051**	**100%**	**205**	**100%**	**1,256**	**100%**

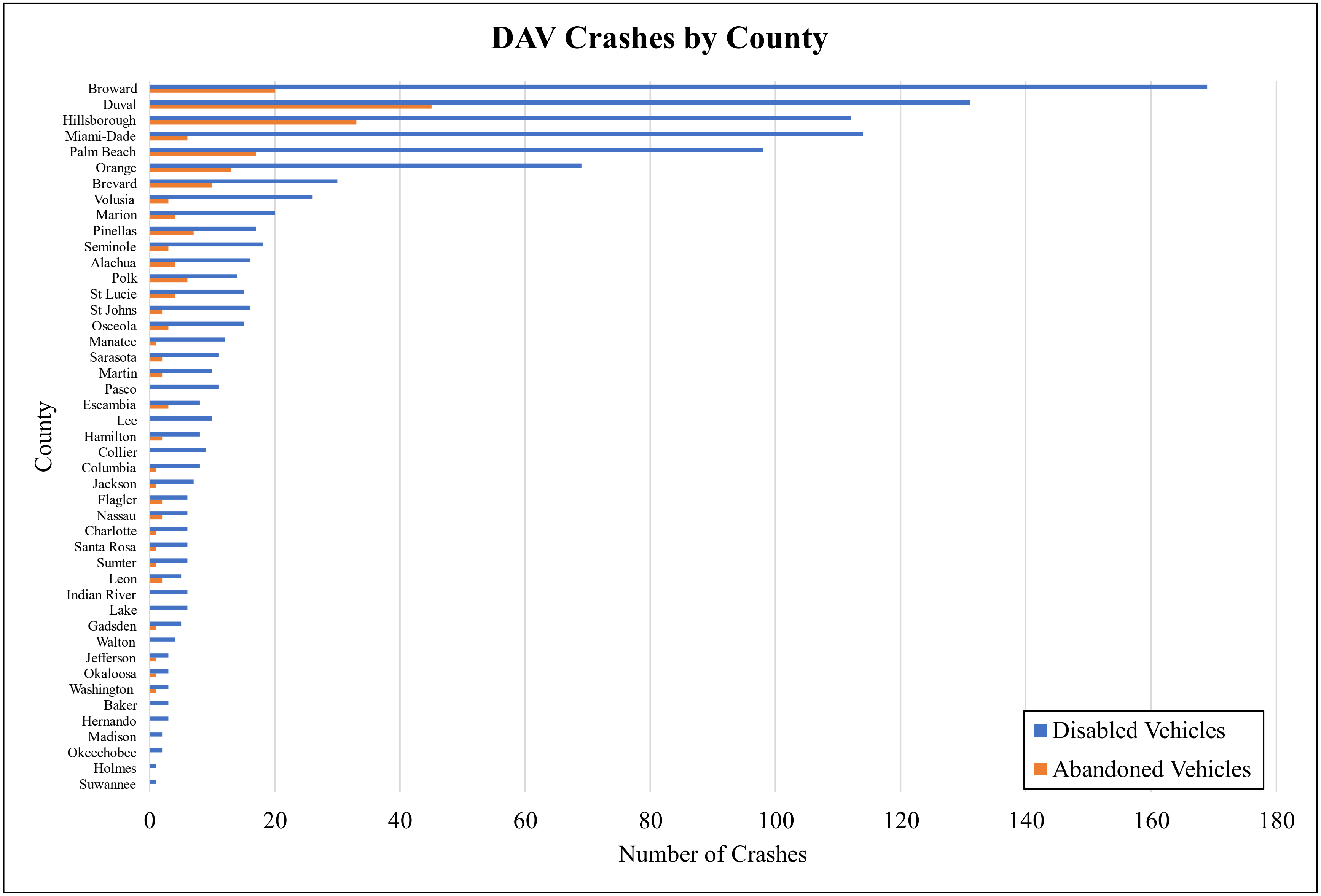

Figure 4-3: Frequency of DAV Crashes by County

Table 4-6 and **Figure 4-4** show the frequency of DAV crashes by roadway. Roadways that had less than 0.1% of all crashes were grouped into the "Other" category. The roadways with the most DAV crashes were among the longest roads in the state, primarily the major interstates. Most notably, over a third of all DAV crashes occurred on I-95, which runs along the eastern coast of Florida through several counties, such as Broward, Duval, Miami-Dade, and Palm Beach. This high frequency of crashes could be due to high traffic volumes and the greater number of lane-miles compared to other roadways. SR-91/SR-821 is the only non-interstate in the top five roadways with the most DAV crashes, which could be due to its high traffic volume and its long length that make it more distinct compared to other regional toll roads, such as SR-417 and SR-826. These regional toll roads and shorter interstate spurs, such as I-195 and I-110, had fewer crashes likely due to having lower traffic volumes and fewer lane-miles.

Table 4-6: Summary of DAV Crashes by Roadway

	Disabled Vehicle Crashes		**Abandoned Vehicle Crashes**		**DAV Crashes**	
Roadway	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
I-95	368	35.0%	67	32.7%	435	34.6%
I-75	159	15.1%	24	11.7%	183	14.6%
I-4	133	12.7%	34	16.6%	167	13.3%
SR-91/SR-821	137	13.0%	15	7.3%	152	12.1%
I-295	60	5.7%	26	12.7%	86	6.8%
I-10	65	6.2%	15	7.3%	80	6.4%
I-275	64	6.1%	15	7.3%	79	6.3%
I-595	24	2.3%	1	0.5%	25	2.0%
SR-869	7	0.7%	1	0.5%	8	0.6%
I-195	6	0.6%	0	0.0%	6	0.5%
SR-589/SR-568	4	0.4%	2	1.0%	6	0.5%
SR-408	4	0.4%	1	0.5%	5	0.4%
I-110	3	0.3%	1	0.5%	4	0.3%
SR-528	2	0.2%	2	1.0%	4	0.3%
SR-417	3	0.3%	0	0.0%	3	0.2%
SR-826	3	0.3%	0	0.0%	3	0.2%
SR-618	2	0.2%	1	0.5%	3	0.2%
SR-202	2	0.2%	0	0.0%	2	0.2%
Other	5	0.5%	0	0.0%	5	0.4%
Total	**1,051**	**100%**	**205**	**100%**	**1,256**	**100%**

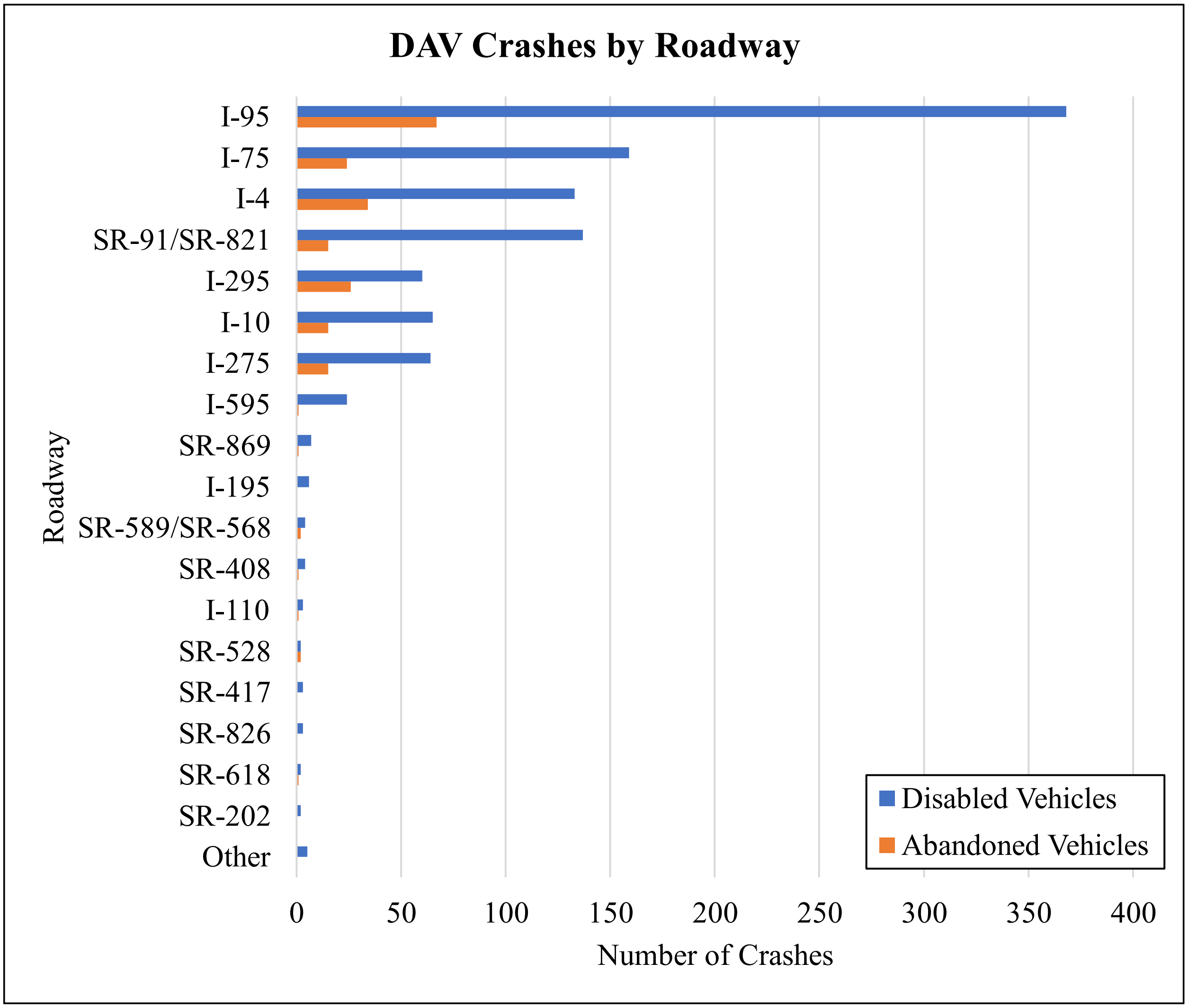

Figure 4-4: Frequency of DAV Crashes by Roadway

DAV crash analyses were also conducted for other characteristics, including the presence of a work zone; involvement of alcohol, drugs, or distracted driving; weather and lighting conditions, and whether any traffic citations were issued. **Table 4-7** shows only 7.6% of all DAV crashes occurred in a work zone (8.8% of disabled vehicle crashes and 1.5% of abandoned vehicle crashes). Work zones can be in the travel lanes or adjacent to the roadway, making them feasible locations for drivers to move their disabled vehicles. These drivers could then subsequently abandon the vehicle in the work zone, where it can pose a hazard to other drivers or to the workers present.

Table 4-7: Frequency of DAV Crashes in Work Zones

	Not in Work Zone		In Work Zone	
Vehicle Type	**Count**	**Percentage**	**Count**	**Percentage**
Disabled Vehicles	959	91.2%	92	8.8%
Abandoned Vehicles	202	98.5%	3	1.5%
Total	**1161**	**92.4%**	**95**	**7.6%**

Table 4-8 shows the frequency and percentage of DAV crashes involving alcohol, drugs, or distractions based on information in the crash reports. From these results, drugs were rarely a contributing factor to DAV crashes with less than 1% of all crashes involving drugs. Alcohol was more common, but only 3.7% of DAV crashes had alcohol as a contributing factor. Compared to drugs and alcohol, distracted driving was more common, as it was a contributing factor in 14.8% of all DAV crashes (14.5% of disabled vehicle crashes and 16.6% of abandoned vehicle crashes). This suggests that reducing distracted driving through public outreach and educational campaigns could help reduce the frequency of DAV crashes. Increasing the use of flashing lights to improve the visibility of DAV (as noted earlier) could also help distracted drivers notice a DAV and possibly avoid crashing into it.

Table 4-8: Frequency of DAV Crashes Involving Alcohol, Drugs, or Distractions

	Alcohol		Drugs		Distractions	
Vehicle Type	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Disabled Vehicles	37 (3.5%)	1,014 (96.5%)	9 (0.9%)	1,042 (99.1%)	152 (14.5%)	899 (85.5%)
Abandoned Vehicles	9 (4.4%)	196 (95.6%)	1 (0.5%)	204 (99.5%)	34 (16.6%)	171 (83.4%)
Total	**46 (3.7%)**	**1,210 (96.3%)**	**10 (0.8%)**	**1,246 (99.2%)**	**186 (14.8%)**	**1,070 (85.2%)**

Environmental conditions can play an important role in the chances of a DAV crash occurring. Two such conditions that are encoded in the crash reports are weather and lighting condition. **Table 4-9** shows the frequency of DAV crashes by the type of weather while **Table 4-10** shows the frequency of DAV crashes by the lighting condition at the time of the crash. About 85% of all DAV crashes occurred in clear or cloudy weather. Higher percentages of disabled vehicle crashes occurred in cloudy or rainy weather compared to abandoned vehicle crashes. Approximately half of all DAV crashes occurred in dark conditions, with about 20% occurring in the dark when no lighting was present. Compared to disabled vehicle crashes, a higher percentage of abandoned vehicle crashes occurred in these dark conditions. This further emphasizes the need for improved visibility of DAVs using flashing lights or other methods to alert other motorists and potentially reduce crashes.

Table 4-9: Frequency of DAV Crashes for Various Weather Conditions

	Clear		Cloudy		Rain		Other	
Vehicle Type	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Disabled Vehicles	633	60.2%	254	24.2%	152	14.5%	12	1.1%
Abandoned Vehicles	145	70.7%	38	18.5%	17	8.3%	5	2.4%
Total	**778**	**61.9%**	**292**	**23.2%**	**169**	**13.5%**	**17**	**1.4%**

Table 4-10: Frequency of DAV Crashes for Various Lighting Conditions

	Dark (Lighted)		Dark (Not Lighted)		Dawn		Daylight		Dusk		Unknown	
Vehicle Type	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Disabled	316	30.1%	201	19.1%	32	3.0%	472	44.9%	28	2.7%	2	0.2%
Abandoned	72	35.1%	49	23.9%	5	2.4%	69	33.7%	5	2.4%	5	2.4%
Total	**388**	**30.9%**	**250**	**19.9%**	**37**	**2.9%**	**541**	**43.1%**	**33**	**2.6%**	**7**	**0.6%**

Table 4-11 shows that 63.6% of DAV crashes resulted in at least one person receiving at least one citation. Only 56.6% of abandoned vehicle crashes had citations associated with them, compared to 65.0% for disabled vehicle crashes. This could be due to the lack of the driver of the abandoned vehicle being present in abandoned vehicle crashes. In disabled vehicle crashes, both the driver of the disabled vehicle and the driver of the vehicle who struck them could receive citations. This contrasts with abandoned vehicle crashes where the only party who could receive a citation is the driver of the vehicle that struck the abandoned vehicle (unless police are able to determine the owner of the abandoned vehicle and issue them a citation after the fact). A wide range of citations were issued for DAV crashes. Some of the most common citations issued were for careless driving or failure to drive in a single lane. These were primarily issued to the vehicle that struck the DAV. Citations for the driver of the DAV were less common, but citations issued to them typically related to creating a circumstance that led to the crash (such as opening their door into moving traffic).

Table 4-11: Frequency of Citations Issued in DAV Crashes

	Citation Issued		No Citation Issued	
Vehicle Type	**Count**	**Percentage**	**Count**	**Percentage**
Disabled Vehicles	683	65.0%	368	35.0%
Abandoned Vehicles	116	56.6%	89	43.4%
Total	**799**	**63.6%**	**457**	**36.4%**

4.2.2 DAV SunGuide Data Analysis

The filtered and cleaned DAV SunGuide data for all Florida limited access facilities from 2018 through 2021 contained information on 1,591,508 events. Of these events, 1,431,722 (90.0%) were disabled vehicle events and 159,786 (10.0%) were abandoned vehicle events. The breakdown of disabled vehicle and abandoned vehicle events by year is shown in **Table 4-12**. DAV events increased from 2018 to 2019 but decreased from 2019 to 2020. From 2020 to 2021, DAV events increased and surpassed their 2019 levels, suggesting that the decrease in DAV events in 2020 was due to the COVID-19 pandemic that affected traffic patterns and led to a temporary reduction in traffic volumes and subsequent DAVs. Of the four years considered, 2021 has the greatest number of DAV events. **Table 4-13** and **Figure 4-5** show that DAV event counts do not vary much month to month, although counts are slightly higher in summer months (which agrees with DAV crash trends).

Table 4-12: Summary of DAV SunGuide Events by Year

Year	Disabled Vehicles	Abandoned Vehicles	Combined Events
2018	330,778	35,983	366,761
2019	368,836	39,819	408,655
2020	348,578	38,957	387,535
2021	383,530	45,027	428,557
Total	**1,431,722**	**159,786**	**1,591,508**

Table 4-13: Summary of DAV SunGuide Events by Month

Month	Disabled Vehicles	Abandoned Vehicles	Combined Events
January	110,139	12,034	122,173
February	106,884	11,374	118,258
March	121,891	12,602	134,493
April	112,084	11,529	123,613
May	122,845	13,128	135,973
June	122,492	13,552	136,044
July	126,649	14,508	141,157
August	126,485	14,828	141,313
September	119,229	14,147	133,376
October	127,091	14,643	141,734
November	117,704	13,896	131,600
December	118,229	13,545	131,774
Total	**1,431,722**	**159,786**	**1,591,508**

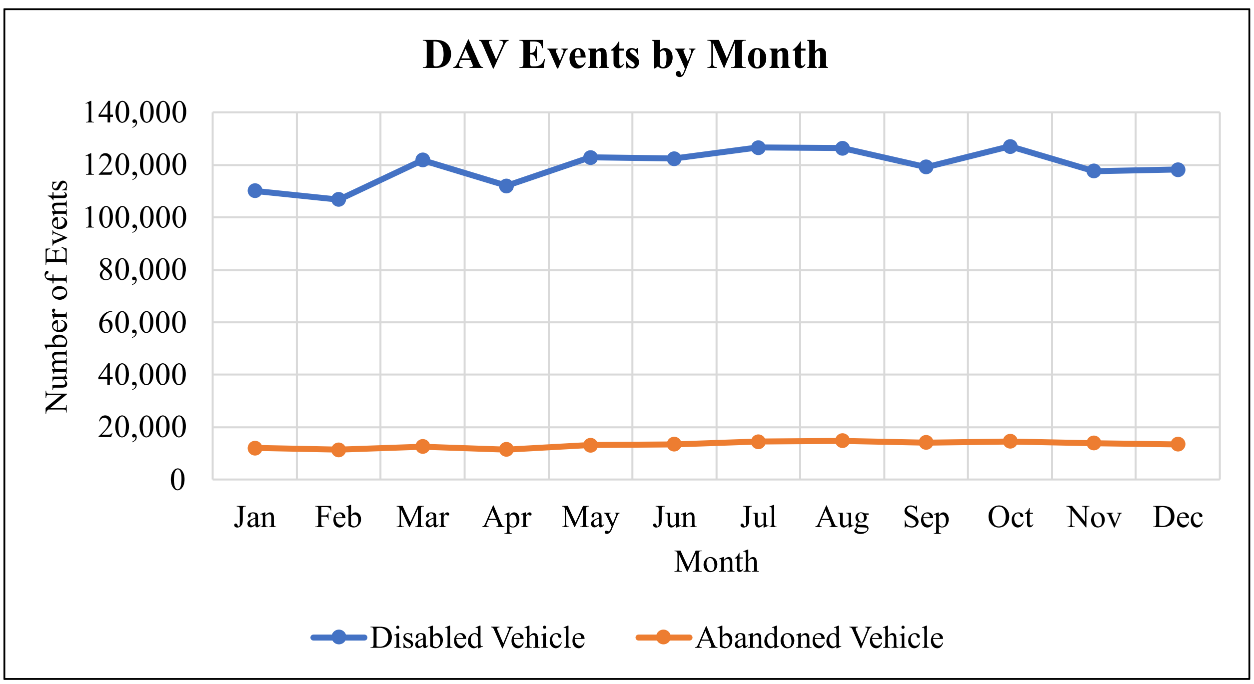

Figure 4-5: DAV SunGuide Events by Month

Analyzing DAV SunGuide events by hour of occurrence provides some additional insights. **Table 4-14**, **Figure 4-6**, and **Figure 4-7** show the number of DAV events for each hour of the day. The fewest reported DAV events occur from 12 AM through 5 AM. From 5 AM to 7 AM, the number of DAV events increase sharply, possibly due to increases in traffic volumes. Disabled vehicle event counts are highest during the afternoon and early evening (2 PM through 5 PM). These hours are consistent with typical afternoon and evening peaks in traffic volumes. Abandoned vehicle event counts are highest in the morning (6 AM through 10 AM), which covers the typical morning peak in traffic volumes. Unlike disabled vehicles which can be classified as disabled vehicles in a short time frame, abandoned vehicles (by their definition) take more time to be classified as abandoned. It is possible the hours from 5 AM to 7 AM are when TMC operators typically classify abandoned vehicles from the previous 24 hours are as abandoned in SunGuide, causing the high counts during these hours. The DAV crash analysis showed that disabled vehicle crashes peaked during similar time periods, although a higher percentage of crashes occurred during early nighttime hours compared to DAV SunGuide events.

Table 4-14: Summary of DAV SunGuide Events by Hour

	Disabled Vehicles		Abandoned Vehicles		Combined Events	
Hour	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
12 AM	35,305	2.5%	4,412	2.8%	39,717	2.5%
1 AM	28,135	2.0%	3,956	2.5%	32,091	2.0%
2 AM	23,939	1.7%	3,494	2.2%	27,433	1.7%
3 AM	21,507	1.5%	3,289	2.1%	24,796	1.6%
4 AM	21,009	1.5%	2,822	1.8%	23,831	1.5%
5 AM	21,732	1.5%	2,799	1.8%	24,531	1.5%
6 AM	42,534	3.0%	7,998	5.0%	50,532	3.2%
7 AM	63,012	4.4%	12,576	7.9%	75,588	4.7%
8 AM	65,081	4.5%	9,795	6.1%	74,876	4.7%
9 AM	65,505	4.6%	7,959	5.0%	73,464	4.6%
10 AM	70,987	5.0%	8,986	5.6%	79,973	5.0%
11 AM	74,401	5.2%	8,449	5.3%	82,850	5.2%
12 PM	74,495	5.2%	7,454	4.7%	81,949	5.1%
1 PM	73,910	5.2%	6,772	4.2%	80,682	5.1%
2 PM	94,648	6.6%	8,911	5.6%	103,559	6.5%
3 PM	102,101	7.1%	8,899	5.6%	111,000	7.0%
4 PM	99,761	7.0%	8,034	5.0%	107,795	6.8%
5 PM	92,597	6.5%	7,264	4.5%	99,861	6.3%
6 PM	84,564	5.9%	7,324	4.6%	91,888	5.8%
7 PM	72,881	5.1%	7,121	4.5%	80,002	5.0%
8 PM	61,040	4.3%	6,028	3.8%	67,068	4.2%
9 PM	50,955	3.6%	4,780	3.0%	55,735	3.5%
10 PM	48,238	3.4%	5,238	3.3%	53,476	3.4%
11 PM	43,385	3.0%	5,426	3.4%	48,811	3.1%
Total	**1,431,722**	**100%**	**159,786**	**100%**	**1,591,508**	**100%**

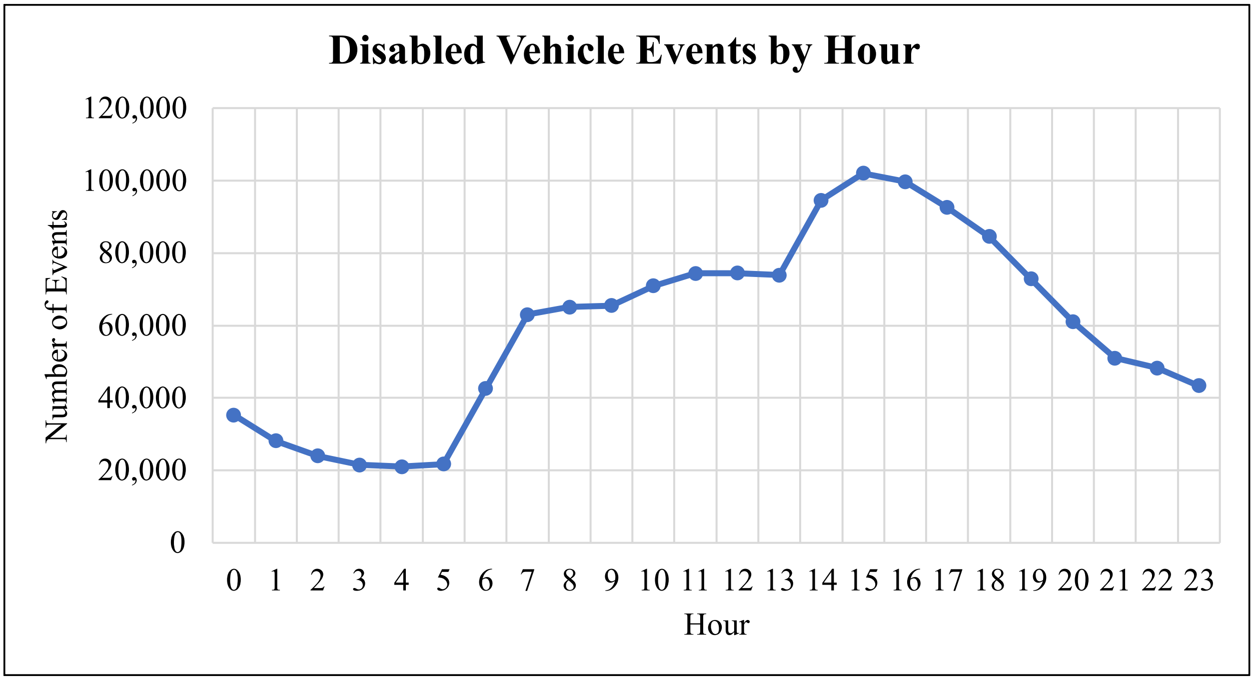

Figure 4-6: Frequency of Disabled Vehicle SunGuide Events by Hour

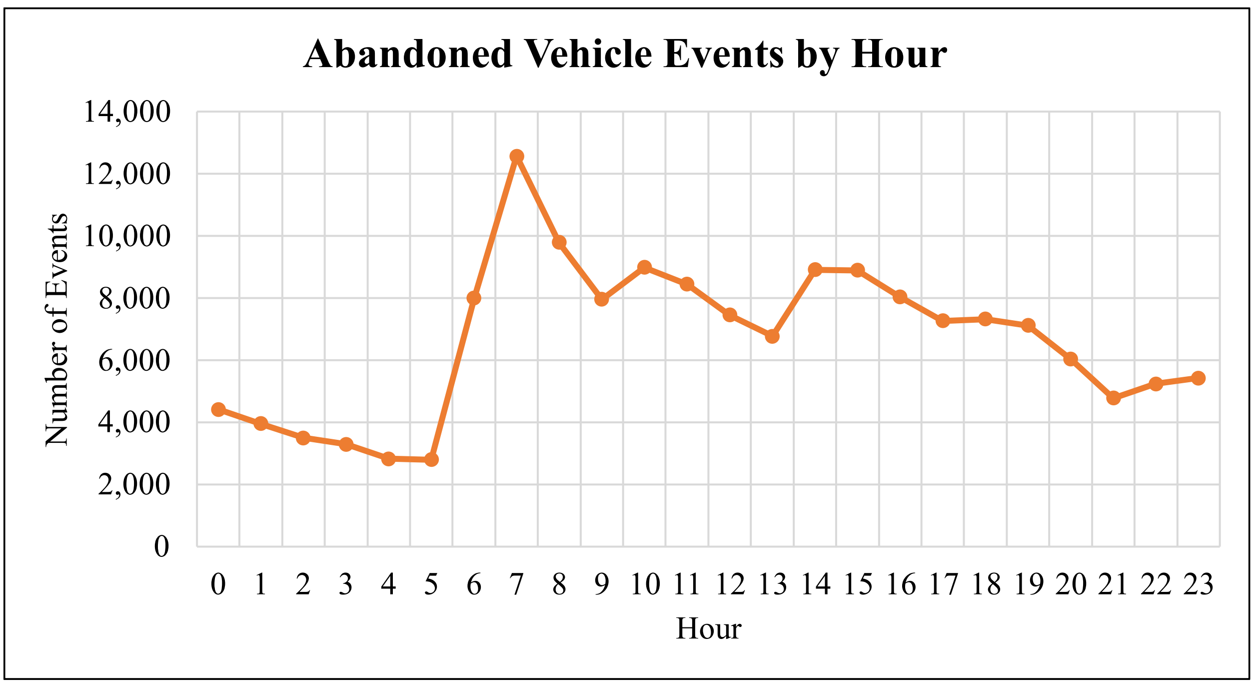

Figure 4-7: Frequency of Abandoned Vehicle SunGuide Events by Hour

Analyses of DAV SunGuide events by FDOT district, county, and roadway show how the frequency of DAV events varies by location. **Table 4-15** and **Figure 4-8** show the number of DAV events by district. FTE had the largest percentage of total DAV events (19.5%), followed by District 4 (16.7%). FTE controls the Florida's Turnpike and several other high-volume toll roadways in the state, so it makes sense that it has the highest percentage of events. Likewise, District 4 is in Southeast Florida and contains several populous counties (such as Broward and

Palm Beach) and high-volume roads (such as I-95 and SR-869), so the high percentage of DAV events is fitting. When looking at abandoned vehicles only, District 4 has the highest percentage of abandoned vehicle events in the state while District 6 (South Florida) has the lowest. Further investigations could examine possible reasons why these neighboring districts have drastically different abandoned vehicle percentages.

Table 4-15: Summary of DAV SunGuide Events by Districts

	Disabled Vehicles		Abandoned Vehicles		Combined Events	
District	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
FTE	280,613	19.6%	29,056	18.2%	309,669	19.5%
D4	231,038	16.1%	34,842	21.8%	265,880	16.7%
D5	182,260	12.7%	33,376	20.9%	215,636	13.5%
D7	169,061	11.8%	26,368	16.5%	195,429	12.3%
D1	173,524	12.1%	13,054	8.2%	186,578	11.7%
D3	172,745	12.1%	9,512	6.0%	182,257	11.5%
D2	113,476	7.9%	7,787	4.9%	121,263	7.6%
D6	109,005	7.6%	5,791	3.6%	114,796	7.2%
Total	**1,431,722**	**100%**	**159,786**	**100%**	**1,591,508**	**100%**

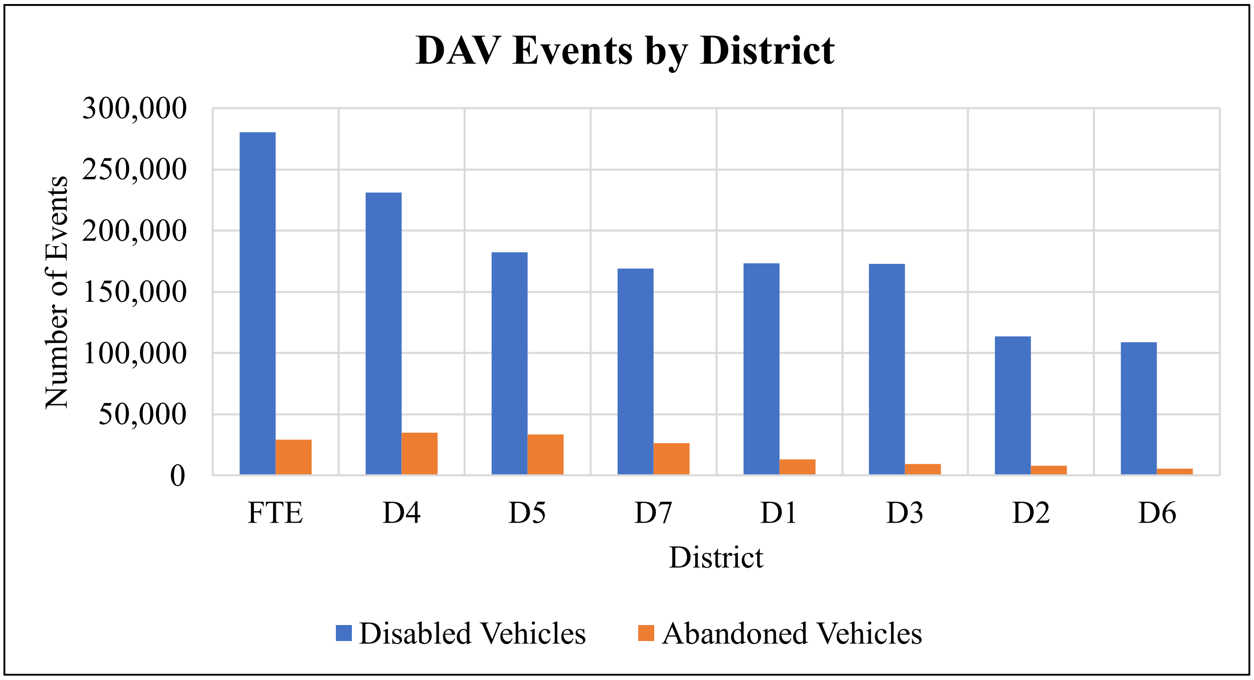

Figure 4-8: Frequency of DAV SunGuide Events by District

DAV events can vary drastically from county to county depending on the limited access roadways within each county. **Table 4-16** and **Figure 4-9** show the number of DAV SunGuide events per county. Broward County had the most DAV SunGuide events (11.1% of all DAV SunGuide events in the state), followed by Miami-Dade County (10.0% of all DAV SunGuide events in the state). These are both populous counties with many high-volume roadways, such as I-75, I-95, and SR-821. Like the DAV crash analysis, urban counties tended to have more DAV SunGuide events. For abandoned vehicle events, Duval County only had 3.2% of the total, compared to 22.0% of the abandoned vehicle crashes. This suggests that abandoned vehicles in Duval County are left in places where they are more likely to cause a crash than in other counties.

Table 4-16: Summary of DAV SunGuide Events by County

	Disabled Vehicles		**Abandoned Vehicles**		**Combined Events**	
County	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
Broward	159,289	11.1%	17,412	10.9%	176,701	11.1%
Miami-Dade	149,245	10.4%	10,145	6.3%	159,390	10.0%
Orange	126,430	8.8%	21,191	13.3%	147,621	9.3%
Hillsborough	109,454	7.6%	16,800	10.5%	126,254	7.9%
Palm Beach	90,394	6.3%	16,708	10.5%	107,102	6.7%
Duval	62,025	4.3%	5,185	3.2%	67,210	4.2%
Lee	57,714	4.0%	3,921	2.5%	61,635	3.9%
Collier	52,256	3.6%	2,585	1.6%	54,841	3.4%
Osceola	45,934	3.2%	5,130	3.2%	51,064	3.2%
St. Lucie	37,966	2.7%	4,108	2.6%	42,074	2.6%
Jackson	36,458	2.5%	880	0.6%	37,338	2.3%
Martin	32,904	2.3%	3,887	2.4%	36,791	2.3%
Polk	30,893	2.2%	4,616	2.9%	35,509	2.2%
Sarasota	31,757	2.2%	3,729	2.3%	35,486	2.2%
Volusia	30,034	2.1%	4,673	2.9%	34,707	2.2%
Pinellas	25,620	1.8%	3,800	2.4%	29,420	1.8%
Manatee	22,587	1.6%	2,345	1.5%	24,932	1.6%
Escambia	22,127	1.5%	2,566	1.6%	24,693	1.6%
Pasco	21,818	1.5%	2,837	1.8%	24,655	1.5%
Seminole	20,374	1.4%	3,451	2.2%	23,825	1.5%

Table 4-16: Summary of DAV SunGuide Events by County

	Disabled Vehicles		Abandoned Vehicles		Combined Events	
County	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
Walton	21,409	1.5%	818	0.5%	22,227	1.4%
Gadsden	19,189	1.3%	1,013	0.6%	20,202	1.3%
Brevard	16,001	1.1%	4,048	2.5%	20,049	1.3%
Santa Rosa	17,455	1.2%	1,696	1.1%	19,151	1.2%
Alachua	17,939	1.3%	975	0.6%	18,914	1.2%
Holmes	16,324	1.1%	398	0.2%	16,722	1.1%
Lake	15,007	1.0%	1,701	1.1%	16,708	1.0%
Charlotte	15,428	1.1%	1,237	0.8%	16,665	1.0%
Indian River	14,764	1.0%	1,728	1.1%	16,492	1.0%
Marion	13,233	0.9%	2,757	1.7%	15,990	1.0%
Sumter	13,003	0.9%	1,821	1.1%	14,824	0.9%
Okaloosa	13,216	0.9%	979	0.6%	14,195	0.9%
Columbia	11,765	0.8%	595	0.4%	12,360	0.8%
Leon	9,536	0.7%	549	0.3%	10,085	0.6%
Washington	9,043	0.6%	433	0.3%	9,476	0.6%
Jefferson	7,973	0.6%	178	0.1%	8,151	0.5%
Hernando	5,887	0.4%	837	0.5%	6,724	0.4%
St. Johns	5,462	0.4%	251	0.2%	5,713	0.4%
Hamilton	5,239	0.4%	254	0.2%	5,493	0.3%
Flagler	3,930	0.3%	805	0.5%	4,735	0.3%
Baker	3,693	0.3%	164	0.1%	3,857	0.2%
Okeechobee	3,565	0.2%	210	0.1%	3,775	0.2%
Suwannee	3,442	0.2%	175	0.1%	3,617	0.2%
Nassau	3,111	0.2%	178	0.1%	3,289	0.2%
Madison	829	0.1%	17	0.0%	846	0.1%
Total	**1,431,722**	**100%**	**159,786**	**100%**	**1,591,508**	**100%**

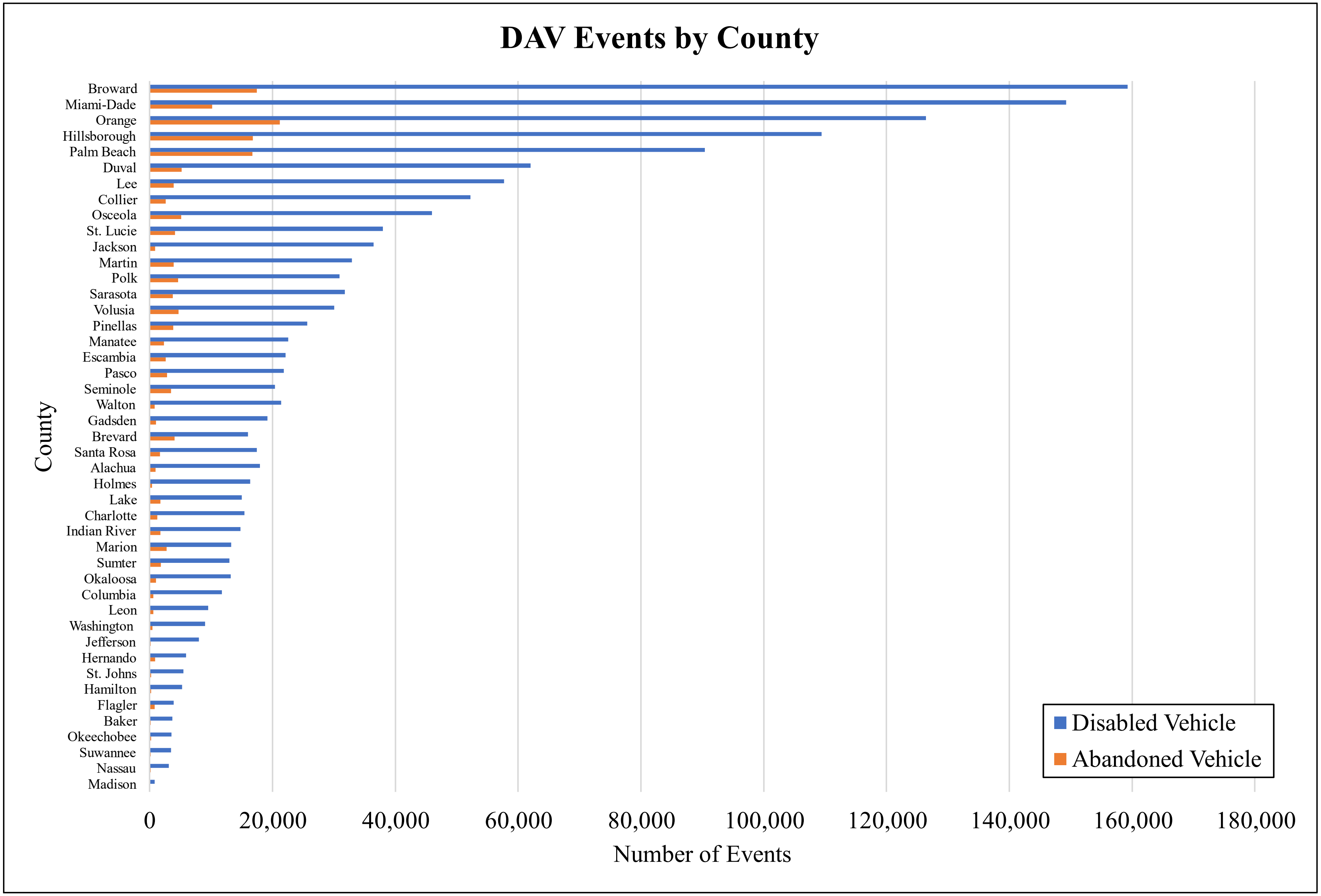

Figure 4-9: Frequency of DAV SunGuide Events by County

Table 4-17 and **Figure 4-10** show the DAV events by roadway. Roadways that had less than 0.1% of all events were grouped into the "Other" category. The roadways with the most DAV events were I-75, I-95, and SR-91/SR-821. This is consistent with the results obtained previously, as these are roadways that all run through Districts 4 and 6 (among others), with SR-91/SR-821 being the main FTE roadway. Shorter roadways with lower volumes tend to have fewer DAV events while longer roadways and those with higher volumes tend to have more DAV events. SR-91/SR-821 is the only non-interstate in the top five roadways with the most DAV events. This is likely due to the high traffic volumes on SR-91/SR-821 and its long length compared to other toll roads, which typically only cover one geographic region (such as SR-408 serving only Central Florida). These regional toll roads tended to have fewer DAV events compared to interstates due to having fewer lane-miles.

Table 4-17: Summary of DAV SunGuide Events by Roadway

	Disabled Vehicles		Abandoned Vehicles		Combined Events	
Roadway	**Count**	**Percentage**	**Count**	**Hour**	**Count**	**Percentage**
I-75	317,384	22.2%	30,779	19.3%	348,163	21.9%
I-95	300,417	21.0%	42,661	26.7%	343,078	21.6%
SR-91/SR-821	216,702	15.1%	21,329	13.3%	238,031	15.0%
I-10	186,037	13.0%	9,611	6.0%	195,648	12.3%
I-4	123,130	8.6%	19,661	12.3%	142,791	9.0%
I-275	61,244	4.3%	8,555	5.4%	69,799	4.4%
SR-826	44,021	3.1%	2,235	1.4%	46,256	2.9%
SR-417	28,055	2.0%	4,843	3.0%	32,898	2.1%
I-295	30,496	2.1%	2,043	1.3%	32,539	2.0%
SR-589/SR-568	27,299	1.9%	2,925	1.8%	30,224	1.9%
SR-528	22,599	1.6%	3,540	2.2%	26,139	1.6%
SR-408	21,190	1.5%	3,781	2.4%	24,971	1.6%
SR-429	18,959	1.3%	3,342	2.1%	22,301	1.4%
SR-869	8,774	0.6%	1,028	0.6%	9,802	0.6%
SR-202	4,643	0.3%	918	0.6%	5,561	0.3%
I-110	4,358	0.3%	794	0.5%	5,152	0.3%
I-595	3,854	0.3%	381	0.2%	4,235	0.3%
SR-570	3,629	0.3%	337	0.2%	3,966	0.2%
I-195	2,703	0.2%	264	0.2%	2,967	0.2%

Table 4-17: Summary of DAV SunGuide Events by Roadway

	Disabled Vehicles		Abandoned Vehicles		Combined Events	
Roadway	**Count**	**Percentage**	**Count**	**Hour**	**Count**	**Percentage**
SR-414	2,028	0.1%	467	0.3%	2,495	0.2%
I-395	1,504	0.1%	83	0.1%	1,587	0.1%
Other	2,696	0.2%	209	0.1%	2,905	0.2%
Total	**1,431,722**	**100%**	**159,786**	**100%**	**1,591,508**	**100%**

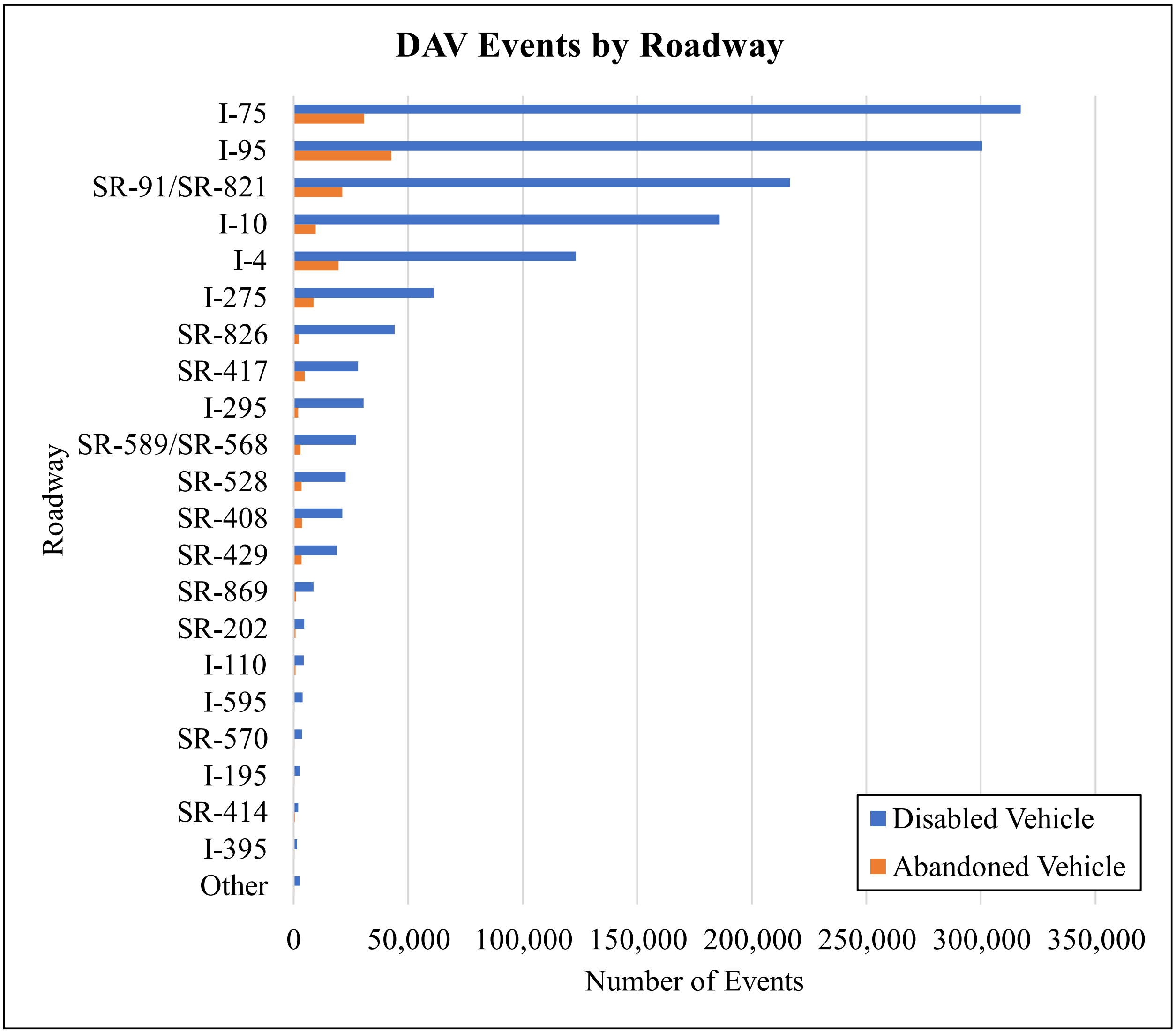

Figure 4-10: Frequency of DAV SunGuide Events by Roadway

4.2.3 Analysis of DAV Waze Data and Overlap Between DAV Waze and SunGuide Data

Analyses were also conducted on the DAV Waze data set and the overlap between DAV Waze and SunGuide data. After removing incomplete and erroneous records, the DAV Waze data set contained 10,319,417 alerts from April 22, 2019, through December 31, 2021. The DAV Waze data did not contain many variables, so these data were only analyzed with respect to time of occurrence and roadway they occurred on.

Table 4-18 and **Figure 4-11** show the number of Waze alerts that occurred for each hour of the day. Most Waze alerts occurred during daytime hours (especially between 8 AM and 6 PM), with very low counts during nighttime hours (especially 11 PM through 5 AM). This is likely due to the lower traffic volumes (and therefore fewer Waze users) during these hours. Overall, the hourly trend of the DAV Waze alerts is very similar to the hourly trend of DAV SunGuide events, although the DAV SunGuide event peak during late afternoon and early evening hours is not as prominent in the Waze data.

Table 4-19 and **Figure 4-12** show the number of DAV Waze alerts by roadway, with the "Other" category containing all roadways that had less than 0.1% of the total Waze alerts. The results are similar to the DAV SunGuide event analysis results by roadway, with longer and higher-volume roadways typically having more Waze alerts. SR-91/SR-821 had the third most DAV alerts, like it did for the SunGuide events, further emphasizing the high frequency of DAVs on this roadway. Some roadways (such as SR-826) had a lower percentage of Waze alerts compared to SunGuide events, suggesting that these roadways might not have many Waze users compared to roadways where these percentages were roughly equal. Conversely, roadways with a higher percentage of Waze alerts compared to SunGuide events (such as I-4) likely have more Waze users compared to other roadways.

Table 4-18: DAV Waze Alerts by Hour of Occurrence

Hour	Count	Percentage
12 AM	131,229	1.3%
1 AM	99,688	1.0%
2 AM	81,174	0.8%
3 AM	82,178	0.8%
4 AM	115,499	1.1%
5 AM	180,278	1.7%
6 AM	304,042	2.9%
7 AM	448,422	4.3%
8 AM	539,507	5.2%
9 AM	582,177	5.6%
10 AM	635,163	6.2%
11 AM	680,071	6.6%
12 PM	691,579	6.7%
1 PM	722,250	7.0%
2 PM	747,411	7.2%
3 PM	753,628	7.3%
4 PM	751,962	7.3%
5 PM	716,487	6.9%
6 PM	593,002	5.7%
7 PM	456,309	4.4%
8 PM	346,579	3.4%
9 PM	270,141	2.6%
10 PM	218,770	2.1%
11 PM	171,871	1.7%
Total	**10,319,417**	**100%**

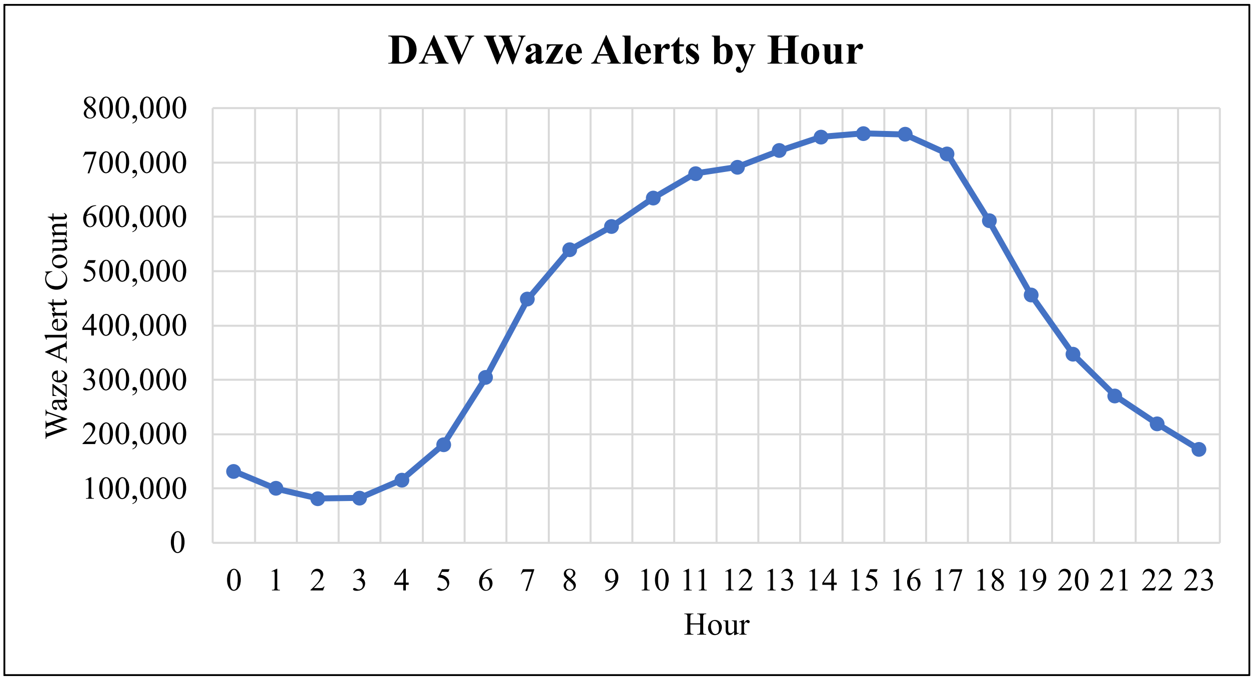

Figure 4-11: DAV Waze Alerts by Hour of Occurrence

Table 4-19: DAV Waze Alerts by Roadway

Roadway	Count	Percentage
I-95	2,482,090	24.1%
I-75	2,473,736	24.0%
SR-91/SR-821	1,577,728	15.3%
I-4	1,196,050	11.6%
I-10	817,063	7.9%
I-275	334,996	3.2%
I-295	246,999	2.4%
SR-528	172,800	1.7%
SR-417	172,235	1.7%
SR-826	116,755	1.1%
SR-429	103,552	1.0%
SR-408	98,680	1.0%
SR-869	90,750	0.9%
SR-589/SR-568	71,528	0.7%
I-595	61,193	0.6%
SR-836	54,849	0.5%
SR-874	31,568	0.3%
SR-202	28,580	0.3%
SR-618	28,509	0.3%
SR-570	23,296	0.2%
I-195	20,568	0.2%
SR-9B	17,802	0.2%
SR-414	11,706	0.1%
Other	86,384	0.8%
Total	**10,319,417**	**100%**

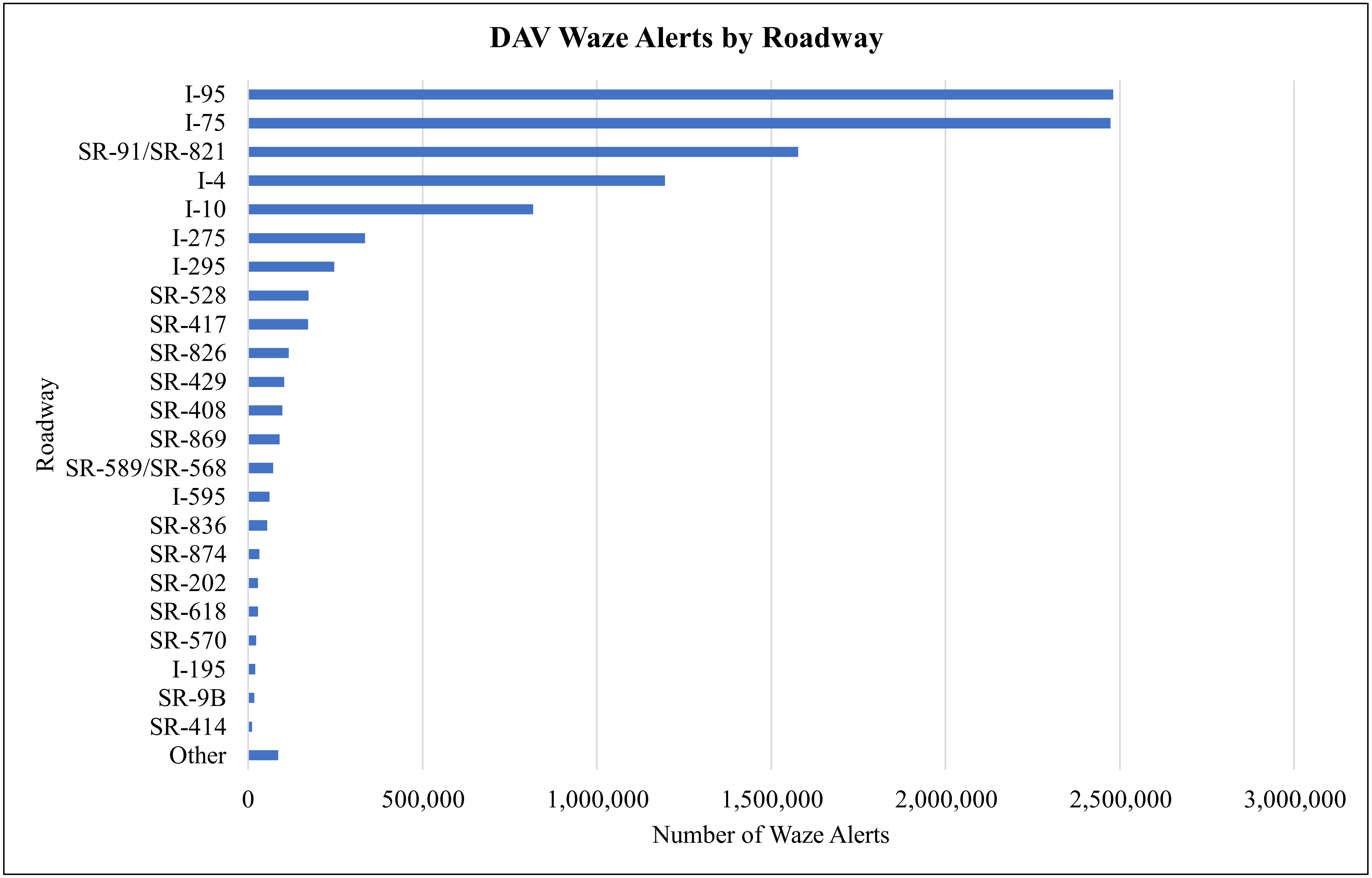

Figure 4-12: DAV Waze Alerts by Roadway

While the analyses of the DAV Waze data provide some insights, more meaningful insights can be obtained by analyzing the overlap between SunGuide and Waze data. Since the available SunGuide data encompassed a longer period than the available Waze data, only SunGuide events that happened during the Waze data period of 4/22/2019 through 12/31/2021 were considered for these analyses. The dates with missing or incomplete Waze data mentioned in Section 4.1.4 were also excluded. During this period, there were 1,036,775 DAV SunGuide events with 928,093 (89.5%) being disabled vehicle events and 108,682 (10.5%) being abandoned vehicle events. These SunGuide events were compared with the 10,319,417 Waze alerts by analyzing the results of the developed SQL queries discussed in Section 4.1.4. Three event types were considered during these analyses: disabled vehicle events, abandoned vehicle events, and all DAV events. Additionally, three different groups of SunGuide events were considered: all SunGuide events during the Waze period, all SunGuide events with at least one overlapping Waze alert, and all SunGuide events with at least one Waze alert which occurred in the 30-minute buffer before the SunGuide event was created. These groups are referred to as "Waze Period", "Waze Overlap" and "Waze Before", respectively, throughout the rest of this report.

Application of the developed SQL queries showed that the Waze Overlap group contained 721,728 SunGuide events (621,823 disabled vehicle events and 99,905 abandoned vehicle events) and the Waze Before group contained 481,839 SunGuide events (429,045 disabled vehicle events and 52,794 abandoned vehicle events). **Figure 4-13** shows the breakdown of each group by event type. Comparing all three groups shows that 69.6% of events in the Waze Period group were in the Waze Overlap group (67.0% of disabled vehicle events and 91.9% of abandoned vehicle events) and 66.8% of the events in the Waze Overlap group were in the Waze Before group (69.0% of disabled vehicle events and 52.8% of abandoned vehicle events). The 721,728 events in the Waze Overlap group had 3,887,524 associated Waze alerts (average of 5.39 Waze alerts per SunGuide event). Disabled vehicle events had 1,955,290 associated Waze alerts (average of 3.14 Waze alerts per disabled vehicle SunGuide event), while abandoned vehicle events had 1,932,234 associated Waze alerts (average of 19.34 Waze alerts per abandoned vehicle SunGuide event). Abandoned vehicle events had a higher percentage of events in the Waze Overlap group and had more Waze alerts per SunGuide event due to abandoned vehicle events typically being much longer than disabled vehicle events.

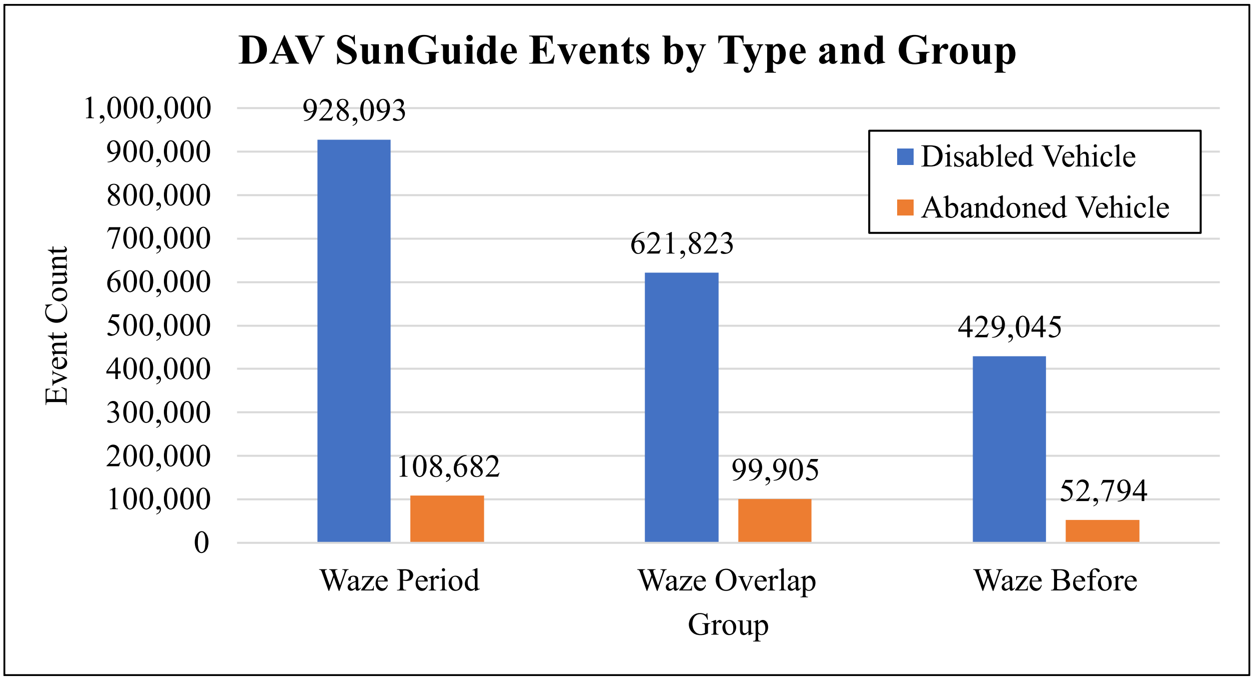

Figure 4-13: DAV SunGuide Events by Type and Group

The Waze and SunGuide events were compared and analyzed with respect to hour of occurrence, FDOT district, county, and roadway for each event type and group. **Table 4-20** through **Table 4-22** show the breakdown of SunGuide events by event group for DAV, disabled vehicle, and abandoned vehicle events, respectively. In these tables (and all similar subsequent tables in this section), column 1 shows the hour; columns 2, 4, and 7 show the number of events in that hour for the specified event group (Waze Period, Waze Overlap, or Waze Before); columns 3, 5, and 8 show the percentage of the total events for that group in each hour; column 6 shows the percentage of the Waze Period events that are in the Waze Overlap group for each hour; column 9 shows the percentage of the Waze Period events that are in the Waze Before group for each hour; and column 10 shows the percentage of the Waze Overlap events that are in the Waze Before group for each hour. The hourly event counts for each event group are also shown in **Figure 4-14** through **Figure 4-16** for DAV, disabled vehicle, and abandoned vehicle events, respectively.

These figures and tables show that most of the events occur between 7 AM and 8 PM (which generally agrees with the SunGuide and Waze alert analyses). A smaller percentage of SunGuide events have associated Waze alerts during nighttime hours compared to daytime hours, likely due to less Waze users being on the road at night. Disabled vehicle events occur most often between 2 PM and 7 PM, while abandoned vehicle events occur most often between 7 AM and 10 AM. Abandoned vehicles are also a larger percentage of DAV events during early morning hours (12 AM to 7 AM) than during other hours. The information in these tables and figures could be used to help identify the optimal times of day to notify TMC operators of DAV Waze alerts.

Table 4-20: DAV SunGuide Events by Hour and Event Group

Hour	Waze Period		Waze Overlap			Waze Before			
12 AM	23,603	2.3%	11,020	1.5%	46.7%	4,833	1.0%	20.5%	43.9%
1 AM	19,918	1.9%	8,571	1.2%	43.0%	3,263	0.7%	16.4%	38.1%
2 AM	17,180	1.7%	6,858	1.0%	39.9%	2,148	0.4%	12.5%	31.3%
3 AM	15,324	1.5%	6,317	0.9%	41.2%	1,822	0.4%	11.9%	28.8%
4 AM	14,362	1.4%	6,175	0.9%	43.0%	1,973	0.4%	13.7%	32.0%
5 AM	15,573	1.5%	7,995	1.1%	51.3%	3,172	0.7%	20.4%	39.7%
6 AM	35,177	3.4%	23,216	3.2%	66.0%	12,399	2.6%	35.2%	53.4%
7 AM	56,004	5.4%	40,920	5.7%	73.1%	25,949	5.4%	46.3%	63.4%
8 AM	56,229	5.4%	41,505	5.8%	73.8%	28,105	5.8%	50.0%	67.7%
9 AM	54,792	5.3%	40,117	5.6%	73.2%	27,387	5.7%	50.0%	68.3%
10 AM	58,080	5.6%	41,924	5.8%	72.2%	28,895	6.0%	49.8%	68.9%
11 AM	56,431	5.4%	41,574	5.8%	73.7%	29,202	6.1%	51.7%	70.2%
12 PM	53,329	5.1%	39,385	5.5%	73.9%	27,590	5.7%	51.7%	70.1%
1 PM	50,732	4.9%	38,076	5.3%	75.1%	27,041	5.6%	53.3%	71.0%
2 PM	67,872	6.5%	51,836	7.2%	76.4%	37,212	7.7%	54.8%	71.8%
3 PM	74,517	7.2%	57,350	7.9%	77.0%	41,668	8.6%	55.9%	72.7%
4 PM	71,464	6.9%	55,777	7.7%	78.0%	41,337	8.6%	57.8%	74.1%
5 PM	65,937	6.4%	51,450	7.1%	78.0%	38,563	8.0%	58.5%	75.0%
6 PM	57,592	5.6%	43,574	6.0%	75.7%	31,993	6.6%	55.6%	73.4%
7 PM	48,755	4.7%	34,757	4.8%	71.3%	24,137	5.0%	49.5%	69.4%
8 PM	37,983	3.7%	24,557	3.4%	64.7%	15,992	3.3%	42.1%	65.1%
9 PM	29,626	2.9%	17,957	2.5%	60.6%	10,771	2.2%	36.4%	60.0%
10 PM	28,798	2.8%	16,430	2.3%	57.1%	9,096	1.9%	31.6%	55.4%
11 PM	27,497	2.7%	14,387	2.0%	52.3%	7,291	1.5%	26.5%	50.7%
Total	**1,036,775**	**100%**	**721,728**	**100%**	**69.6%**	**481,839**	**100%**	**46.5%**	**66.8%**

Table 4-21: Disabled Vehicle SunGuide Events by Hour and Event Group

Hour	Waze Period		Waze Overlap			Waze Before			
12 AM	20,767	2.2%	8,484	1.4%	40.9%	4,010	0.9%	19.3%	47.3%
1 AM	17,185	1.9%	6,137	1.0%	35.7%	2,573	0.6%	15.0%	41.9%
2 AM	14,856	1.6%	4,793	0.8%	32.3%	1,654	0.4%	11.1%	34.5%
3 AM	13,249	1.4%	4,448	0.7%	33.6%	1,404	0.3%	10.6%	31.6%
4 AM	12,613	1.4%	4,575	0.7%	36.3%	1,554	0.4%	12.3%	34.0%
5 AM	13,772	1.5%	6,354	1.0%	46.1%	2,649	0.6%	19.2%	41.7%
6 AM	29,520	3.2%	17,939	2.9%	60.8%	10,188	2.4%	34.5%	56.8%
7 AM	46,070	5.0%	31,666	5.1%	68.7%	21,296	5.0%	46.2%	67.3%
8 AM	48,477	5.2%	34,308	5.5%	70.8%	24,203	5.6%	49.9%	70.5%
9 AM	48,652	5.2%	34,429	5.5%	70.8%	24,200	5.6%	49.7%	70.3%
10 AM	51,874	5.6%	36,403	5.9%	70.2%	25,599	6.0%	49.3%	70.3%
11 AM	51,396	5.5%	36,997	5.9%	72.0%	26,423	6.2%	51.4%	71.4%
12 PM	49,139	5.3%	35,503	5.7%	72.3%	25,213	5.9%	51.3%	71.0%
1 PM	46,871	5.1%	34,515	5.6%	73.6%	24,812	5.8%	52.9%	71.9%
2 PM	62,099	6.7%	46,420	7.5%	74.8%	33,774	7.9%	54.4%	72.8%
3 PM	68,325	7.4%	51,545	8.3%	75.4%	37,960	8.8%	55.6%	73.6%
4 PM	65,846	7.1%	50,504	8.1%	76.7%	37,963	8.8%	57.7%	75.2%
5 PM	60,786	6.5%	46,639	7.5%	76.7%	35,373	8.2%	58.2%	75.8%
6 PM	52,572	5.7%	38,940	6.3%	74.1%	29,132	6.8%	55.4%	74.8%
7 PM	43,719	4.7%	30,133	4.8%	68.9%	21,453	5.0%	49.1%	71.2%
8 PM	34,066	3.7%	21,068	3.4%	61.8%	14,194	3.3%	41.7%	67.4%
9 PM	26,574	2.9%	15,216	2.4%	57.3%	9,501	2.2%	35.8%	62.4%
10 PM	25,468	2.7%	13,387	2.2%	52.6%	7,740	1.8%	30.4%	57.8%
11 PM	24,197	2.6%	11,420	1.8%	47.2%	6,177	1.4%	25.5%	54.1%
Total	**928,093**	**100%**	**621,823**	**100%**	**67.0%**	**429,045**	**100%**	**46.2%**	**69.0%**

Table 4-22: Abandoned Vehicle SunGuide Events by Hour and Event Group

Hour	**Waze Period**		**Waze Overlap**			**Waze Before**			
12 AM	2,836	2.6%	2,536	2.5%	89.4%	823	1.6%	29.0%	32.5%
1 AM	2,733	2.5%	2,434	2.4%	89.1%	690	1.3%	25.2%	28.3%
2 AM	2,324	2.1%	2,065	2.1%	88.9%	494	0.9%	21.3%	23.9%
3 AM	2,075	1.9%	1,869	1.9%	90.1%	418	0.8%	20.1%	22.4%
4 AM	1,749	1.6%	1,600	1.6%	91.5%	419	0.8%	24.0%	26.2%
5 AM	1,801	1.7%	1,641	1.6%	91.1%	523	1.0%	29.0%	31.9%
6 AM	5,657	5.2%	5,277	5.3%	93.3%	2,211	4.2%	39.1%	41.9%
7 AM	9,934	9.1%	9,254	9.3%	93.2%	4,653	8.8%	46.8%	50.3%
8 AM	7,752	7.1%	7,197	7.2%	92.8%	3,902	7.4%	50.3%	54.2%
9 AM	6,140	5.6%	5,688	5.7%	92.6%	3,187	6.0%	51.9%	56.0%
10 AM	6,206	5.7%	5,521	5.5%	89.0%	3,296	6.2%	53.1%	59.7%
11 AM	5,035	4.6%	4,577	4.6%	90.9%	2,779	5.3%	55.2%	60.7%
12 PM	4,190	3.9%	3,882	3.9%	92.6%	2,377	4.5%	56.7%	61.2%
1 PM	3,861	3.6%	3,561	3.6%	92.2%	2,229	4.2%	57.7%	62.6%
2 PM	5,773	5.3%	5,416	5.4%	93.8%	3,438	6.5%	59.6%	63.5%
3 PM	6,192	5.7%	5,805	5.8%	93.8%	3,708	7.0%	59.9%	63.9%
4 PM	5,618	5.2%	5,273	5.3%	93.9%	3,374	6.4%	60.1%	64.0%
5 PM	5,151	4.7%	4,811	4.8%	93.4%	3,190	6.0%	61.9%	66.3%
6 PM	5,020	4.6%	4,634	4.6%	92.3%	2,861	5.4%	57.0%	61.7%
7 PM	5,036	4.6%	4,624	4.6%	91.8%	2,684	5.1%	53.3%	58.0%
8 PM	3,917	3.6%	3,489	3.5%	89.1%	1,798	3.4%	45.9%	51.5%
9 PM	3,052	2.8%	2,741	2.7%	89.8%	1,270	2.4%	41.6%	46.3%
10 PM	3,330	3.1%	3,043	3.0%	91.4%	1,356	2.6%	40.7%	44.6%
11 PM	3,300	3.0%	2,967	3.0%	89.9%	1,114	2.1%	33.8%	37.5%
Total	**108,682**	**100%**	**99,905**	**100%**	**91.9%**	**52,794**	**100%**	**48.6%**	**52.8%**

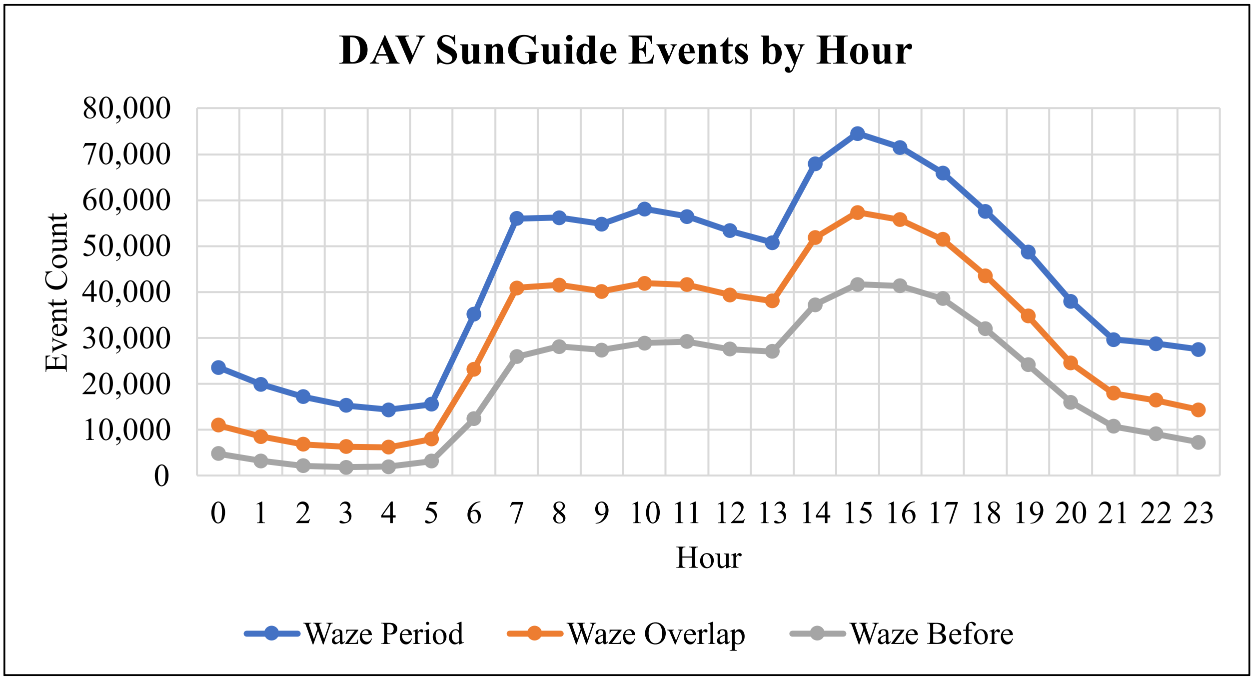

Figure 4-14: DAV SunGuide Events by Hour and Event Group

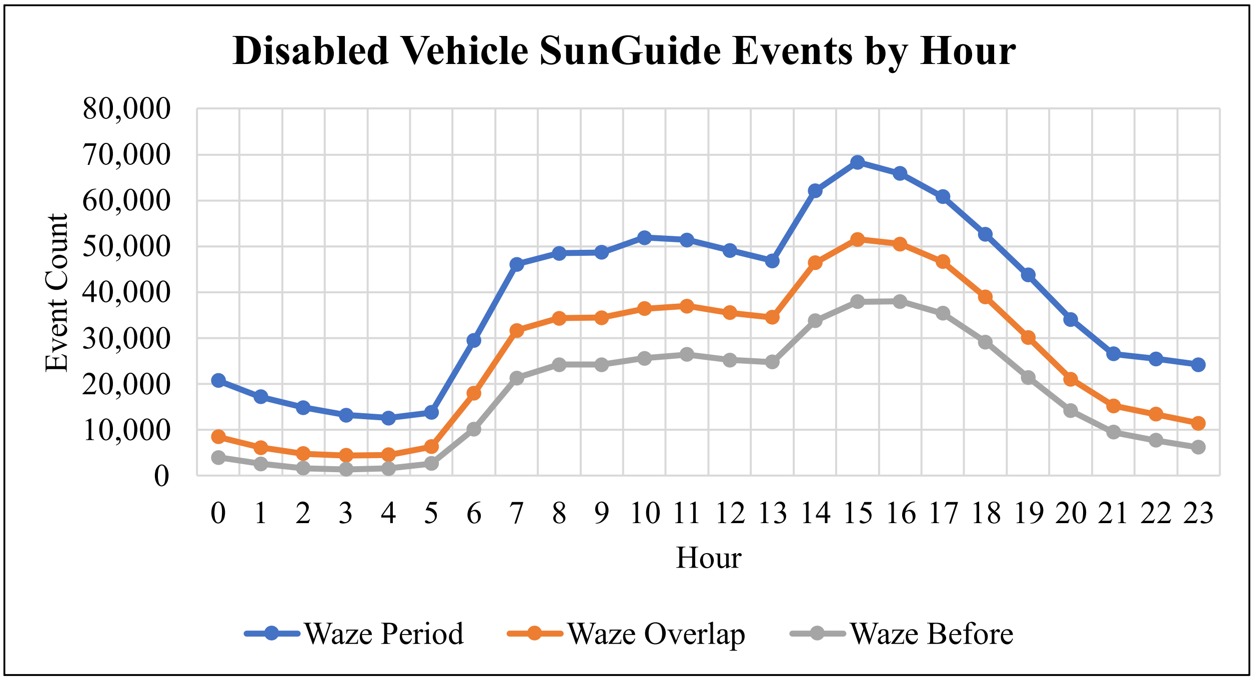

Figure 4-15: Disabled Vehicle SunGuide Events by Hour and Event Group

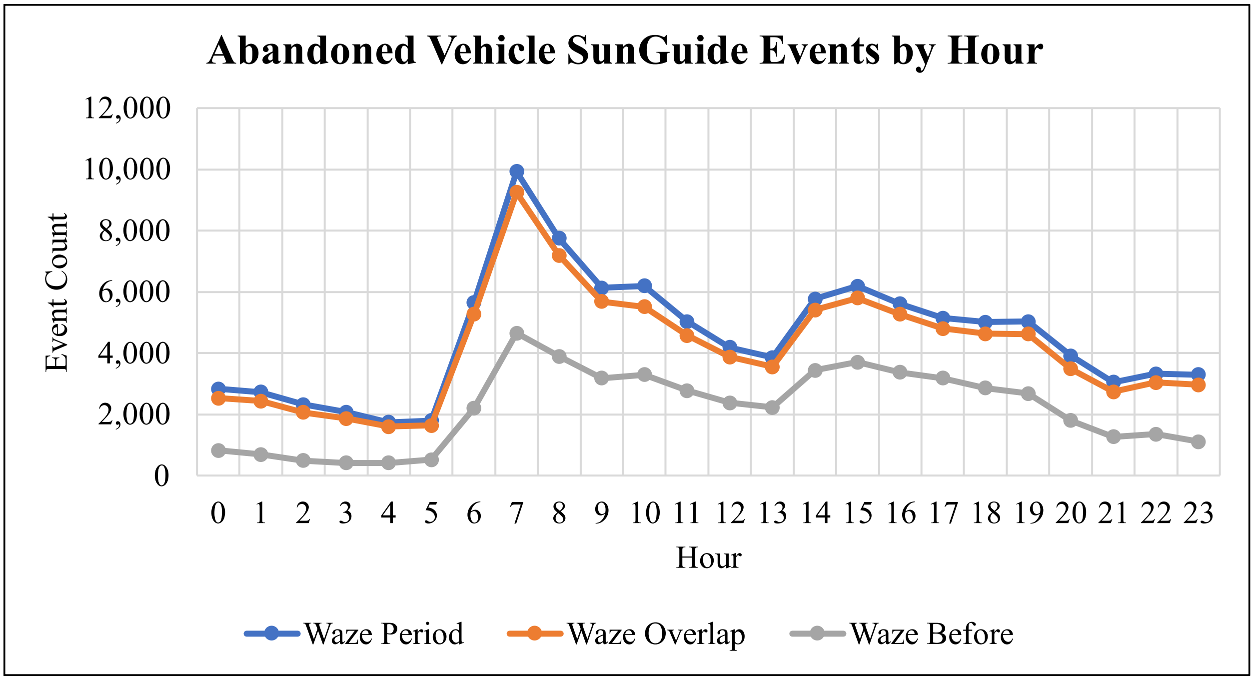

Figure 4-16: Abandoned Vehicle SunGuide Events by Hour and Event Group

Next, the DAV SunGuide events were analyzed by location. **Table 4-23** through **Table 4-25** and **Figure 4-17** through **Figure 4-19** show the breakdown by FDOT district and event group for DAV, disabled vehicle, and abandoned vehicle events, respectively. FTE had the most DAV events, while D4 had the highest percentage of events with overlapping alerts. D7 had the highest percentage of events with Waze alerts before the SunGuide event. D3 had a low percentage of events with overlapping Waze alerts compared to the other districts. When looking at abandoned vehicle events, D5 had the most events. Additionally, D5, D7, and D4 had more than 13% of their DAV events caused by abandoned vehicles (compared to 9% or less for the other districts), suggesting that efforts to reduce abandoned vehicles might be needed in these districts.

Table 4-23: DAV SunGuide Events by FDOT District and Event Group

District	Waze Period		Waze Overlap			Waze Before			
FTE	193,470	18.7%	142,646	19.8%	73.7%	94,954	19.7%	49.1%	66.6%
D4	159,897	15.4%	128,273	17.8%	80.2%	86,783	18.0%	54.3%	67.7%
D5	153,676	14.8%	119,588	16.6%	77.8%	85,247	17.7%	55.5%	71.3%
D3	135,116	13.0%	53,063	7.4%	39.3%	17,794	3.7%	13.2%	33.5%
D7	123,726	11.9%	95,897	13.3%	77.5%	70,552	14.6%	57.0%	73.6%
D1	116,103	11.2%	77,978	10.8%	67.2%	51,448	10.7%	44.3%	66.0%
D2	84,181	8.1%	55,594	7.7%	66.0%	42,413	8.8%	50.4%	76.3%
D6	70,606	6.8%	48,689	6.7%	69.0%	32,648	6.8%	46.2%	67.1%
Total	**1,036,775**	**100%**	**721,728**	**100%**	**69.6%**	**481,839**	**100%**	**46.5%**	**66.8%**

Table 4-24: Disabled Vehicle SunGuide Events by FDOT District and Event Group

District	Waze Period		Waze Overlap			Waze Before			
FTE	174,321	18.8%	125,209	20.1%	71.8%	86,151	20.1%	49.4%	68.8%
D4	137,670	14.8%	107,056	17.2%	77.8%	75,406	17.6%	54.8%	70.4%
D5	128,603	13.9%	96.005	15.4%	74.7%	72,263	16.8%	56.2%	75.3%
D3	128,263	13.8%	47,098	7.6%	36.7%	16,142	3.8%	12.6%	34.3%
D1	107,787	11.6%	70,165	11.3%	65.1%	47,337	11.0%	43.9%	67.5%
D7	105,383	11.4%	78,171	12.6%	74.2%	60,557	14.1%	57.5%	77.5%
D2	79,018	8.5%	52,631	8.5%	66.6%	40,086	9.3%	50.7%	76.2%
D6	67,048	7.2%	45,488	7.3%	67.8%	31,103	7.2%	46.4%	68.4%
Total	**928,093**	**100%**	**621,823**	**100%**	**67.0%**	**429,045**	**100%**	**46.2%**	**69.0%**

Table 4-25: Abandoned Vehicle SunGuide Events by FDOT District and Event Group

District	Waze Period		Waze Overlap			Waze Before			
D5	25,073	23.1%	23,583	23.6%	94.1%	12,984	24.6%	51.8%	55.1%
D4	22,227	20.5%	21,217	21.2%	95.5%	11,377	21.5%	51.2%	53.6%
FTE	19,149	17.6%	17,437	17.5%	91.1%	8,803	16.7%	46.0%	50.5%
D7	18,343	16.9%	17,726	17.7%	96.6%	9,995	18.9%	54.5%	56.4%
D1	8,316	7.7%	7,813	7.8%	94.0%	4,111	7.8%	49.4%	52.6%
D3	6,853	6.3%	5,965	6.0%	87.0%	1,652	3.1%	24.1%	27.7%
D2	5,163	4.8%	2,963	3.0%	57.4%	2,327	4.4%	45.1%	78.5%
D6	3,558	3.3%	3,201	3.2%	90.0%	1,545	2.9%	43.4%	48.3%
Total	**108,682**	**100.0%**	**99,905**	**100.0%**	**91.9%**	**52,794**	**100.0%**	**48.6%**	**52.8%**

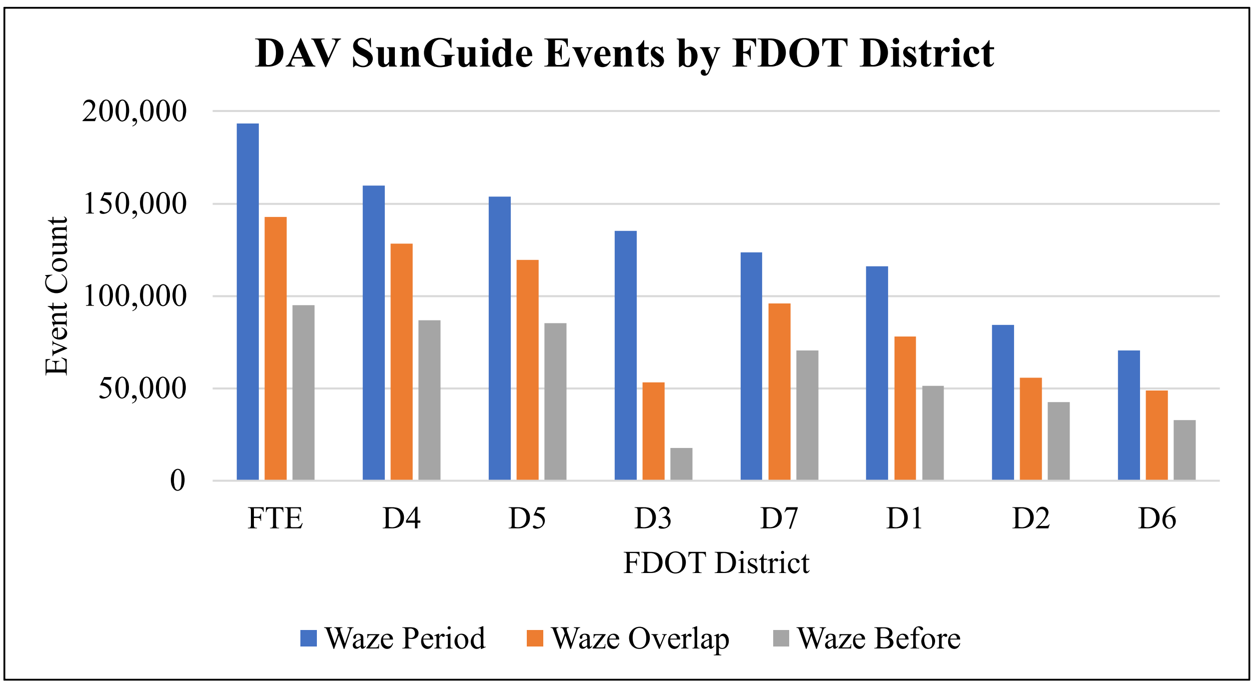

Figure 4-17: DAV SunGuide Events by FDOT District and Event Group

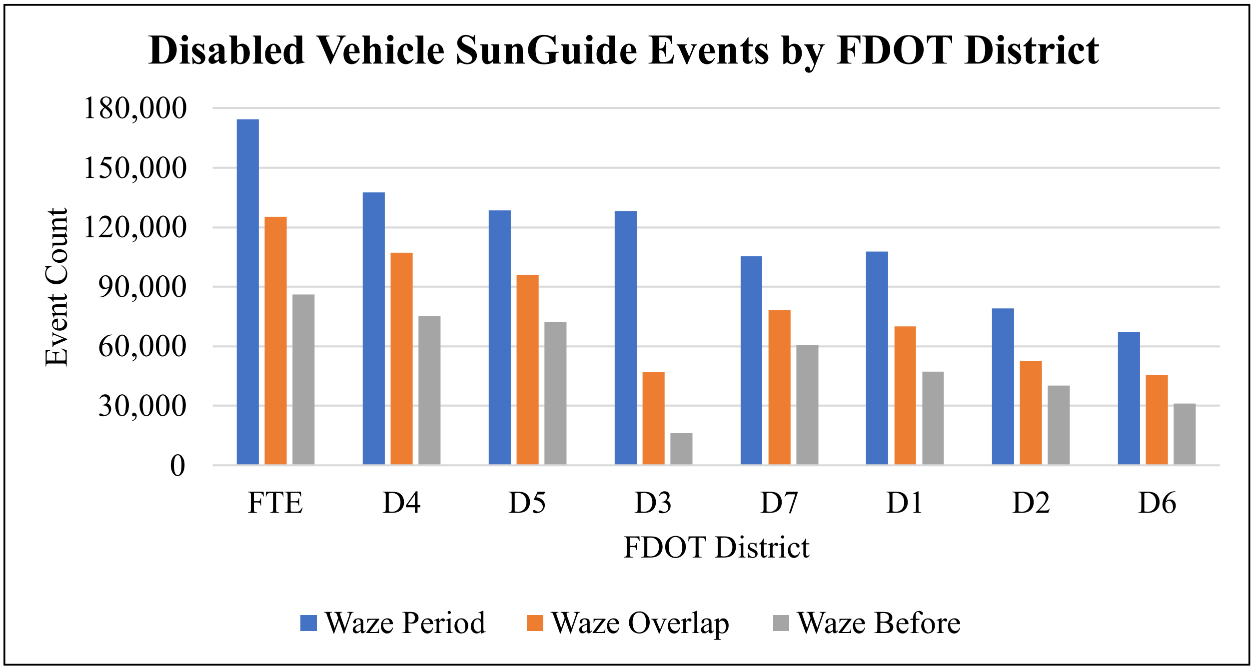

Figure 4-18: Disabled Vehicle SunGuide Events by FDOT District and Event Group

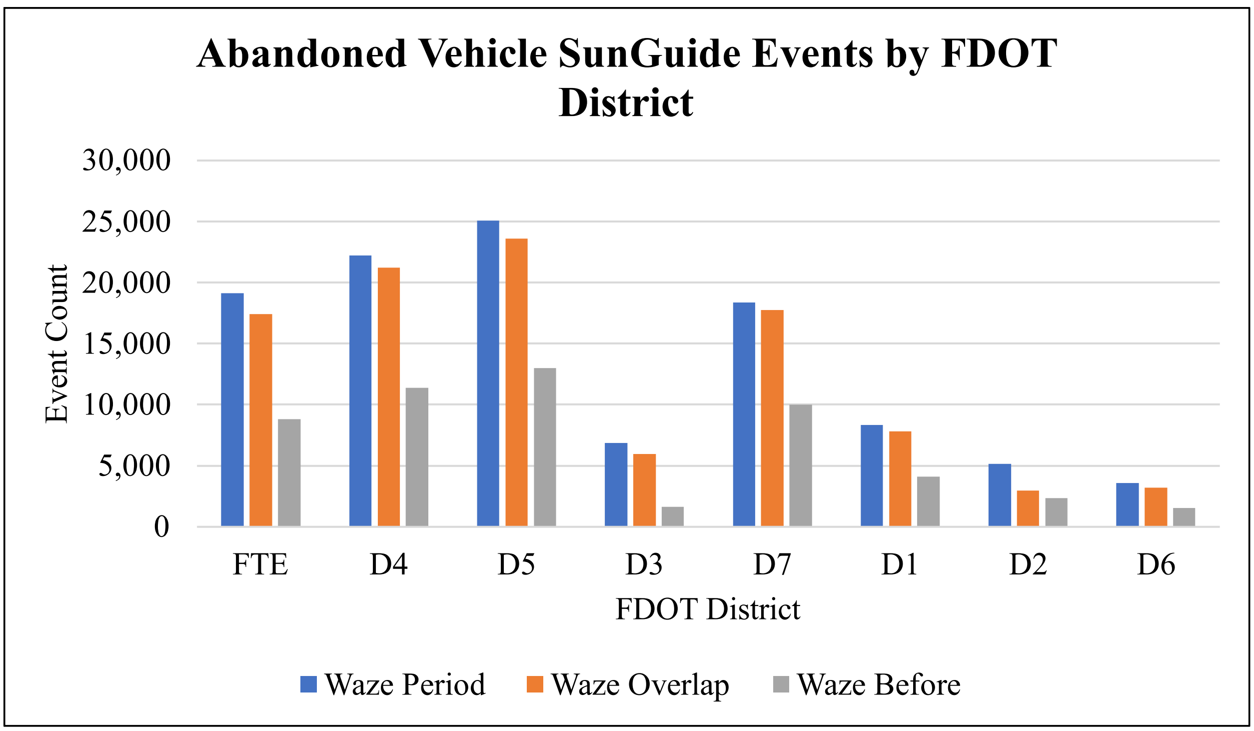

Figure 4-19: Abandoned Vehicle SunGuide Events by FDOT District and Event Group

To further understand how DAV event and Waze alert frequencies differ throughout the state, the events were analyzed by Florida county. **Table 4-26** through **Table 4-28** and **Figure 4-20** through **Figure 4-22** show the DAV, disabled vehicle, and abandoned vehicle event counts, respectively, by county and event group. The "Other" category includes all counties that had less than 0.1% of the DAV events during the Waze period (less than 1,036 events). Broward

County had the most DAV and disabled vehicle events, while Orange County had the most abandoned vehicle events. In general, urban counties had more DAV events and more events with overlapping Waze alerts. However, the counties with the highest event counts did not necessarily have the highest percentage of Waze overlap. For example, Marion County had the highest percentage of Waze overlap (85.4%) but only had the 26th highest count of DAV events. Conversely, Miami-Dade County had the third highest DAV event count, but only the 23rd highest percentage of Waze overlap (69.5%). Some urban counties had a high percentage of abandoned vehicle events (over 20% for Brevard County, over 17% for Flagler and Marion counties, and over 16% for Palm Beach County) while some rural counties (Holmes, Jackson, Jefferson) had only 2% abandoned vehicle events. This suggests that abandoned vehicles are more of an issue in urban areas compared to rural areas.

Table 4-26: DAV SunGuide Events by County and Event Group

County	Waze Period		Waze Overlap			Waze Before			
Broward	103,262	10.0%	79,412	11.0%	76.9%	52,166	11.2%	50.5%	65.7%
Orange	98,479	9.5%	73,943	10.3%	75.1%	52,483	9.2%	53.3%	71.0%
Miami-Dade	96,391	9.3%	67,026	9.3%	69.5%	43,835	9.3%	45.5%	65.4%
Hillsborough	80,185	7.7%	60,963	8.5%	76.0%	44,460	9.5%	55.4%	72.9%
Palm Beach	63,600	6.1%	53,913	7.5%	84.8%	37,734	7.8%	59.3%	70.0%
Duval	44,800	4.3%	28,546	4.0%	63.7%	21,466	5.2%	47.9%	75.2%
Lee	36,048	3.5%	22,189	3.1%	61.6%	14,297	3.1%	39.7%	64.4%
Collier	33,306	3.2%	19,466	2.7%	58.4%	11,907	2.4%	35.8%	61.2%
Osceola	32,652	3.2%	25,787	3.6%	79.0%	18,038	3.7%	55.2%	69.9%
Jackson	27,403	2.6%	7,844	1.1%	28.6%	2,165	0.4%	7.9%	27.6%
St. Lucie	26,016	2.5%	19,622	2.7%	75.4%	12,751	2.6%	49.0%	65.0%
Volusia	24,589	2.4%	19,968	2.8%	81.2%	14,415	3.0%	58.6%	72.2%
Sarasota	23,499	2.3%	18,791	2.6%	80.0%	13,132	2.7%	55.9%	69.9%
Polk	23,098	2.2%	17,579	2.4%	76.1%	13,249	2.9%	57.4%	75.4%
Martin	23,043	2.2%	19,612	2.7%	85.1%	14,442	3.0%	62.7%	73.6%
Escambia	18,811	1.8%	8,941	1.2%	47.5%	3,711	0.8%	19.7%	41.5%
Brevard	18,615	1.8%	14,945	2.1%	80.3%	9,833	1.8%	52.8%	65.8%
Pinellas	17,819	1.7%	13,027	1.8%	73.1%	9,409	2.1%	52.8%	72.2%
Manatee	16,425	1.6%	12,515	1.7%	76.2%	8,835	1.8%	53.8%	70.6%
Pasco	16,278	1.6%	10,396	1.4%	63.9%	6,918	1.4%	42.5%	66.5%

Table 4-26: DAV SunGuide Events by County and Event Group

County	Waze Period		Waze Overlap			Waze Before			
Seminole	15,995	1.5%	12,110	1.7%	75.7%	8,223	1.6%	51.4%	67.9%
Walton	15,806	1.5%	5,172	0.7%	32.7%	1,498	0.3%	9.5%	29.0%
Santa Rosa	14,494	1.4%	7,333	1.0%	50.6%	3,033	0.7%	20.9%	41.4%
Gadsden	14,327	1.4%	5,681	0.8%	39.7%	1,925	0.4%	13.4%	33.9%
Alachua	13,481	1.3%	9,854	1.4%	73.1%	7,868	1.6%	58.4%	79.8%
Marion	12,051	1.2%	10,297	1.4%	85.4%	7,734	1.5%	64.2%	75.1%
Holmes	11,941	1.2%	3,154	0.4%	26.4%	865	0.2%	7.2%	27.4%
Sumter	11,297	1.1%	8,765	1.2%	77.6%	6,158	1.2%	54.5%	70.3%
Charlotte	11,167	1.1%	8,121	1.1%	72.7%	5,516	1.1%	49.4%	67.9%
Lake	10,943	1.1%	8,754	1.2%	80.0%	5,793	1.2%	52.9%	66.2%
Indian River	10,360	1.0%	8,035	1.1%	77.6%	5,174	1.1%	49.9%	64.4%
Okaloosa	9,766	0.9%	4,294	0.6%	44.0%	1,378	0.3%	14.1%	32.1%
Columbia	9,330	0.9%	6,216	0.9%	66.6%	4,782	1.1%	51.3%	76.9%
Leon	8,793	0.8%	4,788	0.7%	54.5%	1,559	0.3%	17.7%	32.6%
Jefferson	6,732	0.7%	3,520	0.5%	52.3%	972	0.2%	14.4%	27.6%
Washington	6,606	0.6%	2,137	0.3%	32.3%	630	0.1%	9.5%	29.5%
Hernando	4,906	0.5%	2,746	0.4%	56.0%	1,741	0.3%	35.5%	63.4%
Flagler	4,410	0.4%	3,657	0.5%	82.9%	2605	0.5%	59.1%	71.2%
Hamilton	4,309	0.4%	2,842	0.4%	66.0%	2,132	0.5%	49.5%	75.0%
St. Johns	3,811	0.4%	2,987	0.4%	78.4%	2388	0.6%	62.7%	79.9%
Baker	3,119	0.3%	1,660	0.2%	53.2%	1173	0.3%	37.6%	70.7%
Suwannee	2,783	0.3%	1,686	0.2%	60.6%	1220	0.3%	43.8%	72.4%
Okeechobee	2,380	0.2%	1,381	0.2%	58.0%	756	0.1%	31.8%	54.7%
Nassau	2,328	0.2%	1,524	0.2%	65.5%	1172	0.3%	50.3%	76.9%
Other	1,321	0.1%	529	0.1%	40.0%	298	0.1%	22.6%	56.3%
Total	**1,036,775**	**100.0%**	**721,728**	**100.0%**	**69.6%**	**481,839**	**100.0%**	**46.5%**	**66.8%**

Table 4-27: Disabled Vehicle SunGuide Events by County and Event Group

County	Waze Period		Waze Overlap			Waze Before			
Broward	92,414	10.0%	69,268	11.1%	75.0%	46,994	11.0%	50.9%	67.8%
Miami-Dade	90,202	9.7%	61,434	9.9%	68.1%	41,170	9.6%	45.6%	67.0%
Orange	83,847	9.0%	60,479	9.7%	72.1%	45,105	10.5%	53.8%	74.6%
Hillsborough	68,424	7.4%	49,758	8.0%	72.7%	38,166	8.9%	55.8%	76.7%
Palm Beach	52,976	5.7%	43,632	7.0%	82.4%	31,890	7.4%	60.2%	73.1%
Duval	41,471	4.5%	26,774	4.3%	64.6%	20,082	4.7%	48.4%	75.0%
Lee	33,628	3.6%	19,926	3.2%	59.3%	13,144	3.1%	39.1%	66.0%
Collier	31,679	3.4%	17,987	2.9%	56.8%	11,268	2.6%	35.6%	62.6%
Osceola	29,126	3.1%	22,420	3.6%	77.0%	16,150	3.8%	55.4%	72.0%
Jackson	26,798	2.9%	7,324	1.2%	27.3%	2,044	0.5%	7.6%	27.9%
St. Lucie	23,316	2.5%	17,084	2.7%	73.3%	11,535	2.7%	49.5%	67.5%
Sarasota	21,085	2.3%	16,474	2.7%	78.1%	11,827	2.8%	56.1%	71.8%
Volusia	20,993	2.3%	16,503	2.7%	78.6%	12,485	2.9%	59.5%	75.7%
Martin	20,495	2.2%	17,137	2.8%	83.6%	13,038	3.0%	63.6%	76.1%
Polk	19,829	2.1%	14,417	2.3%	72.7%	11,273	2.6%	56.9%	78.2%
Escambia	16,990	1.8%	7,419	1.2%	43.7%	3,281	0.8%	19.3%	44.2%
Pinellas	15,354	1.7%	10,676	1.7%	69.5%	8,206	1.9%	53.4%	76.9%
Walton	15,240	1.6%	4,675	0.8%	30.7%	1,383	0.3%	9.1%	29.6%
Manatee	14,897	1.6%	11,053	1.8%	74.2%	7,997	1.9%	53.7%	72.4%
Brevard	14,786	1.6%	11,290	1.8%	76.4%	7,976	1.9%	53.9%	70.6%
Pasco	14,307	1.5%	8,649	1.4%	60.5%	6,130	1.4%	42.8%	70.9%
Gadsden	13,659	1.5%	5,088	0.8%	37.3%	1,753	0.4%	12.8%	34.5%
Seminole	13,628	1.5%	9,904	1.6%	72.7%	7,087	1.7%	52.0%	71.6%
Santa Rosa	13,223	1.4%	6,204	1.0%	46.9%	2,684	0.6%	20.3%	43.3%
Alachua	12,789	1.4%	9,399	1.5%	73.5%	7,503	1.7%	58.7%	79.8%
Holmes	11,668	1.3%	2,924	0.5%	25.1%	815	0.2%	7.0%	27.9%
Charlotte	10,354	1.1%	7,358	1.2%	71.1%	5,097	1.2%	49.2%	69.3%

Table 4-27: Disabled Vehicle SunGuide Events by County and Event Group

County	Waze Period		Waze Overlap			Waze Before			
Marion	10,000	1.1%	8,303	1.3%	83.0%	6,524	1.5%	65.2%	78.6%
Sumter	9,843	1.1%	7,375	1.2%	74.9%	5,406	1.3%	54.9%	73.3%
Lake	9,692	1.0%	7,574	1.2%	78.1%	5,205	1.2%	53.7%	68.7%
Indian River	9,247	1.0%	7,004	1.1%	75.7%	4,706	1.1%	50.9%	67.2%
Okaloosa	9,100	1.0%	3,709	0.6%	40.8%	1,226	0.3%	13.5%	33.1%
Columbia	8,888	1.0%	5,944	1.0%	66.9%	4,567	1.1%	51.4%	76.8%
Leon	8,275	0.9%	4,308	0.7%	52.1%	1,395	0.3%	16.9%	32.4%
Jefferson	6,572	0.7%	3,368	0.5%	51.2%	921	0.2%	14.0%	27.3%
Washington	6,311	0.7%	1,890	0.3%	29.9%	585	0.1%	9.3%	31.0%
Hernando	4,250	0.5%	2,190	0.4%	51.5%	1,524	0.4%	35.9%	69.6%
Hamilton	4,122	0.4%	2,738	0.4%	66.4%	2,050	0.5%	49.7%	74.9%
Flagler	3,642	0.4%	2,913	0.5%	80.0%	2,172	0.5%	59.6%	74.6%
St. Johns	3,624	0.4%	2,844	0.5%	78.5%	2,271	0.5%	62.7%	79.9%
Baker	2,980	0.3%	1,595	0.3%	53.5%	1,122	0.3%	37.7%	70.3%
Suwannee	2,655	0.3%	1,610	0.3%	60.6%	1,163	0.3%	43.8%	72.2%
Okeechobee	2,231	0.2%	1,247	0.2%	55.9%	721	0.2%	32.3%	57.8%
Nassau	2,207	0.2%	1,442	0.2%	65.3%	1,115	0.3%	50.5%	77.3%
Other	1,276	0.1%	513	0.1%	40.2%	289	0.1%	22.6%	56.3%
Total	**928,093**	**100.0%**	**621,823**	**100.0%**	**67.0%**	**429,045**	**100.0%**	**46.2%**	**69.0%**

Table 4-28: Abandoned Vehicle SunGuide Events by County and Event Group

County	Waze Period		Waze Overlap			Waze Before			
Orange	14,632	13.5%	13,464	13.5%	92.0%	7,378	14.0%	50.4%	54.8%
Hillsborough	11,761	10.8%	11,205	11.2%	95.3%	6,294	11.9%	53.5%	56.2%
Broward	10,848	10.0%	10,144	10.2%	93.5%	5,172	9.8%	47.7%	51.0%
Palm Beach	10,624	9.8%	10,281	10.3%	96.8%	5,844	11.1%	55.0%	56.8%
Miami-Dade	6,189	5.7%	5,592	5.6%	90.4%	2,665	5.0%	43.1%	47.7%
Brevard	3,829	3.5%	3,655	3.7%	95.5%	1,857	3.5%	48.5%	50.8%
Volusia	3,596	3.3%	3,465	3.5%	96.4%	1,930	3.7%	53.7%	55.7%
Osceola	3,526	3.2%	3,367	3.4%	95.5%	1,888	3.6%	53.5%	56.1%
Duval	3,329	3.1%	1,772	1.8%	53.2%	1,384	2.6%	41.6%	78.1%
Polk	3,269	3.0%	3,162	3.2%	96.7%	1,976	3.7%	60.4%	62.5%
St. Lucie	2,700	2.5%	2,538	2.5%	94.0%	1,216	2.3%	45.0%	47.9%
Martin	2,548	2.3%	2,475	2.5%	97.1%	1,404	2.7%	55.1%	56.7%
Pinellas	2,465	2.3%	2,351	2.4%	95.4%	1,203	2.3%	48.8%	51.2%
Lee	2,420	2.2%	2,263	2.3%	93.5%	1,153	2.2%	47.6%	51.0%
Sarasota	2,414	2.2%	2,317	2.3%	96.0%	1,305	2.5%	54.1%	56.3%
Seminole	2,367	2.2%	2,206	2.2%	93.2%	1,136	2.2%	48.0%	51.5%
Marion	2,051	1.9%	1,994	2.0%	97.2%	1,210	2.3%	59.0%	60.7%
Pasco	1,971	1.8%	1,747	1.7%	88.6%	788	1.5%	40.0%	45.1%
Escambia	1,821	1.7%	1,522	1.5%	83.6%	430	0.8%	23.6%	28.3%
Collier	1,627	1.5%	1,479	1.5%	90.9%	639	1.2%	39.3%	43.2%
Manatee	1,528	1.4%	1,462	1.5%	95.7%	838	1.6%	54.8%	57.3%
Sumter	1,454	1.3%	1,390	1.4%	95.6%	752	1.4%	51.7%	54.1%
Santa Rosa	1,271	1.2%	1,129	1.1%	88.8%	349	0.7%	27.5%	30.9%
Lake	1,251	1.2%	1,180	1.2%	94.3%	588	1.1%	47.0%	49.8%
Indian River	1,113	1.0%	1,031	1.0%	92.6%	468	0.9%	42.0%	45.4%
Charlotte	813	0.7%	763	0.8%	93.8%	419	0.8%	51.5%	54.9%
Flagler	768	0.7%	744	0.7%	96.9%	433	0.8%	56.4%	58.2%

Table 4-28: Abandoned Vehicle SunGuide Events by County and Event Group

County	Waze Period		Waze Overlap			Waze Before			
Alachua	692	0.6%	455	0.5%	65.8%	365	0.7%	52.7%	80.2%
Gadsden	668	0.6%	593	0.6%	88.8%	172	0.3%	25.7%	29.0%
Okaloosa	666	0.6%	585	0.6%	87.8%	152	0.3%	22.8%	26.0%
Hernando	656	0.6%	556	0.6%	84.8%	217	0.4%	33.1%	39.0%
Jackson	605	0.6%	520	0.5%	86.0%	121	0.2%	20.0%	23.3%
Walton	566	0.5%	497	0.5%	87.8%	115	0.2%	20.3%	23.1%
Leon	518	0.5%	480	0.5%	92.7%	164	0.3%	31.7%	34.2%
Columbia	442	0.4%	272	0.3%	61.5%	215	0.4%	48.6%	79.0%
Washington	295	0.3%	247	0.2%	83.7%	45	0.1%	15.3%	18.2%
Holmes	273	0.3%	230	0.2%	84.2%	50	0.1%	18.3%	21.7%
Hamilton	187	0.2%	104	0.1%	55.6%	82	0.2%	43.9%	78.8%
St. Johns	187	0.2%	143	0.1%	76.5%	117	0.2%	62.6%	81.8%
Jefferson	160	0.1%	152	0.2%	95.0%	51	0.1%	31.9%	33.6%
Okeechobee	149	0.1%	134	0.1%	89.9%	35	0.1%	23.5%	26.1%
Baker	139	0.1%	65	0.1%	46.8%	51	0.1%	36.7%	78.5%
Suwannee	128	0.1%	76	0.1%	59.4%	57	0.1%	44.5%	75.0%
Nassau	121	0.1%	82	0.1%	67.8%	57	0.1%	47.1%	69.5%
Other	45	0.0%	16	0.0%	35.6%	9	0.0%	20.0%	56.3%
Total	**108,682**	**100.0%**	**99,905**	**100.0%**	**91.9%**	**52,794**	**100.0%**	**48.6%**	**52.8%**

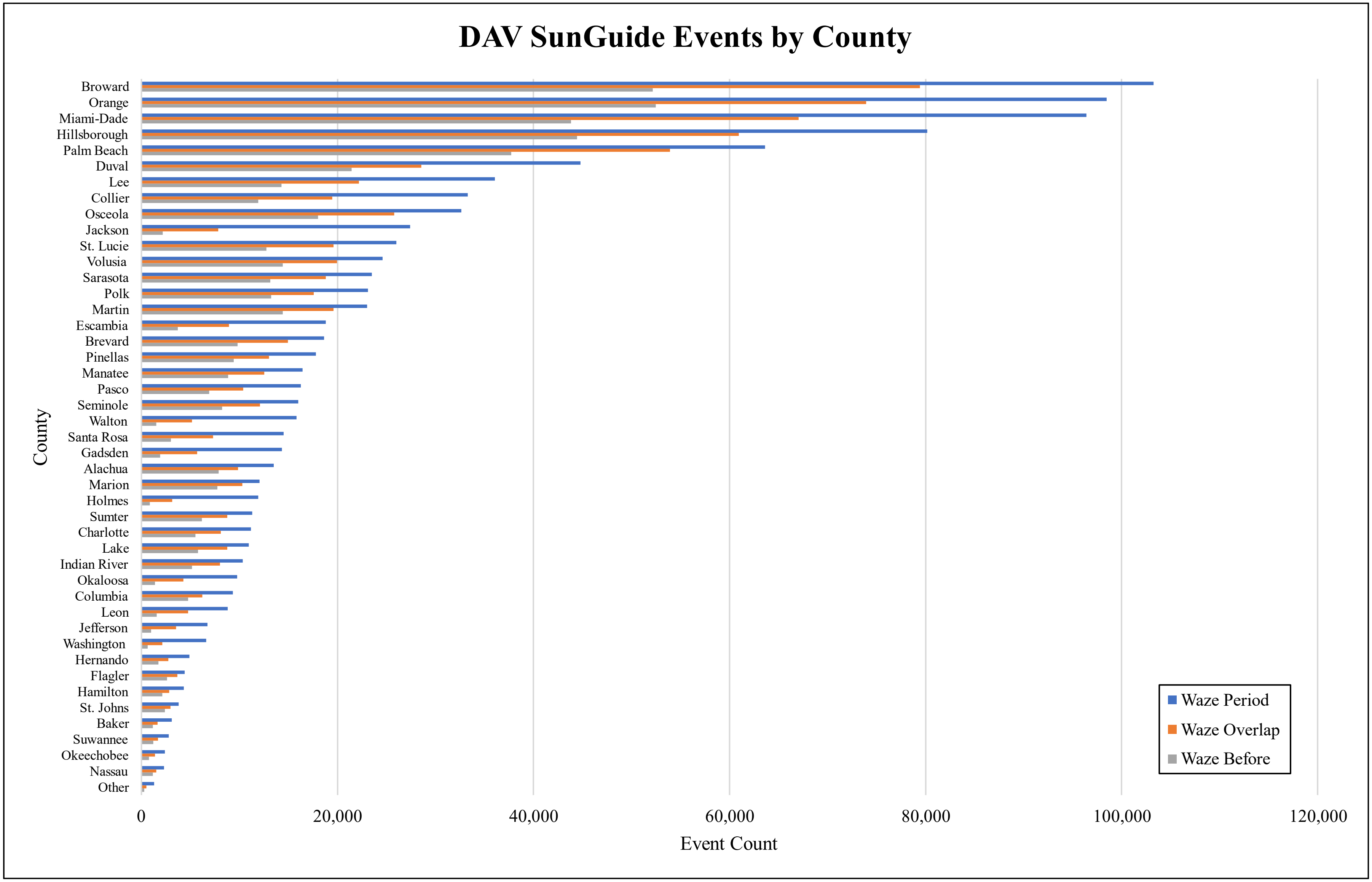

Figure 4-20: DAV SunGuide Events by County and Event Group

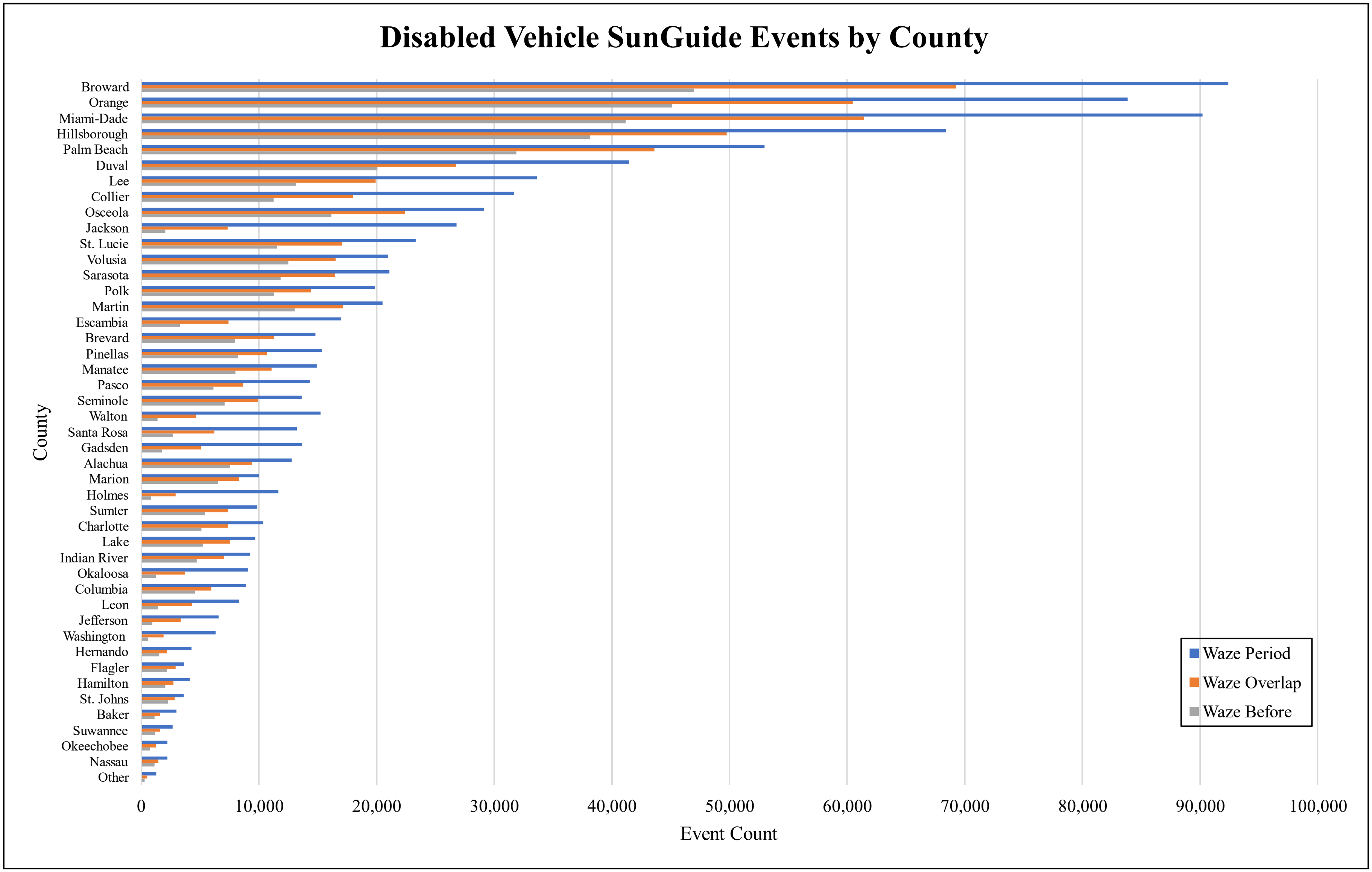

Figure 4-21: Disabled Vehicle SunGuide Events by County and Event Group

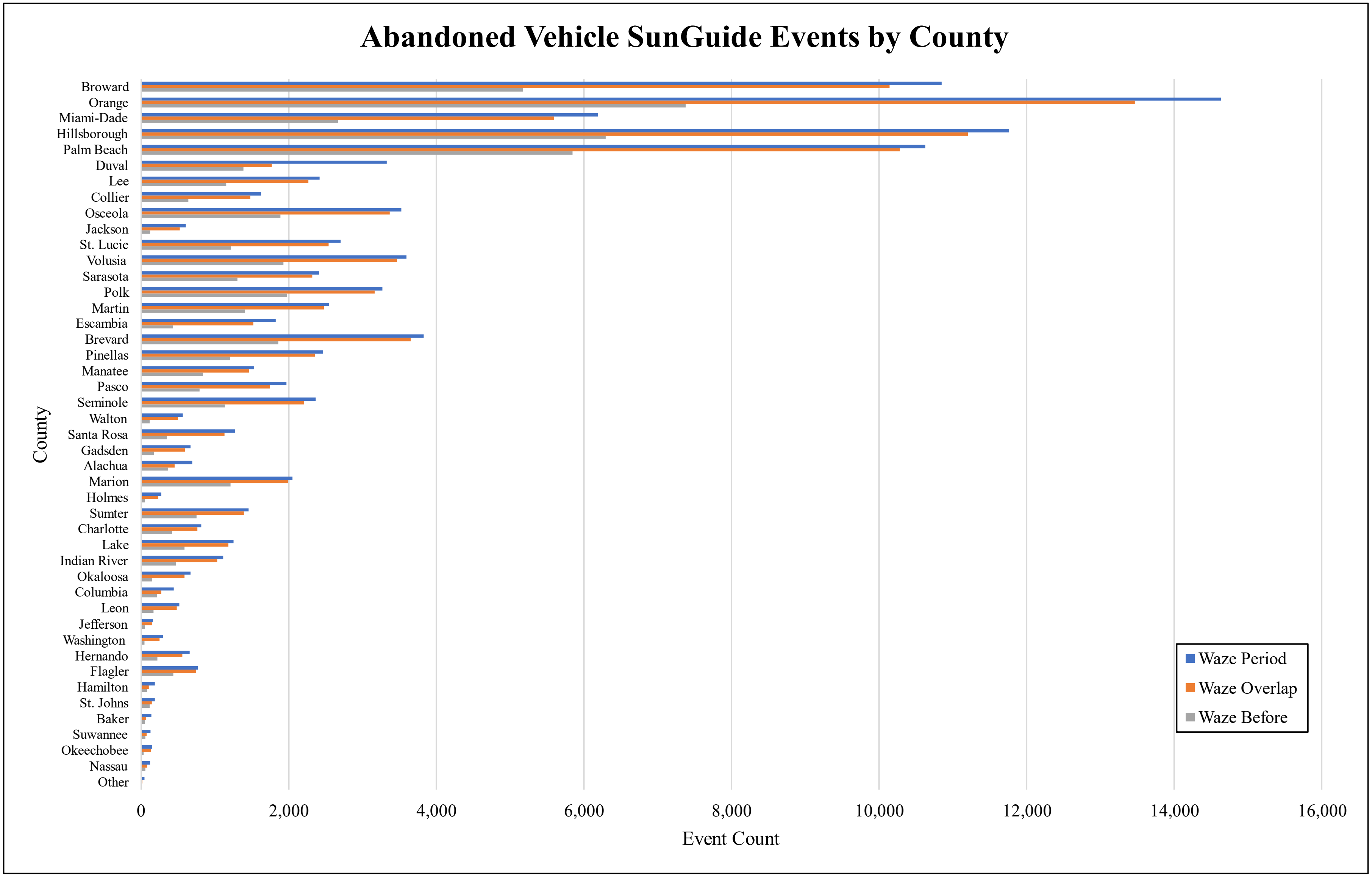

Figure 4-22: Abandoned Vehicle SunGuide Events by County and Event Group

Table 4-29 through **Table 4-31** and **Figure 4-23** through **Figure 4-25** show the breakdown of DAV, disabled vehicle, and abandoned vehicle events, respectively, by roadway and event group. The "Other" category includes all roadways that had less than 0.1% of the DAV events during the Waze period (less than 1,036 events). I-75 was the roadway with the most DAV and disabled vehicle events during the Waze period, while I-95 had the most abandoned vehicle events during the Waze period. I-95 had the most events during the Waze Overlap and Waze Before periods for all event types. These figures and tables indicate that Waze usage is not consistent across all roadways. Some roadways (such as I-4) have a higher percentage of SunGuide events with overlapping Waze alerts (82.1%) while other roadways (such as I-10) have a lower percentage of events with overlapping Waze alerts (41.1%). This information could be used to help identify roadways which could achieve the most benefits by reporting their DAV Waze data to the TMC. SR-414 had a 19.6% abandoned vehicle percentage and five other roadways (SR-429, SR-408, I-4, I-10, and SR-417) had abandoned vehicle percentages over 15%. Most of these roadways are all in the Central Florida area, suggesting that this region could have issues with abandoned vehicles.

Table 4-29: DAV SunGuide Events by Roadway and Event Group

Roadway	Waze Period		Waze Overlap			Waze Before			
I-75	224,222	21.6%	160,310	22.2%	71.5%	111,374	23.1%	49.7%	69.5%
I-95	219,434	21.2%	172,864	24.0%	78.8%	118,383	24.6%	53.9%	68.5%
I-10	144,723	14.0%	59,525	8.2%	41.1%	23,039	4.8%	15.9%	38.7%
SR-91/SR-821	144,604	13.9%	112,347	15.6%	77.7%	75,337	15.6%	52.1%	67.1%
I-4	89,672	8.6%	73,663	10.2%	82.1%	56,059	11.6%	62.5%	76.1%
I-275	43,546	4.2%	32,479	4.5%	74.6%	23,668	4.9%	54.4%	72.9%
SR-826	28,130	2.7%	19,422	2.7%	69.0%	12,994	2.7%	46.2%	66.9%
SR-417	22,326	2.2%	15,904	2.2%	71.2%	10,435	2.2%	46.7%	65.6%
I-295	21,435	2.1%	13,316	1.8%	62.1%	9,911	2.1%	46.2%	74.4%
SR-589/SR-568	19,384	1.9%	10,360	1.4%	53.4%	6,591	1.4%	34.0%	63.6%
SR-528	18,866	1.8%	13,087	1.8%	69.4%	8,719	1.8%	46.2%	66.6%
SR-408	15,907	1.5%	11,584	1.6%	72.8%	8,386	1.7%	52.7%	72.4%
SR-429	15,349	1.5%	10,350	1.4%	67.4%	6,756	1.4%	44.0%	65.3%
SR-869	5,694	0.5%	4,457	0.6%	78.3%	3,025	0.6%	53.1%	67.9%
I-110	3,842	0.4%	1,528	0.2%	39.8%	546	0.1%	14.2%	35.7%
SR-202	3,659	0.4%	2,226	0.3%	60.8%	1,656	0.3%	45.3%	74.4%
SR-570	3,508	0.3%	1,474	0.2%	42.0%	805	0.2%	22.9%	54.6%
I-595	2,547	0.2%	1,917	0.3%	75.3%	1,215	0.3%	47.7%	63.4%
I-195	1,793	0.2%	1,046	0.1%	58.3%	582	0.1%	32.5%	55.6%
SR-414	1,607	0.2%	933	0.1%	58.1%	536	0.1%	33.4%	57.4%
Other	6,527	0.6%	2,936	0.4%	45.0%	1,822	0.4%	27.9%	62.1%
Total	**1,036,775**	**100.0%**	**721,728**	**100.0%**	**69.6%**	**481,839**	**100.0%**	**46.5%**	**66.8%**

Table 4-30: Disabled Vehicle SunGuide Events by Roadway and Event Group

Roadway	Waze Period		Waze Overlap			Waze Before			
I-75	203,359	21.9%	140,862	22.7%	69.3%	100,760	23.5%	49.5%	71.5%
I-95	190,439	20.5%	145,592	23.4%	76.5%	103,531	24.1%	54.4%	71.1%
I-10	137,746	14.8%	53,623	8.6%	38.9%	21,182	4.9%	15.4%	39.5%
SR-91/SR-821	130,908	14.1%	99,488	16.0%	76.0%	68,707	16.0%	52.5%	69.1%
I-4	76,052	8.2%	60,391	9.7%	79.4%	47,868	11.2%	62.9%	79.3%
I-275	37,725	4.1%	26,907	4.3%	71.3%	20,657	4.8%	54.8%	76.8%
SR-826	26,820	2.9%	18,248	2.9%	68.0%	12,436	2.9%	46.4%	68.1%
I-295	20,035	2.2%	12,614	2.0%	63.0%	9,369	2.2%	46.8%	74.3%
SR-417	18,977	2.0%	12,913	2.1%	68.0%	8,953	2.1%	47.2%	69.3%
SR-589/SR-568	17,466	1.9%	8,871	1.4%	50.8%	5,957	1.4%	34.1%	67.2%
SR-528	16,278	1.8%	10,689	1.7%	65.7%	7,529	1.8%	46.3%	70.4%
SR-408	13,463	1.5%	9,391	1.5%	69.8%	7,176	1.7%	53.3%	76.4%
SR-429	12,912	1.4%	8,194	1.3%	63.5%	5,749	1.3%	44.5%	70.2%
SR-869	5,027	0.5%	3,845	0.6%	76.5%	2,715	0.6%	54.0%	70.6%
I-110	3,262	0.4%	1,078	0.2%	33.0%	442	0.1%	13.5%	41.0%
SR-202	3,223	0.3%	2,022	0.3%	62.7%	1,500	0.3%	46.5%	74.2%
SR-570	3,188	0.3%	1,217	0.2%	38.2%	727	0.2%	22.8%	59.7%
I-595	2,312	0.2%	1,698	0.3%	73.4%	1,112	0.3%	48.1%	65.5%
I-195	1,628	0.2%	899	0.1%	55.2%	527	0.1%	32.4%	58.6%
SR-414	1,292	0.1%	678	0.1%	52.5%	454	0.1%	35.1%	67.0%
Other	5,981	0.6%	2,603	0.4%	43.5%	1,694	0.4%	28.3%	65.1%
Total	**928,093**	**100.0%**	**621,823**	**100.0%**	**67.0%**	**429,045**	**100.0%**	**46.2%**	**69.0%**

Table 4-31: Abandoned Vehicle SunGuide Events by Roadway and Event Group

Roadway	Waze Period		Waze Overlap			Waze Before			
I-95	28,995	26.7%	27,272	27.3%	94.1%	14,852	28.1%	51.2%	54.5%
I-75	20,863	19.2%	19,448	19.5%	93.2%	10,614	20.1%	50.9%	54.6%
SR-91/SR-821	13,696	12.6%	12,859	12.9%	93.9%	6,630	12.6%	48.4%	51.6%
I-4	13,620	12.5%	13,272	13.3%	97.4%	8,191	15.5%	60.1%	61.7%
I-10	6,977	6.4%	5,902	5.9%	84.6%	1,857	3.5%	26.6%	31.5%
I-275	5,821	5.4%	5,572	5.6%	95.7%	3,011	5.7%	51.7%	54.0%
SR-417	3,349	3.1%	2,991	3.0%	89.3%	1,482	2.8%	44.3%	49.5%
SR-528	2,588	2.4%	2,398	2.4%	92.7%	1,190	2.3%	46.0%	49.6%
SR-408	2,444	2.2%	2,193	2.2%	89.7%	1,210	2.3%	49.5%	55.2%
SR-429	2,437	2.2%	2,156	2.2%	88.5%	1,007	1.9%	41.3%	46.7%
SR-589/SR-568	1,918	1.8%	1,489	1.5%	77.6%	634	1.2%	33.1%	42.6%
I-295	1,400	1.3%	702	0.7%	50.1%	542	1.0%	38.7%	77.2%
SR-826	1,310	1.2%	1,174	1.2%	89.6%	558	1.1%	42.6%	47.5%
SR-869	667	0.6%	612	0.6%	91.8%	310	0.6%	46.5%	50.7%
I-110	580	0.5%	450	0.5%	77.6%	104	0.2%	17.9%	23.1%
SR-202	436	0.4%	204	0.2%	46.8%	156	0.3%	35.8%	76.5%
SR-570	320	0.3%	257	0.3%	80.3%	78	0.1%	24.4%	30.4%
SR-414	315	0.3%	255	0.3%	81.0%	82	0.2%	26.0%	32.2%
I-595	235	0.2%	219	0.2%	93.2%	103	0.2%	43.8%	47.0%
I-195	165	0.2%	147	0.1%	89.1%	55	0.1%	33.3%	37.4%
Other	546	0.5%	333	0.3%	61.0%	128	0.2%	23.4%	38.4%
Total	**108,682**	**100.0%**	**99,905**	**100.0%**	**91.9%**	**52,794**	**100.0%**	**48.6%**	**52.8%**

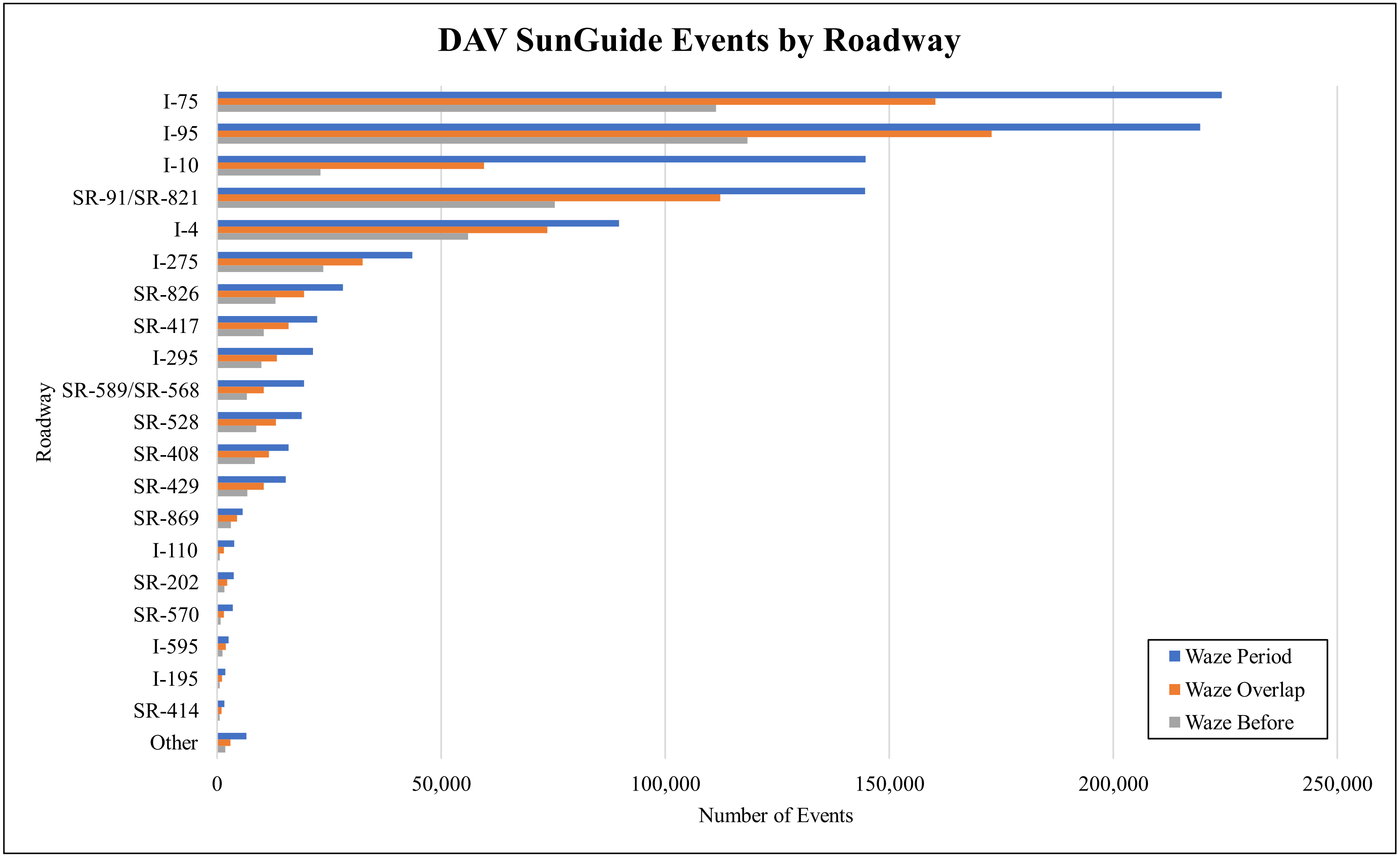

Figure 4-23: DAV SunGuide Events by Roadway and Event Group

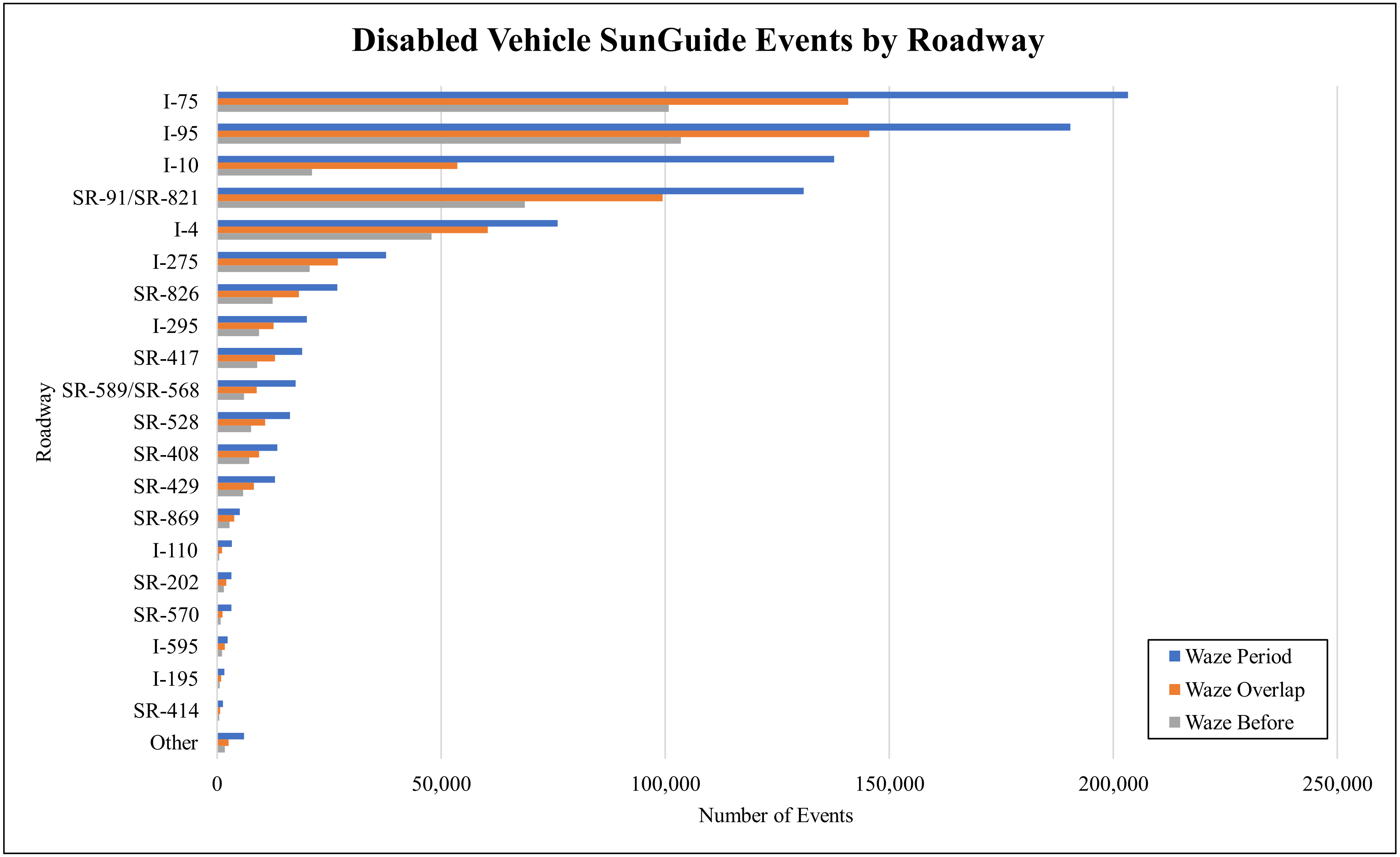

Figure 4-24: Disabled Vehicle SunGuide Events by Roadway and Event Group

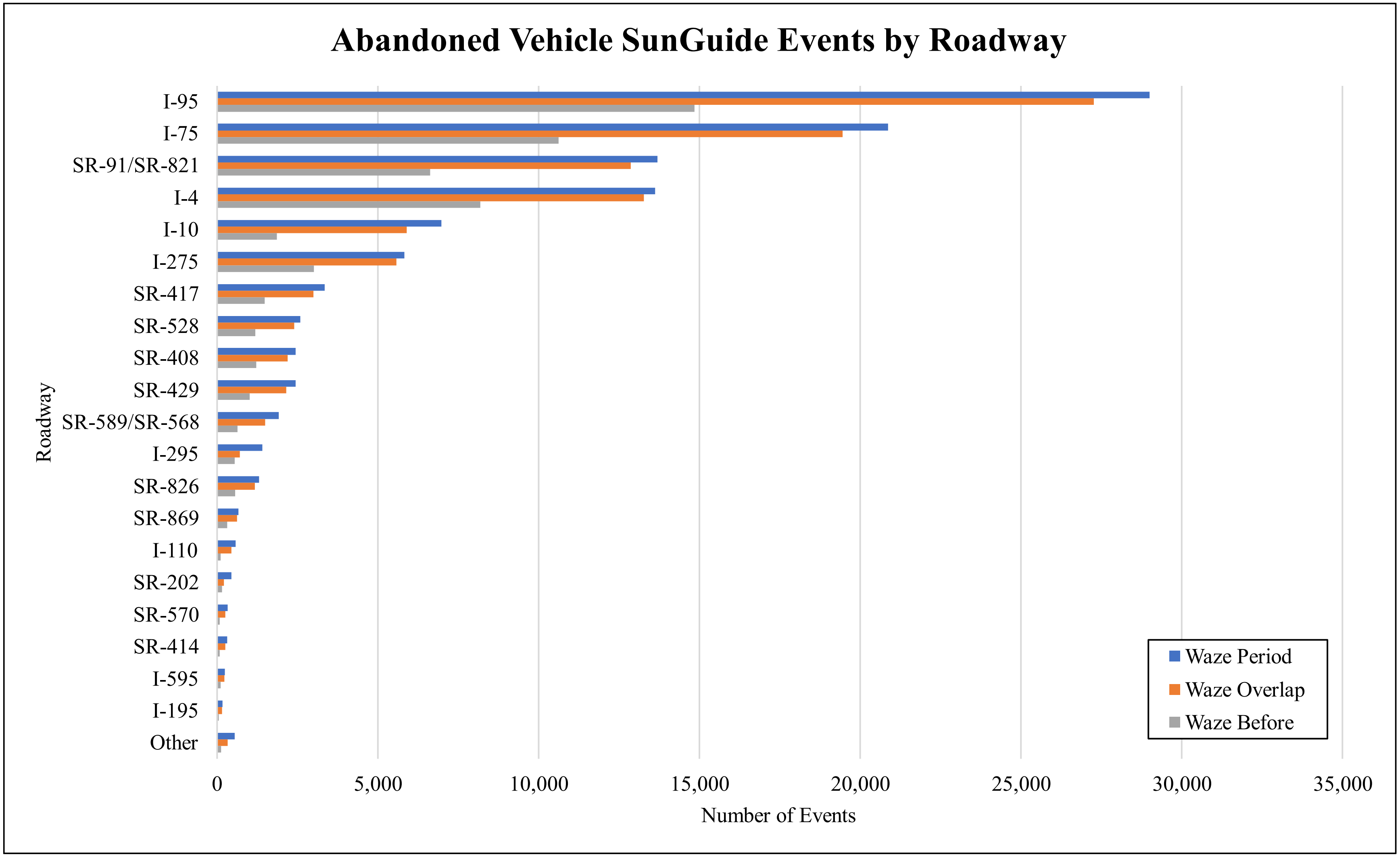

Figure 4-25: Abandoned Vehicle SunGuide Events by Roadway and Event Group

In addition to analyzing the overlap between the Waze and SunGuide data, analyses were also conducted on the time differences between SunGuide events and their first associated Waze alert. The results of these analyses can show the potential improvements in detection time provided by the Waze alerts. These time differences, which are called "Waze Time Before" in this chapter, were only present for the 481,839 SunGuide events in the Waze Before group, as these were the only SunGuide events which had Waze alerts before the SunGuide event. **Table 4-32** and **Figure 4-26** show the distribution of Waze Time Before for all DAV events. The Waze Time Before for each event was rounded up to the nearest minute in this table and figure, meaning that time differences of 1 minute or less were counted as "1", time differences of more than one minute up to two minutes were counted as "2", and so on. This distribution shows that the number of events increases as the Waze Time Before increases, which suggests that Waze data could be a good source to identify DAV events earlier than current TMC procedures. However, care is needed to ensure that the large quantity of Waze alerts does not overwhelm TMC operators. Future research could investigate the best strategies to report DAV Waze data to TMC operators. The average Waze Time Before for all DAV events was 15.95 minutes with a median of 16.43 minutes and standard deviation of 8.68 minutes. The disabled vehicle events had an average Waze Time Before of 15.83 minutes, median of 16.25 minutes, and standard deviation of 8.70 minutes, while the abandoned vehicle events had an average Waze Time Before of 16.89 minutes, median of 17.84 minutes, and standard deviation of 8.48 minutes.

Table 4-32: Waze Time Before for DAV SunGuide Events

Waze Time Before (min)	Count	Percentage
1	13,490	2.80%
2	13,757	2.86%
3	13,700	2.84%
4	14,178	2.94%
5	14,257	2.96%
6	14,302	2.97%
7	14,453	3.00%
8	14,564	3.02%
9	14,811	3.07%
10	14,846	3.08%
11	14,907	3.09%
12	15,246	3.16%
13	15,187	3.15%
14	15,290	3.17%
15	15,473	3.21%

Table 4-32: Waze Time Before for DAV SunGuide Events

Waze Time Before (min)	Count	Percentage
16	15,828	3.28%
17	15,894	3.30%
18	16,286	3.38%
19	16,306	3.38%
20	16,703	3.47%
21	16,892	3.51%
22	17,185	3.57%
23	17,567	3.65%
24	18,010	3.74%
25	18,091	3.75%
26	18,391	3.82%
27	18,318	3.80%
28	18,884	3.92%
29	19,150	3.97%
30	19,873	4.12%
Total	**481,839**	**100.00%**

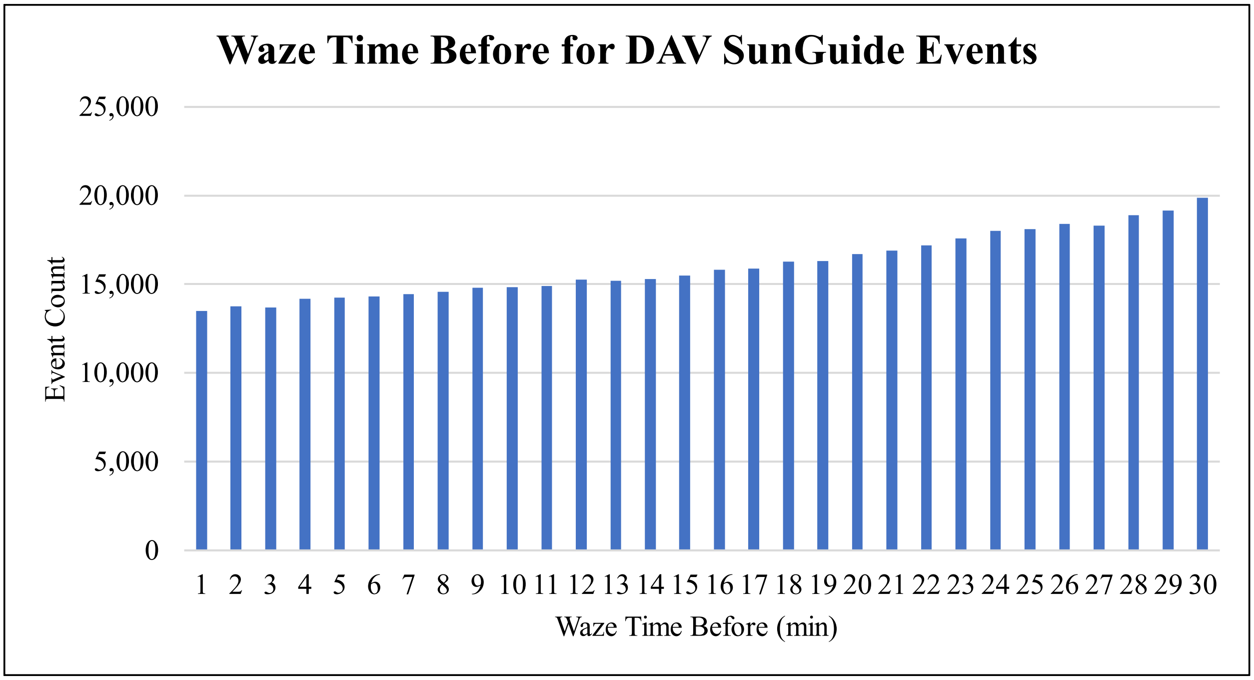

Figure 4-26: Distribution of Waze Time Before for DAV SunGuide Events

The Waze Time Before values for the DAV SunGuide events were also analyzed with respect to hour of the day, FDOT district, county, and roadway. **Table 4-33** and **Figure 4-27** show the average Waze Time Before for each hour. The largest Waze Time Before values occurred from 11 AM through 7 PM, with values greater than the average of 15.95 minutes for all hours in this period. From 1 AM through 6 AM, the average Waze Time Before was less than 15 minutes. These results suggest that utilizing Waze alerts in the afternoon and early evening hours could provide the most potential for early detection of DAV events.

Table 4-33: Waze Time Before by Hour of Day for DAV SunGuide Events

Hour	Average Waze Time Before (min)
12 AM	15.14
1 AM	14.79
2 AM	14.72
3 AM	14.26
4 AM	13.92
5 AM	13.77
6 AM	14.32
7 AM	15.39
8 AM	15.93
9 AM	15.90
10 AM	15.83
11 AM	15.96
12 PM	16.05
1 PM	16.06
2 PM	16.31
3 PM	16.24
4 PM	16.22
5 PM	16.30
6 PM	16.53
7 PM	16.23
8 PM	15.75
9 PM	15.56
10 PM	15.34
11 PM	15.18
Total	**15.95**

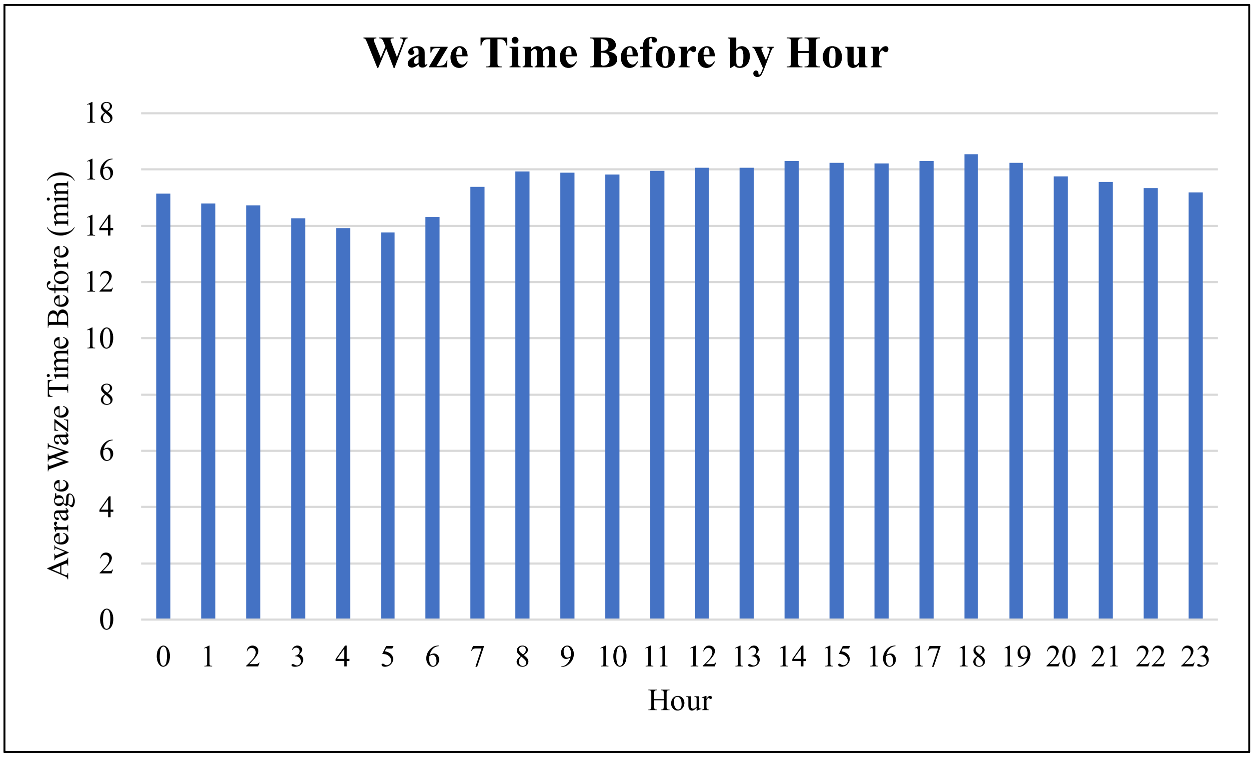

Figure 4-27: Waze Time Before by Hour for DAV SunGuide Events

Table 4-34 and **Figure 4-28** show the average Waze Time Before by FDOT district for the DAV SunGuide events. D4, D7, and D5 all had Waze Time Before values greater than 16 minutes. These districts are mainly urban areas, suggesting that Waze alerts could provide earlier DAV detection in urban areas compared to rural areas. This is further emphasized when analyzing Waze Time Before by county, as shown in **Table 4-35** and **Figure 4-29**. Many counties with large urban areas (Palm Beach, Hillsborough, Orange, Broward) have Waze Time Before values greater than 16 minutes. Additionally, many of the counties with the lowest Waze Time Before values are predominantly rural.

Table 4-34: Waze Time Before by FDOT District for DAV SunGuide Events

District	Average Waze Time Before (min)
D4	16.36
D7	16.34
D5	16.20
FTE	15.96
D6	15.93
D2	15.61
D3	15.03
D1	14.88
Total	**15.95**

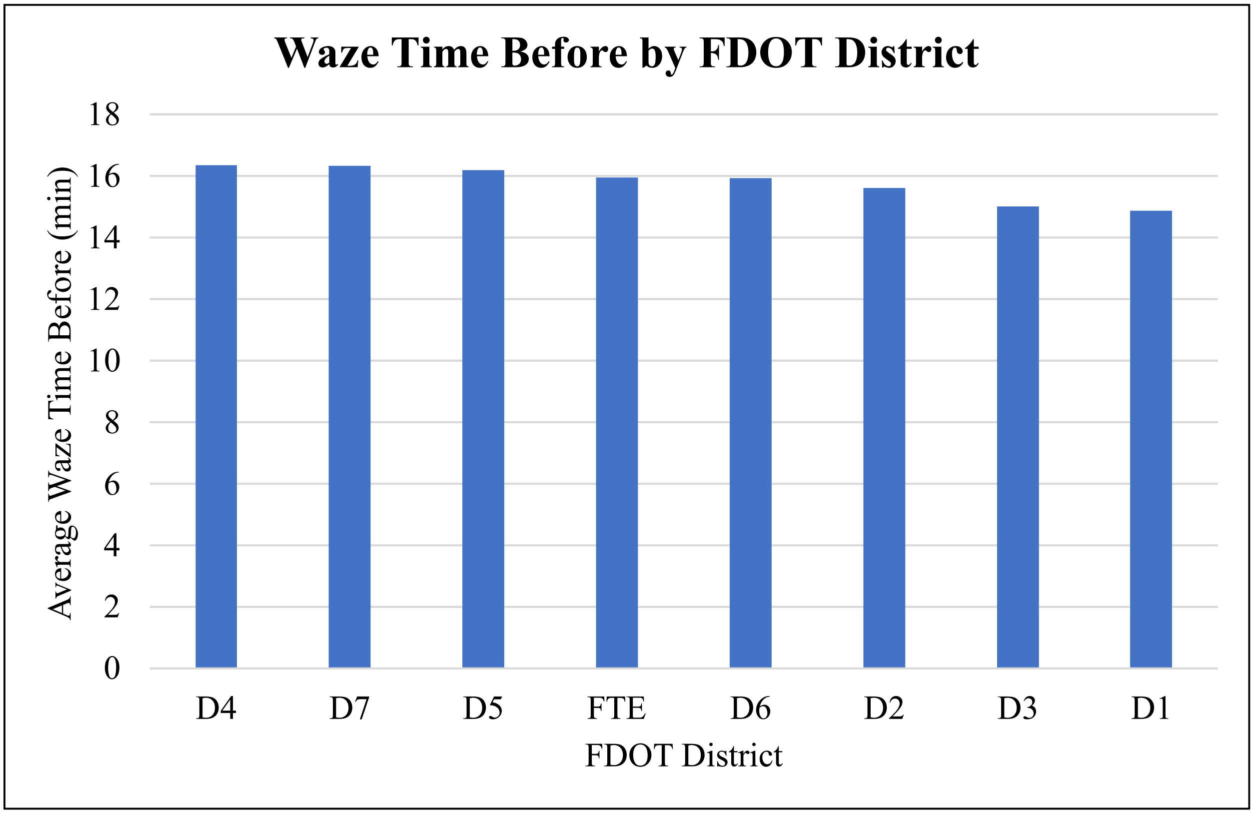

Figure 4-28: Waze Time Before by FDOT District for DAV SunGuide Events

Table 4-35: Waze Time Before by County for DAV SunGuide Events

County	Average Waze Time Before (min)
Martin	16.87
Palm Beach	16.70
St. Johns	16.51
Hillsborough	16.51
Osceola	16.47
Marion	16.37
Orange	16.36
Polk	16.31
Broward	16.19
Volusia	16.08
Pinellas	16.02
Miami-Dade	16.00
Sumter	15.98
Lake	15.78
Flagler	15.77
Nassau	15.71
Duval	15.71
Columbia	15.70
Seminole	15.56
Alachua	15.55
Escambia	15.52
Brevard	15.51
Holmes	15.50
Manatee	15.47
St. Lucie	15.39
Sarasota	15.24
Hernando	15.21

Table 4-35: Waze Time Before by County for DAV SunGuide Events

County	Average Waze Time Before (min)
Okaloosa	15.10
Indian River	15.09
Hamilton	15.08
Lee	15.02
Gadsden	15.01
Santa Rosa	14.96
Jefferson	14.92
Pasco	14.92
Okeechobee	14.83
Leon	14.76
Jackson	14.73
Walton	14.59
Washington	14.58
Baker	14.50
Suwannee	14.42
Charlotte	14.27
Collier	14.22
Madison	13.72
Other	15.33
Total	**15.95**

Figure 4-29: Waze Time Before by County for DAV SunGuide Events

The final Waze Time Before analysis was by roadway. **Table 4-36** and **Figure 4-30** show the average Waze Time Before for each roadway. I-4 (which goes through Tampa and Orlando), I-595 (which is in Miami), and I-95 (which runs along the east coast of Florida) had the highest Waze Time Before values. These roadways are all mainly located in major urban areas, which agrees with the district and county analyses. Further research is needed to identify specific portions of roadways where utilizing Waze alerts could provide the most improvements to DAV detection.

Table 4-36: Waze Time Before by Roadway for DAV SunGuide Events

Roadway	Average Waze Time Before (min)
I-4	16.85
I-595	16.51
I-95	16.21
SR-91/SR-821	16.21
I-275	16.14
SR-869	15.93
SR-826	15.87
SR-408	15.87
SR-429	15.57
I-75	15.53
I-195	15.35
SR-528	15.34
SR-417	15.31
I-295	15.26
I-10	15.05
SR-202	15.01
SR-414	14.87
I-110	14.79
SR-570	14.39
SR-589/SR-568	14.00
Other	15.95
Total	**15.95**

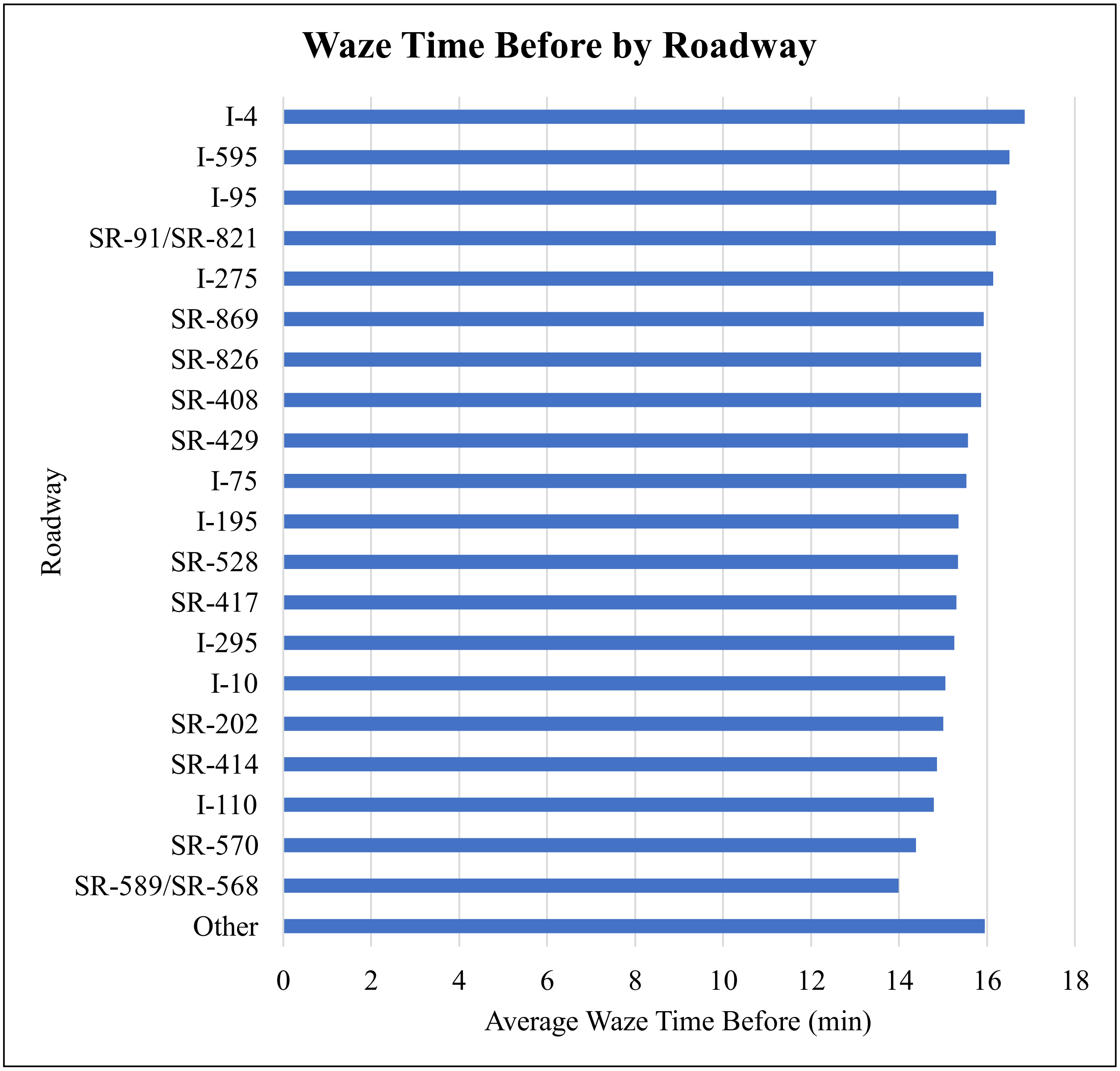

Figure 4-30: Waze Time Before by Roadway for DAV SunGuide Events

4.3 Quantification of DAV Impacts

DAVs can have several quantifiable impacts on traffic operations and safety. These can include injuries and fatalities, monetary damages, lane blockages, and time spent responding to and clearing DAVs. DAV crashes can have all of these impacts, while non-crash DAV events can result in lane blockages (which cause delay to motorists) and time spent by responders and TMC operators responding to and monitoring the event. None of the DAV datasets contained information about queueing and delays caused by the DAVs, so it was not possible to accurately calculate average delay or queue length. Responder and TMC personnel information were also unavailable, as the SunGuide data did not contain any information about the response to the DAV and the crash data only specified if law enforcement or emergency medical services were needed to transport any people involved in the crash. Based on these data limitations, the following four types of impacts are discussed in this chapter: severity and number of injuries and fatalities (crashes only), property and vehicle damages (crashes only), frequency of lane-blocking DAVs (both crash and non-crash events), and various durations associated with detection and response (both crash and non-crash). The frequency of shoulder-blocking DAV crashes and SunGuide events and ramp-blocking DAV crashes are also discussed. The impacts of DAV crashes are discussed in Section 4.3.1 and the impacts of non-crash DAV events are discussed in Section 4.3.2.

4.3.1 DAV Crash Impacts

The DAV crash reports contained many details about the results of the crash, including crash severity, number of injuries and fatalities, and resulting monetary damage (property and vehicle damages). **Table 4-37** shows the distribution of DAV crashes by severity, **Table 4-38** shows the number of injuries and fatalities for DAV crashes, **Table 4-39** shows the comprehensive costs of DAV fatalities and injuries and **Table 4-40** shows the monetary damages from DAV crashes. The results from these tables are for all 1,256 DAV crashes on Florida limited access facilities from 2015 through 2020. The average comprehensive costs for each injury severity were obtained from the National Safety Council (2021) and are from 2019. About half of all DAV crashes were property damage only (PDO), with 51.9% of disabled vehicle crashes and 60.5% of abandoned vehicle crashes falling into this category. Although only 3.3% of all DAV crashes were fatal crashes, they resulted in 53 fatalities. There were 976 total injuries from all DAV crashes, meaning that 1,029 people were either injured or killed due to a DAV crash. Most of these injuries and fatalities (88.8%) were from disabled vehicle crashes, with only one fatality due to abandoned vehicle crashes. As noted previously, some common contributing factors to DAV crashes were distracted driving and dark conditions. Finding ways to reduce distracted driving and increase visibility of disabled vehicles could help reduce these crashes and improve safety. Additionally, quickly detecting abandoned vehicles and ensuring they are adequately visible or moved further away from the travel lanes could help reduce abandoned vehicle crashes.

Overall, the 1,256 DAV crashes had a total comprehensive fatality and injury cost of almost $1 billion (approximately $161,034,000 per year), with an average fatality and injury cost of about $769,000 per DAV crash. Over 61% of these costs were due to the 53 fatalities. These DAV crashes also resulted in $17.3 million in vehicle and property damages over the six-year period, averaging about $2.9 million per year. Most of these damages (98%) were vehicle damages, with only about 2% from property damage. Therefore, the total estimated cost (including fatalities, injuries, and damages) of DAV crashes on Florida limited access facilities from 2015 through 2020 was $983,530,468, or $163,921,745 per year on average. This does not include congestion-related costs, which are discussed in Chapter 5.

Table 4-37: Number of DAV Crashes by Severity

	Fatality		Injury		PDO	
Vehicle Type	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
Disabled Vehicles	40	3.8%	466	44.3%	545	51.9%
Abandoned Vehicles	1	0.5%	80	39.0%	124	60.5%
Total	**41**	**3.3%**	**546**	**43.5%**	**669**	**53.3%**

Table 4-38: Number of Fatalities and Injuries Resulting from DAV Crashes

	Fatalities		Injuries		Combined	
Vehicle Type	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
Disabled Vehicles	52	98.1%	862	88.3%	914	88.8%
Abandoned Vehicles	1	1.9%	114	11.7%	115	11.2%
Total	**53**	**100.0%**	**976**	**100.0%**	**1029**	**100.0%**

Table 4-39: DAV Crash Fatality and Injury Comprehensive Costs

Injury Severity	Count	Average Comprehensive Cost per Injury	Total Comprehensive Cost
Fatality	53	$11,148,000	$590,844,000
Incapacitating	148	$1,219,000	$180,412,000
Non-Incapacitating	368	$336,000	$123,648,000
Possible Injury	460	$155,000	$71,300,000
Total	**1029**		**$966,204,000**

Table 4-40: Monetary Damages Resulting from DAV Crashes

	Property Damage		Vehicle Damage	
Vehicle Type	**Value**	**Percentage**	**Value**	**Percentage**
Disabled Vehicles	$299,100	2.0%	$14,621,593	98.0%
Abandoned Vehicles	$41,325	1.7%	$2,364,450	98.3%
Total	**$340,425**	**2.0%**	**$16,986,043**	**98.0%**

For the 1,051 disabled vehicle crashes, the overall property and vehicle damage amount was $14,920,693, resulting in an average damage cost of about $14,100 per disabled vehicle crash. **Figure 4-31** shows the cumulative distribution of damages for disabled vehicle crashes. Most crashes (96.5%) resulted in less than $50,000 in property and vehicle damages. However, the actual cost of these crashes is much higher as these costs do not account for costs involved in responding to the event, costs associated with queues (such as fuel or time delays), and injury costs.

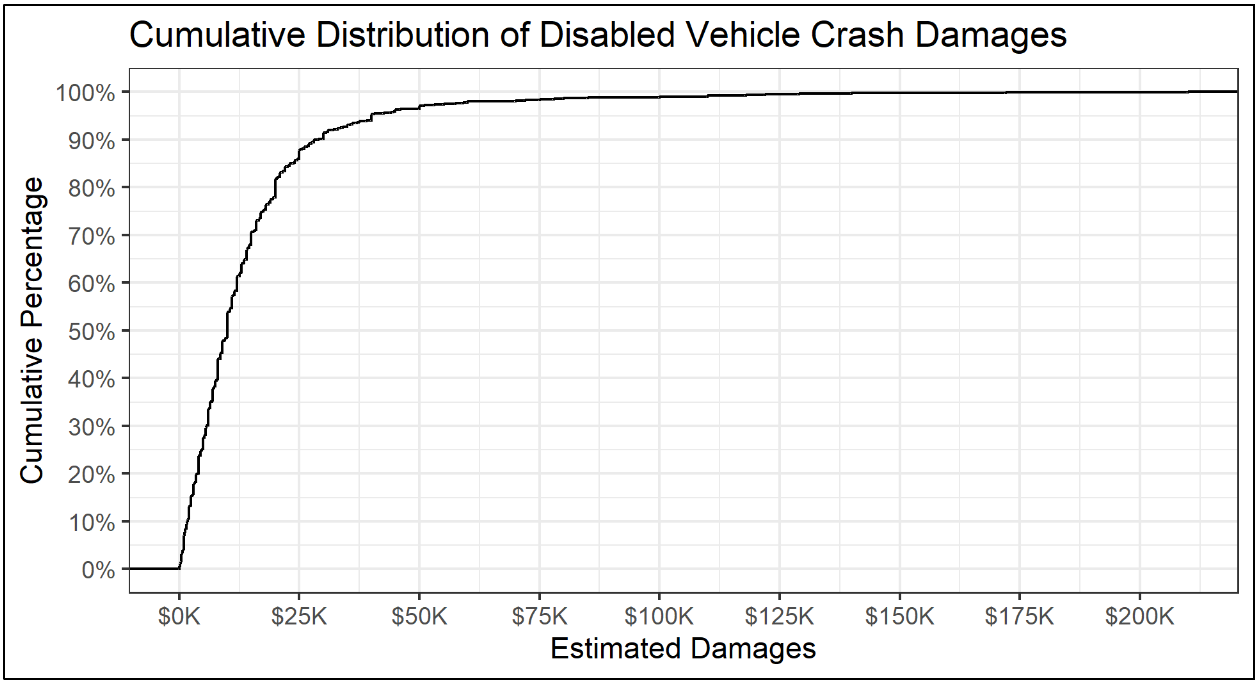

Figure 4-31: Cumulative Distribution of Disabled Vehicle Crash Damages

For the 205 abandoned vehicle crashes, the overall property and vehicle damage amount was $2,405,775, resulting in an average damage cost of about $11,700. **Figure 4-32** shows the cumulative distribution of damages for abandoned vehicle crashes. Most abandoned vehicle crashes (98%) resulted in less than $50,000 in property and vehicle damages. Like the disabled vehicle costs shown in **Figure 4-31**, these costs do not account for response costs, delay costs, and injury costs. Additional costs specific to abandoned vehicles, such as repeated monitoring by law enforcement or TMC personnel, time spent tagging the vehicle and locating its owner, and towing costs, are also not considered since data regarding these costs were not available.

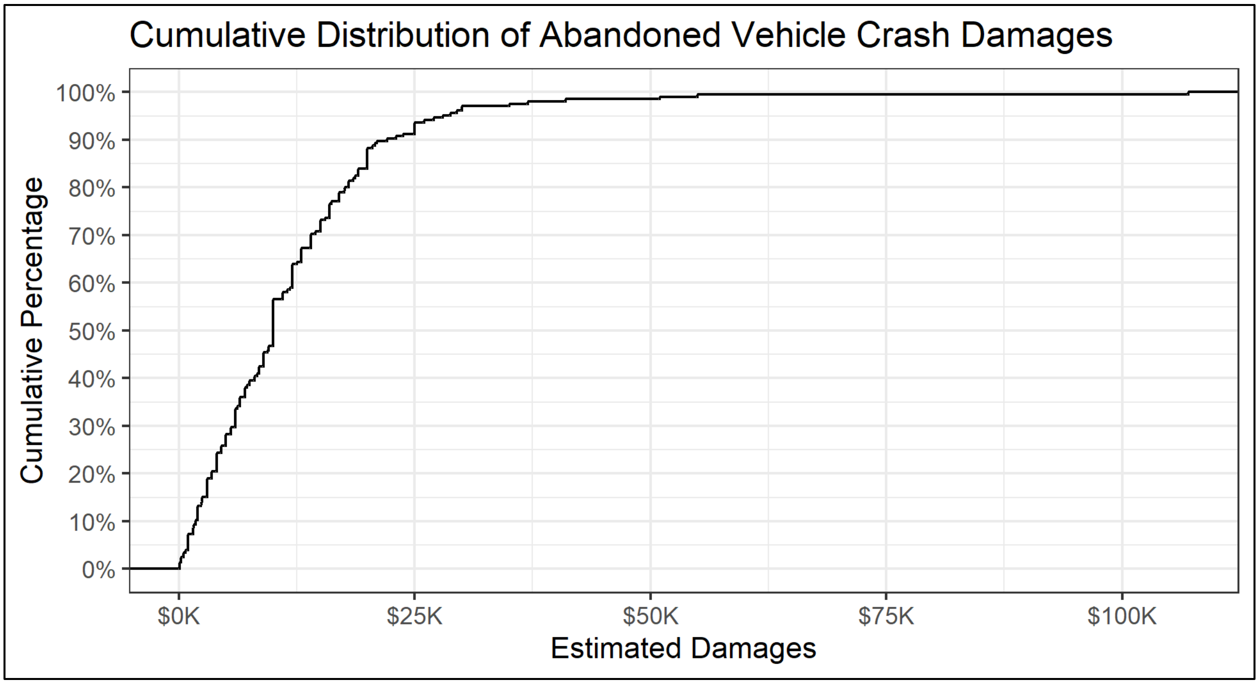

Figure 4-32: Cumulative Distribution of Abandoned Vehicle Crash Damages

The crash report narratives or crash diagrams indicated whether the involved DAVs blocked the travel lanes. As shown in **Table 4-41**, about 34% of all 1,256 DAV crashes involved a DAV that was blocking a travel lane in some capacity. This lane-blocking percentage was 38.8% for disabled vehicle crashes and 9.8% for abandoned vehicle crashes. Public outreach that emphasizes the importance of the Move It law, which requires drivers involved in incidents to move their vehicles out of the travel lanes, could help reduce the number of disabled vehicles that block a travel lane and subsequently lead to a crash.

Table 4-41: Frequency of DAV Crashes that Block Lanes

	Not Lane Blocking		Lane Blocking	
Vehicle Type	**Count**	**Percentage**	**Count**	**Percentage**
Disabled Vehicles	643	61.2%	408	38.8%
Abandoned Vehicles	185	90.2%	20	9.8%
Total	**828**	**65.9%**	**428**	**34.1%**

While lane-blocking DAV crashes on the mainline greatly impact traffic operations and safety, DAV crashes on shoulders and ramps can also negatively impact traffic. **Table 4-42** and **Table 4-43** show the frequency of DAV crashes that are on shoulders and ramps, respectively. It is important to note that a crash could be considered in more than one of the following tables: **Table 4-41**, **Table 4-42**, and **Table 4-43**, depending on where it occurred. For example, some DAV crashes occurred when the DAV was partially in the travel lanes and partially on a shoulder; these would be included in both **Table 4-41** and **Table 4-42**. Based on the results in **Table 4-42**, 72.9% of all DAV crashes occurred while the vehicle was either partially or fully on a shoulder. For both disabled vehicle crashes and abandoned vehicle crashes, at least half of the crashes occurred either partially or fully on the right shoulder. Notably, 92.2% of all abandoned vehicle crashes occurred either partially or fully on a shoulder. If a vehicle was abandoned in a travel lane, it would likely be moved to the shoulder, which can explain why so many abandoned vehicle crashes occurred on shoulders. Only 19% of all DAV crashes occurred either partially or fully on the left shoulder. **Table 4-43** shows that only about 10% of all DAV crashes occurred on an entrance or exit ramp, indicating that most DAV crashes occur on the mainline, where they are typically more dangerous and disruptive to traffic. Slightly more DAV crashes occurred on exit ramps compared to entrance ramps.

Table 4-42: Frequency of DAV Crashes on Shoulders

	Left Shoulder		Right Shoulder		Total	
Vehicle Type	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
Disabled Vehicles	200	19.0%	527	50.1%	727	59.2%
Abandoned Vehicles	39	19.0%	150	73.2%	189	92.2%
Total	**239**	**19.0%**	**677**	**53.9%**	**916**	**72.9%**

Table 4-43: Frequency of DAV Crashes on Ramps

	Entrance Ramp		Exit Ramp		Total	
Vehicle Type	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
Disabled Vehicles	48	4.6%	59	5.6%	107	10.2%
Abandoned Vehicles	8	3.9%	7	3.4%	15	7.3%
Total	**56**	**4.5%**	**66**	**5.3%**	**122**	**9.7%**

Various durations associated with crash detection and response were also analyzed. **Figure 2-1** showed the TIM incident duration timeline with important timestamps and durations defined. As mentioned in Section 4.1, the crash reports contained several important timestamps about the crash. These were the time of crash (T_0), time the crash was reported (T_1), time law enforcement was dispatched (T_D which is not shown in **Figure 2-1** but is between T_1 and T_2), time of arrival to the scene (T_2), and time the scene was cleared (T_5). These timestamps were manually collected for the 674 DAV crashes from 2018 to 2020 and used to calculate four durations based on the timeline in **Figure 2-1**: detection ($T_1 - T_0$), notification ($T_D - T_1$), arrival ($T_2 - T_D$), and response activities ($T_5 - T_2$). The total crash duration is the sum of all these durations and can also be directly calculated using $T_5 - T_0$. **Table 4-44** shows the average length (in minutes) for each of these durations for the 1,256 DAV crashes. The average duration for abandoned vehicle crashes was slightly longer than that of disabled vehicle crashes, primarily due to longer average detection. When a DAV crash occurred, it took on average seven minutes to detect the crash and 14 minutes to arrive at the crash scene. The longest duration for DAV crashes was for response activities, which averaged 101 minutes. The results indicate that improvements could be made to existing detection systems so DAV crashes can be more quickly detected, and responders can be notified more efficiently. Moreover, finding ways to help responders more quickly address the crash can help to restore traffic to regular conditions sooner.

Table 4-44: Average Durations Associated with DAV Crashes

Duration	Average Disabled Vehicle Crash Duration (minutes)	Average Abandoned Vehicle Crash Duration (minutes)	Average DAV Crash Duration (minutes)
Detection ($T_1 - T_0$)	6	9	7
Notification ($T_D - T_1$)	9	9	9
Arrival ($T_2 - T_D$)	14	14	14
Response Activities ($T_5 - T_2$)	101	101	101
Total ($T_5 - T_0$)	**130**	**133**	**130**

4.3.2 Non-Crash DAV Event Impacts

For the studied non-crash DAV SunGuide data, the main impacts were the frequency of lane-blocking and shoulder-blocking events and the durations of the DAV SunGuide events. **Table 4-45** shows the worst type of lane blockage that occurred for the DAV SunGuide events as derived from the worst_blockage field of the data. Each lane blockage text string was reviewed and sorted into one of four categories: travel lane blocked, shoulder blocked, no blockage, or no information. An event was only classified into one category based on its highest severity. For instance, an event that blocked both a travel lane and the shoulder was classified as blocking the travel lane since this is a more severe level of blockage. Only 3.8% of all DAV events blocked a travel lane, with only 1% of abandoned vehicle events having blocked a travel lane. Of these events that blocked a travel lane, 68.6% blocked at most one lane. The remaining 31.4% blocked anywhere from two lanes to all lanes of the roadway. Because the number of lanes on a roadway vary both along the roadway and from roadway to roadway, these 31.4% of lane-blocking events blocked a variable number of lanes. Most of the DAV events either only blocked a shoulder or did not block any lanes at all. About 20% of the events were missing explicit blockage information. It is assumed that if a serious blockage had occurred (such as one that affected travel lanes and would lead to queueing and delays), it would be noted. As such, it is likely that the 20% of events which were missing worst_blockage information did not block a travel lane. Since only the worst blockage was reported, it is unknown if any of the lane-blocking DAVs initially blocked a lane and were then moved before the event was closed. It is also unknown how long these vehicles were lane-blocking before being moved out of the travel lanes or off the facility.

Table 4-45: Summary of the Worst Blockage of DAV Events

	Disabled Vehicles		Abandoned Vehicles		Combined Events	
Worst Blockage	**Count**	**Percentage**	**Count**	**Percentage**	**Count**	**Percentage**
Travel Lane Blocked	59,522	4.2%	1,622	1.0%	61,144	3.8%
Shoulder Blocked	712,401	49.8%	96,425	60.3%	808,826	50.8%
No Blockage	368,357	25.7%	34,185	21.4%	402,542	25.3%
No Information	291,442	20.4%	27,554	17.2%	318,996	20.0%
Total	**1,431,722**	**100.0%**	**159,786**	**100.0%**	**1,591,508**	**100.0%**

Comparing the lane blockage for crash and non-crash DAV events shows that although only 4.2% of disabled vehicle SunGuide events blocked a travel lane, 38.8% of disabled vehicle crashes blocked at least one travel lane. This suggests that lane-blocking disabled vehicles are likely to result in a crash. Quickly addressing a lane-blocking disabled vehicle could greatly minimize the chances of it resulting in a crash. Abandoned vehicles block lanes less frequently than disabled vehicles for both crash and non-crash events.

Although many DAV events did not block a travel lane, most blocked at least one shoulder. Of the 869,970 events that either blocked a travel lane or shoulder, 844,919 (97.1%) blocked at least one shoulder in some capacity. **Table 4-46** shows the frequency of shoulder blockage by DAV events while **Table 4-47** shows the frequency of shoulder blockage by district. In these tables, events categorized as occurring on an unknown shoulder are due to the SunGuide worst_blockage field indicating that a shoulder was blocked but not specifying which one. Most DAV events that blocked a shoulder were disabled vehicle events, which comprised 748,113 (88.5%) of all shoulder blocking events. The right shoulder was blocked most of the time, with 86.9% of all shoulder blocking events blocking only the right shoulder. However, this can vary by district. District 3 had 97.3% of its DAV events block just the right shoulder while District 6 had 74.2% of its DAV events block just the right shoulder. This can be reflective of the variability of traffic patterns in these districts along with shoulder availability. Notably, District 1 had 9.9% of their DAV events identified as blocking both shoulders, which is considerably more than percentages for other districts. Many events in District 1 had their worst blockage listed as “closed”, suggesting that the event led to a full road closure. Investigating the nature of DAV events in this district could reveal possible means of improving the response process to avoid full road closure.

Table 4-46: Summary of DAV Event Shoulder Blockage by Event Type

Vehicle Type	Left Shoulder Only	Right Shoulder Only	Both Shoulders	Unknown Shoulder	Total
Disabled Vehicles	77,299 (10.3%)	649,330 (86.8%)	13,540 (1.8%)	7,944 (1.1%)	748,113 (100.0%)
Abandoned Vehicles	10,617 (11.0%)	84,886 (87.7%)	251 (0.3%)	1,052 (1.1%)	96,806 (100.0%)
Total	**87,916 (10.4%)**	**734,216 (86.9%)**	**13,791 (1.6%)**	**8,996 (1.1%)**	**844,919 (100.0%)**

Table 4-47: Summary of DAV Event Shoulder Blockage by District

District	Left Shoulder Only	Right Shoulder Only	Both Shoulders	Unknown Shoulder	Total
D1	10,412 (8.3%)	102,182 (81.7%)	12,370 (9.9%)	81 (0.1%)	125,045 (100.0%)
D2	6,662 (10.1%)	58,011 (87.6%)	83 (0.1%)	1,438 (2.2%)	66,194 (100.0%)
D3	4,058 (2.4%)	161,175 (97.3%)	124 (0.1%)	372 (0.2%)	165,729 (100.0%)
D4	21,912 (10.7%)	181,859 (89.2%)	51 (0.0%)	15 (0.0%)	203,837 (100.0%)
D5	4,539 (13.8%)	27,307 (83.1%)	56 (0.2%)	965 (2.9%)	32,867 (100.0%)
D6	20,267 (20.9%)	71,842 (74.2%)	948 (1.0%)	3,796 (3.9%)	96,853 (100.0%)
D7	8,637 (18.0%)	38,769 (80.8%)	63 (0.1%)	519 (1.1%)	47,988 (100.0%)
FTE	11,429 (10.7%)	93,071 (87.5%)	96 (0.1%)	1,810 (1.7%)	106,406 (100.0%)
Total	**87,916 (10.4%)**	**734,216 (86.9%)**	**13,791 (1.6%)**	**8,996 (1.1%)**	**844,919 (100.0%)**

Lane-blocking DAV events on ramps can also pose an issue to vehicles trying to enter or exit the roadway. **Table 4-48** shows the number of DAV SunGuide events that that blocked a ramp and the severity of the blockage. Relatively few DAV SunGuide events occurred on ramps as only 0.8% of all DAV SunGuide events were ramp events. In comparison, about 10% of DAV crashes were on ramps. This suggests that, although rarer, DAV ramp events are at an increased risk of being involved in a crash by passing vehicles trying to enter or exit the roadway. About 75% of all ramp events occurred on an exit ramp, which differs from DAV crashes where about 54% of DAV ramp crashes were on exit ramps. Approximately 24% of ramp events caused a full blockage of the ramp, which can prevent vehicles from entering or exiting a roadway and cause significant negative impacts on traffic operations.

Table 4-48: Summary of Ramp-Blocking DAV SunGuide Events

Ramp	Partial Blockage	Full Blockage	Total
Entrance	1,861 (57.6%)	1,372 (42.4%)	3,233 (100.0%)
Exit	7,877 (82.5%)	1,675 (17.5%)	9,552 (100.0%)
Total	**9,738 (76.2%)**	**3,047 (23.8%)**	**12,785 (100.0%)**

The SunGuide DAV events were also analyzed with respect to event duration by time of day and roadway. Overall, the 1,431,722 disabled vehicle SunGuide events from 2018 through 2021 lasted an average of 70 minutes, while the 159,786 abandoned vehicle SunGuide events from 2018 through 2021 lasted an average of 821 minutes (over 13 hours). This long duration for abandoned vehicle events suggests that the impact to traffic from abandoned vehicles is minimal until a crash occurs, as these events would likely be addressed quickly if they posed an immediate hazard. However, frequent monitoring of the abandoned vehicle is likely needed to ensure it does not impact traffic and to see if the driver or owner of the abandoned vehicle returns to the site and removes the vehicle. Comparing the crash and non-crash event durations shows that the average duration of disabled vehicle crashes (130 minutes) was nearly twice the average duration for disabled vehicle non-crash events (70 minutes). Therefore, being able to quickly detect disabled vehicles before they cause a crash can not only improve safety, but also reduce the time needed to respond to the event.

Table 4-49 shows the mean event durations for all DAV SunGuide events by hour, while **Figure 4-33** and **Figure 4-34** show the mean event duration by hour for disabled vehicle and abandoned vehicle events, respectively. For disabled vehicles, the period from 8 AM to 5 PM have consistently lower average event durations (of approximately an hour) compared to nighttime hours. This daytime period is when services such as the Road Rangers are most active and can promptly respond to events. However, the average duration continually increases after 5 PM, peaking at 1 AM with a duration of nearly 2 hours. Earlier analyses found that the period of midnight to 5 AM had the fewest disabled vehicle events, meaning that these relatively few events make up some of the longest durations. These nighttime hours are often when Road Ranger services have ended, which could lead to these longer event durations. A similar trend holds true for the abandoned vehicle events, which had the longest average duration of about 17 hours at 1 AM and the shortest average duration of about 10 hours at 10 AM. However, unlike disabled vehicles that can be quickly resolved, abandoned vehicles intrinsically take more time due to repeated monitoring of the vehicle to ensure it is indeed abandoned. As noted previously, if these events posed an immediate hazard, they would be quickly cleared from the travel lanes or roadway. Quick clearance of DAV events helps to reduce their chances of being involved in a crash, so finding ways to improve response can lead to improvements in safety and operations.

Table 4-49: Average DAV SunGuide Event Durations by Hour

Hour	Disabled Vehicles		Abandoned Vehicles		Combined Events	
	Count	**Mean Duration (minutes)**	**Count**	**Mean Duration (minutes)**	**Count**	**Mean Duration (minutes)**
12 AM	35,305	112	4,412	1,015	39,717	213
1 AM	28,135	114	3,956	1,036	32,091	228
2 AM	23,939	112	3,494	985	27,433	223
3 AM	21,507	104	3,289	974	24,796	219
4 AM	21,009	107	2,822	949	23,831	206
5 AM	21,732	101	2,799	842	24,531	186
6 AM	42,534	84	7,998	878	50,532	210
7 AM	63,012	71	12,576	829	75,588	197
8 AM	65,081	63	9,795	793	74,876	158
9 AM	65,505	59	7,959	712	73,464	130
10 AM	70,987	57	8,986	608	79,973	119
11 AM	74,401	59	8,449	678	82,850	122
12 PM	74,495	59	7,454	733	81,949	121
1 PM	73,910	59	6,772	729	80,682	116
2 PM	94,648	59	8,911	764	103,559	120
3 PM	102,101	57	8,899	747	111,000	113
4 PM	99,761	57	8,034	766	107,795	110
5 PM	92,597	57	7,264	790	99,861	111
6 PM	84,564	62	7,324	849	91,888	125
7 PM	72,881	67	7,121	917	80,002	142
8 PM	61,040	73	6,028	915	67,068	149
9 PM	50,955	86	4,780	910	55,735	157
10 PM	48,238	99	5,238	981	53,476	185
11 PM	43,385	106	5,426	992	48,811	204
Total	**1,431,722**	**70**	**159,786**	**821**	**1,591,508**	**146**

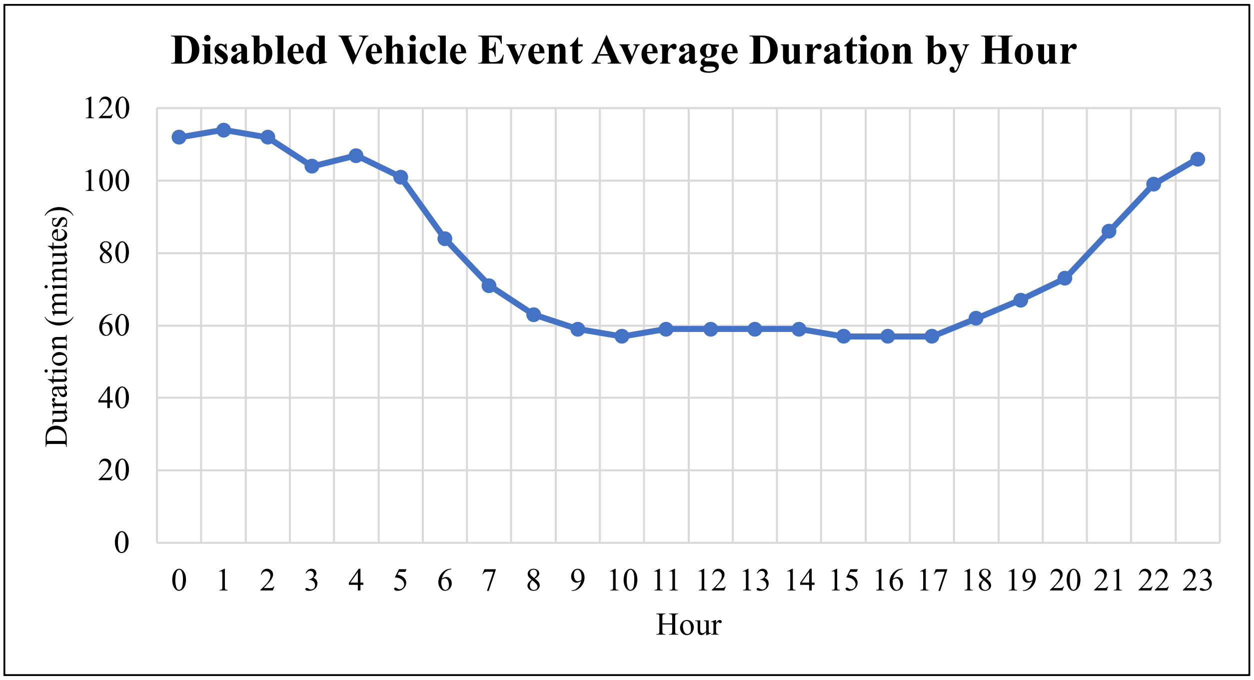

Figure 4-33: Average Disabled Vehicle Event Durations by Hour

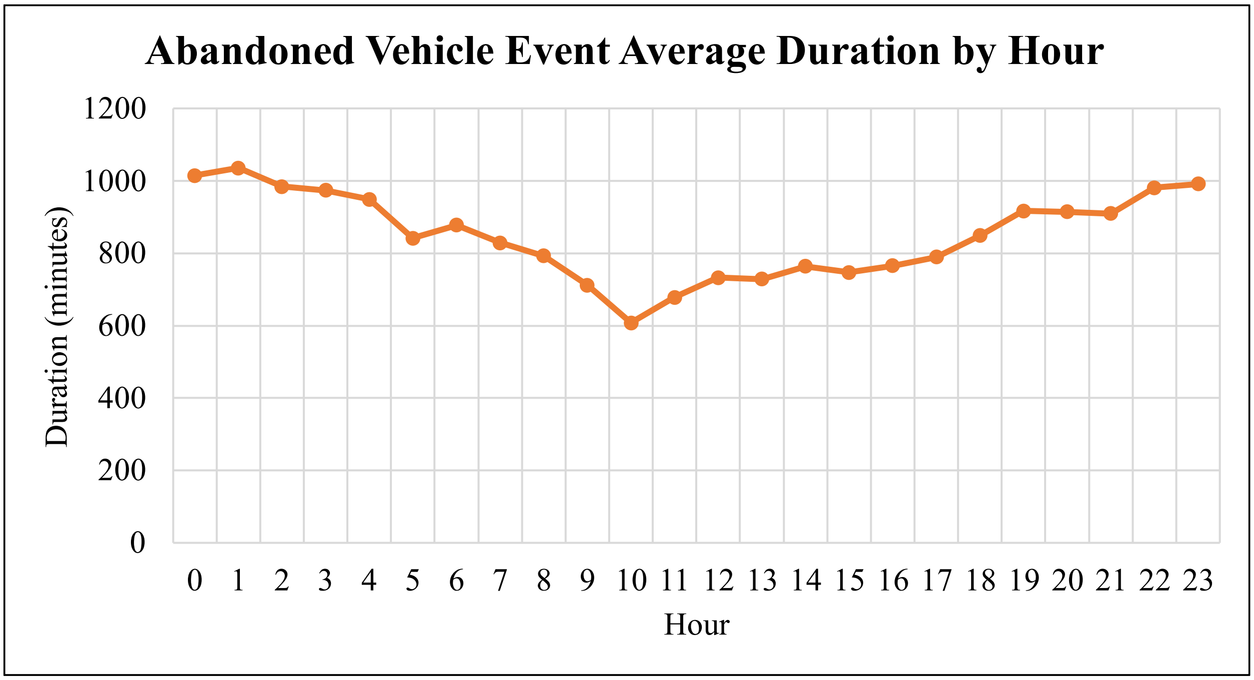

Figure 4-34: Average Abandoned Vehicle Event Duration by Hour

Table 4-50 shows the mean event durations for DAV events by roadway, while **Figure 4-35** and **Figure 4-36** show the mean event duration by roadway for disabled vehicle and abandoned vehicle events, respectively. I-10 had the highest average disabled vehicle event duration in the state, with disabled vehicle events lasting an average of about two hours. I-10 is mainly located in the Florida panhandle, which is largely rural with sparse entry and exit points. As such, a disabled vehicle event that occurs here could take a while to be detected and responded to by law enforcement, Road Rangers, or other agencies. On the other hand, the roadway with the second highest average disabled vehicle event duration was I-595, which is in an urban area of Broward County with several nearby entry and exit points. Further investigation into this roadway is needed to determine why it had excessive disabled vehicle event durations. Since there were fewer abandoned vehicle events compared to disabled vehicle events and these abandoned vehicle events had a much larger range of durations, the mean durations for abandoned vehicle events were much more sensitive to outliers. I-4 had the longest average abandoned vehicle event duration in the state of approximately 19 hours. Several other roadways in Central Florida, such as SR-414 and SR-429, also had some of the longest average abandoned vehicle event durations in the state. It is possible that District 5, which covers Central Florida, has a different approach to handling abandoned vehicles than other districts that caused these long durations. Further investigations into the differences in DAV response policies at the district or agency level could reveal which policies are most effective at addressing DAVs in a timely manner. Furthermore, both I-295 and SR-202 (which are in the same county and district) have very short average abandoned vehicle event durations of 15 and 12 minutes, respectively. This could be due to differences in the reporting of abandoned vehicles to SunGuide in that district.

Table 4-50: Average DAV SunGuide Event Durations by Roadway

Roadway	Disabled Vehicles		Abandoned Vehicles		Combined Events	
	Count	Mean Duration (minutes)	Count	Mean Duration (minutes)	Count	Mean Duration (minutes)
SR-414	2,028	44	467	1,010	2,495	225
I-4	123,130	40	19,661	1,152	142,791	193
SR-417	28,055	59	4,843	906	32,898	184
SR-429	18,959	50	3,342	945	22,301	184
SR-528	22,599	56	3,540	979	26,139	181
SR-408	21,190	45	3,781	876	24,971	170
I-95	300,417	75	42,661	709	343,078	154
I-10	186,037	118	9,611	812	195,648	152
I-110	4,358	51	794	702	5,152	151
SR-91/SR-821	216,702	84	21,329	753	238,031	144
I-595	3,854	84	381	736	4,235	142
SR-869	8,774	79	1,028	618	9,802	136
I-75	317,384	62	30,779	883	348,163	135
I-275	61,244	31	8,555	876	69,799	134
I-195	2,703	58	264	618	2,967	108
SR-589/SR-568	27,299	45	2,925	591	30,224	98
SR-570	3,629	38	337	723	3,966	96
I-395	1,504	56	83	754	1,587	92
SR-826	44,021	53	2,235	516	46,256	76
I-295	30,496	23	2,043	15	32,539	23
SR-202	4,643	20	918	12	5,561	19
Other	2,696	29	209	694	2,905	77
Total	**1,431,722**	**70**	**159,786**	**821**	**1,591,508**	**146**

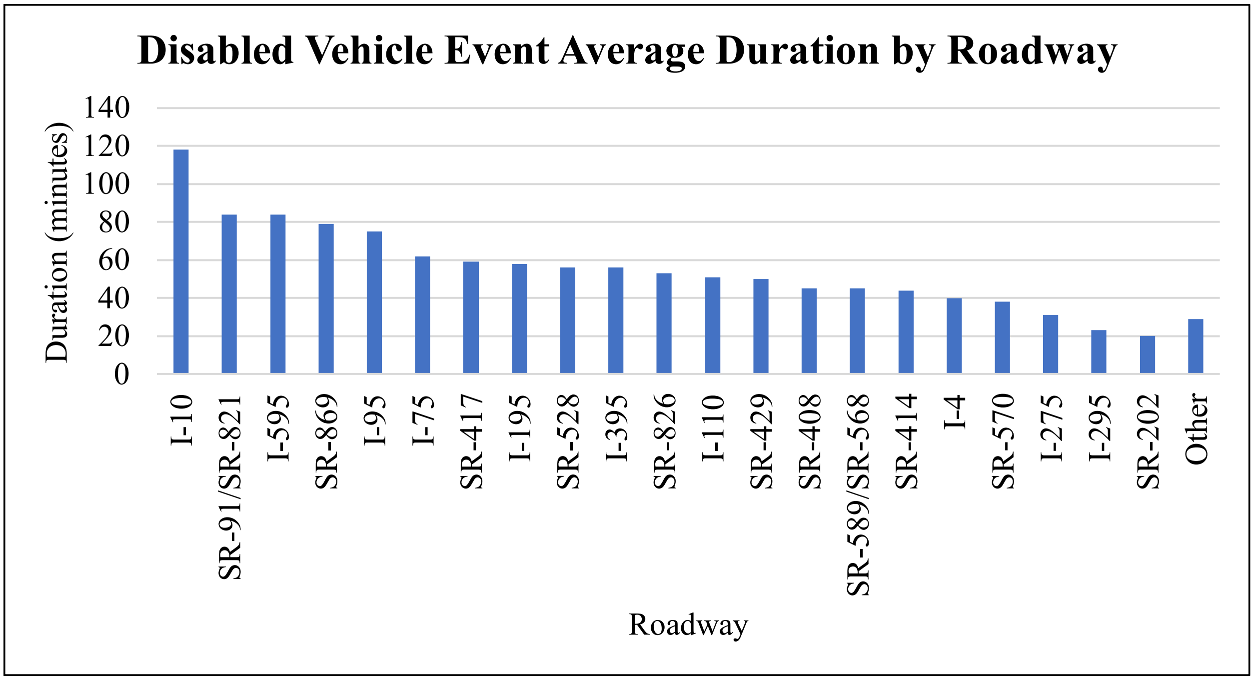

Figure 4-35: Average Disabled Vehicle SunGuide Event Duration by Roadway

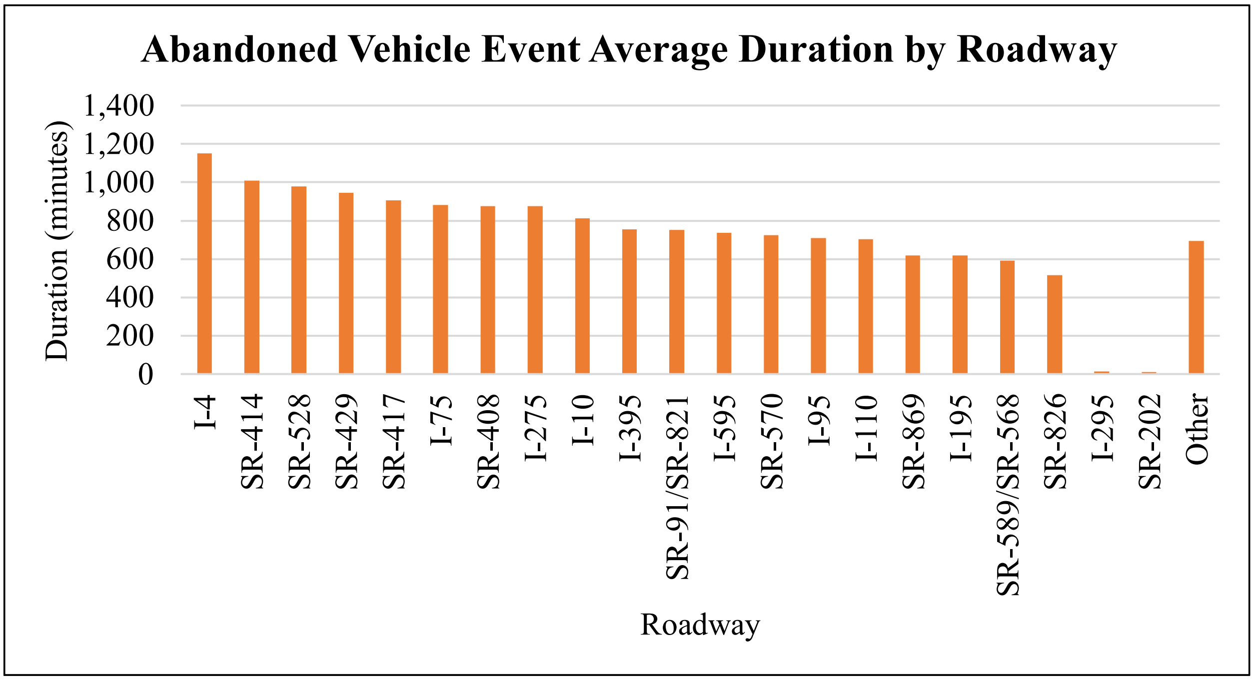

Figure 4-36: Average Abandoned Vehicle SunGuide Event Duration by Roadway

4.4 Summary and Conclusions of DAV Analysis and Quantification of Impacts

DAVs are frequent occurrences on Florida roadways that can have significant impacts on traffic operations and safety. In this chapter, three DAV datasets were analyzed: S4A crash reports, SunGuide non-crash event data, and Waze crowdsourced alert data. Each dataset provided a different insight into the characteristics of DAVs on Florida roadways. Various impacts of these DAVs were also determined and discussed to identify potential improvements.

DAV crash data from 2015-2020 was obtained from S4A using three queries to locate possible DAV crashes. After manually reviewing each of the 5,090 unique crash reports, a total of 1,256 were identified as involving a DAV based on the crash narrative or the crash diagram (1,051 disabled vehicle crashes and 205 abandoned vehicle crashes). The number of DAV crashes per year peaked in 2018 (239 crashes) and has been over 200 crashes per year since 2017. DAV crashes occur most often in spring and summer months (May through August) and during early morning hours and at night, both of which are times when visibility is reduced due to the darkness. These are also times when Road Ranger patrols might be reduced or not operating on certain roadways, which could make it harder for motorists to receive assistance and can put them at a higher risk of being struck by another vehicle. Distraction was also found to be a common contributing factor of DAV crashes, as 15% of all DAV crashes were due to distracted driving. Interstates in urban counties had the highest frequency of DAV crashes, suggesting that improving detection and subsequent response in these areas would lead to the most benefits in terms of reducing crashes and their associated fatalities and injuries. In particular, I-95 had over a third of all DAV crashes in the state for the study period and four urban counties (Broward, Duval, Hillsborough, and Miami-Dade) accounted for 50% of all DAV crashes.

Nearly 1.6 million SunGuide non-crash DAV events from January 2018 through December 2021 were also collected and analyzed. About 90% of these were disabled vehicle events and the remaining 10% were abandoned vehicle events. DAV SunGuide events peaked in summer and early fall (similar to crashes). Most disabled vehicle SunGuide events happened during daytime hours, especially during the afternoon peak hours, while abandoned vehicle events peaked at 7 AM. About 23% of disabled vehicle SunGuide events occurred from 9 PM to 7 AM, but 45% of crashes occurred in this timeframe, suggesting that clear visibility and conspicuity plays an important role in reducing crashes. The FDOT district with the most DAV SunGuide events was FTE, followed by District 4. Like the crashes, urban counties had many of the DAV SunGuide events. Most DAV SunGuide events occurred on the major interstates, but SR-91/SR-821 had the third highest number of events and was the toll road with the greatest DAV event frequency.

Using these DAV crash and SunGuide data, the following DAV impacts were quantified: crash injuries and fatalities, crash property and vehicle damages, the frequency of DAV crash and SunGuide lane-blocking and shoulder-blocking events, and the average duration of DAV crashes and SunGuide events. No data were available on the queues or delays that resulted from DAV crashes or events, so these could not be quantified directly. Additionally, no information was available on the time spent by law enforcement, Road Rangers, or TMC personnel in monitoring or addressing DAV events. There were 53 fatalities, 976 injuries, $17.3 million in property and vehicle damages, and $966 million in comprehensive fatality and injury costs due to DAV crashes from 2015 through 2020, with most of these impacts caused by disabled vehicle crashes. Combining the fatality and injury costs with the property and vehicle damages resulted in an average yearly cost of about $163.9 million. On average, each DAV crash resulted in $13,800 in property and vehicle damages and $769,000 in fatality and injury costs. Over 95% of DAV crashes resulted in less than $50,000 in property and vehicle costs. These DAV crashes lasted an average of 130 minutes each, with an average detection time of seven minutes, average notification time of nine minutes, average arrival time of 14 minutes, and average response time of 101 minutes. Reducing these durations by improving detection and notification or utilizing new response methods to clear the crashes more quickly, could minimize the impacts of these crashes. Over 34% of DAV crashes blocked at least one travel lane, emphasizing the need for quick response to reduce operational impacts.

Compared to the DAV crashes, DAV SunGuide events were less likely to be lane-blocking, with only about 4% of DAV SunGuide events having blocked a travel lane in some capacity. An additional 51% of DAV SunGuide events blocked at least one shoulder. For shoulder-blocking DAV events, only the right shoulder was blocked about 87% of the time and both shoulders were only blocked less than 2% of the time. However, D1 had both shoulders blocked in almost 10% of shoulder-blocking DAV events, suggesting that further investigation is needed to identify the reasons for these significant blockages. Although only 0.8% of DAV SunGuide events occurred on a ramp, about 10% of DAV crashes occurred on a ramp, suggesting that DAV events on ramps are at an increased risk of being involved in a crash compared to DAVs on the mainline. Disabled vehicle SunGuide events lasted about half the time as DAV crash events (70 minutes compared to 130 minutes), but abandoned vehicle SunGuide events lasted over 13 hours on average before being fully cleared from the scene. Promptly moving an abandoned vehicle from the travel lanes to the shoulder or a service plaza can help prevent it from being involved in a crash. Roadways such as I-10, I-595, and SR-91/SR-821 had high disabled vehicle event durations, so investigation is needed to identify potential ways to improve DAV detection and response on these roadways.

Analysis of the approximately 10.3 million DAV Waze alerts from April 2019 through December 2021 showed that Waze alerts occurred more frequently during daytime hours than nighttime hours, with the highest hourly counts between 1 PM and 6 PM, and were more common on high-volume roadways like I-95, I-75, and SR-91/SR-821. Comparing these DAV Waze alerts to DAV SunGuide events during the same period provided additional insights. About 70% of the 1,036,775 DAV SunGuide events during this period had at least one overlapping Waze alert (using a 30-minute buffer and approximately 1-mile radius), with 67% of these overlapping events having at least one Waze alert before the SunGuide event. Abandoned vehicle events had a higher percentage of Waze overlap than disabled vehicle events, due to the longer average duration of abandoned vehicle events.

Further analyses of the SunGuide and Waze overlap showed that this overlap was more present during daytime hours than nighttime hours, which agrees with the hourly distribution of the Waze alerts. Location analyses showed that D5 was the FDOT district with the most overlap with Waze. At the county level, urban counties (Broward, Miami-Dade, Hillsborough, Orange, etc.) typically had more overlap with Waze than rural counties, but there were some exceptions. The analysis by roadway showed that I-95 had the most events with Waze overlap and I-4 had the highest percentage of events with Waze overlap (82.1%). Like the county analysis, roadways through more rural areas (such as I-10) tended to have less Waze overlap than roadways through mainly urban areas (such as I-4). Multiple roadways in the Central Florida area had more than 15% of their events caused by abandoned vehicles, so further investigation into these events and potential causes might be necessary.

For the 481,839 DAV SunGuide events which had Waze alerts before the SunGuide event, the Waze alert occurred about 16 minutes before the SunGuide event, on average. The distribution of this time difference showed that as the time difference increased, the number of events generally increased (i.e., more events had a time difference of 30 minutes than a time difference of 29 minutes, more events had a time difference of 29 minutes than a time difference of 28 minutes, etc.). This time difference was highest during the day (11 AM through 7 PM) and lowest in the early morning (3 AM through 6 AM). Therefore, utilizing Waze alerts during the day would provide more benefits (with respect to early detection) than utilizing Waze alerts in early morning hours. Districts 4, 7, and 5 had the highest time differences of the FDOT Districts (over 16 minutes each), while counties with large urban areas and roadways through these areas had the highest time differences. These results show that Waze alerts could allow for earlier detection of DAV events, with potential benefits greater at certain times of the day and certain locations compared to others.

Overall, this chapter shows the extent of DAV events on Florida limited access facilities and their potential impacts. The frequency of disabled and abandoned vehicle events varies throughout the state and for different times of the day. DAV crashes are more common during nighttime hours even though DAVs are more commonly reported during daytime hours. Overall, DAV Waze alerts could be a useful tool to detect and respond to DAV events quickly. However, more research is needed to determine the optimal times and locations to report DAV Waze data to the TMC to provide the most benefits while not overloading the TMC operators. Earlier detection and response to DAV events could help reduce the safety and operational impacts of DAV events, including the chances of crashes and their associated impacts (fatalities, injuries, property and vehicle damages, etc.). Some roadways have longer DAV event durations than others, so improvement efforts should be focused on these roadways as they have the most potential for improvement. DAVs result in additional impacts besides those discussed in this chapter, but sufficient data were not available to estimate these impacts. Obtaining more information about DAV event response and the queues formed by DAV events can give a greater picture of the impacts they have on traffic. Estimates of congestion caused by DAVs using the available data are discussed in the next chapter, along with evaluations of potential methods to reduce the impacts of DAV events.

Chapter 5: Benefit-Cost Evaluations and Recommended Methods to Reduce DAVs and Their Impacts

This chapter discusses several potential methods to reduce the impacts of DAVs on limited access facilities. First, a general methodology to calculate congestion costs is developed so that these potential methods can be quantified. Next, congestion costs are estimated for select roadways across the state to understand how costly DAVs can be. Then, benefit-cost evaluations are performed for several potential methods to reduce DAV impacts, focusing primarily on faster detection of and response to these DAVs. Lastly, recommendations are given for the best methods to reduce DAV impacts. By considering both crash and non-crash DAV events (collectively referred to as DAV incidents throughout this chapter), these evaluations are able to provide more holistic and accurate insights regarding the benefits and costs of these methods rather than solely focusing on DAV crashes.

5.1 Congestion Cost Methodology and Application to Select Roadways

When a DAV incident occurs and reduces roadway capacity, it can lead to congestion. The cost of this congestion depends on various factors, including the duration of the blockage and the types and numbers of vehicles impacted by the incident, and can become very high on limited access roadways with high traffic volumes. Section 5.1.1 in this chapter discusses the methodology used to calculate the financial impact (congestion costs) of capacity-reducing DAV incidents which resulted in blockage of one or more lanes and/or shoulders. This methodology is then applied to select limited access roadways across Florida in Section 5.1.2 (one limited access roadway per FDOT district) to get an estimate of DAV congestion impacts throughout various areas of the state. This methodology is also adapted and used for the various benefit-cost evaluations discussed in Section 5.2.

5.1.1 Methodology for Estimating Congestion Costs

The methodology developed for the congestion estimation is based on the use of cumulative input-output diagrams (or cumulative arrival and departure curves) to calculate delay. These cumulative curves are based on deterministic queueing theory. **Figure 5-1** shows the cumulative arrival and departure curves of vehicles arriving at and departing from a capacity-reducing incident that causes a bottleneck. The shaded gray area represents the total vehicle delay in vehicle-hours. The total delay equation is based on this shaded area which can be derived from simple triangular relationships as shown in **Equation 5-1**. In **Equation 5-1**, λ is the flow rate for all lanes (veh/hr), μ is the capacity for all lanes (veh/hr), μ^* is the remaining capacity for all lanes due to the capacity-reducing incident (veh/hr), and T is the duration of the incident (hr) while incident capacity reduction is in effect. It is important to note that for the purposes of this methodology, and for simplicity, the flow rates and capacities are assumed to be constant during the period of analysis in this cumulative diagram. While it is possible to derive more complicated equations for non-linear cases with variable arrival and departure rates, this is deemed impractical for this analysis as this would require additional data (which is unavailable) for identifying the non-linearity of the curves. The duration of congestion after the incident has been cleared and capacity reduction is no longer in effect is denoted as X (measured in hours) in **Figure 5-1**. The formula for X is given in **Equation 5-2**, with all terms previously defined.

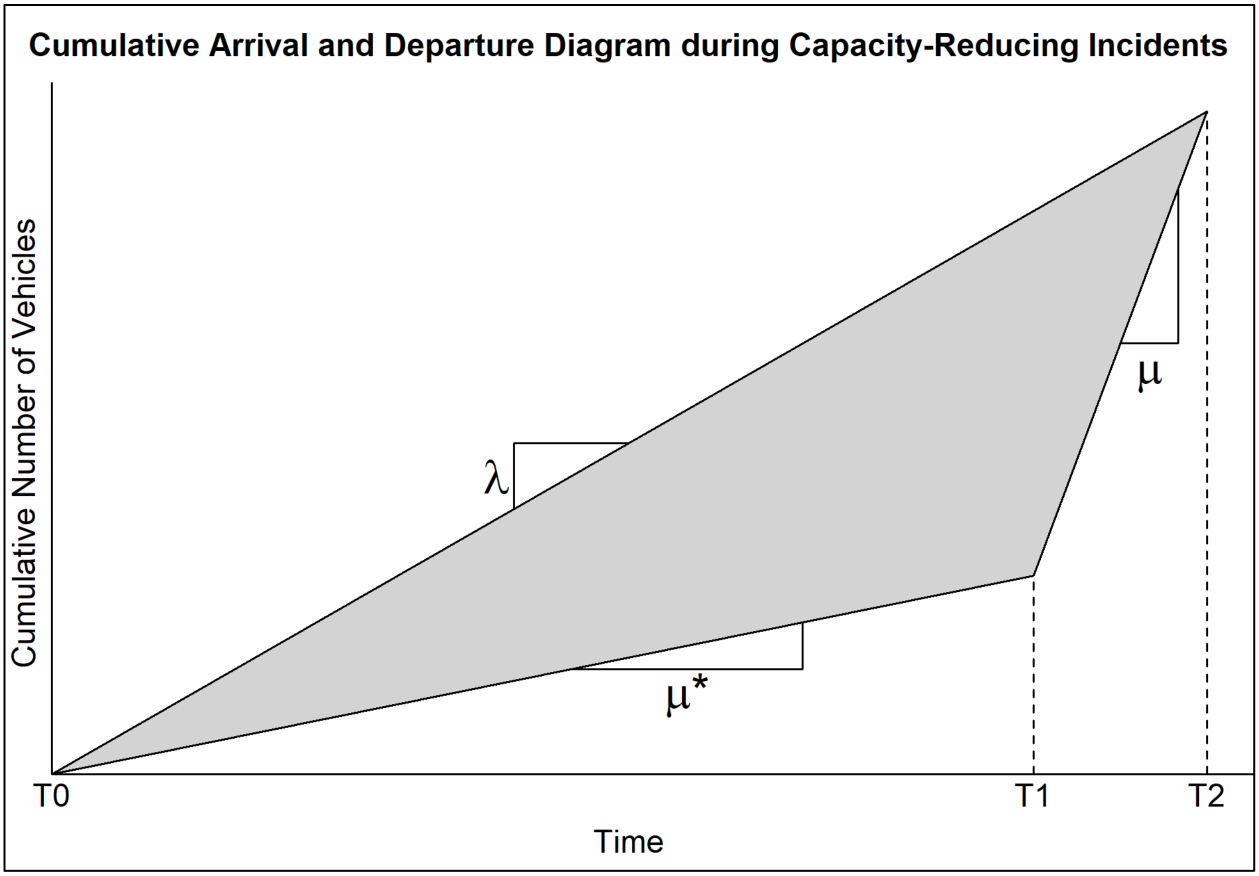

Figure 5-1: Cumulative Arrival and Departure Curves Under Incident Capacity-Reducing Conditions

$$Total\ Vehicle\ Delay = \frac{\lambda T^2}{2}\left(\frac{\mu-\mu^*}{\mu-\lambda}\right)^2 - \frac{\mu^* T^2}{2} - T^2\left(\frac{\lambda-\mu^*}{\mu-\lambda}\right)\left[\frac{\mu}{2}\left(\frac{\lambda-\mu^*}{\mu-\lambda}\right) + \mu^*\right] \quad \textbf{(Equation 5-1)}$$

$$X = T\left(\frac{\lambda-\mu^*}{\mu-\lambda}\right) \quad \textbf{(Equation 5-2)}$$

The available DAV crash and SunGuide event data contained information on the duration of the incident, the incident location, and the number of lanes the incident blocked. They did not contain any information on flow rates or capacities. To gather the necessary information to estimate flow rates and capacities, traffic data were sourced from the geographic information system (GIS) shapefiles available on the FDOT website (FDOT, n.d.-a). Using tools in ArcMap 10.8.1 (Esri, 2020), the following information was extracted for each DAV incident:

- Annual average daily traffic (AADT);
- Proportion of AADT in the peak hour, *K*;
- Proportion of peak hour volume in one direction, *D*;
- Proportion of trucks in traffic, *T*;
- Maximum posted speed limit (miles per hour, or mph); and
- Number of lanes in one direction.

With these data collected, the flow rates for vehicles were estimated by multiplying the AADT by the *K* and *D* factors. To estimate the capacities, methodologies from the sixth edition of the Highway Capacity Manual (HCM6E) by the Transportation Research Board (TRB) were used (TRB, 2016). The free-flow speed (FFS) was estimated by adding 5 mph to the extracted posted speed limit as recommended in HCM6E Exhibit 12-18. The base capacity (in passenger cars per hour per lane) was then determined using HCM6E Exhibit 12-4 with the estimated FFS. To adjust this capacity to vehicles per hour per lane, a peak hour factor (PHF) and heavy vehicle adjustment factor (f_{HV}) were used. The PHF was assumed to be between 0.85 and 0.98 based on the area type where the DAV incident occurred (lower values for rural areas, higher values for urban areas), while f_{HV} was determined using HCM6E Equation 12-10 with the extracted proportion of trucks and an appropriate assumption of level terrain. Then, using the extracted number of directional lanes and the number of lanes blocked by the DAV incident, a capacity adjustment factor (CAF) was estimated using HCM6E Exhibit 11-23. This CAF was multiplied with the base capacity to obtain the remaining capacity, μ^*.

There were several major assumptions made when utilizing this methodology that must be considered when interpreting the results of its application. The first major assumption was that the number of lanes blocked by the DAV incident remained constant and occurred during the entirety of the incident's duration. Detailed information for each DAV incident's timeline was not available, so it was unknown how long the incident reduced capacity. Therefore, it was assumed that the worst reported blockage occurred for the entire DAV incident duration. Additionally, DAV incidents that blocked all lanes of traffic were not considered since the HCM's methodologies do not apply to full road closures.

The second major assumption was that $\mu^* < \lambda \ll \mu$. If $\lambda < \mu^*$, the flow rate is still less than the reduced capacity, indicating that no congestion occurs. If $\lambda > \mu$, the flow rate is already higher than the full capacity, indicating pre-existing congestion, which is not accounted for in the developed cumulative arrival and departure curves diagram. Also, if λ is only slightly smaller than μ, free-flow conditions likely do not exist, making the methodology invalid. The acceptable difference between μ and λ will vary, so the results of Equations 2-1 and 2-2 will be checked for each considered DAV incident to see if they are reasonable or if the incident should be excluded because λ is too close to μ. With this assumption, cases where $\lambda > \mu$ were excluded from the congestion calculations, while cases where $\lambda < \mu^*$ were included but assumed to have zero congestion.

Based on these two assumptions, it is expected that the reported results in this chapter underestimate the actual congestion due to DAV incidents, since the first assumption both overestimates congestion (assumes worst blockage occurs for entire duration) and underestimates congestion (full road closures are excluded) and the second assumption underestimates congestion (cases with pre-existing congestion are excluded). This methodology also does not account for additional fuel costs and the subsequent environmental impacts due to this congestion. The third and final major assumption was that the DAV incidents occurred on basic freeway segments as defined in HCM6E and not within a merge, diverge, or weaving area. To help ensure this final assumption was met consistently, all incidents analyzed in this chapter were filtered to exclude events on entrance or exit ramps.

5.1.2 Congestion Estimates for Select Roadways in Florida

To begin the congestion estimation process, one year of DAV incidents was chosen for analysis. The calendar year 2019 was selected due to it having the most recent complete set of DAV incident data prior to the impacts of COVID-19 on traffic patterns in 2020. Next, the frequency of disabled vehicle incidents was analyzed for one limited access roadway in each FDOT engineering district, with the roadway containing the most disabled vehicle events being selected for each district. **Table 5-1** shows the limited access roadway selected for each district, along with the length of the roadway (in centerline miles) and the number of applicable SunGuide events and crashes. Overall, there were 245,307 disabled vehicle SunGuide events and 101 disabled vehicle crashes on the limited access facilities in **Table 5-1** in 2019. However, to meet the assumptions of the methodology discussed in Section 5.1.1, some events were excluded. First, only disabled vehicle incidents were considered when calculating congestion estimates, as it is unlikely that an abandoned vehicle remains capacity-reducing for a substantial amount of time. Moreover, disabled vehicle incidents are much more common than abandoned vehicle incidents; analysis of statewide DAV events in Chapter 4 found that disabled vehicle incidents occurred approximately nine times more frequently than abandoned vehicles. Next, incidents which occurred on an entrance or exit ramp, had no blockage, lacked lane blockage information, or resulted in all lanes being blocked were also excluded. The remaining incidents were then filtered further to remove any that occurred on express lanes (since their characteristics are different from normal limited access facilities) or where a limited access facility merges into another limited access facility such that the *D* factor is 99.9. Lastly, any outlier incidents which lasted longer than five hours (only 2% of all lane-blocking disabled vehicle incidents) were removed. These outlier incidents were removed as they greatly inflated the estimated congestion costs, giving unrealistically large values (due to the assumptions mentioned in Section 5.1.1). This left a total of 123,591 disabled vehicle events and 84 disabled vehicle crashes to estimate congestion costs on the selected roadways, as shown in **Table 5-1**.

Table 5-1: Disabled Vehicle Incidents on Selected Roadways for 2019 Congestion Cost Estimation

District	Roadway	Centerline Length (miles)	Number of SunGuide Events	Number of Crashes
1	I-75	182.9	33,085	8
2	I-295	60.9	4,457	4
3	I-10	235.3	16,552	5
4	I-95	142.6	37,851	18
5	I-4	74.7	2,407	10
6	I-95	17.2	9,677	8
7	I-275	52.2	3,669	11
FTE	SR-91/SR-821	312.5	15,893	20
Total		**1,078.3**	**123,591**	**84**

The results of applying the congestion cost methodology to the 123,591 disabled vehicle SunGuide events are shown in **Table 5-2** while the results for the 84 disabled vehicle crashes are shown in **Table 5-3**. Due to rounding, the totals shown in these tables might not exactly equal the value obtained from summing the respective column values. An appropriate PHF value was used for each roadway based on the primary area type in the district. The duration of congestion is the summation of the time from the incident occurred until all congestion was cleared ($T + X$ in **Figure 5-1**) for all considered incidents on the roadway. According to Appendix C of the *2021 Urban Mobility Report* (Glover, 2021), the average cost of congestion in 2019 dollars is $28.71 per hour per passenger vehicle (with an assumed occupancy of 1.5 people/vehicle) and $49.49 per hour per commercial truck, neither of which include the cost of fuel. Multiplying these hourly costs with the appropriate vehicle delay for each vehicle type (passenger vehicles and commercial trucks) resulted in a total congestion cost for capacity-reducing disabled vehicle incidents on these roadways of nearly $336 million in 2019 dollars. Capacity-reducing disabled vehicle incidents on these roadways caused approximately 80,000 hours of congestion and led to over 11 million vehicle hours of delay experienced by motorists on these facilities. I-75 in District 1 had the most capacity-reducing disabled vehicle incidents which met the methodology's assumptions, but SR-91 in the FTE district had the most delay and costs, mainly due to DAVs on SR-91 typically having longer incident durations and therefore impacting more vehicles for a longer period. Determining ways to reduce the number of capacity-reducing disabled vehicle incidents or reduce the duration of these incident can help to reduce these delays and costs.

Note that only 13,859 of the 123,591 considered SunGuide events are included in **Table 5-2** and only 23 of the 84 considered crashes are included in **Table 5-3**, as these were the incidents where $\mu^* < \lambda \ll \mu$. The remaining 109,732 SunGuide events and 61 crashes could not have congestion costs estimated using the developed model due to having $\lambda > \mu$, λ that was too close to μ, or $\mu^* > \lambda$, suggesting that there was pre-existing congestion, free-flow conditions did not exist, or no congestion occurred due to the incident, respectively. Overall, shoulder-blocking incidents were much more common than lane-blocking incidents (95.1% of SunGuide events and 61.9% of crashes were shoulder-blocking), and many of these shoulder incidents were not estimated to cause congestion due to $\mu^* > \lambda$. Therefore, some roadways, such as I-10 in D3, have few events included in **Table 5-2** compared to the original counts in **Table 5-1**. Due to the exclusion of the incidents with pre-existing congestion, as well as the other factors mentioned in the discussion of the assumptions in Section 5.1.1, the results in **Table 5-2** and **Table 5-3** are an underestimate of the true congestion costs. For the incidents shown in **Table 5-2** and **Table 5-3**, 83.5% of the SunGuide events and 13.0% of the crashes were only shoulder-blocking.

The results in **Table 5-3** also do not account for property damage or fatality and injury costs, which would substantially increase the financial impact of these crashes. **Table 5-4** shows the estimated crash costs based on fatalities, injuries, and vehicle and property damages. The comprehensive fatality and injury costs were calculated by multiplying the average comprehensive costs for each injury severity level from the National Safety Council (2021) by the number of injuries for that severity level, then adding these costs for all severity levels. According to the National Safety Council (2021), the average comprehensive costs for each severity level are the following: $11,148,000 per fatality, $1,219,000 per incapacitating injury, $336,000 per non-incapacitating injury, and $155,000 per possible injury (all costs in 2019 dollars). The vehicle and property damage values were obtained directly from the crash reports. This table shows that the total estimated comprehensive fatality, injury, and damage cost for all 23 studied disabled vehicle crashes was over $35 million. This is over twice the total congestion cost for these crashes. Only six of the crashes had a fatality and/or injury, with a total of three fatalities, one incapacitating injury, two non-incapacitating injuries, and one possible injury. Roadways that had a fatal crash (I-10, I-4, and I-95 in D6) had much higher comprehensive crash costs than congestion costs.

Table 5-2: 2019 Congestion Cost Estimates for Disabled Vehicle SunGuide Events on Select Roadways

District	Roadway	Number of SunGuide Events	Duration of Congestion (hours)	Vehicle Delay (veh-hours)	Cost to Passenger Vehicles (2019$)	Cost to Trucks (2019$)	Total Congestion Costs (2019$)
1	I-75	4,591	20,859	1,504,700	$38,425,790	$8,229,638	$46,655,428
2	I-295	1,136	1,376	366,972	$9,611,397	$1,593,413	$11,204,810
3	I-10	83	12,921	82,263	$1,885,488	$821,006	$2,706,494
4	I-95	4,086	18,490	2,785,087	$73,993,734	$10,284,350	$84,278,083
5	I-4	895	1,488	1,213,091	$32,357,372	$4,258,576	$36,615,947
6	I-95	1,004	1,961	1,425,553	$39,421,525	$2,596,232	$42,017,757
7	I-275	210	889	218,373	$5,930,820	$583,801	$6,514,621
FTE	SR-91/SR-821	1,854	21,345	2,987,703	$77,061,794	$15,023,113	$92,084,908
	Total	**13,859**	**79,328**	**10,583,742**	**$278,687,919**	**$43,390,129**	**$322,078,048**

Table 5-3: 2019 Congestion Cost Estimates for Disabled Vehicle Crashes on Select Roadways

District	Roadway	Number of Crashes	Duration of Congestion (hours)	Vehicle Delay (veh-hours)	Cost to Passenger Vehicles (2019$)	Cost to Trucks (2019$)	Total Congestion Costs (2019$)
1	I-75	5	69	284,966	$7,297,797	$1,523,123	$8,820,920
2	I-295	2	18	39,661	$1,004,293	$231,610	$1,235,904
3	I-10	3	19	6,332	$147,033	$59,928	$206,961
4	I-95	0	0	0	$0	$0	$0
5	I-4	5	31	63,448	$1,698,149	$212,798	$1,910,947
6	I-95	1	7	23,937	$661,812	$43,832	$705,644
7	I-275	2	11	5,667	$153,775	$15,395	$169,170
FTE	SR-91/SR-821	5	46	15,834	$423,061	$54,376	$477,437
	Total	**23**	**202**	**439,845**	**$11,385,921**	**$2,141,063**	**$13,526,983**

Table 5-4: Estimated Fatality, Injury, and Damage Costs for Included Disabled Vehicle Crashes

District	Roadway	Number of Crashes	Number of Fatalities	Number of Incapacitating Injuries	Number of Non-Incapacitating Injuries	Number of Possible Injuries	Comprehensive Fatality and Injury Costs (2019$)	Vehicle and Property Damages (2019$)	Total Costs
1	I-75	5	0	0	0	0	$0	$7,550	**$7,550**
2	I-295	2	0	0	0	1	$155,000	$11,100	**$166,100**
3	I-10	3	1	0	0	0	$11,148,000	$35,000	**$11,183,000**
4	I-95	0	0	0	0	0	$0	$0	**$0**
5	I-4	5	1	0	1	0	$11,484,000	$65,000	**$11,549,000**
6	I-95	1	1	0	0	0	$11,148,000	$16,000	**$11,164,000**
7	I-275	2	0	0	0	0	$0	$37,000	**$12,000**
FTE	SR-91/SR-821	5	0	1	1	0	$1,555,000	$64,100	**$45,100**
Total		**23**	**3**	**1**	**2**	**1**	**$35,490,000**	**$235,750**	**$35,725,750**

5.2 Benefit-Cost Evaluations for Potential Improvements

As seen in Section 5.1, DAV incidents can have significant financial impacts by creating congestion and causing crashes which result in fatalities, injuries, and vehicle and property damages. This section discusses three potential improvements to reduce the impacts of DAVs by decreasing the time the DAV is on the road, thereby reducing the associated congestion time and costs. The first potential improvement (Section 5.2.1) is increasing existing Road Ranger patrols, which would ideally help reduce the time needed to detect and respond to a DAV through prompt assistance. The second potential improvement (Section 5.2.2) is implementing instant dispatch tow, which can reduce the time it takes to move a DAV from the travel lanes, decreasing the amount of congestion caused by lane blockages. The third potential improvement (Section 5.2.3) is reporting Waze data to TMCs, which can help improve detection and response times, reducing congestion and even potentially allowing responders to get to the DAV before a crash occurs.

5.2.1 Benefit-Cost Evaluations of Increasing Road Ranger Patrols to Improve DAV Response

One potential way to reduce the impacts of DAVs is to increase the time periods that Florida Road Ranger patrols are active. On some limited access facilities in Florida, Road Rangers are active for 24 hours a day, 7 days a week, making them available for incident response at any time. However, on other roadways, Road Rangers are only active for certain days or hours of the day. Expanding the times Road Rangers are active on these roadways could improve response for DAVs that occur during current non-active hours. To estimate the benefits and costs associated with expanding Road Ranger patrols, evaluations were conducted for each relevant roadway in **Table 5-1** which does not currently have active Road Rangers 24 hours a day, 7 days a week. These evaluations used DAV incident data and Road Ranger patrol data for calendar year 2019. The first evaluation was for I-295 in FDOT D2 (discussed in Section 5.2.1.1). This roadway had a significantly longer event duration when Road Rangers were not active compared to when Road Rangers were active, so expanding patrol hours could better address these events during current inactive periods and lower the average event duration (McCombs et al., 2022). The second evaluation was for I-10 in FDOT D3 (discussed in Section 5.2.1.2). This roadway section was chosen due to its high number of DAV events that occur when Road Ranger patrols are not active and the prolonged event durations as a result. This roadway segment had 54% of its disabled vehicle events occur when Road Ranger patrols were not active, suggesting that expanding patrol hours could address many more events (McCombs et al., 2022). The results for the remaining roadways are discussed in Section 5.2.1.3.

5.2.1.1 Benefit-Cost Evaluation of Increasing Road Ranger Patrols for I-295 in FDOT D2

In 2019, there were two Road Ranger patrols on I-295 in FDOT D2, one patrol for the east beltway and one patrol for the west beltway. Both Road Ranger patrols were active on Monday to Friday from 6:30 AM to 6:30 PM, with neither patrol having any coverage on the weekends. For this evaluation, the proposed increase to Road Ranger patrol hours was to add weekend coverage from 9:00 AM to 9:00 PM, which is an additional 24 hours of coverage per week per Road Ranger. It was assumed that two Road Rangers would be assigned to each patrol for these new patrol hours, giving a total of 96 additional hours of coverage. It was also assumed that each of these Road Rangers would be driving a pickup truck and not a tow-capable vehicle.

After excluding all outlier incidents which lasted longer than five hours, there were 4,462 disabled vehicle incidents on I-295 in D2 in 2019. Comparing the average event durations between the active and non-active Road Ranger periods showed that disabled vehicle events lasted 59% longer on average during non-active periods compared to active periods. Since the goal of increasing Road Ranger patrols is to reduce the duration of events which occur during current periods of Road Ranger inactivity, it was assumed that expanding the patrol hours of Road Rangers would reduce event durations during these new hours by 59%. While it is unknown exactly how much these incident durations would have been reduced if a Road Ranger was present, this is the most reasonable assumption based on the available data. Under the proposed additional hours, Road Rangers would have addressed an additional 436 disabled vehicle incidents.

To calculate the benefits of increasing Road Ranger patrols for I-295 in D2, the methodology outlined in Section 5.1.1 was used to estimate congestion costs for the capacity-reducing disabled vehicle events which occurred during the new patrol hours (9:00 AM to 9:00 PM on Saturday and Sunday) and met the assumptions discussed in Section 5.1.1. For each event, delay was first calculated using the reported incident duration, then calculated again using an incident duration equal to 41% (100% minus the assumed duration reduction of 59% due to Road Rangers being active) of the reported incident duration. The second delay value was then subtracted from the first delay value, resulting in the delay reduction due to Road Rangers being active. This delay reduction was then multiplied by the congestion costs to obtain the congestion reduction savings. A PHF of 0.90 was assumed due to I-295 existing in an urban area (Jacksonville) with moderate traffic volumes surrounded by more rural areas. The results of the congestion reduction calculations are shown in **Table 5-5**. Note that 208 of the 436 identified incidents had $\lambda > \mu$ or λ close to μ, so they were excluded since they did not meet the assumptions of the methodology. An additional 114 events had $\lambda < \mu^*$ and were expected not to cause congestion. Therefore, only 114 incidents were considered for the congestion reduction estimation.

Table 5-5: Estimated Reduction in Congestion and Associated Savings for DAV Incidents by Increasing Road Ranger Patrols on I-295 in FDOT D2 for 2019

Number of Incidents	114
Vehicle Delay Reduction (veh-hours)	45,897
Reduction in Congestion Costs for Passenger Vehicles (2019$)	$1,197,693
Reduction in Congestion Costs for Trucks (2019$)	$206,894
Total Congestion Reduction Savings (2019$)	$1,404,587

In total, based on the assumptions previously discussed, increasing Road Ranger patrols on I-295 in D2 could reduce congestion costs by $1,404,587 per year (average congestion savings of $12,321 per incident). To calculate the costs of this expansion, the number of additional hours worked by the Road Rangers was used. Under the proposed plan, four Road Rangers would each work an additional 24 hours per week for each week of the year. The average cost for a Road Ranger pickup truck is $65 per hour (as provided by Enforcement

Engineering, Inc.), meaning it costs $81,120 per Road Ranger per year ($65/hour * 24 hours/week * 52 weeks/year), assuming the newly added Road Ranger vehicle is active for just the newly added hours. To add four Road Rangers as proposed (two for each patrol of I-295 in D2), the cost would be $324,480 per year, resulting in a benefit-cost ratio of $1,404,587/$324,480 = 4.33. As previously mentioned, the estimated benefits are underestimates as they do not account for any DAV crashes (and their associated fatality, injury, and damage costs) that could have possibly been prevented if a Road Ranger had been available to provide timely assistance to a DAV event. Additionally, they do not account for instances of non-linear congestion; considering the alleviation of this congestion would increase the benefits even further. The expansion of Road Ranger hours could also provide benefits to non-DAV related events (such as by improving crash response for non-DAV crashes during current inactive hours). The costs would also be higher if more than two Road Ranger vehicles are used during the new proposed hours.

5.2.1.2 Benefit-Cost Evaluation of Increasing Road Ranger Patrols for I-10 in FDOT D3

In 2019, Road Rangers in FDOT D3 operated along three main segments of I-10, with each having their own patrol patterns. A map showing these labelled segments is shown in **Figure 5-2**. Two of these segments (Segment 1 and Segment 3) had Road Rangers patrolling on Monday to Friday from 5:00 AM. to 9:00 PM. while Segment 2 had Road Ranger coverage Monday to Friday from 6:00 AM. to 6:00 PM. No segment had Road Ranger coverage on the weekends. To account for these differences in patrol patterns for the benefit-cost evaluations, ArcMap 10.8.1 (Esri, 2020) was used to determine which segment a DAV incident occurred on. For this evaluation, the proposed increase in Road Ranger patrol hours was to make all three segments have operating hours of Monday to Friday from 5:00 AM. to 9:00 PM. and Saturday and Sunday from 9:00 AM to 9:00 PM. These additional hours would provide weekend coverage for all three segments and ensure all segments have the same weekday operating hours by providing an extra four hours of coverage per weekday to Segment 2. To ensure circulation time does not decrease due to these longer hours, an additional Road Ranger was assigned to each segment in this scenario. For cost estimating, it was assumed that these additional Road Rangers would drive pickup trucks (not tow-capable trucks).

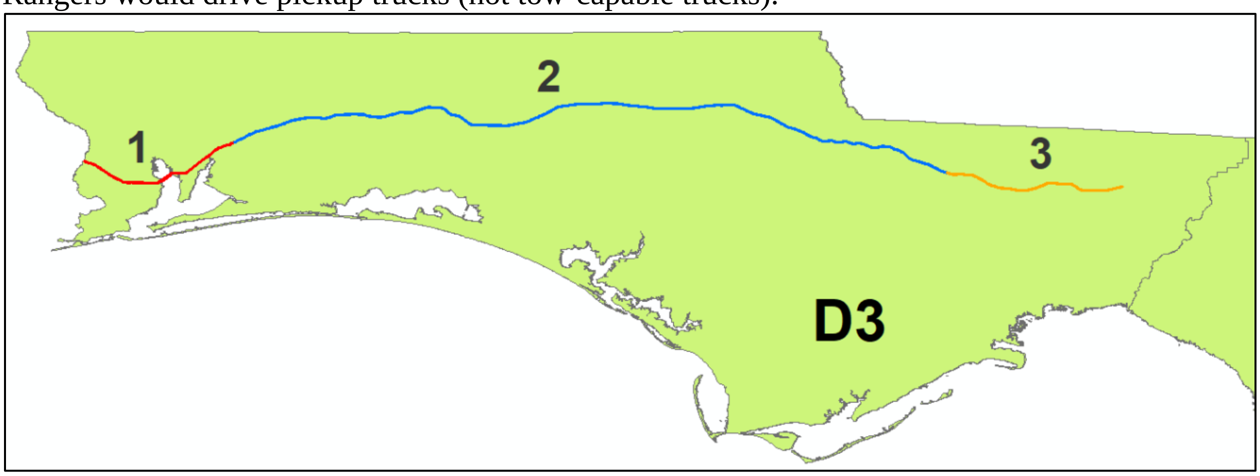

Figure 5-2: Map of Road Ranger Coverage on I-10 in District 3 for 2019

After excluding any outlier incidents which lasted longer than five hours, there were 16,557 disabled vehicle incidents on I-10 in D3. Comparing the average event durations between the active and non-active Road Ranger periods showed that disabled vehicle events lasted 27% longer than on average during non-active periods compared to active periods. As such, it was assumed that expanding the patrol hours of Road Rangers would reduce the incident durations during these new hours by 27%. Under the proposed additional hours, Road Rangers would have addressed an additional 2,480 disabled vehicle incidents. However, only 20 incidents met the assumptions of the methodology, and all 20 incidents were lane-blocking incidents. Notably, Segment 3 did not have any lane-blocking incidents, so only Segments 1 and 2 were considered for Road Ranger patrol hours expansion.

To calculate the benefits of increasing Road Ranger patrols for Segments 1 and 2 of I-10 in D3, the same methodology and procedures used for the I-295 in D2 evaluation were used to estimate the reduction in congestion costs, but with the second delay calculated using 73% of the reported incident duration since the expected reduction in incident duration due to Road Rangers was 27%. This methodology was applied to the 20 lane-blocking disabled vehicle incidents which occurred during the new patrol hours (9:00 AM to 9:00 PM on Saturday and Sunday for both segments, along with the hours of 5:00 AM to 6:00 AM and 6:00 PM to 9:00 PM for Segment 2) and met the assumptions discussed in Section 5.1.1. A PHF value of 0.85 was assumed since I-10 in D3 is in a rural area with low traffic volumes. The results of the congestion reduction calculations are shown in **Table 5-6**.

Table 5-6: Estimated Reduction in Congestion and Associated Savings for DAV Incidents by Increasing Road Ranger Patrols on I-10 in FDOT D3 for 2019

Number of Incidents	20
Vehicle Delay Reduction (veh-hours)	13,421
Reduction in Congestion Costs for Passenger Vehicles (2019$)	$298,718
Reduction in Congestion Costs for Trucks (2019$)	$149,262
Total Congestion Reduction Savings (2019$)	$447,980

In total, based on the assumptions previously discussed, increasing Road Ranger patrols on Segments 1 and 2 of I-10 in D3 could reduce congestion costs by $447,980 per year. To calculate the costs of this expansion, the number of additional hours worked by the Road Rangers was used. Under the proposed plan, Road Rangers would work an additional four hours each day for five days of the week on Segment 2 (20 hours per week) and 12 hours each day for two days of the week on Segments 1 and 2 (48 hours per week), for a total of 68 additional hours a week for each week of the year. The average cost for a Road Ranger in a pickup truck is $65 per hour (as provided by Enforcement Engineering, Inc.), meaning that it costs $229,840 per year ($65/hour * 68 hours/week * 52 weeks/year) to add one Road Ranger to each of the two segments with lane-blocking incidents, assuming the newly added Road Rangers are active for just the newly added hours. This ultimately leads to a benefit-cost ratio of $447,980/$229,840 = 1.95, which is lower than the benefit-cost ratio found for I-295 in D2. The lower benefit-cost ratio for I-10 compared to I-295 is likely due to two key differences between these roadways: fewer lane-blocking incidents and lower traffic volumes on I-10 compared to I-295. Since the benefits are based on congestion reduction, having fewer incidents which affect fewer vehicles leads to a lower estimated congestion reduction (and therefore fewer benefits).

5.2.1.3 Benefit-Cost Evaluation of Increasing Road Ranger Patrols on Other Roadways

As discussed previously, evaluations for expansion of Road Ranger patrol hours were conducted for each relevant roadway in **Table 5-1**. Of the eight roadways shown in this table, only the two discussed in Sections 5.2.1.1 and 5.2.1.2 (I-295 in D2 and I-10 in D3) were able to have full evaluations of potential expansions to Road Ranger patrol hours. Three common reasons affected the ability to estimate benefits and costs for similar expansions on the remaining six roadways. The first reason was that D4 and D6 already have around-the-clock Road Ranger coverage, so there were no possible expansions to consider for the two roadways in these districts. The second reason involved the ability to calculate the reduction in incident duration due to the presence of Road Rangers. For I-75 in D1 and I-275 in D7, the average incident duration when Road Rangers were active was longer than the average incident duration when Road Rangers were not active, suggesting that there is not a need to expand Road Rangers to address these inactive events. This finding suggests that DAV incidents when Road Rangers are not present on these roadways are already being handled effectively. The third reason relates to the proportion of incidents that occurred during periods of Road Ranger inactivity. For both I-4 in D5 and SR-91 for areas without full Road Ranger coverage, very few incidents occurred when Road Rangers were inactive. As such, the resulting percent reduction in incident duration due to Road Ranger presence would be based on only a few incidents and would not be an accurate representation of the impact Road Rangers can have on event duration. On these roadways, the existing Road Ranger patrols effectively handle nearly all capacity-reducing incidents, so expanding patrols would only address a few additional incidents and would likely not be cost-effective.

Based on these reasons, combined with the results of Sections 5.2.1.1. and 5.2.1.2, it appears that the existing Road Ranger scheduling in most districts is sufficient to address many DAV incidents. The only potential Road Ranger patrol expansion which could be cost-effective is the proposed expansion for I-295 in D2 discussed in Section 5.2.1.1, which had a benefit-cost ratio of 4.33. For the other studied roadways, Road Ranger patrol hour expansions are either not possible or not recommended for addressing DAV incidents. However, other alternative and innovative methods to reduce the impacts of DAV incidents could be used instead. Two such methods are discussed in the next sections.

5.2.2 Benefit-Cost Evaluations of Implementing Instant Dispatch Tow to Improve DAV Response

Once a DAV is reported, moving it from the travel lanes or off the facility is an important step to ensure traffic operations can begin to return to normal. One possible way to remove a DAV from the travel lanes is with a tow truck, especially if the vehicle was involved in a crash and cannot be moved under its own motive power. In Florida, the current standard for moving disabled vehicles is to wait for an FHP officer to arrive at the scene of a DAV incident and check with the driver to see if they already made towing arrangements. However, few drivers request their own tow truck, with most relying on FHP to arrange a tow to move the vehicle, thereby unnecessarily increasing clearance time by requiring the trooper verification step be performed first (FDOT, 2019).

An approach to help reduce clearance time by eliminating the trooper verification step is instant dispatch tow (sometimes called instant tow or instant tow dispatch), which simultaneously dispatches a tow truck to an incident along with an FHP officer. The earliest implementation of instant dispatch tow was a pilot program in Washington state in 2002, which found that the program reduced incident clearance time by an average of 15 minutes (Nee & Hallenback, 2003). In Oregon, it was estimated that instant dispatch tow helped to reduce the average incident duration by about 25% (Hathaway, 2012). Typically, these types of programs reimburse the tow truck company for their time if a tow truck was dispatched to an incident where it was not needed (referred to as a "dry run"). VDOT piloted an instant tow program and estimated that only 5% of dispatches resulted in a tow truck not being needed, costing around $2,000 a month in reimbursements (Dougald et al., 2016).

Florida does not currently operate an IDT program, so the benefits and costs of such a program are unknown. The closest known similar program in the state is the SafeTow program in D2. In this program, a tow truck is dispatched to a lane-blocking event to clear it from the travel lanes to minimize the impact to traffic operations (North Florida Regional Transportation Management Center, n.d.). Data from the SafeTow program indicates that the cost to respond to each incident was $65 (as provided by Enforcement Engineering, Inc.). This cost information from the SafeTow program along with the information from other states' programs was used to estimate the costs of implementing instant dispatch tow on select Florida limited access roadways. It is important to note that no information on the responding trooper's salary was available, so this cost is not included. Including these costs would increase program costs and decrease the calculated benefit-cost ratios.

Two benefit-cost evaluations for a hypothetical instant dispatch tow program were performed. The first evaluation was for I-10 in FDOT D3 using DAV events from 2019 (discussed in Section 5.2.2.1). This roadway section was chosen due to how rural and expansive it is. Due to these characteristics, it can take a significant amount of time for an FHP trooper to arrive on the scene and check if a tow truck is needed (and it can take significant time for a tow truck to reach the incident if one is needed). Dispatching a trooper and tow truck simultaneously would help reduce how long the DAV poses a hazard. The second evaluation was for SR-91 in counties located in FDOT D5 using DAV events from 2019 (discussed in Section 5.2.2.2). This roadway section was chosen due to the high volume of incidents, the high traffic volume, and the fact it is a toll road instead of an interstate. As such, clearing DAV incidents from the roadway quickly is essential to prevent congestion and a degraded driver experience.

5.2.2.1 Benefit-Cost Evaluation for Implementing Instant Dispatch Tow on I-10 in FDOT D3

To estimate the impacts of instant dispatch tow on I-10 in D3, the DAV incidents from 2019 were first filtered to keep only lane-blocking incidents and to remove any outlier events that lasted longer than five hours. This resulted in 84 disabled vehicle incidents being kept for analysis. To calculate the benefits associated with implementing instant dispatch tow, the methodology in Section 5.1.1 was used to estimate the congestion costs. Similar to the Road Ranger evaluations, delay was first calculated using the reported incident duration, then calculated again using an incident duration equal to 75% of the reported incident duration. This 25% reduction in incident duration due to instant dispatch tow was used based on previous research (Hathaway, 2012). The second delay value was then subtracted from the first delay value, resulting in the delay reduction due to Road Rangers being active. This delay reduction was then multiplied by the congestion costs to obtain the congestion reduction savings. A PHF value of 0.85 was assumed due to I-10 in D3 being a rural area with low traffic volumes. The results of the calculations for the 84 disabled vehicle incidents are shown in **Table 5-7**. Note that all these events and crashes met the assumptions of the methodology, so no incidents were removed.

Table 5-7: Estimated Reduction in Congestion and Associated Savings for DAV Incidents by Implementing Instant Dispatch Tow on I-10 in FDOT D3

Number of Incidents	84
Vehicle Delay Reduction (veh-hours)	38,760
Reduction in Congestion Costs for Passenger Vehicles (2019$)	$889,228
Reduction in Congestion Costs for Trucks (2019$)	$385,409
Total Congestion Reduction Savings (2019$)	$1,274,637

This table shows that, with the assumptions previously discussed, implementing instant dispatch tow on I-10 in D3 could reduce congestion costs by $1,274,637 per year. Although there is no known cost for operating an instant dispatch tow program in Florida, two possible cost approaches were considered. The first approach was using cost information from the VDOT pilot program (Dougald et al., 2016). For this program, it was estimated that reimbursements to tow truck companies for dry runs was $2,000 a month, resulting in a cost of $24,000 per year. The resulting benefit-cost ratio using this cost was $1,274,637/$24,000 = 53.11. The second approach was using cost information from the SafeTow program in D2. Assuming all 84 incidents had a tow truck dispatched to them at a cost of $65 per incident, the cost of the instant dispatch tow program would be $5,460. The resulting benefit-cost ratio using this cost was $1,274,637/$5,460 = 233.45. Since both ratios are over 1.00, there are more benefits from operating the program than costs. This ratio could potentially be higher by considering other types of incidents (such as those only on the shoulder) or the reduction of other attributes, such as the reduction in fuel consumption and its subsequent environmental impacts. However, this ratio is very sensitive to the cost of the program, as implementing instant dispatch tow in Florida could have different costs than the pilot program done by VDOT or the SafeTow program by D2. Therefore, it is not recommended to rely solely on the benefit-cost ratio when comparing this program to the other evaluations conducted in this chapter. Nonetheless, as the assumptions of the methodology lead to severe underestimates of the benefits, an instant dispatch tow program is still likely to have a large benefit-cost ratio regardless of these costs.

5.2.2.2 Benefit-Cost Evaluation for Implementing Instant Dispatch Tow on SR-91 in FDOT D5 Counties

Similar steps to the instant dispatch tow evaluation for I-10 in D3 were followed to estimate the impacts of instant dispatch tow on SR-91 in D5 counties for 2019. First, the disabled vehicle incidents were filtered to keep only lane-blocking incidents and to remove any outlier events that lasted longer than five hours. This resulted in a total of 103 disabled vehicle

SunGuide events. However, 27 of these events were excluded from the analysis because they had pre-existing congestion, and 16 were estimated to not lead to congestion. Therefore, only 60 applicable disabled vehicle events were kept for analysis. The same procedures used for the I-10 in D3 instant dispatch tow evaluation were used to estimate the reduction in congestion costs, with an assumed PHF of 0.95 since SR-91 in D5 is urban and has high traffic volumes. The same assumed congestion reduction of 25% of the original incident duration due to instant dispatch tow was used. **Table 5-8** shows the results of the calculations for the 76 applicable disabled vehicle events.

Table 5-8: Estimated Reduction in Congestion and Associated Costs for DAV Incidents by Implementing Instant Dispatch Tow on SR-91 in FDOT D5

Number of Incidents	60
Vehicle Delay Reduction (veh-hours)	230,565
Reduction in Congestion Costs for Passenger Vehicles (2019$)	$5,522,134
Reduction in Congestion Costs for Trucks (2019$)	$1,891,682
Total Congestion Reduction Savings (2019$)	$7,413,816

Overall, with the assumptions previously discussed, implementing instant dispatch tow on SR-91 in D5 could reduce congestion costs by $7,413,816 per year. Like the I-10 example, two possible cost approaches were considered. Using a yearly cost of $24,000 based on the VDOT pilot program (Dougald et al., 2016), the resulting benefit-cost ratio was $7,413,816/$24,000 = 308.91. The second approach used cost information from the SafeTow program in D2. Assuming all 60 incidents had a tow truck dispatched to them at a cost of $65 per incident, the cost of the instant dispatch tow program would be $3,900. The resulting benefit-cost ratio using this cost was $7,413,816/$3,900 = 1,900.98. Both ratios are substantially higher than the ratios for I-10 in D3, primarily due to how SR-91 in D5 has more traffic volume, thereby increasing vehicle delay and the subsequent cost of this delay. Because the ratios are significantly over 1.00, there are more benefits from operating the program than costs. As previously mentioned, this ratio could potentially be higher by considering other types of incidents or the reduction of other attributes and is very sensitive to the cost of the program. Therefore, it is not recommended to compare this benefit-cost ratio with the benefit-cost ratios for the other evaluated methods in this chapter without more accurate cost information. However, these example evaluations show that instant dispatch tow has significant potential to reduce congestion due to DAV events, especially in urban areas. It also seems to be much more cost-effective than expanding Road Ranger patrol hours.

5.2.3 Benefit-Cost Evaluations of Reporting DAV Waze Data to TMCs

Another method that could reduce the congestion impacts of DAV incidents is the incorporation of DAV Waze alerts into SunGuide. This could help TMC operators more quickly detect and respond to reported DAV incidents. To showcase the potential benefits of using Waze data to detect DAV events, two evaluations using DAV Waze, SunGuide, and crash data were conducted. The first evaluation was for I-4 in FDOT D5 (discussed in Section 5.2.3.1). This roadway section was chosen as I-4 was the roadway with the highest percentage of overlap between Waze and SunGuide (82.1% of DAV Waze alerts had an associated SunGuide event) and over half of I-4 is in D5. The second evaluation was for SR-91 in counties located in FDOT D4 (discussed in Section 5.2.3.2). This roadway section was chosen since the FTE district (which contains all of SR-91) and D4 were the FDOT districts with the most DAV events and SR-91 is the toll road with the most DAV events. For both evaluations, a six-month period from July 2019 through December 2019 was considered as this period included data from all three DAV data sources (Waze, SunGuide, and crash) while avoiding any potential effects from the COVID-19 pandemic which started in early 2020.

Data from all three DAV data sources were compared for the identified period and roadway segments to estimate the potential benefits if all DAV Waze alerts were reported to the TMC. Some of these Waze alerts could provide earlier detection of DAV events, which could reduce the duration of the DAV events and lead to reduced congestion. These estimated congestion savings represent the benefits of utilizing these Waze data. Only congestion savings due to lane-blocking DAVs were estimated in these evaluations; this means that congestion was not estimated for DAVs which did not block any travel lanes. Additionally, it is possible that earlier detection of a DAV could allow Road Ranger or other responders to assist the vehicle before a crash occurs. This potential crash prevention was also considered. Since the Waze data includes many alerts that do not correspond to a reported DAV event, the TMC operators would have to spend time checking and verifying each Waze alert. Therefore, the cost of reporting all the DAV Waze alerts to the TMC was represented by the cost of time spent by operators responding to all of these alerts. This does not include any initialization costs for setting up a Waze connection to TMCs; instead, this focuses on the recurring cost that continues as long as the TMC attempts to sort out Waze data related to DAVs. While there are other potential benefits and costs of utilizing Waze data, (such as the ability to detect additional DAVs not previously reported in SunGuide, the benefits of which cannot be calculated based on currently available data), only the reduced congestion due to lane-blocking DAV events and crash prevention potential were considered as benefits in these evaluations, with the cost of time spent by TMC operators the only considered cost. Future research could conduct a more thorough evaluation of Waze data throughout the state to better understand the benefits and costs for different regions, roadways, and times of day.

Before conducting these evaluations, all DAV crash data from 2015 through 2020 were added to the DAV database previously developed to compare DAV Waze and SunGuide data (as discussed in Chapter 4). The raw DAV crash data were cleaned and appropriately formatted during the input process to be compatible with the DAV Waze and SunGuide data. A total of 1,256 DAV crashes were added to the database for use in these evaluations.

5.2.3.1 DAV Waze Data Benefit-Cost Evaluation for I-4 in FDOT D5

To conduct the I-4 evaluation, various data sets needed to be obtained. These data sets were obtained using Structured Query Language (MySQL, SQL) with phpMyAdmin front-end. **Table 5-9** lists the 11 queries that were developed for this evaluation (including the output data set from the query and the number of data points in the output data set), with the detailed queries shown in Appendix C. **Figure 5-3** contains a flowchart showing how these queries were used to filter the data sets and identify overlap between them. Each of these queries were prepared to select relevant columns for all data points within the study period (July 1, 2019 – December 31,

2019) and study location (I-4 in FDOT D5). Since the DAV Waze data did not contain district information, latitude and longitude limits and county constraints were used in the Waze queries to ensure that only DAV alerts in D5 counties (Osceola, Orange, Seminole, and Volusia) were selected. Additionally, only DAV Waze alerts with street values of "I-4 E" and "I-4 W" were selected, as these were the only street values corresponding to I-4. For the DAV SunGuide queries, district, county, and roadway constraints were used, with the appropriate values determined from a review of the DAV SunGuide data. The DAV crash queries contained constraints to only select crashes in D5 counties and which had a roadway value of "I-4" (only value corresponding to I-4 in the DAV crash data set).

Table 5-9: Data Queries for I-4 in FDOT D5 (July 1, 2019 – December 31, 2019)

Query Number	Output Data Set	Number of Data Points
1	All DAV Waze Alerts	103,413
2	All DAV SunGuide Events	9,867
3	All DAV Crashes	8
4	All DAV SunGuide Events with Waze Overlap	7,316
5	All DAV Waze Alerts with SunGuide Overlap	54,939 (39,821 unique)
6	All DAV Crashes with Waze Overlap	4
7	All DAV Waze Alerts with Crash Overlap	9 (all unique)
8	All DAV SunGuide Events with Waze Before	5,598
9	All DAV Crashes with Waze Before	3
10	All Lane-Blocking DAV SunGuide Events with Waze Before	340
11	All Lane-Blocking DAV Crashes with Waze Before	0

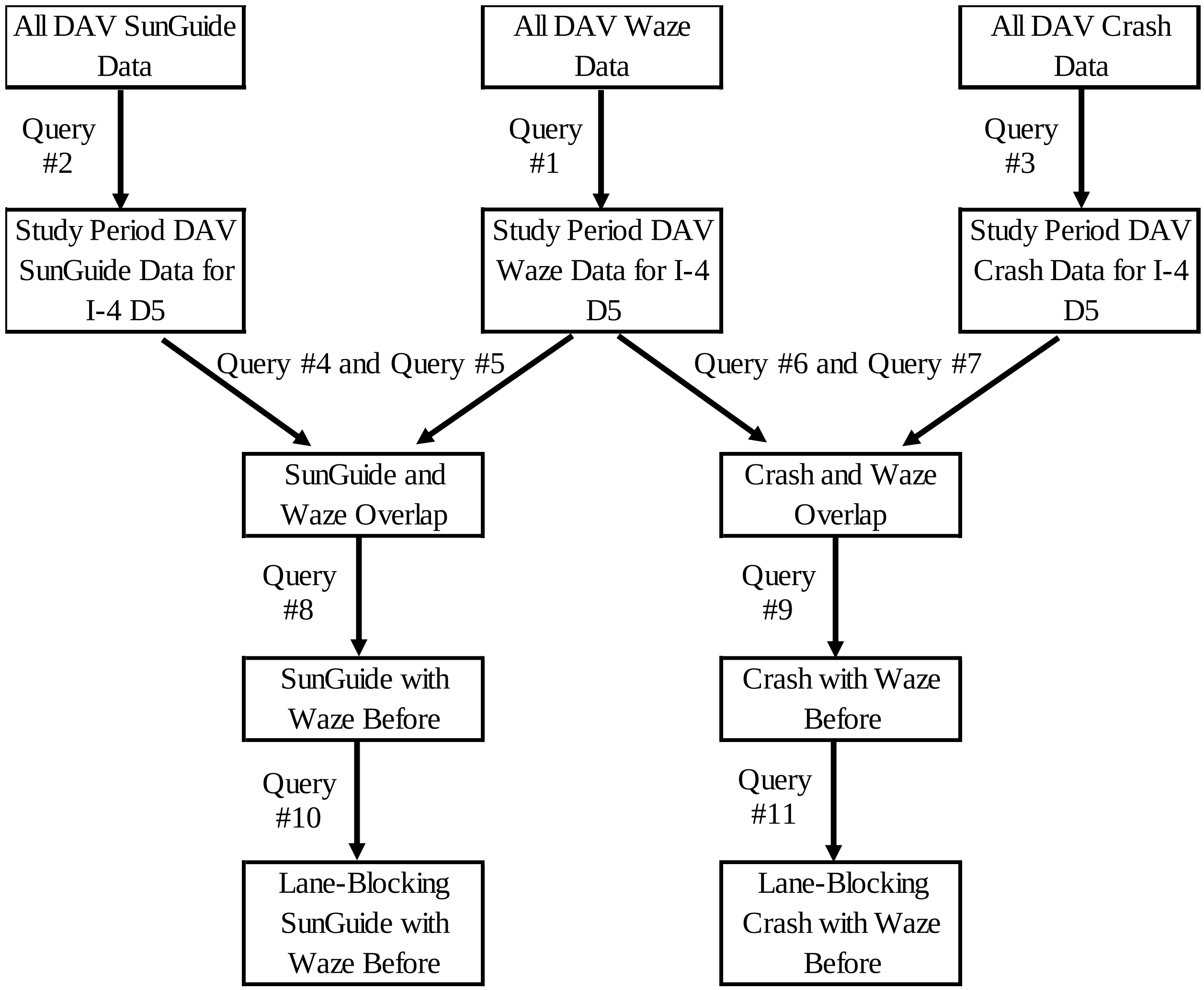

Figure 5-3: Query Flowchart for I-4 DAV Waze Evaluation

First, queries #1, #2, and #3 were used to filter the DAV Waze, SunGuide, and crash databases, respectively, for only the data points on I-4 in D5 from July 1, 2019, through December 31, 2019. The output data sets from these queries contained 103,413 DAV Waze alerts, 9,867 DAV SunGuide events, and eight DAV crashes. Next, queries #4 and #5 were used to identify the overlap between the DAV Waze data from query #1 and the DAV SunGuide data from query #2, while queries #6 and #7 were used to identify the overlap between the DAV Waze data from query #1 and the DAV crash data from query #3. Two queries were used for each set of overlap as the first queries (query #4 and query #6) identified the SunGuide or crash events that had Waze overlap, while the second queries (query #5 and query #7) identified the specific DAV Waze alerts that overlapped with these SunGuide or crash events. Both queries were needed to identify the unique DAV Waze alerts which overlapped with the SunGuide or crash events. Since the time and location information for the DAV Waze data might not be as precise as the DAV SunGuide and crash data, temporal and spatial buffers were used when identifying overlap between the DAV Waze and DAV SunGuide or crash data sets. The buffers used for this evaluation were a temporal buffer of 30 minutes before the SunGuide created date or time of crash and spatial buffers of ±0.015 latitude and ±0.017 longitude (approximately one-mile buffer in all directions from the SunGuide or crash location). Applying these queries showed that 7,316 of the 9,867 SunGuide events (74.1%) had one or more overlapping Waze alerts, with a total of 54,939 overlapping Waze alerts (of which 39,821 were unique Waze alerts). For the crashes, four of the eight crashes (50%) had one or more overlapping Waze alerts, with a total of nine overlapping Waze alerts (all unique). Therefore, a total of 39,830 Waze alerts overlapped with either the SunGuide or the crash data, meaning that 38.5% of the reported DAVs had at least one associated Waze alert.

The next two queries (query #8 and query #9) identified the DAV SunGuide events and DAV crashes, respectively, which had at least one DAV Waze alert before the SunGuide created date or time of crash. These queries showed that 5,598 DAV SunGuide events had at least one DAV Waze alert before the SunGuide created date, with a total of 8,574 DAV Waze alerts (8,084 unique alerts) occurring before their associated DAV SunGuide events. For the DAV crashes, three crashes had at least one DAV Waze alert before the time of crash, with a total of four DAV Waze alerts occurring before their associated DAV crashes.

The final two queries (query #10 and query #11) selected only the lane-blocking DAV events from the results of query #8 and query #9, respectively. Only SunGuide events which had at least one non-shoulder lane blocked (based on the value in the worst_blockage column) were selected by query #10, while only crashes that were marked as lane-blocking based on the manual review of the crash reports were selected by query #11. From query #10, there were 340 lane-blocking DAV SunGuide events with 447 associated DAV Waze alerts (442 unique alerts) which occurred before these SunGuide events. These 340 lane-blocking DAV SunGuide events were considered in the congestion estimation (as discussed in the next paragraphs). No DAV crashes which had at least one Waze alert before the crash were lane-blocking, so estimates of congestion reduction were not calculated for DAV crashes. However, savings due to the potential prevention of crashes with associated Waze alerts before the crash occurred were estimated; these estimates are discussed later in this section.

Since the methodology discussed in Section 5.1.1 to estimate congestion reduction does not apply to incidents which occurred on an entrance or exit ramp, the DAV SunGuide events that occurred on ramps were excluded from consideration. Also excluded were events without information on the number of lanes blocked (as it is impossible to estimate the congestion impacts of the event without this information) and events which resulted in a full road closure (since the methodology in Section 5.1.1, which is partially based on the methodology in HCM6E, is not applicable to full road closure as previously discussed). Any events that did not meet the other assumptions of the methodology regarding incident duration and the relationships between flow rate and capacities were also excluded. After excluding all these events, 133 lane-blocking DAV SunGuide events remained for consideration in the congestion calculations.

To estimate the congestion costs, a PHF was assumed as the PHF at the time of any given event was unknown. I-4 in D5 is in an urban area, so an assumed PHF value of 0.95 was used based on guidance from HCM6E. Another key component needed to calculate the congestion costs was event durations. Two event durations were used: the full incident duration and the reduced incident duration. The full incident duration represents the amount of time from the first Waze alert to the reported end of the incident. This includes the reported event duration plus the time between when the first Waze alert occurred and the SunGuide created date. For the reduced incident duration, it was assumed that the reported event duration would remain the same, but the event would have been created at the first Waze alert time rather than the SunGuide created date. This means that both the full and reduced incident durations start at the time of the first Waze alert, but the full incident duration ends at the SunGuide end data while the reduced incident duration ends at the SunGuide end data minus the time difference between the SunGuide created date and the first Waze alert. To estimate the potential congestion reduction savings due to the earlier detection provided by Waze, the delay was first calculated for the full incident duration. Next, the delay was calculated for the reduced incident duration. The delay using the reduced incident duration was then subtracted from the delay using the full incident duration, resulting in the estimated vehicle delay reduction. This vehicle delay reduction was multiplied by the congestion costs to obtain the congestion reduction savings due to Waze. These procedures were used for all 133 applicable lane-blocking DAV SunGuide events which had at least one Waze alert before the SunGuide created date. **Table 5-10** shows the results of these congestion calculations.

Table 5-10: Estimated Reduction in Congestion and Associated Savings for DAV Incidents by Reporting DAV Waze Alerts on I-4 in FDOT D5 (July 2019 – December 2019)

Number of Events	133
Vehicle Delay Reduction (veh-hours)	140,573
Reduction in Congestion Costs for Passenger Vehicles (2019$)	$3,759,637
Reduction in Congestion Costs for Trucks (2019$)	$476,121
Total Congestion Reduction Savings (2019$)	$4,235,759

Overall, the total estimated congestion reduction savings due to early Waze detection for the 133 applicable lane-blocking DAV SunGuide events were $4,235,759. To estimate the costs of reporting all DAV Waze data to the TMC, the anticipated amount of time spent by operators responding to these Waze alerts was determined. There were 103,413 DAV Waze alerts on I-4 in D5 during the study period. Assuming it takes 2 minutes for a TMC operator to check and dismiss each of these alerts (based on the event confirmation target time of 2 minutes for TMC operators in D6) (FDOT, District Six: Transportation Systems Management and Operations, 2020), it would take over 3,447 hours to handle these alerts. The average salary for a TMC operator is $20.60 per hour (as provided by FDOT), resulting in a cost of approximately $71,010 to handle these alerts. Therefore, the benefit-cost ratio was $4,235,759/$71,010 = 59.65. This ratio is much larger than 1.00, indicating that the benefits of reporting all DAV Waze alerts to SunGuide can significantly outweigh the costs. It is important to note that these benefits only consider the congestion reduction due to earlier detection of lane-blocking DAVs. If other benefits, such as the congestion reduction due to earlier detection of DAVs which only block the shoulder and the ability to detect previously unreported DAVs were considered, this benefit-cost ratio would be even higher. Also, if the process of sorting Waze alerts becomes automated (which can be a subject for future research), the cost of operator time will shrink down significantly to almost nothing. This will increase the benefit-cost ratio even more.

The potential prevention of DAV crashes is another benefit. To showcase these potential benefits, the three DAV crashes on I-4 in D5 from July 2019 through December 2019 which had at least one associated Waze alert before the crash occurred were examined in detail. Since it is unknown whether quicker detection and response would have actually prevented these crashes or not, these benefits are not combined with the congestion reduction benefits (and are therefore not included in the benefit-cost ratio calculation). **Table 5-11** shows information about these three studied DAV crashes. This information includes date and time of crash, date and time of earliest Waze alert, time of crash, time for responders to get to the scene after they were dispatched, number of injuries by severity level, estimated comprehensive injury costs, and reported property and vehicle damages. The estimated comprehensive injury costs were calculated by multiplying the average comprehensive costs for each injury severity level from the National Safety Council (2021) by the number of injuries for that severity level, then adding these costs for all severity levels.

Table 5-11: Information for I-4 DAV Crashes in D5 from July 2019 – December 2019 with At Least One Associated Waze Alert Before Time of Crash

Date and Time of Crash	Date and Time of Earliest Waze Alert	Time for Responders to Get to Scene (minutes)	Number of Injuries by Severity Level	Estimated Comprehensive Injury Costs	Reported Vehicle and Property Damages
8/1/2019 12:13 AM	7/31/2019 11:43 PM	0	No injuries	$0	$2500
9/14/2019 12:10 AM	9/13/2019 11:41 PM	12	3 Incapacitating Injuries, 1 Non-Incapacitating Injury, 1 Possible Injury	$4,148,000	$12,000
12/17/2019 10:34 AM	12/17/2019 10:27 AM	42	No injuries	$0	$1000

Using the information from the second and third columns of **Table 5-11**, it can be determined whether responders could have reached the crash scene before the crash occurred, thereby possibly preventing the crash from happening. For the crash on 8/1/2019, the crash was first reported by a law enforcement officer at the scene, which is why the time to get to the scene was zero minutes. If the TMC was notified of this DAV by the Waze alert at 11:43 PM on 7/31/2019, this would give the responders 30 minutes to get to the DAV before the crash. Assuming this is the case, it is possible that the crash would have been prevented, resulting in savings of $2500 due to no vehicle or property damage. For the crash on 9/14/2019, responders would have been able to get to the DAV before the crash occurred if they were notified by the Waze alert at 11:41 PM on 9/13/2019. This means it is possible that this crash could have been prevented, resulting in a total savings of $4,160,000 ($1,219,000 for each of the three incapacitating injuries, $336,000 for the non-incapacitating injury, $155,000 for the possible injury, and $12,000 for the vehicle and property damages). For the crash on 12/17/2019, the earlier detection provided by the Waze alert would not have been enough for responders to get to the scene before the crash occurred, so the crash still would have happened (no savings). Therefore, the total potential savings due to DAV crash prevention was $4,162,500. These savings are much higher than the congestion reduction savings, but it is unknown how much of these crash savings would have been realized if the earlier detection provided by the Waze alerts was available.

5.2.3.2 DAV Waze Data Benefit-Cost Evaluation for SR-91 in FDOT D4 Counties

Like the I-4 evaluation, 11 queries were developed for the SR-91 evaluation using MySQL and SQL with phpMyAdmin front-end to obtain the needed datasets containing DAV Waze alerts, DAV SunGuide events, and DAV crashes on SR-91 in FDOT D4 counties (Broward, Indian River, Martin, Palm Beach, and St. Lucie) during the study period (July 1, 2019 – December 31, 2019). **Table 5-12** contains information on these 11 queries (with the detailed queries shown in Appendix C), while the flowchart in **Figure 5-4** shows how these queries were used to filter the data sets and identify overlap between them. Appropriate latitude and longitude limits, county constraints, and applicable roadway values for SR-91 were used in the Waze queries to ensure that only DAV alerts on SR-91 in D4 counties were selected. The DAV SunGuide queries used district, county, and roadway constraints, while the DAV crash queries had county and roadway constraints.

Table 5-12: Data Queries for SR-91 in FDOT D4 Counties (July 1, 2019 – December 31, 2019)

Query Number	**Output Data Set**	**Number of Data Points**
12	All DAV Waze Alerts	139,299
13	All DAV SunGuide Events	12,975
14	All DAV Crashes	4
15	All DAV SunGuide Events with Waze Overlap	9,960
16	All DAV Waze Alerts with SunGuide Overlap	43,865 (37,032 unique)
17	All DAV Crashes with Waze Overlap	3
18	All DAV Waze Alerts with Crash Overlap	7 (all unique)
19	All DAV SunGuide Events with Waze Before	6,593
20	All DAV Crashes with Waze Before	1
21	All Lane-Blocking DAV SunGuide Events with Waze Before	54
22	All Lane-Blocking DAV Crashes with Waze Before	0

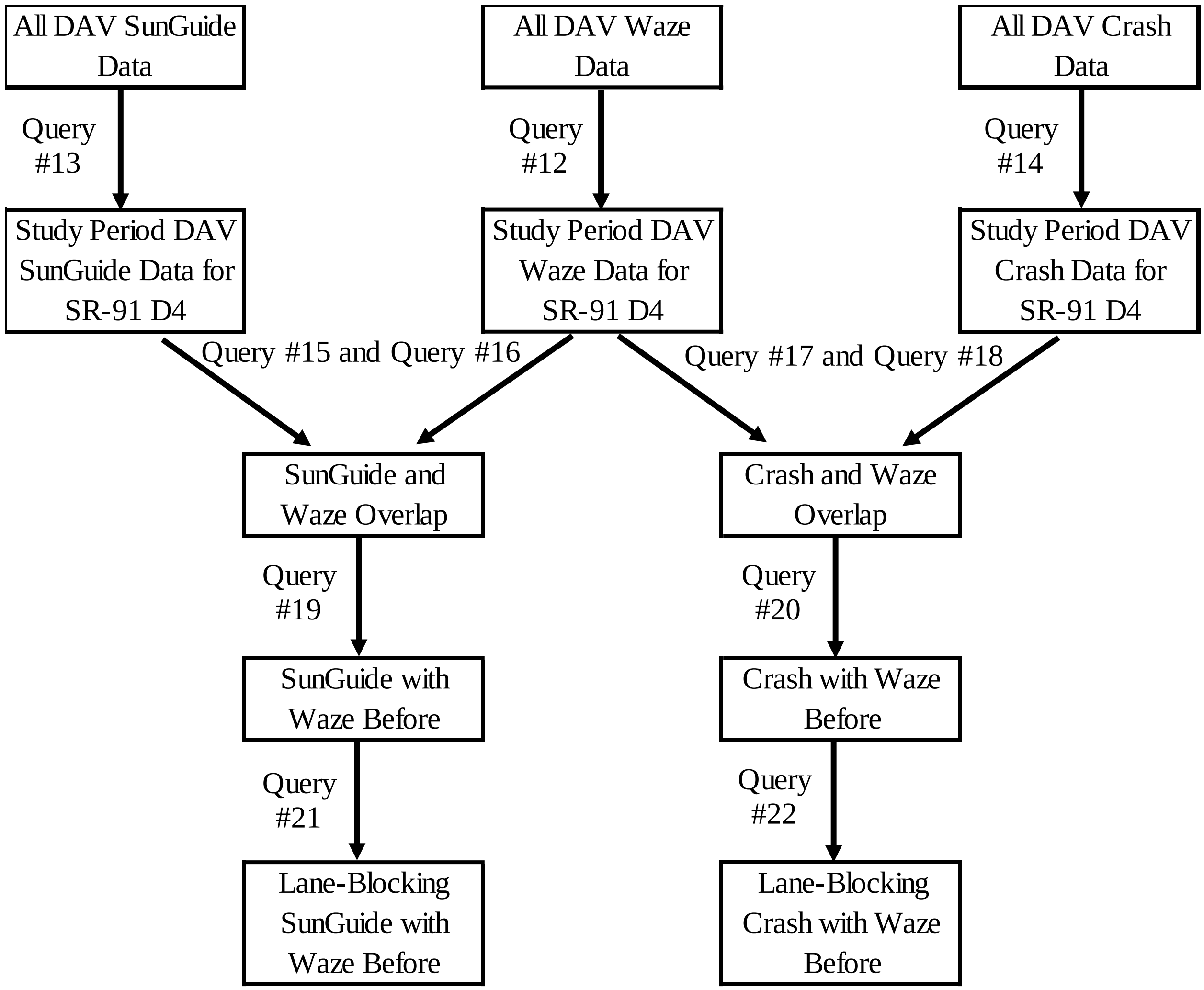

Figure 5-4: Query Flowchart for SR-91 DAV Waze Evaluation

First, queries #12, #13, and #14 were used to filter the DAV Waze, SunGuide, and crash databases, respectively, for only the data points on SR-91 in D4 counties from July 1, 2019, through December 31, 2019. The output data sets from these queries contained 139,299 DAV Waze alerts, 12,975 DAV SunGuide events, and four DAV crashes. Next, queries #15 and #16 were used to identify the overlap between the DAV Waze data from query #12 and the DAV SunGuide data from query #13, while queries #17 and #18 were used to identify the overlap between the DAV Waze data from query #12 and the DAV crash data from query #14. The same temporal and spatial buffers used in the I-4 evaluation were used for this SR-91 evaluation as well. Applying these queries showed that 9,960 of the 12,975 SunGuide events (76.8%) had one or more overlapping Waze alerts, with a total of 43,865 overlapping Waze alerts (of which 37,032 were unique Waze alerts). For the crashes, three of the four crashes (75%) had one or more overlapping Waze alerts, with a total of seven overlapping Waze alerts (all unique). Therefore, a total of 37,039 Waze alerts (26.6% of the 139,299 DAV Waze alerts) overlapped with either the SunGuide or the crash data.

The next two queries (query #19 and query #20) identified the DAV SunGuide events and DAV crashes, respectively, which had at least one DAV Waze alert before the SunGuide created date or time of crash. These queries showed that 6,593 DAV SunGuide events had at least one DAV Waze alert before the SunGuide created date, with a total of 9,416 DAV Waze alerts (9,013 unique alerts) occurring before their associated DAV SunGuide events. For the DAV crashes, one crash had at least one DAV Waze alert before the time of crash, with a total of two DAV Waze alerts occurring before this DAV crash.

The final two queries (query #21 and query #22) selected only the lane-blocking DAV events from the results of query #19 and query #20, respectively. Only SunGuide events which had at least one non-shoulder lane blocked (based on the value in the worst_blockage column) were selected by query #21, while only crashes that were marked as lane-blocking based on the manual review of the crash reports were selected by query #22. From query #21, there were 54 lane-blocking DAV SunGuide events with 82 associated DAV Waze alerts (all unique) which occurred before these SunGuide events. These 54 lane-blocking DAV SunGuide events were considered in the congestion estimation (as discussed in the next paragraphs). No DAV crashes which had at least one Waze alert before the crash were lane-blocking, so estimates of congestion reduction were not calculated for DAV crashes. Therefore, only the savings due to the potential prevention of crashes with associated Waze alerts before the crash occurred were estimated; these estimates are discussed later in this section.

Like the I-4 evaluation, the 54 events were filtered to only keep DAV SunGuide events where the methodology was applicable. This left 26 lane-blocking DAV SunGuide events to be considered for the congestion calculations. Since SR-91 in D4 is located in an urban area, an assumed PHF value of 0.95 was used based on guidance from HCM6E. Delay and congestion reductions were calculated using the same procedures as in the I-4 in D5 evaluation. **Table 5-13** shows the results of the congestion calculations for the remaining 26 applicable lane-blocking DAV SunGuide events.

Table 5-13: Estimated Reduction in Congestion and Associated Savings for DAV Incidents by Reporting DAV Waze Alerts on SR-91 in FDOT D4 (July 2019 – December 2019)

Number of Events	26
Vehicle Delay Reduction (veh-hours)	57,237
Reduction in Congestion Costs for Passenger Vehicles (2019$)	$1,483,114
Reduction in Congestion Costs for Trucks (2019$)	$276,087
Total Congestion Reduction Savings (2019$)	$1,759,201

Overall, the total estimated congestion reduction savings due to early Waze detection for the 26 applicable lane-blocking DAV SunGuide events were $1,759,201. To estimate the costs of reporting all DAV Waze data to the TMC, the anticipated amount of time spent by operators responding to the DAV Waze alerts was determined. There were 139,299 DAV Waze alerts on SR-91 in D4 during the study period. Assuming it takes 2 minutes for a TMC operator to check and dismiss each of these alerts, it would take over 4,643 hours to handle these alerts. Using the average salary for a TMC operator of $20.60 per hour results in a total cost of $95,652 to handle these alerts. Therefore, the benefit-cost ratio was $1,759,201/$95,652 = 18.39. This ratio is much larger than 1.00, indicating that the benefits of reporting all DAV Waze alerts to SunGuide can significantly outweigh the costs. Compared to the I-4 evaluation (benefit-cost ratio of 59.65), the SR-91 evaluation resulted in a lower benefit-cost ratio. This is due to two main factors: the SR-91 evaluation having more DAV Waze alerts not associated with DAV SunGuide events or DAV crashes (which increased the costs) and the SR-91 evaluation having fewer lane-blocking DAV events (and therefore less chance for congestion reduction benefits). These differing results suggest that a more detailed examination of the DAV Waze overlap with SunGuide and crash data is needed to determine the optimal strategies to utilize these Waze data most effectively. However, both of these example evaluations suggest that utilizing Waze data can be a very cost-effective way to improve DAV response. Like the I-4 evaluation, the benefits in this SR-91 evaluation only consider the congestion reduction due to earlier detection of lane-blocking DAVs. If other benefits, such as the congestion reduction due to earlier detection of DAVs which only block the shoulder and the ability to detect previously unreported DAVs, were considered, the benefit-cost ratio would be even higher.

As shown in the I-4 evaluation, the potential prevention of DAV crashes is another benefit of utilizing DAV Waze data which could be higher than the benefits due to congestion reduction. **Table 5-14** shows information about the one DAV crash which had an associated Waze alert before the crash occurred. The estimated comprehensive injury costs were calculated by multiplying the average comprehensive costs for each injury severity level from the National Safety Council (2021) by the number of injuries for that severity level, then adding these costs for all severity levels. For this crash, responders would have been able to get to the DAV before the crash occurred if they were notified by the Waze alert at 11:38 AM on 12/4/2019. This means it is possible that this crash could have been prevented, resulting in a total savings of $164,500 ($155,000 for the possible injury and $9500 for the vehicle and property damages).

Table 5-14: Information for DAV Crashes with At Least One Associated Waze Alert Before Time of Crash

Date and Time of Crash	Date and Time of Earliest Waze Alert	Time for Responders to Get to Scene (minutes)	Number of Injuries by Severity Level	Estimated Comprehensive Injury Costs	Reported Vehicle and Property Damages
12/4/2019 12:03 PM	12/4/2019 11:38 AM	17	1 possible injury	$155,000	$9500

5.3 Summary and Conclusions of Benefit-Cost Evaluations for Reducing DAV Impacts

DAVs are a common and costly occurrence on Florida roadways that can negatively impact traffic operations by creating congestion. In this chapter, example applications of three potential methods to reduce the impacts of DAVs were evaluated. These three methods (expanding Road Ranger patrol hours, implementing instant dispatch tow, and utilizing Waze alerts for earlier detection of DAV events) can help reduce the time the DAV is on the road, thereby reducing the associated congestion time and costs. The methodology developed in this chapter was used to estimate the reduction in congestion time and associated costs achieved by implementing these three potential methods, with this congestion reduction serving as the primary benefit considered. Benefit-cost evaluations were used to identify whether these methods would be cost effective for example limited access roadway segments in Florida.

The methodology developed in this chapter uses vehicle delay as the basis from which to calculate congestion. The arriving vehicle flow rate was approximated by using historic traffic information at the site of each DAV incident. Capacities (both normal and reduced due to the incident) were calculated using methodologies from HCM6E. Once delay was determined, congestion costs from the Urban Mobility Report were used to generate a financial cost associated with congestion. This methodology was only applicable to DAV incidents that occurred on a basic freeway segment; it was not applicable to DAV incidents that occurred on an entrance or exit ramp. A major assumption used in the methodology was assuming that the worst blockage of the DAV incident lasted for the entire duration of the reported incident. This assumption was made because timeline information for each DAV incident was unknown and only information on the worst blockage was available. Another major assumption was that there was no pre-existing congestion at the time of the incident.

Using the developed methodology, one roadway per FDOT district was chosen to calculate the cost of congestion due to DAV incidents, which include both non-crash DAV SunGuide events and DAV crashes. Using data from calendar year 2019, the roadway in each district with the most DAV incidents was selected. Only capacity-reducing DAV incidents on the selected roadways were used to calculate the congestion costs based on the assumptions of the methodology. A total of 13,882 applicable DAV incidents (13,859 DAV SunGuide events and 23 DAV crashes) were used in these calculations. These 13,882 incidents were estimated to have caused over 79,000 hours of congestion which led to over 11 million vehicle-hours of delay. This congestion ultimately costs nearly $336 million in 2019 dollars. It is important to note that this is likely an underestimate, as the methodology excluded all incidents where congestion was present before the incidents occurred. Moreover, it does not consider the cost of fuel used by vehicles in congestion and the subsequent negative environmental impacts of the fuel emissions.

The first evaluated method to reduce DAV congestion costs was increasing the existing Road Ranger patrol hours to address more events. Eight roadways (one per FDOT district) were considered, with two different roadways being examined in full: I-295 in FDOT D2, which is an urban roadway that had a significant difference in average incident duration between periods when Road Rangers were active and when they were inactive; and I-10 in FDOT D3, a rural roadway that had a high number of DAV incidents. For I-295, the proposed increase to patrol hours would have additional coverage on weekends from 9:00 AM to 9:00 PM and come at an estimated additional cost of $324,480 per year. With these increased hours, it is estimated that 45,897 vehicle hours of delay and $1,404,587 of congestion costs would be saved, giving a benefit-cost ratio of 4.33. For I-10, the proposed increase to patrol hours would have two of its three segments operate patrols on Monday to Friday from 5:00 AM to 9:00 PM and Saturday and Sunday from 9:00 AM to 9:00 PM, which would have an estimated additional cost of $229,840 per year. The estimated benefits for this expansion were 11,697 vehicle hours of delay reduction and $447,980 of congestion cost reduction, giving a benefit-cost ratio of 1.95. For the remaining considered roadways, full evaluations were not performed due to either having existing around-the-clock Road Ranger coverage, no benefit to expanding patrol hours due to lower incident durations during periods of Road Ranger inactivity compared to periods when Road Rangers are active, or very few incidents during periods of Road Ranger inactivity (suggesting that expanding Road Rangers would provide little to no benefit).

The second evaluated method to reduce DAV congestion costs was implementing an instant dispatch tow program. With this program, a tow truck is dispatched simultaneously with a trooper to address a lane-blocking DAV incident. Tow truck companies are reimbursed for their time should their services not be needed to clear an incident from the roadway. Although there was no data available on costs for instant dispatch tow in Florida, states such as Virginia have implemented such a program. For the Virginia program, expected reimbursements to operators were about $2,000 a month, giving an annual cost of $12,000. Costs for a similar program in the state of Florida called SafeTow were also used to calculate possible costs for an instant dispatch tow program; the cost of this program was $65 per incident. The state of Washington found that instant dispatch tow helped reduce the average incident duration by 25%, and this 25% reduction in duration was used in the developed methodology to calculate the saved congestion costs due to implementing such a program. Two example instant dispatch tow implementation scenarios were evaluated for lane-blocking DAV incidents on I-10 in FDOT D3 and SR-91 in FDOT D5. These two roadways were chosen as they are located in different areas (rural for I-10 and urban for SR-91), have long distances between exits (I-10), have high traffic volumes and DAV incident counts (SR-91), and are an interstate and a toll road, respectively. For I-10, implementing an instant dispatch tow program was estimated to save 38,760 vehicle hours of delay and $1,274,637 in congestion costs, resulting in a benefit-cost ratio of 53.11 when using the Virginia costs and a benefit-cost ratio of 233.45 when using the SafeTow costs. For SR-91, an estimated 230,565 vehicle hours and $7,413,816 in congestion costs would be saved with such a program, resulting in a benefit-cost ratio of 308.91 when using the Virginia costs and a benefit-cost ratio of 1900.98 when using the SafeTow costs. Due to the uncertainty in the costs of implementing an instant dispatch tow program, it is recommended to focus on the estimated benefits of the program and not the benefit-cost ratio. The high benefits of this program (especially on SR-91) suggest that instant dispatch tow would likely be more cost-effective than Road Ranger expansion to reduce the impacts of DAVs.

The third and final evaluated method to reduce DAV congestion costs was reporting DAV Waze data to TMCs for earlier detection of DAV events. Two example evaluations were conducted for I-4 in FDOT D5 and SR-91 in FDOT D4 using data from the second half of 2019. I-4 was chosen due to the high overlap between Waze and SunGuide events (81.9% of DAV Waze alerts had an associated SunGuide event), and SR-91 in D4 was chosen as this district had many DAV events and SR-91 was the toll road with the most DAV events. The time difference between the earliest associated Waze alert for a DAV incident and the time it was first reported in SunGuide or a crash occurred was used to estimate the congestion reduction. This time difference represents the improved response time that could have been achieved if Waze alert were utilized, which corresponds to the DAV being on the road for a shorter amount of time and causing less congestion. For I-4, the results indicated that reporting these Waze alerts to the TMC could lead to 140,573 fewer vehicle hours of delay and $4,235,759 of congestion costs saved. The cost for TMC operators in this district to review these DAV Waze alerts was estimated to be $71,010, giving a benefit-cost ratio of 59.65. For SR-91, an estimated 57,237 vehicle hours of delay and $1,759,201 would be saved. The cost for TMC operators in this district to review these DAV Waze alerts was estimated to be $95,652, giving a benefit-cost ratio of 18.39. These benefit-cost ratios are much larger than 1.00, indicating that utilizing DAV Waze alerts for earlier DAV detection would be cost effective.

Table 5-15 shows the summary results of each benefit-cost evaluation. The two evaluated methods to improve DAV response with the highest estimated benefits were reporting DAV Waze alerts to the TMC for lane-blocking DAV events on I-4 in FDOT D5 (annual congestion savings of almost $8.5 million) and implementing an instant dispatch tow program to respond to lane-blocking DAV incidents on SR-91 in FDOT D5 (annual congestion savings of $7.4 million). D5 is a predominantly urban area with high traffic volumes and many DAV incidents, and the results indicate that the most congestion savings can be obtained in this district as a result. The lowest benefit-cost ratios were for expansions to Road Ranger patrols, which suggests that the existing operating schedules are effective and there would be minimal benefit (relative to the costs) in increasing them further.

Table 5-15: Summary of Benefit-Cost Evaluation Results

Potential Improvement	Road	Analysis Period	Vehicle Delay Reduction (veh-hours)	Estimated Congestion Savings ($2019)	Estimated Implementation Cost (2019$)	Benefit-Cost Ratio
Increasing Road Ranger Patrols to Respond to DAVs	I-295 in D2	Jan. 1, 2019 - Dec. 31, 2019	45,897	$1,404,587	$324,480	4.33
	I-10 in D3	Jan. 1, 2019 - Dec. 31, 2019	13,421	$447,980	$229,840	1.95
Implementing Instant Tow Dispatch to Respond to DAVs	I-10 in D3	Jan. 1, 2019 - Dec. 31, 2019	38,760	$1,274,637	$24,000	53.11*
	SR-91 in D5	Jan. 1, 2019 - Dec. 31, 2019	230,565	$7,413,816	$24,000	308.91*
Reporting DAV Waze Data to TMCs	I-4 in D5	Jul. 1, 2019 - Dec. 31, 2019	140,573	$4,235,759 ($8,471,518 per year)	$71,010	59.65
	SR-91 in D4	Jul. 1, 2019 - Dec. 31, 2019	57,237	$1,759,201 ($3,518,402 per year)	$95,652	18.39

*The costs used to calculate these benefit-cost ratios were from Virginia; therefore, it is not recommended to compare these benefit-cost ratios with the other ones in this table, which used Florida costs.

Chapter 6: Conclusions and Recommendations

DAVs are a common occurrence that can greatly impact traffic operations and safety. The main goal of this research was to enhance and increase safety on FDOT roadways by evaluating the operational and safety impacts of DAVs on FDOT limited access roadways, identifying and evaluating methods to reduce these impacts; and estimating the benefits and costs of these methods. To achieve this goal, several tasks were performed. First, a literature review on DAV handling procedures and response programs in Florida and other states was conducted to identify effective methods and appropriate ways to evaluate potential improvements. A national survey of stakeholders was then developed and disseminated to transportation agencies, law enforcement, and SSPs throughout the country to better understand the operational and safety impacts of DAVs and how agencies respond to these events. Significant data collection and analysis of DAV crash reports, SunGuide non-crash DAV events, and DAV Waze alerts were performed to understand the nature and frequency of these events as well as their impacts on operations and safety. A congestion cost methodology was then used to quantify the congestion impacts of DAVs and perform benefit-cost analyses of implementing three potential methods to improve the response to and handling of DAVs for select roadways: expansion of active Road Ranger hours, implementation of instant dispatch tow, and incorporation of DAV Waze alerts into SunGuide for earlier detection of DAV events.

The literature review showed that FDOT has effective laws and procedures related to DAV handling and response, but there are some innovative methods being used in other states that could be beneficial in Florida. Florida's Open Roads Policy, Road Ranger program, and other specialty response programs (RISC, SIRV, safe tow, etc.) help improve roadway and incident clearance times. However, towing programs used in other states, such as instant dispatch tow, could provide additional benefits, especially for DAV events. The literature review also showed approaches used by other agencies to evaluate response programs, with travel delay being the most common element considered in these evaluations.

The DAV stakeholder survey was sent to state DOTs, turnpike/toll road authorities, state and local law enforcement, and SSPs across the United States to understand the characteristics of DAV events and their subsequent handling. Among the 60 respondents who completed the survey, 27 represented state DOTs, four represented turnpike/toll road authorities (path 1), 12 represented state law enforcement agencies, 13 represented state SSPs, and four represented FDOT districts. The survey contained three paths of questions, with path 1 for state DOTs and turnpike/toll road authorities, path 2 for law enforcement agencies, and path 3 for SSPs (including FDOT districts).

Path 1 was focused on the characteristics of DAVs and the response programs used by DOTs and toll road agencies. Most of the path 1 respondents reported 10 to 50 disabled vehicle events and 11 to 25 abandoned vehicles per day on average, with most of these events occurring during daytime hours. These respondents indicated that clearing DAV events in urban and suburban areas is of high importance, but DAV clearance might not be as high priority if the DAV is not lane-blocking or an immediate hazard. Agencies that notified other drivers of DAV events tended to most commonly use traveler information systems (such as 511 or a phone app) or highway message signs, but 29% of agencies did not notify other drivers of any DAV. With respect to clearance, disabled vehicles are generally moved to the shoulder within 30 minutes but can take longer to be fully cleared. Many of the path 1 respondents also reported that their agency does not directly work with DAVs, either having law enforcement handle them directly or coordinating with a TIM program or SSP. Respondents of this path had four main suggestions to improve DAV response: improving interagency coordination and establishing a greater sense of urgency to clear vehicles; improving the detection and response times; establishing an SSP (if the agency did not already have one) or expanding an existing SSP; and having a better way to track events and manage the data involved in identifying and responding to DAV events. Some of the described innovative DAV response programs focused on clearing abandoned vehicles sooner, clearing vehicles from construction zones, and upgrading or equipping existing vehicles in the SSP fleet with tow capabilities to remove DAVs on their own without waiting for a tow truck. The agencies piloting these programs indicated that they have reduced clearance times and have had positive effects on traffic operations and safety.

Most of the path 2 (law enforcement) respondents indicated that an average of 10 to 50 disabled vehicle events and 1 to 10 abandoned vehicle events happen each day. These respondents also indicated that clearing DAV events which are not lane-blocking or immediate hazards are low priority. Disabled vehicles are usually moved to the shoulder within 45 minutes but can take longer to fully clear from the roadway, and abandoned vehicles are usually cleared within 24 to 72 hours. All path 2 respondents indicated that vehicles in their agency's fleet are equipped with push bumpers, and most can use them to move DAVs from the travel lanes. Over 80% of respondents indicated that an officer in their agency had been struck by a vehicle while responding to a disabled vehicle; accordingly, all respondents were at least somewhat concerned for the safety of officers in their agency. When asked for ways to improve the response process, respondents indicated that improving the tracking of DAVs would be beneficial as time is crucial in the removal process. Identifying vehicles earlier can help to expedite their eventual removal.

Path 3 (SSP) respondents indicated that 10 to 50 disabled vehicle events and 1 to 5 abandoned vehicle events are typical on a given day. Over half of the respondents' agencies did not have vehicles that were tow capable. Of those with tow capable vehicles in their fleet, all were allowed to relocate the vehicle, typically to the shoulder or side slope of the road. Most fleet vehicles had push bumpers that could move vehicles out of the travel lanes. Nearly two-thirds of respondents indicated that someone in their agency had been struck while responding to a disabled vehicle, and most indicated that responders in their agency were very concerned for their safety. Respondents suggested expanding SSP programs (larger fleets, more funding, additional responders) might assist with the prompt removal of DAVs. The four respondents from the FDOT districts indicated that their districts had a high number of DAV events compared to other SSPs nationally. These four respondents also ranked DAVs as a more serious problem than respondents from other states, reinforcing that these districts have many DAVs compared to other states. All four FDOT district respondents also indicated that responders in their agency are very concerned for their safety, highlighting the importance for FDOT to find ways which can keep responders safe when responding to DAVs.

The results of the DAV stakeholder survey give valuable insights into the characteristics of DAVs and how different agencies handle them around the country. State DOTs and turnpike/toll road authorities often rely on law enforcement and SSPs to handle DAV events, showing how interagency communication and cooperation is key to the timely detection of and response to DAVs. These agencies noted how DAVs are a much greater problem in urban and suburban areas, which typically receive most events during daytime hours. Ensuring that SSPs are patrolling during these periods can help address these events quickly to reduce their impacts on traffic. As suggested by some respondents, giving SSPs greater resources (such as additional fleet vehicles or more funding to expand patrols) and capabilities (such as being able to tag abandoned vehicles or relocate more DAVs without waiting for law enforcement) can be the most practical and effective solutions for improving responses to DAVs. FDOT could investigate some of the innovative methods and improvements used and suggested by other agencies to see if they could effectively be implemented in Florida. Strengthening TIM coordination in Florida and the response to DAVs can help make FDOT a national leader in event response. Investigating methods to improve first responder safety is also important. Ultimately, finding ways to improve existing procedures and integrate new ones can keep the motoring public and first responders safe.

To understand the impact DAVs have on traffic operations and safety for Florida limited access facilities, three DAV datasets were analyzed: Signal 4 Analytics crash reports, SunGuide non-crash event data, and Waze crowdsourced alert data. A total of 1,256 crashes were identified as involving a DAV based on the crash narrative or the crash diagram. There were 53 fatalities, 976 injuries, $17.3 million in property and vehicle damages, and $966 million in comprehensive fatality and injury costs due to DAV crashes from 2015 through 2020, with most of these impacts caused by disabled vehicle crashes. Combining the fatality and injury costs with the property and vehicle damages resulted in an average yearly cost of about $163.9 million. These DAV crashes lasted an average of 130 minutes each. Over 34% of DAV crashes blocked at least one travel lane, emphasizing the need for quick response to reduce operational impacts. Distraction was also found to be a common contributing factor of DAV crashes, as 15% of all DAV crashes were due to distracted driving. Interstates in urban counties had the highest frequency of DAV crashes, suggesting that improving detection and subsequent response in these areas would lead to the most benefits in terms of reducing crashes and their associated fatalities and injuries.

Nearly 1.6 million SunGuide non-crash DAV events from January 2018 through December 2021 were collected and analyzed. About 90% of these were disabled vehicle events and the remaining 10% were abandoned vehicle events. About 22% of disabled vehicle SunGuide events occurred from 9 PM to 7 AM, but 45% of crashes occurred in this timeframe, suggesting that clear visibility and conspicuity plays an important role in reducing crashes. Compared to the DAV crashes, DAV SunGuide events were less likely to be lane-blocking, with only about 4% of DAV SunGuide events having blocked a travel lane in some capacity. Disabled vehicle SunGuide events lasted about half the time as DAV crash events, but abandoned vehicle SunGuide events lasted over 13 hours on average before being fully cleared from the scene.

There were approximately 10.3 million DAV Waze alerts from April 2019 through December 2021. These Waze alerts were most common during daytime hours and on high-volume roadways. Overlap between the DAV Waze alerts and SunGuide events was identified using MySQL and appropriate spatial and temporal buffers, with the results showing that approximately 70% of the DAV SunGuide events had at least one overlapping Waze alert.

Additionally, 67% of these events with Waze overlap had at least one Waze alert before the SunGuide event. This overlap was more present during daytime hours and in urban counties (Broward, Miami-Dade, Hillsborough, Orange, etc.). For the events which had Waze alerts before the SunGuide event, the Waze alert occurred about 16 minutes before the SunGuide event, on average. Utilizing Waze alerts during the day would provide more benefits (with respect to early detection) than utilizing Waze alerts in early morning hours.

Based on the literature review findings, survey responses, and data analyses, three potential methods to reduce the impacts of DAVs were selected for evaluation. These three methods (expanding Road Ranger patrol hours, implementing instant dispatch tow, and utilizing Waze alerts for earlier detection of DAV events) can help reduce the time the DAV is on the road, thereby reducing the associated congestion time and costs. Benefit-cost evaluations were used to identify whether these methods would be cost effective for select limited access roadway segments in Florida. These evaluations used the reduction in congestion time (and associated savings) due to the evaluation method as the primary benefit. A congestion cost methodology was developed which uses vehicle delay as the basis. The arriving vehicle flow rate was approximated by using historic traffic information at the site of each DAV incident. Capacities (both normal and reduced due to the incident) were calculated using methodologies from the sixth edition of the Highway Capacity Manual. Once delay was determined, congestion costs from the Urban Mobility Report were used to generate a financial cost associated with congestion. This methodology was only applicable to DAV incidents that blocked a lane on a basic freeway segment; it was not applicable to DAV incidents that only occurred on the shoulder or occurred on an entrance or exit ramp. A major assumption used in the methodology was assuming that the worst blockage of the DAV incident lasted for the entire duration of the reported incident. This assumption was made because timeline information for each DAV incident was unknown and only information on the worst blockage was available. Another major assumption was that there was no pre-existing congestion at the time of the incident.

Using the developed methodology, the roadway with the most DAV events in each FDOT district was chosen to calculate the cost of congestion due to DAV incidents, which include both non-crash DAV SunGuide events and DAV crashes. Only capacity-reducing DAV incidents from calendar year 2019 on the selected roadways were used to calculate the congestion costs based on the assumptions of the methodology. A total of 13,882 applicable DAV incidents (13,859 DAV SunGuide events and 23 DAV crashes) were used in these calculations. These 13,882 incidents were estimated to have caused over 80,000 hours of congestion which led to over 11 million vehicle-hours of delay. This congestion ultimately cost nearly $336 million in 2019 dollars. It is important to note that this is likely an underestimate, as the methodology does not consider any shoulder incidents that can still negatively impact traffic operations and lead to congestion and excluded all incidents where congestion was present before the incidents occurred. Moreover, it does not consider the cost of fuel used by vehicles in congestion and the subsequent negative environmental impacts of the fuel emissions. The total estimated comprehensive crash cost for the 23 DAV crashes was almost $36 million; this includes these costs of fatalities, injuries, and vehicle and property damages.

After evaluating all three potential methods to improve DAV detection and response, the two evaluated methods with the most benefits were reporting DAV Waze alerts to the TMC for lane-blocking DAV events on I-4 in FDOT District 5 (estimated annual congestion savings of $8.5 million) and implementing an instant dispatch tow program to respond to lane-blocking DAV incidents on SR-91 in FDOT District 5 (estimated annual congestion savings of $7.4 million). District 5 is a predominantly urban area with high traffic volumes and many DAV incidents, and the results indicate that the most congestion savings can be obtained in this district as a result. Conversely, the lowest benefits were for expansions to Road Ranger patrols (estimated annual congestion savings from $447,980 to $1,404,587). The benefit-cost ratios for these expansions were also not much larger than 1.00, which suggests that the existing operating schedules are effective and there would be minimal benefit (relative to the costs) in increasing them further.

Overall, this research shows the scope and impacts of DAV events on Florida roadways. It also shows that there are methods which could be implemented to cost-effectively reduce these impacts. Both DAV crash and non-crash events are common and have significant negative impacts to both safety and operations. Their frequency varies by time and location, with DAV crashes more common during nighttime and in urban areas while non-crash events are more common during daytime and in urban areas. Based on the results of the example benefit-cost evaluations conducted in this report, it is recommended that the reporting of Waze alerts for lane-blocking DAV events to the TMC be investigated further. The analyses of DAV Waze data show that these data have significant potential to help TMC operators more quickly detect DAVs compared to existing practices. However, a more detailed investigation of Waze data for Florida roadways is needed to identify the optimal locations and times for which these Waze alerts should be reported to the TMC to provide early warning of DAVs without overwhelming TMC operators due to the enormous quantity of Waze data. This detailed investigation is outside the scope of this current project, but is recommended as it could provide significant benefits even if DAV Waze alerts are only utilized at a few locations for select hours of the day. By pursuing this area of research further, FDOT could more thoroughly understand the characteristics of DAV Waze alerts (including how they could be used for real-time DAV detection) and identify potential areas where these alerts could be best utilized to reduce the frequency and duration of DAV events, improving traffic operations and reducing injuries and fatalities. If Waze alerts were sorted automatically, this could make Waze the most economical method among the three methods described in this report.

Another recommended method is the implementation of instant dispatch tow in D5 or another urban area with high traffic volumes. This program can reduce the length of time DAVs are lane-blocking, helping to alleviate congestion and prevent crashes. Expanding an instant dispatch tow program to also address lane-blocking disabled vehicles (instead of focusing on just crashes) is recommended to help ensure that the impacts of lane-blocking disabled vehicles are reduced in a cost-effective way. More detailed investigations of shoulder-blocking DAVs (to identify what conditions make these vehicles more likely to cause a crash) and DAVs which cause full road closures or ramp closures could be conducted in the future to better determine the operational and financial impacts of these events. These investigations will require additional information (such as timelines of roadway blockage conditions for each event) which were not available in the data used for this study. Future research could also be conducted on how connected and automated vehicles might affect roadway clearance and DAV response, as well as how other data sources (such as TrafficVision, which can automatically detect incidents and collect real-time data) could be used as a supplement or alternative to Waze data. By following these recommendations and pursuing additional research on this topic, FDOT can continue improving their existing DAV detection and response procedures to reduce congestion and increase safety while providing an example of effective TIM practices for other states to follow.

References

American Automobile Association. (n.d.). *Digest of motor laws: Move over law*. Retrieved April 7, 2021, from https://drivinglaws.aaa.com/tag/move-over-law/

Amin-Naseri, M., Chakraborty, P., Sharma, A., Gilbert, S., & Hong, M. (2018). Evaluating the reliability, coverage, and added value of crowdsourcing traffic incident reports from Waze. *Transportation Research Record: Journal of the Transportation Research Board*, *2672*(43), 34–43. https://doi.org/10.1177/0361198118790619

Arizona Department of Transportation (ADOT). (n.d.). *Incident response unit – sponsored by State Farm*. Retrieved April 8, 2021, from https://azdot.gov/about/transportation-safety/incident-response-unit-sponsored-state-farm

Carson, J. (2008). *Traffic incident management quick clearance laws: A national review of best practices* (Report No. FHWA-HOP-09-005). Federal Highway Administration. https://ops.fhwa.dot.gov/publications/fhwahop09005/quick_clear_laws.pdf

Chimba, D., Kutela, B., Ogletree, G., Horne, F., & Tugwell, M. (2013). Impact of abandoned and disabled vehicles on freeway incident duration. *Journal of Transportation Engineering*, *140*(3). https://doi.org/10.1061/(ASCE)TE.1943-5436.0000635

City of Houston. (n.d.). *Tow and go*. Retrieved April 2, 2021, from https://www.houstontx.gov/towandgo/

Disabled vehicles obstructing traffic. Fla. Stat. §316.071 (2020). http://www.leg.state.fl.us/statutes/index.cfm?App_mode=Display_Statute&URL=0300-0399/0316/Sections/0316.071.html

Dougald, L., Goodall, N., & Venkatanarayana, R. (2016). *Traffic incident management quick clearance guidance and implications* (Report No. FHWA/VTRC 16-R9). Virginia Department of Transportation. http://www.virginiadot.org/vtrc/main/online_reports/pdf/16-R9.pdf.

Esri. (2020). ArcMap Version 10.8.1. Redlands, CA.

Federal Highway Administration. (2019). *National traffic incident management (TIM) responder training program: Michigan student handout*. https://www.michigan.gov/documents/mdot/1-TIM_4-Hour_Student_Handout_-_MI_-_082415_517559_7.pdf

Federal Highway Administration. (2021). *Reducing non-recurring congestion*. Retrieved April 4, 2021, from https://ops.fhwa.dot.gov/program_areas/reduce-non-cong.htm

Federal Highway Administration Center for Accelerating Innovation. (2021). *Sample crowdsourcing for operations applications.* EDC-5: Crowdsourcing for Operations. https://www.fhwa.dot.gov/innovation/everydaycounts/edc_5/docs/crowdsourcing_applications.pdf

Florida Department of Transportation. (n.d.-a). *Geographic information system (GIS)*. Retrieved March 15, 2022, from https://www.fdot.gov/statistics/gis/default.shtm.

Florida Department of Transportation. (n.d.-b). *Traffic Incident Management Dashboard: Traffic incident management performance measures for lane blocking events on freeways fiscal year 2020/2021*. Retrieved March 13, 2021, from https://timdashboardtest.fdot.gov/Public/Dashboard

Florida Department of Transportation. (2014). *Open Roads Policy agreement*. https://www.fdot.gov/docs/default-source/traffic/traf_incident/pdf/Open_Roads_Policy_FDOT_FHP.pdf

Florida Department of Transportation. (2017). *Traffic incident management: TIM teams*. Retrieved March 25, 2021, from http://floridatim.com/Teams.htm

Florida Department of Transportation. (2019). *Florida traffic incident management (TIM) 2019 strategic plan*. https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/traffic/doc_library/pdf/fdot-tim-strat-plan-2019---finalabb4c861ece14a97a59673d03e1cd0f4.pdf?sfvrsn=34558202_0

Florida Department of Transportation. (2020). *Severe Incident Response Vehicle (SIRV) arterial patrol*. National Operations Center of Excellence. https://transops.s3.amazonaws.com/uploaded_files/FDOT-SIRV-Case%20Study_0.pdf

Florida Department of Transportation Commercial Vehicle Operations and Traffic Incident Management Program. (2017a). *Rapid Incident Scene Clearance (RISC) annual report: Fiscal year 2016/2017*. http://www.floridatim.com/documents/RISC/Rapid%20Incident%20Scene%20Clearance%20(RISC)%20FY16-17%2%20Annual%20Report%20-%20Final.pdf

Florida Department of Transportation Commercial Vehicle Operations and Traffic Incident Management Program. (2017b). *Road Ranger comment card annual report: July 2016 – June 2017*. http://www.floridatim.com/documents/RoadRangers/Road%20Ranger%20Comment%20Card%20Data%20FY%2016-17%20-%20Annual%20Report%20-%20FINAL.PDF

Florida Department of Transportation Commercial Vehicle Operations and Traffic Incident Management Program. (2017c). *Statewide Road Ranger survey for incident responders*. http://www.floridatim.com/documents/RoadRangers/2016-17%20Statewide%20Road%20Ranger%20Survey%20for%20Incident%20Responders%20-%20FINAL.PDF

Florida Department of Transportation Commercial Vehicle Operations and Traffic Incident Management Program. (2018). *Road ranger performance measures annual report: July 2017 - June 2018*. http://www.jax511.com/D2TIMwp/wp-content/uploads/2018/09/Road-Ranger-Assist-Data-FY-17-18-Annual-Report_FINAL.pdf.

Florida Department of Transportation District Four Intelligent Transportation Systems. (2013). *Severe Incident Response Vehicle*. https://www.smartsunguide.com/pdf/SIRV.pdf

Florida Department of Transportation, District Six: Transportation Systems Management and Operations. (2020). *Annual report FY2019–2020*. https://sunguide.info/reports/annual-reports/District-Six-ITS-Annual-Report/2020-District-Six-TSMO-Annual-Report.pdf

Florida Department of Transportation Traffic Engineering and Operations Office. (2021). *SunGuide software*. Retrieved June 24, 2021, from https://www.fdot.gov/traffic/its/projects-arch/sunguide.shtm

Florida Highway Patrol wrecker operator system; penalties for operation outside of system. Fla. Stat. §321.051 (2020). http://www.leg.state.fl.us/statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=0300-0399/0321/Sections/0321.051.html

Florida's Turnpike Enterprise. (n.d.). *STARR*. Retrieved April 8, 2021, from https://floridasturnpike.com/traveler-resources/safety-and-assistance/starr/

The Geoplan Center. (2021). *Signal Four Analytics.* https://signal4analytics.com

Georgia Traffic Incident Management Enhancement Task Force. (2020). *Towing & recovery incentive program of Georgia: TRIP program specifications*. http://timetaskforce.com/wp-content/uploads/2020/01/TRIP_specs_April2020_final.pdf

Glover, B. (2021). *2021 Urban Mobility Report: Appendix C – Value of Delay Time for Use in Mobility Monitoring Efforts*. Texas A&M Transportation Institute. https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2021-appx-c.pdf.

Goodall, N. & Lee, E. (2019). Comparison of Waze crash and disabled vehicle records with video ground truth. *Transportation Research Interdisciplinary Perspectives*, *1*, Article 100019. https://doi.org/10.1016/j.trip.2019.100019

Guin, A., Porter, C., Smith, B., & Holmes, C. (2007). Benefits analysis for incident management program integrated with intelligent transportation systems operations: case study. *Transportation Research Record: Journal of the Transportation Research Board*, *2000*(1), 78–87. https://doi.org/10.3141/2000-10

Hamlin, C., Fries, R., Chowdhury, M., Ma, Y., & Ozbay, K. (2007). *Incident "quick clearance" legislation: Will it effectively reduce congestion?* [Paper presentation]. Transportation Research Board 86th Annual Meeting, Washington, D.C., United States.

Hathaway, E. (2012). *Tow Truck Response Strategy Evaluation*. Kittelson & Associates. https://transops.s3.amazonaws.com/uploaded_files/tow_truck_response_0.pdf.

I-95 Corridor Coalition. (2007). *I-95 Corridor Coalition coordinated incident management: Toolkit for quick clearance*. https://www.dvrpc.org/operations/incidentmanagement/pdf/2009-02_I-95CCToolkitQuickClearance.pdf

Indiana Department of Transportation. (n.d.). *Hoosier Helpers*. Retrieved April 5, 2021, from https://www.in.gov/indot/2408.htm

Khalilzadeh, Z. (2020). *Benefit-cost analysis of the Iowa Department of Transportation's safety service patrol program* [Master's thesis, Iowa State University]. Iowa State University Capstones, Theses, and Dissertations. https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1630&context=creativecomponents

Kinney, S. (2020). *Evaluating data to review Open Roads Policy*. Talking TIM Webinar Series: January 2020. https://transops.s3.amazonaws.com/uploaded_files/Evaluating%20Data%20to%20Review%20Open%20Roads%20Policy_Kinney_FDOT.pdf

Larson, K. (2020, December). Incident response unit assists 10,000-plus traffic incidents in first year. *The Inside Lane*, *4*(12), 4. https://apps.azdot.gov/files/inside_lane/2020-12-insidelane.pdf

Latoski, S., Pal, P., & Sinha, K. (1998). *A cost-effectiveness evaluation of the Hoosier Helper freeway service patrol* (Report No. FHWA/IN/JTRP-97/9). Indiana Department of Transportation.

Lin, P., Fabregas, A., Chen, H., Zhou, H., & Wang, Q. (2012). *Review and update of Road Ranger cost benefit analysis*. Florida Department of Transportation. https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/traffic/traf_incident/rrangers/pdf/bdk84-977-15-final-report-2012.pdf?sfvrsn=71f0ae34_0

Lomax, T., & Stein, R. (2014). *SafeClear performance report 2014*. https://www.houstontx.gov/council/committees/pshs/20150728/2014safeclear.pdf

Ma, J., Lochrane, T., & Jodoin, P. (2016). Traffic incident management programs and benefit-cost analysis. *ITE Journal*, *86*(5), 30–36.

Margiotta, R., Dowling, R., & Paracha, J. (2012). *Analysis, modeling, and simulation for traffic incident management applications* (Report No. FHWA-HOP-12-045). Federal Highway Administration. https://ops.fhwa.dot.gov/publications/fhwahop12045/fhwahop12045.pdf

Maryland Department of Transportation Coordinated Highways Action Response Team. (n.d.). *CHART traffic incident management*. Retrieved April 9, 2021, from https://chart.maryland.gov/about/incident_management.asp

Mauch, M., & Skabardonis, A. (2016). *California's freeway service patrol program: FSP beat evaluation model; methodology and parameter estimation (FY 2014-15)* (Report No. UCB-ITS-RR-2016-01). California Department of Transportation. https://escholarship.org/content/qt90r29164/qt90r29164.pdf

McCombs, J., Al-Deek, H., Sandt, A., Carrick, G., & Uddin, N. (2022). Analyzing Disabled Vehicle Incident Durations and Crash Response to Identify Service Patrol Expansions and Reduce the Need for Law Enforcement Involvement. *Transportation Research Record*: *Journal of the Transportation Research Board*. https://doi.org/10.1177/03611981221082583.

Minnesota Department of Transportation. (2013). *FIRST program 2011 summary report*. https://www.dot.state.mn.us/rtmc/reports/first/2011FIRSTannualreport.pdf

National Safety Council. (2021). *Guide to Calculating Costs*. https://injuryfacts.nsc.org/all-injuries/costs/guide-to-calculating-costs/data-details/

Nee, J., & Hallenbeck, M. (2003). *Evaluation of the instant tow dispatch pilot program in the Tacoma area* (Report No. WA-RD 518.2). Washington State Department of Transportation. https://www.wsdot.wa.gov/research/reports/fullreports/518.2.pdf

North Florida Regional Transportation Management Center. (n.d.). *Incident management*. Retrieved May 10, 2022, from https://northeastfloridatraffic.com/incident-management/.

Operation of vehicles and actions of pedestrians on approach of an authorized emergency, sanitation, or utility service vehicle. Fla. Stat. §316.126 (2020). http://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&URL=0300-0399/0316/Sections/0316.126.html

PBSJ & Serco. (2011). *Evaluation of the Towing and Recovery Incentive Program (TRIP)* (Report No. NAV01-203). Georgia Department of Transportation. https://transops.s3.amazonaws.com/uploaded_files/GADOT-NAV01-203-Evaluation-of-the-Towing-and-Recovery-Incentive-Program-%28TRIP%29.pdf

Pecheux, K., Shah., V., & O'Donnell, C. (2016). *Making the business case for traffic incident management* (Report No. FHWA-HOP-16-084). Federal Highway Administration. https://ops.fhwa.dot.gov/publications/fhwahop16084/fhwahop16084.pdf

Schrank, D., Eisele, B., & Lomax, T. (2019). *2019 urban mobility report*. Texas A&M Transportation Institute. https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2019.pdf

Skabardonis, A., Noeimi, H., Petty, K., Rydzewski, D., Varaiya, P., & Al-Deek, H. (1995). *Freeway service patrol evaluation* (Report No. UCB-ITS-PRR-95-5). University of California, Berkeley, California Partners for Advanced Transportation Technology. https://escholarship.org/uc/item/36r1t2m2

Skabardonis, A., Petty, K., Varaiya, P., & Bertini, R. (1998). *Evaluation of the freeway service patrol (FSP) in Los Angeles* (Report No. UCB-ITS-PRR-98-31). University of California, Berkeley, California Partners for Advanced Transportation Technology. https://escholarship.org/uc/item/3920p806

Souleyrette, R., Chen, M., Zang, X., Green, E., & Sagar, S. (2018). *Improving the quality of traffic records for traffic incident management* (Report No. KTC-18-22/SPR18-567-1F). Kentucky Transportation Cabinet. https://doi.org/10.13023/ktc.rr.2018.22

Spicer, R., Bahouth, G., Vahabaghaie, A., & Drayer, R. (2021). Frequency and cost of crashes, fatalities, and injuries involving disabled vehicles. *Accident Analysis & Prevention, 152*, Article 105974. https://doi.org/10.1016/j.aap.2021.105974

State Farm Assist Patrol. (n.d.). *About Assist Patrol*. Retrieved April 5, 2021, from https://www.assistpatrol.com/about

Sun, C., Chilukuri, V., Ryan, T., & Trueblood, M. (2010). *Evaluation of freeway Motorist Assist program* (Report No. OR10-018). Missouri Department of Transportation. https://spexternal.modot.mo.gov/sites/cm/CORDT/or10018.pdf

Transportation Research Board. (2016). *Highway Capacity Manual, 6th Edition: A Guide for Multimodal Mobility Analysis*. National Academies of Science, Engineering, and Medicine.

Wang, J., & Cicchino, J. (2020). Fatal pedestrian crashes on interstates and other freeways in the United States. *Journal of Safety Research*, *74*, 1–7. https://doi.org/10.1016/j.jsr.2020.04.009

Waze. (n.d.). *About us*. Retrieved October 28, 2021, from https://www.waze.com/about

Zhang, X., Souleyrette, R., Wang, A., Ross, P., Green, E., & Chen, M. (2020). *Traffic incident management dashboard* (Report No. KTC-20-23/SPR 20-584-1F). Kentucky Transportation Cabinet. https://doi.org/10.13023/ktc.rr.2020.23

Appendix A: Disabled and Abandoned Vehicle Survey

The University of Central Florida (UCF), in conjunction with the Florida Department of Transportation (FDOT) and Florida's Turnpike Enterprise (FTE), is researching the impacts of disabled and abandoned vehicles on traffic safety and operations. Part of this research involves surveying agencies across the United States regarding the frequency, characteristics, and handling of disabled and abandoned vehicles on limited access facilities in their jurisdictions. The results of this survey will help FDOT and FTE understand the current practices used to handle disabled vehicle and abandoned vehicle events. This survey will ask about the frequency and characteristics of these events in your jurisdiction and how your agency responds to these events. If you have any questions about this survey, please contact Haitham Al-Deek, Ph.D., P.E. (the UCF Principal Investigator for this project) at Haitham.Al-Deek@ucf.edu. For any general questions about this research project, please contact Eric Gordin (the FTE Project Manager for this project) at Eric.Gordin@dot.state.fl.us, or Jeff Frost (the FDOT Project Co-Manager for this project) at Jeff.Frost@dot.state.fl.us. After completion of the research project, published results stemming from this survey can be shared with any interested agencies who participate in this survey.

(Unless it is stated in the programming instructions that participants can select multiple responses, only one response should be able to be selected for each multiple-choice question)

Would you like to participate in this survey?
- ○ Yes
- ○ No **(If selected, End Survey)**

Starting Questions

1. Please provide the following information **(Free response for each of the six items in this question). (All items below must be answered before proceeding to the next question)**:
   Name:
   Job Title:
   Agency Name:
   State:
   Email:
   Phone:

2. Which of the following options best describes the agency you work for?
   - State Department of Transportation (DOT) **(Proceed to Section 1)**
   - Turnpike/toll road authority **(Proceed to Section 1)**
   - State law enforcement **(Proceed to Section 2)**
   - Local law enforcement **(Proceed to Section 2)**
   - Safety service patrol **(Proceed to Section 3)**

Section 1: DOT and Turnpike/Toll Road Authority Questions

This section number and title should not appear onscreen for the survey participant.

The following paragraph should stay on screen during Questions 3-6.

The definitions of disabled vehicles and abandoned vehicles can vary from one jurisdiction to another. An example definition of a disabled vehicle is "a vehicle that is unable to operate under its own motive power or is unsafe to operate". An example definition of an abandoned vehicle is "a vehicle that is unattended, unaccompanied, or unoccupied on a public right-of-way for any amount of time". The following questions will ask about how well these definitions apply to limited access facilities in your jurisdiction.

3. Is the above definition of a **disabled vehicle** similar to how your jurisdiction formally defines a disabled vehicle?
    - Yes **(If selected, proceed to Question 5)**
    - No, my jurisdiction defines a disabled vehicle differently. **(If selected, proceed to Question 4)**

4. Please describe how your jurisdiction defines a disabled vehicle.

    (Text box for free response)

5. Is the above definition of an **abandoned vehicle** similar to how your jurisdiction formally defines an abandoned vehicle?
    - Yes **(If selected, proceed to Question 7)**
    - No, my jurisdiction defines an abandoned vehicle differently. **(If selected proceed to Question 6)**

6. Please describe how your jurisdiction defines an abandoned vehicle.

    (Text box for free response)

7. In centerline miles, how large is the limited access roadway network your agency maintains?
    - Less than 50 miles
    - 50 to 100 miles
    - 101 to 200 miles
    - 201 to 500 miles
    - 501 to 1000 miles
    - More than 1000 miles

8. How many **disabled vehicle** events typically occur on limited access facilities within your agency's jurisdiction **per day**?
   - Less than 10 disabled vehicle events
   - 10 to 50 disabled vehicle events
   - 51 to 100 disabled vehicle events
   - 101 to 250 disabled vehicle events
   - 251 to 500 disabled vehicle events
   - More than 500 disabled vehicle events

9. How many **abandoned vehicle** events typically occur on limited access facilities within your agency's jurisdiction **per day**?
   - Less than 1 abandoned vehicle event
   - 1 to 5 abandoned vehicle events
   - 6 to 10 abandoned vehicle events
   - 11 to 25 abandoned vehicle events
   - 26 to 50 abandoned vehicle events
   - More than 50 abandoned vehicle events

10. For each area type (urban, suburban, and rural), please rate how serious of a problem disabled vehicle and abandoned vehicle events are in your jurisdiction.
   (For this question, the survey participant should be able to select only one value from 1 to 5 for each of the three categories shown in the table: Urban, Suburban, and Rural.)

	Urban	Suburban	Rural
1 – Not a problem at all			
2			
3			
4			
5 – Very serious problem			

11. At what priority level does your agency place disabled vehicle and abandoned vehicle event response for events that are not lane-blocking or immediate safety hazards?
   - 1 – Not a priority
   - 2
   - 3
   - 4
   - 5 – Essential priority

12. What time of day do disabled vehicle and abandoned vehicle events most often occur in your jurisdiction?
    - 12:00 AM – 5:59 AM
    - 6:00 AM – 11:59 AM
    - 12:00 PM – 5:59 PM
    - 6:00 PM – 11:59 PM

13. When a **disabled vehicle** event occurs, how does your agency notify other drivers of the event? (Select all that apply) **Participant can select multiple responses, unless the last option is selected.**
    - ❒ Highway message signs (VMS, CMS, DMS)
    - ❒ Highway advisory radio (HAR)
    - ❒ Traveler information systems (511 or phone app developed for your state or jurisdiction)
    - ❒ Navigation providers (Waze, Google Maps, GPS units, etc.)
    - ❒ Posting to social media (Facebook, Twitter, etc.)
    - ❒ Other (please specify) **(Text box for free response)**
    - ❒ My agency does not notify other drivers of disabled vehicle events. **(If this response is selected, no other responses to this question can be selected.)**

14. Once a **disabled vehicle** is reported **in the travel lane(s)**, approximately how long does it take (on average) for it to be removed from the travel lane(s) to the shoulder?
    - Less than 15 minutes
    - 15 minutes to less than 30 minutes
    - 30 minutes to less than 45 minutes
    - 45 minutes to less than 1 hour
    - 1 hour to less than 2 hours
    - 2 hours or more

15. Once a **disabled vehicle** is reported **on the shoulder**, approximately how long does it take (on average) for it to be cleared (removed from the facility)?
    - Less than 30 minutes
    - 30 minutes to less than 1 hour
    - 1 hour to less than 2 hours
    - 2 hours to less than 4 hours
    - 4 hours or more

16. Once an **abandoned vehicle** is reported **on the shoulder**, approximately how long does it take (on average) for it to be cleared (removed from the facility)?
    - Less than 6 hours
    - 6 hours to less than 12 hours
    - 12 hours to less than 24 hours
    - 24 hours to less than 48 hours
    - 48 hours to less than 72 hours
    - 72 hours or more

17. Who can remove/tow a **disabled vehicle** that is **not blocking the travel lanes** off the facility? (Select all that apply) **Participant can select multiple responses.**
    - ❒ State DOT contracted vendor
    - ❒ Law enforcement
    - ❒ Private entity
    - ❒ Other (please specify) **(Text box for free response)**

18. Who can remove/tow an **abandoned vehicle** that is **not blocking the travel lanes** off the facility? (Select all that apply) **Participant can select multiple responses.**
    - ❒ State DOT contracted vendor
    - ❒ Law enforcement
    - ❒ Private entity
    - ❒ Other (please specify) **(Text box for free response)**

19. Do your state's statutes or laws define a minimum and/or maximum amount of time that an **abandoned vehicle** can be left on the shoulder or side of a roadway before it is towed? If yes, please provide these time limits and relevant laws/statutes.
    - Yes **(Text box for free response)**
    - No

20. What information sources does your agency use to obtain information (both current and historical) about disabled vehicle and abandoned vehicle events? (Select all that apply) **Participant can select multiple responses, unless the last option is selected.**
    - ❒ 911 calls/computer aided dispatch (CAD) data
    - ❒ Citation data
    - ❒ Crash reports
    - ❒ Secondary crash information
    - ❒ Traffic management center (TMC) reports
    - ❒ Crowdsourced data (such as Waze)
    - ❒ Safety service patrols
    - ❒ Other (please specify) **(Text box for free response)**
    - ❒ My agency does not obtain information about these events. **(If this response is selected, no other responses to this question can be selected. If this response is selected, proceed to Question 22.)**

21. What kind of data are available about disabled vehicle and abandoned vehicle events in your jurisdiction? (Select all that apply) **Participant can select multiple responses.**
    - ❒ Event general location (such as roadway)
    - ❒ Event detailed location (such as lane or shoulder location)
    - ❒ Event duration
    - ❒ Event cause
    - ❒ Severity level (for crashes)
    - ❒ Secondary crashes involving disabled or abandoned vehicles
    - ❒ Traffic impacts (lane closures, delays)
    - ❒ Property damage costs
    - ❒ Towing costs
    - ❒ Response details (responding agency, response time, removal time, etc.)
    - ❒ Other (please specify) **(Text box for free response)**

22. What are your agency's existing programs or procedures regarding the removal/clearance of disabled vehicles and abandoned vehicles on limited access facilities? Please do not include information about pilot programs or response plans still in development.
    (Text box for free response)

23. Has your agency performed any evaluations of the procedures discussed in the previous question?
    - ○ Yes **(If selected, proceed to Question 24)**
    - ○ No **(If selected, proceed to Question 25)**

24. Please describe the evaluations performed and the results of these evaluations.
    (Text box for free response)

25. How can your agency's existing programs or procedures be improved?
    (Text box for free response)

26. Is your agency piloting or utilizing any new or innovative methods for responding to disabled vehicle or abandoned vehicle events?
    - Yes **(If selected, proceed to Question 27)**
    - No **(If selected, proceed to Question 32)**
    - Unknown **(If selected, proceed to Question 32)**

27. Please describe these new or innovative methods your agency is piloting or utilizing.
    (Text box for free response)

28. When did your agency first start piloting or utilizing these innovative methods for disabled vehicle or abandoned vehicle event response?
    - Less than 6 months ago
    - 6 months – 1 year ago
    - More than 1 year ago

29. Please describe any evaluations performed on these innovative methods and the results of these evaluations.
    (Text box for free response)

30. Has your agency witnessed any improvements in safety and/or operations after implementing these new or innovative methods?
    - Yes **(If selected, proceed to Question 31)**
    - No **(If selected, proceed to Question 32)**
    - Unknown **(If selected, proceed to Question 32)**

31. Please specify what improvements your agency has witnessed after implementing these innovative methods.
    (Text box for free response)

32. If your agency has any published research reports related to disabled vehicle and abandoned vehicle events, removal procedures, or their evaluations, please provide their details below (titles, authors, links, etc.).
    (Text box for free response)

End of Section 1. Proceed to Section 4.

Section 2: State and Local Law Enforcement Questions

This section number and title should not appear onscreen for the survey participant.

The following paragraph should stay on screen during Questions 33-36.

The definitions of disabled vehicles and abandoned vehicles can vary from one jurisdiction to another. An example definition of a disabled vehicle is “a vehicle that is unable to operate under its own motive power or is unsafe to operate”. An example definition of an abandoned vehicle is “a vehicle that is unattended, unaccompanied, or unoccupied on a public right-of-way for any amount of time”. The following questions will ask about how well these definitions apply to limited access facilities in your jurisdiction.

33. Is the above definition of a **disabled vehicle** similar to how your agency formally defines a disabled vehicle?
    - Yes. **(If selected, proceed to Question 35)**
    - No, my agency defines a disabled vehicle differently. **(If selected, proceed to Question 34)**

34. Please describe how your agency defines a disabled vehicle. If applicable, please cite any specific statutes or laws that define a disabled vehicle.

    (Text box for free response)

35. Is the above definition of an **abandoned vehicle** similar to how your agency formally defines an abandoned vehicle?
    - Yes. **(If selected, proceed to Question 37)**
    - No, my agency defines an abandoned vehicle differently. **(If selected, proceed to Question 36)**

36. Please describe how your agency defines an abandoned vehicle. If applicable, please cite any specific statutes or laws that define an abandoned vehicle.

    (Text box for free response)

37. In centerline miles, how large is the limited access roadway network your agency patrols?
    - Less than 50 miles
    - 50 to 100 miles
    - 101 to 200 miles
    - 201 to 500 miles
    - 501 to 1000 miles
    - More than 1000 miles

38. How frequently do **disabled vehicle** events typically occur on limited access facilities within your agency's patrolling area **per day**?
    - Less than 10 disabled vehicle events
    - 10 to 50 disabled vehicle events
    - 51 to 100 disabled vehicle events
    - 101 to 250 disabled vehicle events
    - 251 to 500 disabled vehicle events
    - More than 500 disabled vehicle events

39. How frequently do **abandoned vehicle** events typically occur on limited access facilities within your agency's patrolling area **per day**?
    - Less than 1 abandoned vehicle event
    - 1 to 5 abandoned vehicle events
    - 6 to 10 abandoned vehicle events
    - 11 to 25 abandoned vehicle events
    - 26 to 50 abandoned vehicle events
    - More than 50 abandoned vehicle events

40. How serious of a problem are disabled vehicle and abandoned vehicle events in your agency's patrolling area?
    - 1 – Not a problem at all
    - 2
    - 3
    - 4
    - 5 – Very serious problem

41. At what priority level does your agency place disabled vehicle and abandoned vehicle event response for events that are not lane-blocking or immediate safety hazards?
    - 1 – Not a priority
    - 2
    - 3
    - 4
    - 5 – Essential priority

42. Once a **disabled vehicle** is reported **in the travel lane(s)**, approximately how long does it take (on average) for it to be removed from the travel lane(s) to the shoulder?
    - Less than 15 minutes
    - 15 minutes to less than 30 minutes
    - 30 minutes to less than 45 minutes
    - 45 minutes to less than 1 hour
    - 1 hour to less than 2 hours
    - 2 hours or more

43. Once a **disabled vehicle** is reported **on the shoulder**, approximately how long does it take (on average) for it to be cleared (removed from the facility)?
    - Less than 30 minutes
    - 30 minutes to less than 1 hour
    - 1 hour to less than 2 hours
    - 2 hours to less than 4 hours
    - 4 hours or more

44. Once an **abandoned vehicle** is reported **on the shoulder**, approximately how long does it take (on average) for it to be cleared (removed from the facility)?
    - Less than 6 hours
    - 6 hours to less than 12 hours
    - 12 hours to less than 24 hours
    - 24 hours to less than 48 hours
    - 48 hours to less than 72 hours
    - 72 hours or more

45. Does your agency have the authority to remove/tow **disabled vehicles** off the facility?
    - Yes
    - No

46. Does your agency have the authority to remove/tow **abandoned vehicles** off the facility?
    - Yes
    - No

47. Do your state's statutes or laws define a minimum and/or maximum amount of time that an **abandoned vehicle** can be left on the shoulder or side of a roadway before it is towed? If yes, please provide these time limits and relevant laws/statutes.
    - Yes **(Text box for free response)**
    - No

48. Are vehicles in your agency's fleet equipped with push bumpers that could be used to move disabled vehicles and abandoned vehicles out of the travel lanes and onto the shoulder? If so, is your agency allowed to use these push bumpers to move disabled or abandoned vehicles out of the travel lanes and onto the shoulder?
    - Vehicles in my agency's fleet are equipped with push bumpers and my agency is allowed to use push bumpers on disabled or abandoned vehicles.
    - Vehicles in my agency's fleet are equipped with push bumpers, but my agency is **not** allowed to use push bumpers on disabled or abandoned vehicles.
    - Vehicles in my agency's fleet are **not** equipped with push bumpers.

49. Are officers in your agency trained to use a non-traffic side approach when responding to disabled vehicle or abandoned vehicle events?
    - Yes
    - No

50. Have any officers in your agency been struck while responding to a **disabled vehicle**?
    - Yes
    - No

51. How concerned are officers in your agency for their safety when responding to **disabled vehicles**?
    - Not concerned at all
    - Slightly concerned
    - Somewhat concerned
    - Moderately concerned
    - Very concerned

52. What are common reasons for a vehicle to become disabled or abandoned? Rank the below options from most common (1) to least common (4).
    For this question, participants should be able to rank each response with a value of 1, 2, 3, or 4.
    - Vehicle was involved in a crash.
    - Mechanical issue with the vehicle (dead car battery, flat tires, out of gas, high temperatures, etc.), but vehicle was not involved in a crash.
    - Extreme weather-related events (heavy snowfall, mudslides, flooding, etc.).
    - Driver condition (fatigue, passed out, DUI, etc.).

53. When dealing with the removal of an **abandoned vehicle**, does your agency provide any leniency to the driver/vehicle owner, such as providing additional time to remove the vehicle?
    - Yes
    - No

54. Based on your experience working with disabled vehicle and abandoned vehicle events, do you have any suggestions to improve the response process (including towing/removal)?
    (Text box for free response)

End of Section 2. Proceed to Section 4.

Section 3: Safety Service Patrol Questions

This section number and title should not appear onscreen for the survey participant.

55. In miles, how large is the limited access roadway network your agency services?
    - Less than 50 miles
    - 50 to 100 miles
    - 101 to 200 miles
    - 201 to 500 miles
    - 501 to 1000 miles
    - More than 1000 miles

56. How frequently do **disabled vehicle** events typically occur on limited access facilities within your agency's service area **per day**?
    - Less than 10 disabled vehicle events
    - 10 to 50 disabled vehicle events
    - 51 to 100 disabled vehicle events
    - 101 to 250 disabled vehicle events
    - 251 to 500 disabled vehicle events
    - More than 500 disabled vehicle events

57. How frequently do **abandoned vehicle** events typically occur on limited access facilities within your agency's service area **per day**?
    - Less than 1 abandoned vehicle event
    - 1 to 5 abandoned vehicle events
    - 6 to 10 abandoned vehicle events
    - 11 to 25 abandoned vehicle events
    - 26 to 50 abandoned vehicle events
    - More than 50 abandoned vehicle events

58. What are common reasons for a vehicle to become disabled or abandoned? Rank the below options from most common (1) to least common (4).

    For this question, participants should be able to rank each response with a value of 1, 2, 3, or 4.

    - Vehicle was involved in a crash.
    - Mechanical issue with the vehicle (dead car battery, flat tires, out of gas, high temperatures, etc.), but vehicle was not involved in a crash.
    - Extreme weather-related events (heavy snowfall, mudslides, flooding, etc.).
    - Driver condition (fatigue, passed out, etc.).

59. How serious of a problem are disabled vehicle and abandoned vehicle events in your service area?
    - 1 – Not a problem at all
    - 2
    - 3
    - 4
    - 5 – Very serious problem

60. How many vehicles in your service patrol's fleet have the capability to tow a disabled vehicle?
    - None of the vehicles **(If selected, proceed to Question 62)**
    - Less than half of the vehicles
    - Half of the vehicles
    - Majority of the vehicles
    - All the vehicles

61. Are responders in your agency allowed to tow a **disabled vehicle**? If yes, where can they move it to?
    - Yes, fully off the facility.
    - Yes, onto the shoulder or side slope of the facility.
    - Yes, to a safe area (such as a rest area or service plaza).
    - No, they are not allowed to tow a disabled vehicle.

62. Are vehicles in your agency's fleet equipped with push bumpers that could be used to move disabled vehicles and abandoned vehicles out of the travel lanes and onto the shoulder? If so, is your agency allowed to use these push bumpers to move disabled or abandoned vehicles out of the travel lanes and onto the shoulder?
    - Vehicles in my agency's fleet are equipped with push bumpers and my agency is allowed to use push bumpers on disabled or abandoned vehicles.
    - Vehicles in my agency's fleet are equipped with push bumpers, but my agency is **not** allowed to use push bumpers on disabled or abandoned vehicles.
    - Vehicles in my agency's fleet are **not** equipped with push bumpers.

63. Are service patrol responders in your agency trained to use a non-traffic side approach when responding to disabled vehicle or abandoned vehicle events?
    - Yes
    - No

64. Have any responders in your agency been struck while responding to a **disabled vehicle**?
    - Yes
    - No

65. How concerned are service patrol responders in your agency for their safety when responding to disabled vehicles?
    - Not concerned at all
    - Slightly concerned
    - Somewhat concerned
    - Moderately concerned
    - Very concerned

66. Do you have any suggestions to improve the response process (including towing/removal) for disabled or abandoned vehicles?
    (Text box for free response)

End of Section 3. Proceed to Section 4.

Section 4: Finishing Questions

This section number and title should not appear onscreen for the survey participant.

67. Please leave any additional comments or information you would like to share about disabled vehicle and abandoned vehicle events on limited access facilities.

    (Text box for free response)

68. May we contact you for a possible follow-up online interview based on your responses? Answering "Yes" to this question does not mean that you definitely will be contacted for an interview.
    - Yes
    - No

Thank you for completing this survey. Your responses will help FDOT better understand the characteristics of disabled vehicle and abandoned vehicle events and improve the handling of these events.

End Survey

Appendix B: Summary of Survey Results

Starting Questions

Table B-1: Q2 Summary of Responses

Which of the following options best describes the agency you work for?

Response	Total Frequency	Total Percentage
State Department of Transportation (DOT)	27	45%
Turnpike/toll road authority	4	7%
State law enforcement	12	20%
Local law enforcement	0	0%
Safety service patrol	17	28%
Total	**60**	**100%**

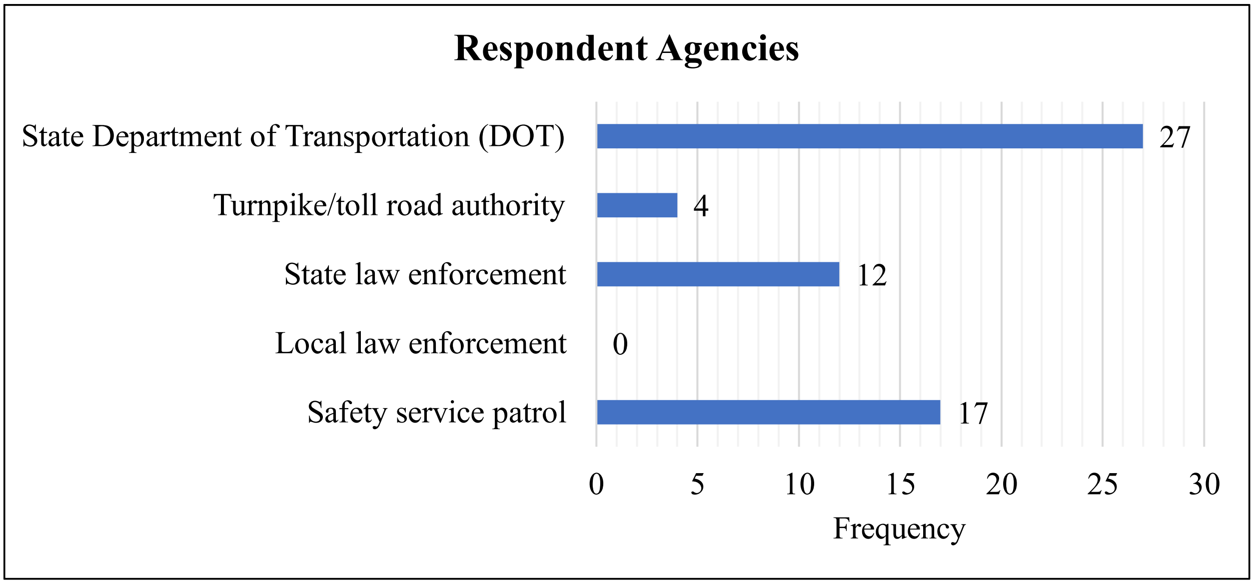

Figure B-1: Respondent Agencies

Section 1: DOT and Turnpike/Toll Road Authority Questions

The definitions of disabled vehicles and abandoned vehicles can vary from one jurisdiction to another. An example definition of a disabled vehicle is "a vehicle that is unable to operate under its own motive power or is unsafe to operate". An example definition of an abandoned vehicle is "a vehicle that is unattended, unaccompanied, or unoccupied on a public right-of-way for any amount of time". The following questions will ask about how well these definitions apply to limited access facilities in your jurisdiction.

Table B-2: Q3 Summary of Responses

Is the above definition of a disabled vehicle similar to how your jurisdiction formally defines a disabled vehicle?

Response	Total Frequency	Total Percentage
Yes	31	100%
No	0	0%
Total	**31**	**100%**

Table B-3: Q5 Summary of Responses

Is the above definition of an abandoned vehicle similar to how your jurisdiction formally defines an abandoned vehicle?

Response	Total Frequency	Total Percentage
Yes	31	100%
No	0	0%
Total	**31**	**100%**

Table B-4: Q7 Summary of Responses

In centerline miles, how large is the limited access roadway network your agency maintains?

Response	Total Frequency	Total Percentage
Less than 50 miles	1	3%
50 to 100 miles	2	6%
101 to 200 miles	1	3%
201 to 500 miles	4	13%
501 to 1000 miles	3	10%
More than 1000 miles	20	65%
Total	**31**	**100%**

Table B-5: Q8 Summary of Responses

How many disabled vehicle events typically occur on limited access facilities within your agency's jurisdiction per day?

Response	Total Frequency	Total Percentage
Less than 10 disabled vehicle events	6	19%
10 to 50 disabled vehicle events	12	39%
51 to 100 disabled vehicle events	7	23%
101 to 250 disabled vehicle events	5	16%
251 to 500 disabled vehicle events	0	0%
More than 500 disabled vehicle events	1	3%
Total	**31**	**100%**

Table B-6: Q9 Summary of Responses

How many abandoned vehicle events typically occur on limited access facilities within your agency's jurisdiction per day?

Response	Total Frequency	Total Percentage
Less than 1 abandoned vehicle event	4	13%
1 to 5 abandoned vehicle events	6	19%
6 to 10 abandoned vehicle events	7	23%
11 to 25 abandoned vehicle events	10	32%
26 to 50 abandoned vehicle events	1	3%
More than 50 abandoned vehicle events	3	10%
Total	**31**	**100%**

Table B-7: Q10 Summary of Responses

For each area type (urban, suburban, and rural), please rate how serious of a problem disabled vehicle and abandoned vehicle events are in your jurisdiction.

	Urban		Suburban		Rural	
Response	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
1 – Not a problem at all	2	6%	7	23%	13	42%
2	7	23%	6	19%	9	29%
3	5	16%	12	39%	5	16%
4	10	32%	6	19%	3	10%
5 – Very serious problem	7	23%	0	0%	1	3%
Total	**31**	**100%**	**31**	**100%**	**31**	**100%**

Table B-8: Q11 Summary of Responses
At what priority level does your agency place disabled vehicle and abandoned vehicle event response for events that are not lane-blocking or immediate safety hazards?

Response	Total Frequency	Total Percentage
1 – Not a priority	5	16%
2	9	29%
3	10	32%
4	4	13%
5 – Essential priority	3	10%
Total	**31**	**100%**

Table B-9: Q12 Summary of Responses
What time of day do disabled vehicle and abandoned vehicle events most often occur in your jurisdiction?

Response	Total Frequency	Total Percentage
12:00 AM – 5:59 AM	7	23%
6:00 AM – 11:59 AM	10	32%
12:00 PM – 5:59 PM	14	45%
6:00 PM – 11:59 PM	0	0%
Total	**31**	**100%**

Table B-10: Q13 Summary of Responses

When a disabled vehicle event occurs, how does your agency notify other drivers of the event?

Response*	**Total Frequency**	**Total Percentage**†
Highway message signs (VMS, CMS, DMS)	14	45%
Highway advisory radio (HAR)	0	0%
Traveler information systems (511 or phone app developed for your state or jurisdiction)	16	52%
Navigation providers (Waze, Google Maps, GPS units, etc.)	8	26%
Posting to social media (Facebook, Twitter, etc.)	2	6%
Other	2	6%
My agency does not notify other drivers of disabled vehicle events.	9	29%

* Respondents could select more than one response.
† Percentage out of 31 respondents.

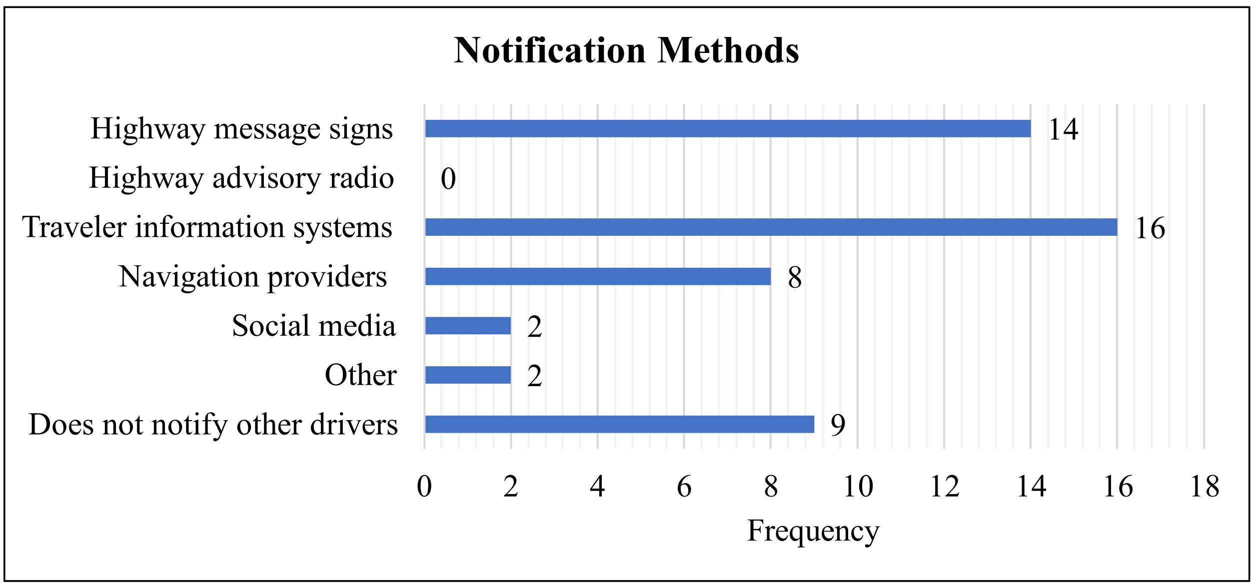

Figure B-2: Notification Methods

Table B-11: Q14 Summary of Responses

Once a disabled vehicle is reported in the travel lane(s), approximately how long does it take (on average) for it to be removed from the travel lane(s) to the shoulder?

Response	Total Frequency	Total Percentage
Less than 15 minutes	6	19%
15 minutes to less than 30 minutes	15	48%
30 minutes to less than 45 minutes	6	19%
45 minutes to less than 1 hour	1	3%
1 hour to less than 2 hours	2	6%
2 hours or more	1	3%
Total	**31**	**100%***

* Unrounded percentages sum to 100%.

Table B-12: Q15 Summary of Responses

Once a disabled vehicle is reported on the shoulder, approximately how long does it take (on average) for it to be cleared (removed from the facility)?

Response	Total Frequency	Total Percentage
Less than 30 minutes	5	16%
30 minutes to less than 1 hour	8	26%
1 hour to less than 2 hours	4	13%
2 hours to less than 4 hours	4	13%
4 hours or more	10	32%
Total	**31**	**100%**

Table B-13: Q16 Summary of Responses

Once an abandoned vehicle is reported on the shoulder, approximately how long does it take (on average) for it to be cleared (removed from the facility)?

Response	Total Frequency	Total Percentage
Less than 6 hours	4	13%
6 hours to less than 12 hours	1	3%
12 hours to less than 24 hours	4	13%
24 hours to less than 48 hours	11	35%
48 hours to less than 72 hours	9	29%
72 hours or more	2	6%
Total	**31**	**100%***

* Unrounded percentages sum to 100%.

Table B-14: Q17 Summary of Responses

Who can remove/tow a disabled vehicle that is not blocking the travel lanes off the facility?

Response*	Total Frequency	Total Percentage†
State DOT contracted vendor	11	35%
Law enforcement	27	87%
Private entity	17	55%
Other	4	13%

* Respondents could select more than one response.
† Percentage out of 31 respondents.

Table B-15: Q18 Summary of Responses

Who can remove/tow an abandoned vehicle that is not blocking the travel lanes off the facility?

Response*	Total Frequency	Total Percentage†
State DOT contracted vendor	9	29%
Law enforcement	27	87%
Private entity	13	42%
Other	3	10%

* Respondents could select more than one response.

† Percentage out of 31 respondents.

Table B-16: Q19 Summary of Responses

Do your state's statutes or laws define a minimum and/or maximum amount of time that an abandoned vehicle can be left on the shoulder or side of a roadway before it is towed?

Response	Total Frequency	Total Percentage
Yes	23	74%
No	8	26%
Total	**31**	**100%**

Table B-17: Q20 Summary of Responses

What information sources does your agency use to obtain information (both current and historical) about disabled vehicle and abandoned vehicle events?

Response*	**Total Frequency**	**Total Percentage†**
911 calls/computer aided dispatch (CAD) data	25	81%
Citation data	4	13%
Crash reports	11	35%
Secondary crash information	6	19%
Traffic management center (TMC) reports	25	81%
Crowdsourced data (such as Waze)	6	19%
Safety service patrols	21	68%
Other (please specify)	3	10%
My agency does not obtain information about these events.	2	6%

* Respondents could select more than one response.

† Percentage out of 31 respondents.

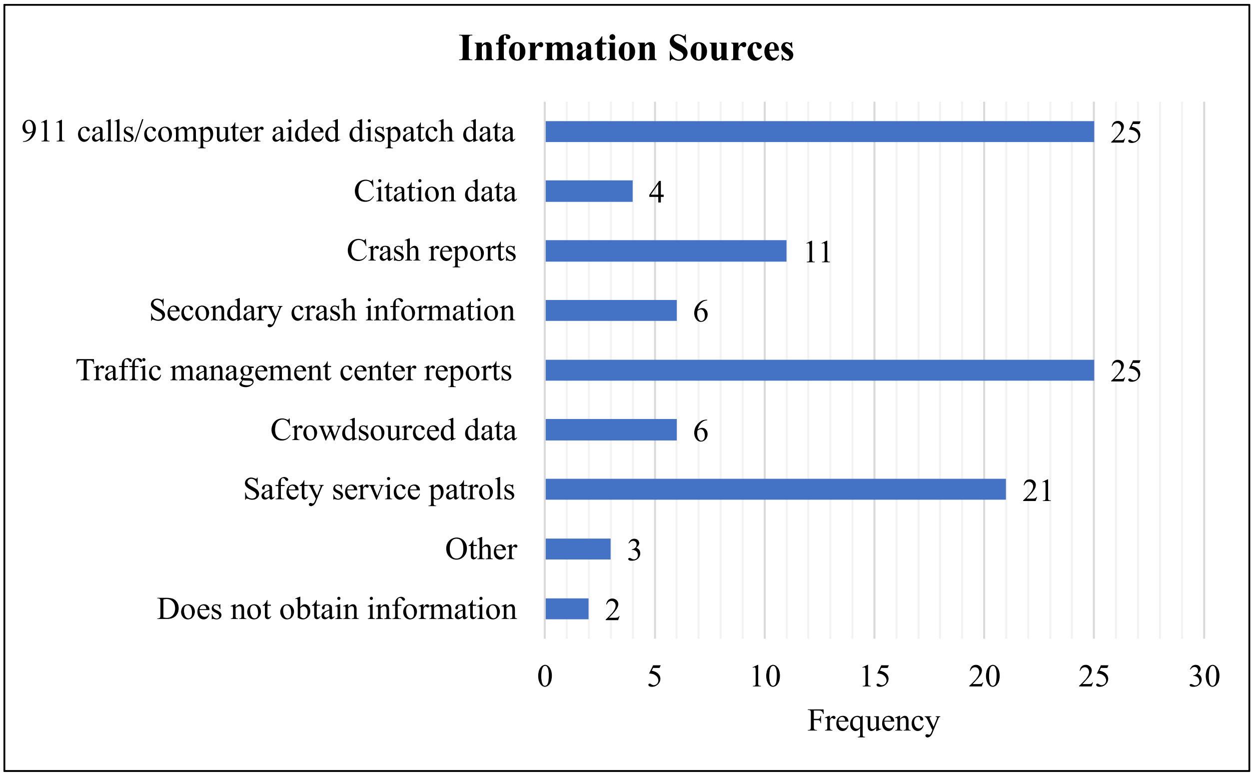

Figure B-3: Information Sources

Table B-18: Q21 Summary of Responses
What kind of data are available about disabled vehicle and abandoned vehicle events in your jurisdiction?

Response*	Total Frequency	Total Percentage†
Event general location (such as roadway)	21	72%
Event detailed location (such as lane or shoulder location)	21	72%
Event duration	16	55%
Event cause	10	34%
Severity level (for crashes)	13	45%
Secondary crashes involving disabled or abandoned vehicles	6	21%
Traffic impacts (lane closures, delays)	18	62%
Property damage costs	2	7%
Towing costs	0	0%
Response details (responding agency, response time, removal time, etc.)	13	45%
Other (please specify)	2	7%

* Respondents could select more than one response.
† Percentage out of 29 respondents.

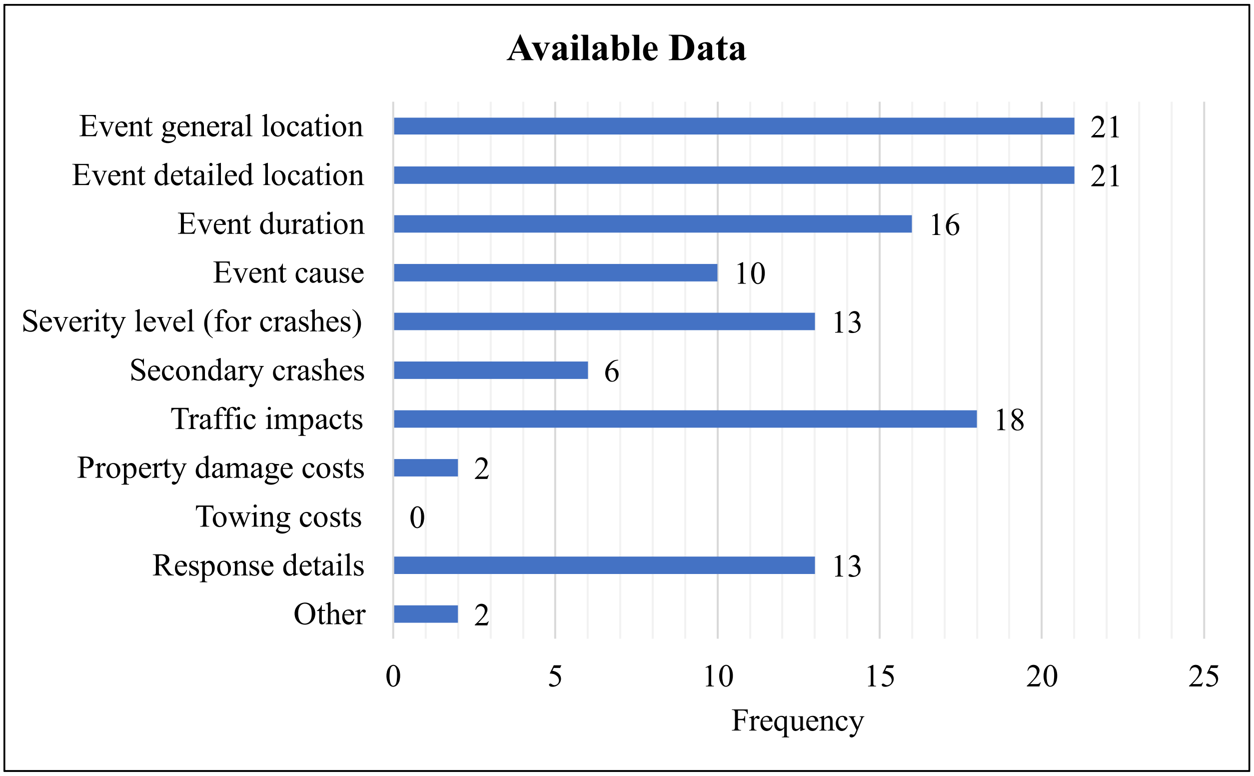

Figure B-4: Available Data

Table B-19: Q23 Summary of Responses

Has your agency performed any evaluations of the procedures discussed in the previous question?

Response	Total Frequency	Total Percentage
Yes	11	35%
No	20	65%
Total	**31**	**100%**

Table B-20: Q26 Summary of Responses
Is your agency piloting or utilizing any new or innovative methods for responding to disabled vehicle or abandoned vehicle events?

Response	Total Frequency	Total Percentage
Yes	6	19%
No	22	71%
Unknown	3	10%
Total	**31**	**100%**

Table B-21: Q28 Summary of Responses
When did your agency first start piloting or utilizing these innovative methods for disabled vehicle or abandoned vehicle event response?

Response	Total Frequency	Total Percentage
Less than 6 months ago	0	0%
6 months – 1 year ago	1	17%
More than 1 year ago	5	83%
Total	**6**	**100%**

Table B-22: Q30 Summary of Responses
Has your agency witnessed any improvements in safety and/or operations after implementing these new or innovative methods?

Response	Total Frequency	Total Percentage
Yes	4	67%
No	0	0%
Unknown	2	33%
Total	**6**	**100%**

Section 2: State and Local Law Enforcement Questions

The definitions of disabled vehicles and abandoned vehicles can vary from one jurisdiction to another. An example definition of a disabled vehicle is "a vehicle that is unable to operate under its own motive power or is unsafe to operate". An example definition of an abandoned vehicle is "a vehicle that is unattended, unaccompanied, or unoccupied on a public right-of-way for any amount of time". The following questions will ask about how well these definitions apply to limited access facilities in your jurisdiction.

Table B-23: Q33 Summary of Responses

Is the above definition of a disabled vehicle similar to how your jurisdiction formally defines a disabled vehicle?

Response	Total Frequency	Total Percentage
Yes	12	100%
No	0	0%
Total	**12**	**100%**

Table B-24: Q35 Summary of Responses

Is the above definition of an abandoned vehicle similar to how your jurisdiction formally defines an abandoned vehicle?

Response	Total Frequency	Total Percentage
Yes	12	100%
No	0	0%
Total	**12**	**100%**

Table B-25: Q37 Summary of Responses
In centerline miles, how large is the limited access roadway network your agency patrols?

Response	Total Frequency	Total Percentage
Less than 50 miles	0	0%
50 to 100 miles	0	0%
101 to 200 miles	0	0%
201 to 500 miles	1	8%
501 to 1000 miles	4	33%
More than 1000 miles	7	58%
Total	**12**	**100%***

* Unrounded percentages sum to 100%.

Table B-26: Q38 Summary of Responses
How frequently do disabled vehicle events typically occur on limited access facilities within your agency's patrolling area per day?

Response	Total Frequency	Total Percentage
Less than 10 disabled vehicle events	2	17%
10 to 50 disabled vehicle events	6	50%
51 to 100 disabled vehicle events	2	17%
101 to 250 disabled vehicle events	1	8%
251 to 500 disabled vehicle events	0	0%
More than 500 disabled vehicle events	1	8%
Total	**12**	**100%**

Table B-27: Q39 Summary of Responses

How frequently do abandoned vehicle events typically occur on limited access facilities within your agency's patrolling area per day?

Response	Total Frequency	Total Percentage
Less than 1 abandoned vehicle event	0	0%
1 to 5 abandoned vehicle events	4	33%
6 to 10 abandoned vehicle events	4	33%
11 to 25 abandoned vehicle events	0	0%
26 to 50 abandoned vehicle events	2	17%
More than 50 abandoned vehicle events	2	17%
Total	**12**	**100%**

Table B-28: Q40 Summary of Responses

How serious of a problem are disabled vehicle and abandoned vehicle events in your agency's patrolling area?

Response	Total Frequency	Total Percentage
1 – Not a problem at all	0	0%
2	4	33%
3	6	50%
4	1	8%
5 – Very serious problem	1	8%
Total	**12**	**100%***

* Unrounded percentages sum to 100%.

Table B-29: Q41 Summary of Responses

At what priority level does your agency place disabled vehicle and abandoned vehicle event response for events that are not lane-blocking or immediate safety hazards?

Response	Total Frequency	Total Percentage
1 – Not a priority	1	8%
2	5	42%
3	5	42%
4	0	0%
5 – Essential priority	1	8%
Total	**12**	**100%**

Table B-30: Q42 Summary of Responses

Once a disabled vehicle is reported in the travel lane(s), approximately how long does it take (on average) for it to be removed from the travel lane(s) to the shoulder?

Response	Total Frequency	Total Percentage
Less than 15 minutes	3	25%
15 minutes to less than 30 minutes	4	33%
30 minutes to less than 45 minutes	4	33%
45 minutes to less than 1 hour	1	8%
1 hour to less than 2 hours	0	0%
2 hours or more	0	0%
Total	**12**	**100%***

* Unrounded percentages sum to 100%.

Table B-31: Q43 Summary of Responses

Once a disabled vehicle is reported on the shoulder, approximately how long does it take (on average) for it to be cleared (removed from the facility)?

Response	Total Frequency	Total Percentage
Less than 30 minutes	0	0%
30 minutes to less than 1 hour	4	33%
1 hour to less than 2 hours	2	17%
2 hours to less than 4 hours	0	0%
4 hours or more	6	50%
Total	**12**	**100%**

Table B-32: Q44 Summary of Responses

Once an abandoned vehicle is reported on the shoulder, approximately how long does it take (on average) for it to be cleared (removed from the facility)?

Response	Total Frequency	Total Percentage
Less than 6 hours	0	0%
6 hours to less than 12 hours	0	0%
12 hours to less than 24 hours	1	8%
24 hours to less than 48 hours	6	50%
48 hours to less than 72 hours	4	33%
72 hours or more	1	8%
Total	**12**	**100%***

* Unrounded percentages sum to 100%.

Table B-33: Q45 Summary of Responses

Does your agency have the authority to remove/tow disabled vehicles off the facility?

Response	Total Frequency	Total Percentage
Yes	12	100%
No	0	0%
Total	**12**	**100%**

Table B-34: Q46 Summary of Responses

Does your agency have the authority to remove/tow abandoned vehicles off the facility?

Response	Total Frequency	Total Percentage
Yes	12	100%
No	0	0%
Total	**12**	**100%**

Table B-35: Q47 Summary of Responses

Do your state's statutes or laws define a minimum and/or maximum amount of time that an abandoned vehicle can be left on the shoulder or side of a roadway before it is towed?

Response	Total Frequency	Total Percentage
Yes	11	92%
No	1	8%
Total	**12**	**100%**

Table B-36: Q48 Summary of Responses

Are vehicles in your agency's fleet equipped with push bumpers that could be used to move disabled vehicles and abandoned vehicles out of the travel lanes and onto the shoulder? If so, is your agency allowed to use these push bumpers to move disabled or abandoned vehicles out of the travel lanes and onto the shoulder?

Response	Total Frequency	Total Percentage
Vehicles in my agency's fleet are equipped with push bumpers and my agency is allowed to use push bumpers on disabled or abandoned vehicles.	11	92%
Vehicles in my agency's fleet are equipped with push bumpers, but my agency is not allowed to use push bumpers on disabled or abandoned vehicles.	1	8%
Vehicles in my agency's fleet are not equipped with push bumpers.	0	0%
Total	**12**	**100%**

Table B-37: Q49 Summary of Responses

Are officers in your agency trained to use a non-traffic side approach when responding to disabled vehicle or abandoned vehicle events?

Response	Total Frequency	Total Percentage
Yes	12	100%
No	0	0%
Total	**12**	**100%**

Table B-38: Q50 Summary of Responses

Have any officers in your agency been struck while responding to a disabled vehicle?

Response	Total Frequency	Total Percentage
Yes	10	83%
No	2	17%
Total	**12**	**100%**

Table B-39: Q51 Summary of Responses
How concerned are officers in your agency for their safety when responding to disabled vehicles?

Response	Total Frequency	Total Percentage
Not concerned at all	0	0%
Slightly concerned	0	0%
Somewhat concerned	6	50%
Moderately concerned	4	33%
Very concerned	2	17%
Total	**12**	**100%**

Table B-40: Q52 Summary of Responses
What are common reasons for a vehicle to become disabled or abandoned? Rank the below options from most common (1) to least common (4).

Response	1	2	3	4	Weighted Score	Overall Rank
Vehicle was involved in a crash.	5	2	4	1	25	2
Mechanical issue with the vehicle (dead car battery, flat tires, out of gas, high temperatures, etc.), but vehicle was not involved in a crash.	7	4	0	1	19	1
Extreme weather-related events (heavy snowfall, mudslides, flooding, etc.).	0	6	2	4	34	3
Driver condition (fatigue, passed out, DUI, etc.).	0	0	6	6	42	4

Table B-41: Q53 Summary of Responses
When dealing with the removal of an abandoned vehicle, does your agency provide any leniency to the driver/vehicle owner, such as providing additional time to remove the vehicle?

Response	Total Frequency	Total Percentage
Yes	12	100%
No	0	0%
Total	**12**	**100%**

Section 3: Safety Service Patrol Questions

Table B-42: Q55 Summary of Responses
In miles, how large is the limited access roadway network your agency services?

Response	Total Frequency	Total Percentage
Less than 50 miles	2	12%
50 to 100 miles	0	0%
101 to 200 miles	3	18%
201 to 500 miles	6	35%
501 to 1000 miles	1	6%
More than 1000 miles	5	29%
Total	**17**	**100%**

Table B-43: Q56 Summary of Responses
How frequently do disabled vehicle events typically occur on limited access facilities within your agency's service area per day?

Response	Total Frequency	Total Percentage
Less than 10 disabled vehicle events	0	0%
10 to 50 disabled vehicle events	9	53%
51 to 100 disabled vehicle events	4	24%
101 to 250 disabled vehicle events	3	18%
251 to 500 disabled vehicle events	0	0%
More than 500 disabled vehicle events	1	6%
Total	**17**	**100%***

* Unrounded percentages sum to 100%.

Table B-44: Q57 Summary of Responses

How frequently do abandoned vehicle events typically occur on limited access facilities within your agency's service area per day?

Response	Total Frequency	Total Percentage
Less than 1 abandoned vehicle event	0	0%
1 to 5 abandoned vehicle events	7	41%
6 to 10 abandoned vehicle events	3	18%
11 to 25 abandoned vehicle events	4	24%
26 to 50 abandoned vehicle events	2	12%
More than 50 abandoned vehicle events	1	6%
Total	**17**	**100%***

* Unrounded percentages sum to 100%.

Table B-45: Q58 Summary of Responses

What are common reasons for a vehicle to become disabled or abandoned? Rank the below options from most common (1) to least common (4).

Response	1	2	3	4	Weighted Score	Overall Rank
Vehicle was involved in a crash.	1	11	3	2	40	2
Mechanical issue with the vehicle (dead car battery, flat tires, out of gas, high temperatures, etc.), but vehicle was not involved in a crash.	15	1	0	1	21	1
Extreme weather-related events (heavy snowfall, mudslides, flooding, etc.).	1	2	4	10	57	4
Driver condition (fatigue, passed out, DUI, etc.).	0	3	10	4	52	3

Table B-46: Q59 Summary of Responses

How serious of a problem are disabled vehicle and abandoned vehicle events in your service area?

Response	Total Frequency	Total Percentage
1 – Not a problem at all	2	12%
2	2	12%
3	7	41%
4	4	24%
5 – Very serious problem	2	12%
Total	**17**	**100%***

* Unrounded percentages sum to 100%.

Table B-47: Q60 Summary of Responses

How many vehicles in your service patrol's fleet have the capability to tow a disabled vehicle?

Response	Total Frequency	Total Percentage
None of the vehicles	9	53%
Less than half of the vehicles	4	24%
Half of the vehicles	0	0%
Majority of the vehicles	2	12%
All the vehicles	2	12%
Total	**17**	**100%***

* Unrounded percentages sum to 100%.

Table B-48: Q61 Summary of Responses

Are responders in your agency allowed to tow a disabled vehicle? If yes, where can they move it to?

Response	Total Frequency	Total Percentage
Yes, fully off the facility.	2	25%
Yes, onto the shoulder or side slope of the facility.	5	62%
Yes, to a safe area (such as a rest area or service plaza).	1	12%
No, they are not allowed to tow a disabled vehicle.	0	0%
Total	**8**	**100%***

* Unrounded percentages sum to 100%.

Table B-49: Q62 Summary of Responses

Are vehicles in your agency's fleet equipped with push bumpers that could be used to move disabled vehicles and abandoned vehicles out of the travel lanes and onto the shoulder? If so, is your agency allowed to use these push bumpers to move disabled or abandoned vehicles out of the travel lanes and onto the shoulder?

Response	Total Frequency	Total Percentage
Vehicles in my agency's fleet are equipped with push bumpers and my agency is allowed to use push bumpers on disabled or abandoned vehicles.	15	88%
Vehicles in my agency's fleet are equipped with push bumpers, but my agency is not allowed to use push bumpers on disabled or abandoned vehicles.	0	0%
Vehicles in my agency's fleet are not equipped with push bumpers.	2	12%
Total	**17**	**100%**

Table B-50: Q63 Summary of Responses

Are service patrol responders in your agency trained to use a non-traffic side approach when responding to disabled vehicle or abandoned vehicle events?

Response	Total Frequency	Total Percentage
Yes	15	88%
No	2	12%
Total	**17**	**100%**

Table B-51: Q64 Summary of Responses

Have any responders in your agency been struck while responding to a disabled vehicle?

Response	Total Frequency	Total Percentage
Yes	10	59%
No	7	41%
Total	**17**	**100%**

Table B-52: Q65 Summary of Responses

How concerned are service patrol responders in your agency for their safety when responding to disabled vehicles?

Response	Total Frequency	Total Percentage
Not concerned at all	1	6%
Slightly concerned	0	0%
Somewhat concerned	1	6%
Moderately concerned	3	18%
Very concerned	12	71%
Total	**17**	**100%***

* Unrounded percentages sum to 100%.

Appendix C: SQL Queries for DAV Waze Benefit-Cost Evaluations

Query #1: All DAV Waze Alerts for I-4 in D5 from July 2019 through December 2019

```
SELECT datez, lat, looong, street
FROM waze
WHERE (DATE(datez) BETWEEN '2019-07-01' AND '2019-12-31') AND lat > 28.2513
AND looong > -81.6232 AND street IN ("I-4 E", "I-4 W") AND (county IN
("Osceola","Orange","Seminole","Volusia","") OR county IS NULL);
```

Query #2: All DAV SunGuide Events for I-4 in D5 from July 2019 through December 2019

```
SELECT created_date, closed_date, event_type, roadway, county, location, lat, looong,
worst_blockage
FROM sunguide
WHERE DATE(created_date) BETWEEN '2019-07-01' AND '2019-12-31' AND county in
("Orange","Orange County","Osceola","Osceola County","Seminole","Seminole
County","Volusia") AND district = "D5" AND roadway in ("I-4","I4","SR-400");
```

Query #3: All DAV Crashes for I-4 in D5 from July 2019 through December 2019

```
SELECT HSMV_Report_Number, Time_Crash, Time_Reported, Time_Dispatched,
Time_Scene, Time_Cleared, Crash_Street, Intersecting_Street, Vehicles, Non_Motorists,
Fatalities, Injuries, Weather_Condition, Light_Condition, Possible_Injuries,
Non_Incapacitating_Injuries, Incapacitating_Injuries, Property_Dmg_Amt,
Vehicle_Dmg_Amt, looong, lat, Event_Type, Lane_Blockage
FROM crashes
WHERE DATE(Time_Crash) BETWEEN '2019-07-01' AND '2019-12-31' AND county IN
("Orange","Osceola","Seminole","Volusia") AND Roadway = "I-4" ORDER BY
HSMV_Report_Number;
```

Query #4: All Overlapping DAV Waze Alerts for Each DAV SunGuide Event with Waze Overlap for I-4 in D5 from July 2019 through December 2019

```
SELECT s.created_date, s.closed_date, s.event_type, s.roadway, s.county, s.location, s.lat,
s.looong, s.worst_blockage, COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as
earliest_ping, IF(MIN(w.datez)<s.created_date,’1’,’0’) AS ping_before_sg_start
FROM
(SELECT created_date, closed_date, event_type, roadway, county, location, lat, looong,
worst_blockage FROM sunguide WHERE (‘2019-07-01’<=DATE(created_date) AND
DATE(created_date)<=’2019-12-31’) AND county in (‘Orange’,’Orange
County’,’Osceola’,’Osceola County’,’Seminole’,’Seminole County’,’Volusia’) AND district
= ‘D5’ AND roadway in (‘I-4’,’I4’,’SR-400’)) s
JOIN
(SELECT datez, lat, looong FROM waze WHERE street IN (‘I-4 E’, ‘I-4 W’) AND (‘2019-
07-01’<=DATE(datez) AND DATE(datez)<=’2019-12-31’) AND (county IN
(‘Osceola’,’Orange’,’Seminole’,’Volusia’,’’) OR county IS NULL)) w
WHERE (s.created_date – interval 30 minute<=datez AND datez<=s.closed_date) AND
(s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017) GROUP BY s.created_date, s.closed_date, s.lat, s.looong;
```

Query #5: All Overlapping DAV SunGuide Events for Each DAV Waze Alert with SunGuide Overlap for I-4 in D5 from July 2019 through December 2019

```
SELECT s.created_date, s.closed_date, s.event_type, s.roadway, s.county, s.location, s.lat,
s.looong, s.worst_blockage, w.datez AS waze_date, w.lat AS waze_lat, w.looong AS
waze_long, w.street AS waze_street, IF(w.datez<s.created_date,'1','0') as
ping_before_sg_start, IF(s.worst_blockage IN (SELECT block FROM blockage),'1','0') as
lane_blockage
FROM
(SELECT created_date, closed_date, event_type, roadway, county, location, lat, looong,
worst_blockage FROM sunguide WHERE ('2019-07-01'<=DATE(created_date) AND
DATE(created_date)<='2019-12-31') AND county in ('Orange','Orange
County','Osceola','Osceola County','Seminole','Seminole County','Volusia') AND district =
'D5' AND roadway in ('I-4','I4','SR-400')) s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE street IN ('I-4 E', 'I-4 W') AND
('2019-07-01'<=DATE(datez) AND DATE(datez)<='2019-12-31') AND (county IN
('Osceola','Orange','Seminole','Volusia','') OR county IS NULL)) w
WHERE (s.created_date - interval 30 minute<=datez AND datez<=s.closed_date) AND
(s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017);
```

Query #6: All Overlapping DAV Waze Alerts for Each DAV Crash with Waze Overlap for I-4 in D5 from July 2019 through December 2019

```
SELECT s.HSMV_Report_Number, s.Time_Crash, s.Time_Reported, s.Time_Dispatched,
s.Time_Scene, s.Time_Cleared, s.Crash_Street, s.Intersecting_Street, s.Vehicles,
s.Non_Motorists, s.Fatalities, s.Injuries, s.Weather_Condition, s.Light_Condition,
s.Possible_Injuries, s.Non_Incapacitating_Injuries, s.Incapacitating_Injuries,
s.Property_Dmg_Amt, s.Vehicle_Dmg_Amt, s.looong, s.lat, s.Event_Type, s.Lane_Blockage,
COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as earliest_ping,
IF(MIN(w.datez)<s.Time_Crash,'1','0') AS ping_before_sg_start
FROM
(SELECT HSMV_Report_Number, Time_Crash, Time_Reported, Time_Dispatched,
Time_Scene, Time_Cleared, Crash_Street, Intersecting_Street, Vehicles, Non_Motorists,
Fatalities, Injuries, Weather_Condition, Light_Condition, Possible_Injuries,
Non_Incapacitating_Injuries, Incapacitating_Injuries, Property_Dmg_Amt,
Vehicle_Dmg_Amt, looong, lat, Event_Type, Lane_Blockage FROM crashes WHERE
('2019-07-01'<=DATE(Time_Crash) AND DATE(Time_Crash)<='2019-12-31') AND county
IN ('Orange','Osceola','Seminole','Volusia') AND Roadway = 'I-4') s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE street IN ('I-4 E', 'I-4 W') AND
('2019-07-01'<=DATE(datez) AND DATE(datez)<='2019-12-31') AND (county IN
('Osceola','Orange','Seminole','Volusia','') OR county IS NULL)) w
WHERE (s.Time_Crash - interval 30 minute<=datez AND datez<=s.Time_Cleared) AND
(s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017)
GROUP BY s.Time_Crash, s.Time_Cleared, s.lat, s.looong;
```

Query #7: All Overlapping DAV Crashes for Each DAV Waze Alert with Crash Overlap for I-4 in D5 from July 2019 through December 2019

```
SELECT s.HSMV_Report_Number, s.Time_Crash, s.Time_Reported, s.Time_Dispatched,
s.Time_Scene, s.Time_Cleared, s.Crash_Street, s.Intersecting_Street, s.Vehicles,
s.Non_Motorists, s.Fatalities, s.Injuries, s.Weather_Condition, s.Light_Condition,
s.Possible_Injuries, s.Non_Incapacitating_Injuries, s.Incapacitating_Injuries,
s.Property_Dmg_Amt, s.Vehicle_Dmg_Amt, s.looong, s.lat, s.Event_Type, s.Lane_Blockage,
w.datez AS waze_date, w.lat AS waze_lat, w.looong AS waze_long, w.street AS waze_street,
IF(w.datez<s.Time_Crash,'1','0') as ping_before_crash_start, IF(s.lane_blockage = 1,'1','0') as
lane_blockage
FROM
(SELECT HSMV_Report_Number, Time_Crash, Time_Reported, Time_Dispatched,
Time_Scene, Time_Cleared, Crash_Street, Intersecting_Street, Vehicles, Non_Motorists,
Fatalities, Injuries, Weather_Condition, Light_Condition, Possible_Injuries,
Non_Incapacitating_Injuries, Incapacitating_Injuries, Property_Dmg_Amt,
Vehicle_Dmg_Amt, looong, lat, Event_Type, Lane_Blockage FROM crashes WHERE
('2019-07-01'<=DATE(Time_Crash) AND DATE(Time_Crash)<='2019-12-31') AND county
IN ('Orange','Osceola','Seminole','Volusia') AND Roadway = 'I-4') s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE street IN ('I-4 E', 'I-4 W') AND
('2019-07-01'<=DATE(datez) AND DATE(datez)<='2019-12-31') AND (county IN
('Osceola','Orange','Seminole','Volusia',") OR county IS NULL)) w
WHERE (s.Time_Crash - interval 30 minute<=datez AND datez<=s.Time_Cleared) AND
(s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017);
```

Query #8: All DAV SunGuide Events with at Least One Waze Alert Before SunGuide Created Date for I-4 in D5 from July 2019 through December 2019

```
SELECT s.created_date, s.closed_date, s.event_type, s.roadway, s.county, s.location, s.lat,
s.looong, s.worst_blockage, COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as
earliest_ping, TIMESTAMPDIFF(MINUTE,MIN(w.datez),s.created_date)+1 AS
time_before_minutes, TIMESTAMPDIFF(SECOND,MIN(w.datez),s.created_date) AS
time_before_seconds
FROM
(SELECT created_date, closed_date, event_type, roadway, county, location, lat, looong,
worst_blockage FROM sunguide WHERE ('2019-07-01'<=DATE(created_date) AND
DATE(created_date)<='2019-12-31') AND county in ('Orange','Orange
County','Osceola','Osceola County','Seminole','Seminole County','Volusia') AND district =
'D5' AND roadway in ('I-4','I4','SR-400')) s
JOIN
(SELECT datez, lat, looong FROM waze WHERE street IN ('I-4 E', 'I-4 W') AND ('2019-07-
01'<=DATE(datez) AND DATE(datez)<='2019-12-31') AND (county IN
('Osceola','Orange','Seminole','Volusia',") OR county IS NULL)) w
WHERE (s.created_date - interval 30 minute<=datez AND datez<s.created_date) AND (s.lat-
0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017)
```

```
GROUP BY s.created_date, s.closed_date, s.lat, s.looong;
```

Query #9: All DAV Crashes with at Least One Waze Alert Before Time of Crash for I-4 in D5 from July 2019 through December 2019

```
SELECT s.HSMV_Report_Number, s.Time_Crash, s.Time_Reported, s.Time_Dispatched,
s.Time_Scene, s.Time_Cleared, s.Crash_Street, s.Intersecting_Street, s.Vehicles,
s.Non_Motorists, s.Fatalities, s.Injuries, s.Weather_Condition, s.Light_Condition,
s.Possible_Injuries, s.Non_Incapacitating_Injuries, s.Incapacitating_Injuries,
s.Property_Dmg_Amt, s.Vehicle_Dmg_Amt, s.looong, s.lat, s.Event_Type, s.Lane_Blockage,
COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as earliest_ping,
TIMESTAMPDIFF(MINUTE,MIN(w.datez),s.Time_Crash)+1 AS time_before_minutes,
TIMESTAMPDIFF(SECOND,MIN(w.datez),s.Time_Crash) AS time_before_seconds
FROM
(SELECT HSMV_Report_Number, Time_Crash, Time_Reported, Time_Dispatched,
Time_Scene, Time_Cleared, Crash_Street, Intersecting_Street, Vehicles, Non_Motorists,
Fatalities, Injuries, Weather_Condition, Light_Condition, Possible_Injuries,
Non_Incapacitating_Injuries, Incapacitating_Injuries, Property_Dmg_Amt,
Vehicle_Dmg_Amt, looong, lat, Event_Type, Lane_Blockage FROM crashes WHERE
('2019-07-01'<=DATE(Time_Crash) AND DATE(Time_Crash)<='2019-12-31') AND county
IN ('Orange','Osceola','Seminole','Volusia') AND Roadway = 'I-4') s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE street IN ('I-4 E', 'I-4 W') AND
('2019-07-01'<=DATE(datez) AND DATE(datez)<='2019-12-31') AND (county IN
('Osceola','Orange','Seminole','Volusia','') OR county IS NULL)) w
WHERE (s.Time_Crash - interval 30 minute<=datez AND datez<s.Time_Crash) AND (s.lat-
0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017)
GROUP BY s.Time_Crash, s.Time_Cleared, s.lat, s.looong;
```

Query #10: All Lane-Blocking DAV SunGuide Events with at Least One Waze Alert Before SunGuide Created Date for I-4 in D5 from July 2019 through December 2019

```
SELECT s.created_date, s.closed_date, s.event_type, s.roadway, s.county, s.location, s.lat,
s.looong, s.worst_blockage, COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as
earliest_ping, TIMESTAMPDIFF(MINUTE,MIN(w.datez),s.created_date)+1 AS
time_before_minutes, TIMESTAMPDIFF(SECOND,MIN(w.datez),s.created_date) AS
time_before_seconds FROM SELECT s.created_date, s.closed_date, s.event_type,
s.roadway, s.county, s.location, s.lat, s.looong, s.worst_blockage, COUNT(w.datez) AS
num_waze_overlaps, MIN(w.datez) as earliest_ping,
TIMESTAMPDIFF(MINUTE,MIN(w.datez),s.created_date)+1 AS time_before_minutes,
TIMESTAMPDIFF(SECOND,MIN(w.datez),s.created_date) AS time_before_seconds
FROM
(SELECT created_date, closed_date, event_type, roadway, county, location, lat, looong,
worst_blockage FROM sunguide WHERE (‘2019-07-01’<=DATE(created_date) AND
DATE(created_date)<=’2019-12-31’) AND county in (‘Orange’,’Orange
County’,’Osceola’,’Osceola County’,’Seminole’,’Seminole County’,’Volusia’) AND district
= ‘D5’ AND roadway in (‘I-4’,’I4’,’SR-400’)) s
```

```
JOIN
(SELECT datez, lat, looong FROM waze WHERE street IN (‘I-4 E’, ‘I-4 W’) AND (‘2019-
07-01’<=DATE(datez) AND DATE(datez)<=’2019-12-31’) AND (county IN
(‘Osceola’,’Orange’,’Seminole’,’Volusia’,’’) OR county IS NULL)) w
WHERE (s.created_date – interval 30 minute<=datez AND datez<s.created_date) AND
(s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017) AND s.worst_blockage IN (SELECT block FROM blockage)
GROUP BY s.created_date, s.closed_date, s.lat, s.looong;
```

Query #11: All Lane-Blocking DAV Crashes with at Least One Waze Alert Before Time of Crash for I-4 in D5 from July 2019 through December 2019

```
SELECT s.HSMV_Report_Number, s.Time_Crash, s.Time_Reported, s.Time_Dispatched,
s.Time_Scene, s.Time_Cleared, s.Crash_Street, s.Intersecting_Street, s.Vehicles,
s.Non_Motorists, s.Fatalities, s.Injuries, s.Weather_Condition, s.Light_Condition,
s.Possible_Injuries, s.Non_Incapacitating_Injuries, s.Incapacitating_Injuries,
s.Property_Dmg_Amt, s.Vehicle_Dmg_Amt, s.looong, s.lat, s.Event_Type, s.Lane_Blockage,
COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as earliest_ping,
TIMESTAMPDIFF(MINUTE,MIN(w.datez),s.Time_Crash)+1 AS time_before_minutes,
TIMESTAMPDIFF(SECOND,MIN(w.datez),s.Time_Crash) AS time_before_seconds
FROM
(SELECT HSMV_Report_Number, Time_Crash, Time_Reported, Time_Dispatched,
Time_Scene, Time_Cleared, Crash_Street, Intersecting_Street, Vehicles, Non_Motorists,
Fatalities, Injuries, Weather_Condition, Light_Condition, Possible_Injuries,
Non_Incapacitating_Injuries, Incapacitating_Injuries, Property_Dmg_Amt,
Vehicle_Dmg_Amt, looong, lat, Event_Type, Lane_Blockage FROM crashes WHERE
('2019-07-01'<=DATE(Time_Crash) AND DATE(Time_Crash)<='2019-12-31') AND county
IN ('Orange','Osceola','Seminole','Volusia') AND Roadway = 'I-4') s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE street IN ('I-4 E', 'I-4 W') AND
('2019-07-01'<=DATE(datez) AND DATE(datez)<='2019-12-31') AND (county IN
('Osceola','Orange','Seminole','Volusia','') OR county IS NULL)) w
WHERE (s.Time_Crash - interval 30 minute<=datez AND datez<=s.Time_Crash) AND
(s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017) AND Lane_Blockage = 1
GROUP BY s.Time_Crash, s.Time_Cleared, s.lat, s.looong;
```

Query #12: All DAV Waze Alerts for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT datez, lat, looong, street
FROM waze
WHERE (DATE(datez) BETWEEN '2019-07-01' AND '2019-12-31')
AND (county IN ("Broward","Indian River","Martin","Palm Beach", "St. Lucie") OR county
IS NULL) AND ((25.9570 < lat AND lat < 27.5620 AND -80.7773 < looong) OR (27.6423 <
lat AND lat < 27.6650 AND -80.8528 < looong AND looong < -80.8734))
AND street IN ("Florida's Tpk N", "Florida's Tpk S", "Florida's Tpke N", "Florida's Tpke S");
```

Query #13: All DAV SunGuide Events for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT  created_date, closed_date, event_type, roadway, county, location, lat, looong,
worst_blockage
FROM sunguide
WHERE (DATE(created_date) BETWEEN ‘2019-07-01’ AND ‘2019-12-31’)
AND county IN (“Broward”,”Broward County”,”Indian River”,”Indian River
County”,”Martin”,”Martin County”,”Palm Beach”,”Palm Beach County”,”St. Lucie”,”St.
Lucie County”) AND district in (“D4”,”FTE”)
AND roadway = “91 Mainline”;
```

Query #14: All DAV Crashes for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT HSMV_Report_Number, Time_Crash, Time_Reported, Time_Dispatched,
Time_Scene, Time_Cleared, Crash_Street, Intersecting_Street, Vehicles, Non_Motorists,
Fatalities, Injuries, Weather_Condition, Light_Condition, Possible_Injuries,
Non_Incapacitating_Injuries, Incapacitating_Injuries, Property_Dmg_Amt,
Vehicle_Dmg_Amt, looong, lat, Event_Type, Lane_Blockage
FROM crashes
WHERE (DATE(Time_Crash) BETWEEN '2019-07-01' AND '2019-12-31')
AND County in ("Broward","Indian River","Martin","Palm Beach","St Lucie")
AND roadway = "SR-91";
```

Query #15: All Overlapping DAV Waze Alerts for Each DAV SunGuide Event with Waze Overlap for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT s.created_date, s.closed_date, s.event_type, s.roadway, s.county, s.location, s.lat,
s.looong, s.worst_blockage, COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as
earliest_ping, IF(MIN(w.datez)<s.created_date,'1','0') AS ping_before_sg_start
FROM (SELECT  created_date, closed_date, event_type, roadway, county, location, lat,
looong, worst_blockage FROM sunguide WHERE (DATE(created_date) BETWEEN '2019-
07-01' AND '2019-12-31') AND county IN ("Broward","Broward County","Indian
River","Indian River County","Martin","Martin County","Palm Beach","Palm Beach
County","St. Lucie","St. Lucie County") AND district in ("D4","FTE") AND roadway = "91
Mainline") s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE (DATE(datez) BETWEEN '2019-
07-01' AND '2019-12-31') AND (county IN ("Broward","Indian River","Martin","Palm
Beach", "St. Lucie") OR county IS NULL) AND street IN ("Florida's Tpk N", "Florida's Tpk
S", "Florida's Tpke N", "Florida's Tpke S")) w
WHERE (s.created_date - interval 30 minute<=datez AND datez<=s.closed_date) AND
(s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017) GROUP BY s.created_date, s.closed_date, s.lat, s.looong;
```

Query #16: All Overlapping DAV SunGuide Events for Each DAV Waze Alert with SunGuide Overlap for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT s.created_date, s.closed_date, s.event_type, s.roadway, s.county, s.location, s.lat,
s.looong, s.worst_blockage, w.datez AS waze_date, w.lat AS waze_lat, w.looong AS
waze_long, w.street AS waze_street, IF(w.datez<s.created_date,’1’,’0’) as
ping_before_sg_start, IF(s.worst_blockage IN (SELECT block FROM blockage),’1’,’0’) as
lane_blockage
FROM
(SELECT  created_date, closed_date, event_type, roadway, county, location, lat, looong,
worst_blockage FROM sunguide WHERE (DATE(created_date) BETWEEN ‘2019-07-01’
AND ‘2019-12-31’) AND county IN (“Broward”,”Broward County”,”Indian River”,”Indian
River County”,”Martin”,”Martin County”,”Palm Beach”,”Palm Beach County”,”St.
Lucie”,”St. Lucie County”) AND district in (“D4”,”FTE”) AND roadway = “91 Mainline”) s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE (DATE(datez) BETWEEN ‘2019-
07-01’ AND ‘2019-12-31’) AND (county IN (“Broward”,”Indian River”,”Martin”,”Palm
Beach”, “St. Lucie”) OR county IS NULL) AND street IN (“Florida’s Tpk N”, “Florida’s
Tpk S”, “Florida’s Tpke N”, “Florida’s Tpke S”)) w
WHERE (s.created_date – interval 30 minute<=datez AND datez<=s.closed_date) AND
(s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017);
```

Query #17: All Overlapping DAV Waze Alerts for Each DAV Crash with Waze Overlap for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT s.HSMV_Report_Number, s.Time_Crash, s.Time_Reported, s.Time_Dispatched,
s.Time_Scene, s.Time_Cleared, s.Crash_Street, s.Intersecting_Street, s.Vehicles,
s.Non_Motorists, s.Fatalities, s.Injuries, s.Weather_Condition, s.Light_Condition,
s.Possible_Injuries, s.Non_Incapacitating_Injuries, s.Incapacitating_Injuries,
s.Property_Dmg_Amt, s.Vehicle_Dmg_Amt, s.looong, s.lat, s.Event_Type, s.Lane_Blockage,
COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as earliest_ping,
IF(MIN(w.datez)<s.Time_Crash,'1','0') AS ping_before_sg_start
FROM
(SELECT HSMV_Report_Number, Time_Crash, Time_Reported, Time_Dispatched,
Time_Scene, Time_Cleared, Crash_Street, Intersecting_Street, Vehicles, Non_Motorists,
Fatalities, Injuries, Weather_Condition, Light_Condition, Possible_Injuries,
Non_Incapacitating_Injuries, Incapacitating_Injuries, Property_Dmg_Amt,
Vehicle_Dmg_Amt, looong, lat, Event_Type, Lane_Blockage FROM crashes WHERE
(DATE(Time_Crash) BETWEEN '2019-07-01' AND '2019-12-31') AND County in
("Broward","Indian River","Martin","Palm Beach","St Lucie") AND roadway = "SR-91") s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE (DATE(datez) BETWEEN '2019-
07-01' AND '2019-12-31') AND (county IN ("Broward","Indian River","Martin","Palm
Beach", "St. Lucie") OR county IS NULL) AND street IN ("Florida's Tpk N", "Florida's Tpk
S", "Florida's Tpke N", "Florida's Tpke S")) w
```

```
WHERE (s.Time_Crash - interval 30 minute<=datez AND datez<=s.Time_Cleared) AND
(s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017)
GROUP BY s.Time_Crash, s.Time_Cleared, s.lat, s.looong;
```

Query #18: All Overlapping DAV Crashes for Each DAV Waze Alert with Crash Overlap for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT s.HSMV_Report_Number, s.Time_Crash, s.Time_Reported, s.Time_Dispatched,
s.Time_Scene, s.Time_Cleared, s.Crash_Street, s.Intersecting_Street, s.Vehicles,
s.Non_Motorists, s.Fatalities, s.Injuries, s.Weather_Condition, s.Light_Condition,
s.Possible_Injuries, s.Non_Incapacitating_Injuries, s.Incapacitating_Injuries,
s.Property_Dmg_Amt, s.Vehicle_Dmg_Amt, s.looong, s.lat, s.Event_Type, s.Lane_Blockage,
w.datez AS waze_date, w.lat AS waze_lat, w.looong AS waze_long, w.street AS waze_street,
IF(w.datez<s.Time_Crash,'1','0') as ping_before_crash_start, IF(s.lane_blockage = 1,'1','0') as
lane_blockage
FROM
(SELECT HSMV_Report_Number, Time_Crash, Time_Reported, Time_Dispatched,
Time_Scene, Time_Cleared, Crash_Street, Intersecting_Street, Vehicles, Non_Motorists,
Fatalities, Injuries, Weather_Condition, Light_Condition, Possible_Injuries,
Non_Incapacitating_Injuries, Incapacitating_Injuries, Property_Dmg_Amt,
Vehicle_Dmg_Amt, looong, lat, Event_Type, Lane_Blockage FROM crashes WHERE
(DATE(Time_Crash) BETWEEN '2019-07-01' AND '2019-12-31') AND County in
("Broward","Indian River","Martin","Palm Beach","St Lucie") AND roadway = "SR-91") s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE (DATE(datez) BETWEEN '2019-
07-01' AND '2019-12-31') AND (county IN ("Broward","Indian River","Martin","Palm
Beach", "St. Lucie") OR county IS NULL) AND street IN ("Florida's Tpk N", "Florida's Tpk
S", "Florida's Tpke N", "Florida's Tpke S")) w
WHERE (s.Time_Crash - interval 30 minute<=datez AND datez<=s.Time_Cleared) AND
(s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017);
```

Query #19: All DAV SunGuide Events with at Least One Waze Alert Before SunGuide Created Date for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT s.created_date, s.closed_date, s.event_type, s.roadway, s.county, s.location, s.lat,
s.looong, s.worst_blockage, COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as
earliest_ping, TIMESTAMPDIFF(MINUTE,MIN(w.datez),s.created_date)+1 AS
time_before_minutes, TIMESTAMPDIFF(SECOND,MIN(w.datez),s.created_date) AS
time_before_seconds
FROM
(SELECT  created_date, closed_date, event_type, roadway, county, location, lat, looong,
worst_blockage FROM sunguide WHERE (DATE(created_date) BETWEEN '2019-07-01'
AND '2019-12-31') AND county IN ("Broward","Broward County","Indian River","Indian
River County","Martin","Martin County","Palm Beach","Palm Beach County","St.
Lucie","St. Lucie County") AND district in ("D4","FTE") AND roadway = "91 Mainline") s
JOIN
```

```
(SELECT datez, lat, looong, street FROM waze WHERE (DATE(datez) BETWEEN '2019-
07-01' AND '2019-12-31') AND (county IN ("Broward","Indian River","Martin","Palm
Beach", "St. Lucie") OR county IS NULL) AND street IN ("Florida's Tpk N", "Florida's Tpk
S", "Florida's Tpke N", "Florida's Tpke S")) w
WHERE (s.created_date - interval 30 minute<=datez AND datez<s.created_date) AND (s.lat-
0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017)
GROUP BY s.created_date, s.closed_date, s.lat, s.looong;
```

Query #20: All DAV Crashes with at Least One Waze Alert Before Time of Crash for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT s.HSMV_Report_Number, s.Time_Crash, s.Time_Reported, s.Time_Dispatched,
s.Time_Scene, s.Time_Cleared, s.Crash_Street, s.Intersecting_Street, s.Vehicles,
s.Non_Motorists, s.Fatalities, s.Injuries, s.Weather_Condition, s.Light_Condition,
s.Possible_Injuries, s.Non_Incapacitating_Injuries, s.Incapacitating_Injuries,
s.Property_Dmg_Amt, s.Vehicle_Dmg_Amt, s.looong, s.lat, s.Event_Type, s.Lane_Blockage,
COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as earliest_ping,
TIMESTAMPDIFF(MINUTE,MIN(w.datez),s.Time_Crash)+1 AS time_before_minutes,
TIMESTAMPDIFF(SECOND,MIN(w.datez),s.Time_Crash) AS time_before_seconds
FROM
(SELECT HSMV_Report_Number, Time_Crash, Time_Reported, Time_Dispatched,
Time_Scene, Time_Cleared, Crash_Street, Intersecting_Street, Vehicles, Non_Motorists,
Fatalities, Injuries, Weather_Condition, Light_Condition, Possible_Injuries,
Non_Incapacitating_Injuries, Incapacitating_Injuries, Property_Dmg_Amt,
Vehicle_Dmg_Amt, looong, lat, Event_Type, Lane_Blockage FROM crashes WHERE
(DATE(Time_Crash) BETWEEN ‘2019-07-01’ AND ‘2019-12-31’) AND County in
(“Broward”,”Indian River”,”Martin”,”Palm Beach”,”St Lucie”) AND roadway = “SR-91”) s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE (DATE(datez) BETWEEN ‘2019-
07-01’ AND ‘2019-12-31’) AND (county IN (“Broward”,”Indian River”,”Martin”,”Palm
Beach”, “St. Lucie”) OR county IS NULL) AND street IN (“Florida’s Tpk N”, “Florida’s
Tpk S”, “Florida’s Tpke N”, “Florida’s Tpke S”)) w
WHERE (s.Time_Crash – interval 30 minute<=datez AND datez<s.Time_Crash) AND (s.lat-
0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND
w.looong<=s.looong+0.017)
GROUP BY s.Time_Crash, s.Time_Cleared, s.lat, s.looong;
```

Query #21: All Lane-Blocking DAV SunGuide Events with at Least One Waze Alert Before SunGuide Created Date for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT s.created_date, s.closed_date, s.event_type, s.roadway, s.county, s.location, s.lat,
s.looong, s.worst_blockage, COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as
earliest_ping, TIMESTAMPDIFF(MINUTE,MIN(w.datez),s.created_date)+1 AS
time_before_minutes, TIMESTAMPDIFF(SECOND,MIN(w.datez),s.created_date) AS
time_before_seconds
FROM
```

```
(SELECT  created_date, closed_date, event_type, roadway, county, location, lat, looong, worst_blockage FROM sunguide WHERE (DATE(created_date) BETWEEN '2019-07-01' AND '2019-12-31') AND county IN ("Broward","Broward County","Indian River","Indian River County","Martin","Martin County","Palm Beach","Palm Beach County","St. Lucie","St. Lucie County") AND district in ("D4","FTE") AND roadway = "91 Mainline") s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE (DATE(datez) BETWEEN '2019-07-01' AND '2019-12-31') AND (county IN ("Broward","Indian River","Martin","Palm Beach", "St. Lucie") OR county IS NULL) AND street IN ("Florida's Tpk N", "Florida's Tpk S", "Florida's Tpke N", "Florida's Tpke S")) w
WHERE (s.created_date - interval 30 minute<=datez AND datez<s.created_date) AND (s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND w.looong<=s.looong+0.017) AND s.worst_blockage IN (SELECT block FROM blockage)
GROUP BY s.created_date, s.closed_date, s.lat, s.looong;
```

Query #22: All Lane-Blocking DAV Crashes with at Least One Waze Alert Before Time of Crash for SR-91 in D4 Counties from July 2019 through December 2019

```
SELECT s.HSMV_Report_Number, s.Time_Crash, s.Time_Reported, s.Time_Dispatched, s.Time_Scene, s.Time_Cleared, s.Crash_Street, s.Intersecting_Street, s.Vehicles, s.Non_Motorists, s.Fatalities, s.Injuries, s.Weather_Condition, s.Light_Condition, s.Possible_Injuries, s.Non_Incapacitating_Injuries, s.Incapacitating_Injuries, s.Property_Dmg_Amt, s.Vehicle_Dmg_Amt, s.looong, s.lat, s.Event_Type, s.Lane_Blockage, COUNT(w.datez) AS num_waze_overlaps, MIN(w.datez) as earliest_ping, TIMESTAMPDIFF(MINUTE,MIN(w.datez),s.created_date)+1 AS time_before_minutes, TIMESTAMPDIFF(SECOND,MIN(w.datez),s.created_date) AS time_before_seconds
FROM
(SELECT HSMV_Report_Number, Time_Crash, Time_Reported, Time_Dispatched, Time_Scene, Time_Cleared, Crash_Street, Intersecting_Street, Vehicles, Non_Motorists, Fatalities, Injuries, Weather_Condition, Light_Condition, Possible_Injuries, Non_Incapacitating_Injuries, Incapacitating_Injuries, Property_Dmg_Amt, Vehicle_Dmg_Amt, looong, lat, Event_Type, Lane_Blockage FROM crashes WHERE (DATE(Time_Crash) BETWEEN '2019-07-01' AND '2019-12-31') AND County in ("Broward","Indian River","Martin","Palm Beach","St Lucie") AND roadway = "SR-91") s
JOIN
(SELECT datez, lat, looong, street FROM waze WHERE (DATE(datez) BETWEEN '2019-07-01' AND '2019-12-31') AND (county IN ("Broward","Indian River","Martin","Palm Beach", "St. Lucie") OR county IS NULL) AND street IN ("Florida's Tpk N", "Florida's Tpk S", "Florida's Tpke N", "Florida's Tpke S")) w
WHERE (s.Time_Crash - interval 30 minute<=datez AND datez<s.Time_Crash) AND (s.lat-0.015<=w.lat AND w.lat<=s.lat+0.015) AND (s.looong-0.017<=w.looong AND w.looong<=s.looong+0.017) AND s.Lane_Blockage = 1
GROUP BY s.Time_Crash, s.Time_Cleared, s.lat, s.looong;
```