

Warrants, Design, and Safety of Road Ranger Service Patrols

Draft Final Report

Prepared for



THE FLORIDA DEPARTMENT OF TRANSPORTATION
RESEARCH OFFICE

FDOT Contract BDV31-977-52 (UF Project 00125501)

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November 2016

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

METRIC CONVERSION CHART

U.S. UNITS TO METRIC (SI) UNITS

LENGTH

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

METRIC (SI) UNITS TO U.S. UNITS

LENGTH

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Warrants, Design, and Safety of Road Ranger Service Patrols		5. Report Date November 2016	
		6. Performing Organization Code UF	
7. Author(s) Sivaramakrishnan Srinivasan, Grady Carrick, Yafeng Yin, Khajonsak Jermprapai, Xiaotong Sun, Nima Shirmohammadi, and Mehrdad Shahabi		8. Performing Organization Report No.	
9. Performing Organization Name and Address Department of Civil and Coastal Engineering, University of Florida, 365 Weil Hall PO BOX 116580, Gainesville, FL 32611.		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. BDV31-977-52	
12. Sponsoring Organization Name and Address The Florida Department of Transportation Research Center 605 Suwannee Street, MS 30 Tallahassee, FL 32399		13. Type of Report and Period Covered Final Report (Jan – Nov 2016)	
		14. Sponsoring Agency Code	
15. Supplementary Notes			
<p>16. Abstract</p> <p>This research project created a decision support system for managers who must decide if a roadway “warrants” the addition of the Safety Service Patrol (SSP). Meetings with Florida Department of Transportation (FDOT) service patrol program managers and a survey of national state points of contact for service patrols provided insight into critical factors that might contribute to guidelines. Historical incidents from Florida fed models that predict incidents and crashes on candidate roadways, using proven negative-binomial regression models like those found in the Highway Safety Manual. Qualitative and quantitative thresholds for critical factors were established in the form of rules in decision tables that when evaluated, render recommended actions for SSP decisions. A computer tool was developed to facilitate the input of critical information about roadway segments necessary for the analysis. Where warranted, the tool also provides guidance on beat configuration and number of trucks recommended. While the safety benefits of SSP have been researched, this research is among the first to evaluate safety of SSP operations, based on crash data and operator surveys. A set of concrete recommendations to improve SSP safety and/or additional research are important products of this project</p>			
17. Key Words Road Rangers, Warrants, Predictive Models, Beat Design, Safety		18. Distribution Statement No restrictions.	
19. Security Classif. (of this report) Unclassified.	20. Security Classif. (of this page) Unclassified.	21. No. of Pages 143	22. Price

ACKNOWLEDGMENTS

This research was sponsored and funded by the Florida Department of Transportation Research Office. The authors wish to thank Mr. Alan El-Urfali and Mr. Shawn Kinney who served as project managers, as well as all of the FDOT District Program Managers for Traffic Incident Management (TIM) and Road Rangers.

EXECUTIVE SUMMARY

Roadway incidents cause congestion that often results in motorists' delay, economic impacts, and secondary crashes. To mitigate the impacts that incidents have on roadways, many transportation agencies have implemented programs where dedicated personnel patrol and seek incidents in an effort to remove them quickly. Under the name "safety service patrols" (SSP), specially trained and equipped personnel, typically under contract with the transportation agency, handle roadway debris, vehicle disablements, traffic control at crashes, and other responsibilities. The Florida Department of Transportation contracts freeway service patrols under the well-known branding "Road Rangers." Road Rangers are "full-function service patrols," and as such, they go beyond simple motorist assistance, and they are actively engaged in supporting other incident responders with temporary traffic control and incident management.

Despite their documented benefits, funding constraints preclude deploying Road Rangers on all Florida freeways. Consequently, management decisions have to be made as to which roadways should be included in coverage. To date, most deployment decisions have been made fairly subjectively, with consideration given to the number of historical incidents and observed traffic volumes/congestion sometimes guiding the process.

In the above context, the fundamental objective of this study was to provide a decision support system for managers who must decide if a roadway "warrants" the addition of Road Ranger service. Should one be deemed necessary, procedures to design the beat configuration and number of vehicles needed was provided next. These methods were implemented in a spreadsheet tool. Finally, the study also examined the safety issues associated with Road Ranger programs by examining crash data and by performing a survey of the patrol drivers.

Meetings with Florida Department of Transportation (FDOT) service patrol program managers and a survey of national state points of contact for service patrols provided insight into critical factors that might determine where Road Rangers are needed. Historical data on traffic incidents from Florida were used to develop models that predict incidents and crashes on candidate roadways, using proven negative-binomial regression models like those found in the Highway Safety Manual. Four sets of models were developed representing four time-of-day periods: (1) weekday day time, (2) weekday night time, (3) weekend day time, and (4) weekend night time. Qualitative and quantitative thresholds for critical factors were established in the form of rules in decision tables that when evaluated, render recommended actions for SSP decisions. By adding the use of decision tables, multiple criteria can be evaluated together to render recommendations. Strengths of the decision table approach are evidenced by scalability and flexibility in design, and perhaps most importantly, by the ability to consider alternatives beyond the simple "yes" or "no" that is typical of warrants.

The SSP guidelines developed herein were validated with an actual roadway segment in Florida where SSP is envisioned, but not yet deployed. In meetings with stakeholders, the predictive models and decision tables worked effectively to recommend addition of SSP on the candidate segment. Evaluating each critical factor, the stakeholders were in agreement with the approach and recommendations. Coincidentally, another candidate roadway with much lower AADT did not result in a recommendation for addition.

While this study employed a systematic data-driven procedure to develop quantitative methods to determine roadway segments that warrant SSP, it is also useful to acknowledge that this is perhaps a first attempt to integrate roadway incident data at the statewide level (by collating

data from individual districts) to develop statistical equations. Therefore, there are clear opportunities for improving the reliability of the models.

Three different models were developed to design the operational characteristics of the patrol on “warranted” roadways. The first model minimizes the total number of patrol vehicles of the corridor when the target response time is given. Under the condition where the total fleet size is known, the second model attempts to minimize the total average response time. The third model solves the deployment problem for corridors when neither the fleet size nor the target response time is specified. The objective of this third model is then to maximize total social benefits, which usually include benefits associated with delay savings, reduced fuel consumption, emission reduction, and reductions in secondary incidents.

The Road Ranger Service Patrol (RRSP) Integrated Interface which is an Excel tool that provides planning guidelines and patrolling beat design for safety service patrols using the developed methods is presented. The interface has been embedded with expansion decision tables, incident performance functions, and design algorithms.

It is important to note that the RRSP Integrated Interface is designed and intended for use by knowledgeable practitioners who need to evaluate roadways where there are currently no RRSP assigned. Adding RRSP typically implies deploying trucks on weekdays during daytime hours. Realizing that most Florida freeways already have some form of RRSP, the tool also has the capability to evaluate additional days of the week (weekends) and additional hours (extended nighttime hours). Addition of weekday-daytime patrols necessarily precludes all other planning guidelines. The use of the tool and, particularly, planning guidelines and beat design are not substitutes for engineering and/or managerial judgement. Results and recommendations produced by the tool are guidance to assist managers and practitioners with RRSP deployment decisions.

While the safety benefits of SSP have been researched, little research has been done to understand the safety of SSP operators themselves. This study undertook an analysis of crash data and a survey of Road Rangers in Florida to understand the safety issues associated with the SSP operators themselves.

Research has indicated rear-end collisions are common for RRSP vehicles, and they are struck while parked and on the shoulder at a higher rate than the larger population of freeway crashes. Vehicle conspicuity is very important to mitigate these crash hazards. Passive treatments like rear-facing markings on vehicles that including contrasting, fluorescent, and retro-reflective materials complement emergency lighting.

Compliance with Florida’s Move Over law has the potential to improve safety. Public information, coupled with proactive high visibility enforcement by law enforcement, is needed to reinforce the move over requirements where RRSP are involved. Emergency vehicle lighting and the use of vehicle-mounted arrow boards have the potential to improve Move Over compliance, but these treatments need to be studied further.

RRSP operators are more likely to be struck as pedestrians, making situational awareness and the use of high visibility safety apparel (HVSA) more important. Drivers have indicated that the use of “traffic vests” might be replaced with newer uniform technologies that incorporate MUTCD-compliant ANSI standards in shirts and pants. Additionally, rain gear, traffic gloves, and safety glasses should be examined further.

RRSP operator training appears to be adequate from the driver point of view, however the required training is very minimal and should be examined. A formal training needs assessment would identify competencies and guide contractor training, potentially improving safety. The following recommendations are made for policy changes:

- Conduct a training needs assessment, and create a set of basic competencies for operators to guide contractor training.
- Create a requirement for operators to attend the 4-hour FHWA National Traffic Incident Management Responder Training course.
- Create a requirement for recurring training to ensure operators are current.
- Engage law enforcement to do Move Over enforcement involving RRSP.
- Creation of a systematic reporting system for all RRSP crashes.
- Evaluate RRSP equipment to consider inclusion of jump boxes and tools to speed tire changes.

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CHAPTER 1: INTRODUCTION

According to the Manual on Uniform Traffic Control Devices (MUTCD), “A traffic incident is an emergency road user occurrence, a natural disaster, or a special event that affects or impedes the normal flow of traffic” (U.S Department of Transportation, 2009). Roadway incidents cause congestion that often results in motorists delay, economic impacts, and secondary crashes. The Federal Highway Administration (FHWA) estimates that about 25 percent of congestions can be attributed to traffic incidents (Houston et al., 2008). Given the impacts of roadway incidents, quick detection, response, and clearance are foundational principles of transportation systems management and operations (TSM&O).

To mitigate the impacts that incidents have on roadways, many transportation agencies have implemented programs where dedicated personnel patrol and seek incidents in an effort to remove them quickly. Under the name “safety service patrols” (SSP), specially trained and equipped personnel, typically under contract with the transportation agency, handle roadway debris, vehicle disablements, traffic control at crashes, and other responsibilities.

The Florida Department of Transportation contracts freeway service patrols under the well-known branding “Road Rangers.” Road Rangers are “full-function service patrols” and as such, they go beyond simple motorist assistance, and they are actively engaged in supporting other incident responders with temporary traffic control and incident management. On any given weekday in Florida, more than 100 Road Rangers assist motorists, incident responders, and transportation agencies on Florida freeways, covering more than 1500 centerline miles. During 2013, Road Rangers made 374,971 assists, and since the program inception, they have made over 4.3 million assists (Florida Department of Transportation, 2014a). A 2010 study funded by the FDOT found that the benefit-cost ratio of the entire Road Ranger program to be 6.68:1 (Lin et al., 2012).

Road Ranger services are contractually arranged by individual FDOT districts, the Turnpike Enterprise, Expressway Authorities, and by construction contractors on major projects. Road Ranger deployment began more than two decades ago, mainly in urban areas during peak traffic hours. Statewide program funding began in December of 1999 (Florida Department of Transportation, 2014b). Since then, the roadways covered and hours of operation have expanded greatly. Despite their documented benefits, funding constraints preclude deploying Road Rangers on all Florida freeways. Consequently, management decisions have to be made as to which roadways should be included in coverage. To date, most deployment decisions have been made fairly subjectively, with consideration given to the number of historical incidents and observed traffic volumes/congestion sometimes guiding the process.

This research had the objective to provide a decision support system for managers who must decide if a roadway “warrants” the addition of Road Ranger service (Chapter 2). Should one be deemed necessary, a procedure to design the beat configuration and number of vehicles needed was provided next (Chapter 3). These methods were implemented in a spreadsheet tool (Chapter 4). Finally, the study also examined the safety issues associated with Road Ranger programs by examining crash data and by performing a survey of the patrol drivers (Chapter 5).

CHAPTER 2: CRITERIA FOR DETERMINING WHEN ROAD RANGER SERVICE PATROLS ARE WARRANTED

2.1. Background

There is currently no accepted method for evaluating where safety service patrols should be used. No method for warranting service patrols has been defined by research or advanced in literature. There are however some examples where the idea of service patrol allocation was discussed, conceptualized, or advanced.

Bertini and McGill (2012) evaluated a rural incident response (IR) program implemented on two corridors in Oregon using computer aided dispatch (CAD) data. The benefits of the program were quantified to determine thresholds where the program might be expanded or implemented. A naïve before and after analysis showed that the service patrols had a positive impact on crash rate, incident delay, and fuel consumption. A simple benefit-cost demonstrated the potential return on investment. The study found that the effectiveness of the service patrol program was a function of the segment length, crash rate, and average daily traffic (ADT). The authors point out that traffic volume can help model delay on similar facilities to determine, “whether the roadway under consideration should be given additional review when considering future IR programs.”

Practitioners have played a significant role in past decisions to use safety service patrols, and that is evidenced by a 2003 white paper from an Ohio DOT employee, Howard Wood. The white paper, entitled, “Freeway Service Patrol Warrants” categorically established seven conditions where deployment of service patrols might be justified (Wood, 2003). The paper realizes the relationship between volume and incidents using a single example from Ohio. Construction, air quality monitoring, infrastructure, traffic volume, V/C ratio, crash frequency, and shoulder width are listed as guidance for district traffic engineers at the DOT. While the conditions listed are apt considerations for service patrols, the accompanying thresholds were rather subjective. Service patrols might be permitted where there is construction, air quality conformance issues, or critical infrastructure like bridges, tunnels, or bottlenecks. Ultimately the “recommended” use of service patrols are pinned to a freeway volume greater than 75,000 AADT and shoulder width <6 feet. According to officials at the Ohio DOT, the white paper was never implemented and is not used to this date. The white paper is a thoughtful consideration for applying warrants to service patrols but it ultimately lacked any methodological or empirical foundation.

Khattak et al. sought to prioritize candidate locations for service patrol expansion by examining traffic crashes, traffic volumes, and delay estimations. Incident estimations were derived from the ratio of crashes to other incidents from the Charlotte and Greensboro areas, 7:2.1. Using an accompanying decision tool, candidate sites were ranked and compared to each other, using traffic volumes and historical crashes. Ultimately the research promoted using benefit-cost as the means to prioritize facilities under consideration (Khattak et al., 2004). In a similar approach, Edara and Dougald sought to prioritize Virginia service patrol beats in a planning tool using AADT to predict incidents and subsequently feed a benefit-cost comparison (Douglas and Edara, 2007).

The California Streets and Highways Code Section 2560-2565 directs that a formula-based allocation be used to deploy funding for service patrols in the state. With funding from the State Highway Account in the Transportation Fund, the law established a grant program for local/regional entities to apply for funding. For the applying agency, funding is based on the

number of urban freeway lane miles as compared to all participating areas (25%), the ratio of population for the applicant as it relates to all participating areas (50%), and the CALTRANS most recent Statewide Highway Traffic Congestion Monitoring Program (25%). Applicants must demonstrate an overall benefit-cost ratio of 3 to 1. Funding for new applicants is phased in over 3 years. California Streets and Highways Code Section 2560-2565 primarily supports the distribution of funds but does not direct which roadways should be patrolled.

2.2. Overview of Methodology

Given the absence of a standardized approach to determine where SSP should be deployed, a new procedure is advanced herein. To accomplish the research objective, original survey research and analysis of historical incident data are used within a warrant framework to provide criteria by which SSP deployment decisions might be made.

While there is general familiarity with the need to meet certain conditions to justify installing traffic signals, commonly referred to as signal warrants, similar processes are uncommon for other traffic engineering deployments. The Enterprise Pooled Fund ITS Planning Guidance project that was created in 2006 as a way to replicate the signal warrant process for other types of investment decisions. Specifically, the Enterprise Pooled Fund Guidance seeks to identify where technology might be best applied to solve transportation issues. Focused narrowly on ITS and related technology, the Enterprise project has successfully created guidance for implementing things like closed circuit television, dynamic message signs, road weather information systems, and variable speed limits. The model advanced by Enterprise entails 1) defining the purpose, 2) identification of critical factors, 3) planning guideline development, and 4) preliminary testing and planning guideline adjustment.

While SSP is not a technology-based treatment, they are typically packaged with ITS deployments, creating an opportunity to use an approach similar to those used by the Enterprise project. The following sections describe the planning guideline approach that has been successfully used for ITS deployments.

Early in the planning guidance project (Athey Creek Consultants, 2015), a decision was made to describe the recommendations as “guidance” rather than “warrants” to avoid “statutory/legal requirements associated with the publication of official warrants”. The naming convention for establishing “guidelines” seems like a good approach and one that will be replicated for SSP.

Obtaining input from SSP program managers helps define the purpose for SSP expansion and the critical factors that might be considered for each, the first two steps in the model. Stakeholder input is coincidentally a prominent part of the Enterprise model. Meetings with FDOT program managers and a survey of national SSP points of contact provide an understanding of how deployment decisions have been made in the past and how they should be approached in the future.

With mature programs for ITS, traffic incident management (TIM), and SSP, the Florida Department of Transportation (FDOT) has a rich set of traffic management center (TMC) incident data. More than 2.5 million incident records can be evaluated statistically to better understand their characteristics. Statistical modeling allows for the creation of an incident prediction model, similar to the safety performance function found in the Highway Safety Manual User Guide (Kolody et al., 2014). The quantitative and qualitative inputs are examined to establish thresholds in development of planning guidelines, step three in the framework.

Ultimately critical factors are considered together in a series of decision tables that render a range of recommendations as to whether or not the considered SSP expansion should be undertaken, as well as potential alternatives. This is the final step in the planning guideline model.

2.3. Interviews with FDOT Program Managers

A series of in-person discussions were conducted with all FDOT districts and the Florida Turnpike Enterprise (FTE) to better understand Road Ranger Service Patrol (RRSP) deployment in Florida. The research team arranged meetings at each Traffic Management Center (TMC) location with a combination of interested individuals selected by the district. Some combination or subset of District ITS Engineers, RRSP Program Managers, TIM Program Managers, TMC Managers, District Consultants, and partnering local transportation agencies were the typical participants. Meetings typically lasted approximately 2 hours.

Since overarching concepts related TIM are an important part of RRSP, topical expertise by the research team was invaluable. To facilitate discussion, the research team developed a discussion outline which was provided to participants prior to each meeting. The discussion outline was beneficial for ensuring that important topics were covered during the meeting, but the research team also sought emergent information to fully understand how RRSP are deployed and operate in each district. The district meetings enjoyed a conversational tone that allowed for the free exchange of information and ideas. The research team benefited immensely from each visit, as each host/participant provided a wealth of information about RRSP.

The research team made notes during each visit which are summarized in the sections that follow. In addition to the information herein, each district provided their current RRSP beats, days & hours of operation, and vehicle type. Beat information was provided in various formats including printed maps, tables. The research team will coalesce district RRSP beats into a single GIS format to facilitate analysis, visualization, and presentation.

The following sections present the findings of the research team, generally following the format of the aforementioned discussion template. Tables and bulleted information accompany a narrative description by topic, and where possible information is categorized.

The research team envisioned identifying the inputs that were used when RRSP were initially deployed. Given statewide deployment occurred in 2000, most of the decision-makers are no longer part of the current program and consequently the precise inputs elusive. The question was reframed to capture both original deployments and future deployments, to determine inputs that would be important in the decision to deploy RRSP on a particular roadway. During meetings with the districts, the table that was provided generally led to a group discussion and consensus among participants, which were recorded by the research team. The results of the discussion are provided in Table 2-1.

Table 2-1 Inputs that would be considered for RRSP deployment

Potential Input	D1	D 2	D 3	D 4	D 5	D 6	D 7	TP	Row Tot.	Rank
Traffic volume		X	X		X	X	X	X	6	3
Number of historical incidents in general	X	X	X	X	X	X	X	X	8	1
Number of historical traffic crashes	X	X	X	X	X	X	X	X	8	1
Type/severity of historical incidents	X		X		X	X			4	5
Bottlenecks/recurring congestion				X		X	X		3	6
Knowledge of the area	X	X	X	X	X		X	X	7	2
Availability of other responders (law enforcement, fire, etc.)		X	X		X				3	6
Available funding		X	X	X		X	X	X	6	3
Benefit-Cost Analysis					X		X		2	7
Political considerations				X					1	8
Number of lanes and/or presence of shoulders	x		X	X	X	x		x	5	4
Presence of bridges, tunnels, etc.		X	X		X		X		4	5
Distance between interchanges	X		X	X	X				4	5
Volume/Capacity Ratio (V/C)										
Input from stakeholders					X				1	8

All districts readily accepted historical incidents and historical traffic crashes as important considerations for deployment. The majority of RRSP activities involve assisting motorists and removing debris, but it is generally understood that RRSP provide a valuable service assisting other responders at traffic crash scenes. RRSP typically provide temporary traffic control, a blocking vehicle, and advance warning with their vehicle-mounted arrow board.

All but one of the districts indicated that “knowledge of the area” was a factor in RRSP decisions. Practitioners often have experience and intuition that is difficult to quantify. Familiarity with the locale, roadways, traffic patterns, and driver behaviors were examples of the type of knowledge participants noted as important.

Traffic volume was cited as important in all districts except D1 (Southwest) and D3 (Northwest) where there are no large metropolitan/urbanized areas. District 3 also noted that truck traffic along the I-10 corridor was a significant factor in their rural setting and that at times it may represent as much as 30% of the AADT.

All but two districts recognized the role of available funding in RRSP deployment decisions. As a matter of fact, all districts discussed the availability of funding as a constraint to their desired implementation of RRSP. The formulation of initial funding decisions in 1999-2000, when the RRSP began, may contribute to some of the current difficulties with RRSP allocation. The statewide budget reductions during 2008 exacerbated already difficult RRSP deployment decision-making.

In addition to the above, D5 noted peak hours and tourists as important. D4 noted input from RRSP operators and law enforcement as important for beat changes. D3 noted truck traffic and average clearance time while D6 identified the level of customer service desired as an input.

Whereas identifying inputs proved to be a good way to introduce the topic of things to be considered when considering RRSP, attaching significance was the objective of the follow-up activity. Using the same table of potential inputs, the districts were asked to rank their top five

inputs. The exercise created some healthy discussion that ultimately resulted in a consensus. With a numerical ranking, the team is able to quantify the relative importance of inputs. Table 2-2 presents the ranking by each district, the weighted score, and the ordered ranking of inputs.

Table 2-2 Inputs that would be considered for RRSP deployment ranked

Potential Input	D1	D2	D3	D4	D5	D6	D7	TP	Wtd	Rank
Traffic volume		5	5		3	2	3	1	17	3
Number of historical incidents in general	5	2	1	2	1	4	1	2	30	1
Number of historical traffic crashes		1	1		2		2	5	19	2
Type/severity of historical incidents	3		1	3		5			12	4
Bottlenecks/recurring congestion									0	
Knowledge of the area	4			4	5		4		7	7
Availability of other responders (law enforcement, fire, etc.)									0	
Available funding		3		1				3	11	5
Benefit-Cost Analysis									0	
Political considerations									0	
Number of lanes and/or presence of shoulders	2					1		4	11	5
Presence of bridges, tunnels, etc.		4					5		3	8
Distance between interchanges	1			5	4				8	6
Volume/Capacity Ratio (V/C)									0	
Input from stakeholders									0	
Other			4						2	9

Similar to Table 2-1, historical incidents, historical crashes, and traffic volume were viewed as the most important factors for determining if RRSP are warranted. Drilling into the characteristics of incidents like type, duration and lane blockage grew in significance with ranking. Funding continued to be prominently represented, and sensitivity to available funding was prioritized by 3 of the districts, and the number one issue for D4 (Ft. Lauderdale).

The introduction of roadway characteristics like the number of lanes and presence of shoulders comes into view as equally important to funding. Quite similarly, roadway attributes like the distance between interchanges and bridges demonstrate that the built environment is key for operations and safety.

D3 was the only district to rank an “other” (truck traffic and average clearance time in their top 5); Turnpike noted geometry in general under “lanes/shoulders.” D3 felt that there were 3 inputs that were likely to be equally important.

Expanding RRSP is not as simple as adding trucks and roadways to the current beat configuration. Meetings with each district produced quite different views on how expansion might occur under a hypothetical scenario where new dollars were available. A summary of options for expanding RRSP are presented and weighted in Table 2-3. Null responses indicate that the item was not applicable in light of current operations (i.e., already 7 days, already 24/7, already cover all freeways, presence of tow, safe tow or STAR tow, etc.)

Table 2-3 Prioritization of Expansion Options

	D1	D2	D3	D4	D5	D6	D7	TP	Row	Wtd.	Rank
Expand days of operation to 7 days a week	5	1	1				1	1	9	1.8	1
Expand hours of operation to 24/7	1		3		1		2	2	9	1.8	1
Add additional miles to current beats/roadways	4	2	4		3			4	17	3.4	5
Add additional roadways, beats/trucks	2	3	2	2	2	1		3	15	2.1	3
Change vehicle type (tow)	3		5	1	4		3		16	3.2	4

Improving the current level of service as it relates to the days and hours of operation were clearly desired by most districts with 6 of the 8 picking this form of expansion as their number one priority. A weighted ranking of available options indicates that expanding days and hours are tied for the top two priorities statewide.

Adding additional roadways, beats/trucks was the next priority in terms of a weighted score. All but one district identified this form of expansion as a priority with the lone exception being D6 (Miami) where all of the expressways are currently covered. Among those districts that list this as their preferred method of expansion, all 7 rated it in their top 3 with 5 of the 7 placing it in their top two priorities. This is important because it indicates there may be a need for warranting new roads or optimizing the current beats.

D4 (Ft. Lauderdale) was most sensitive to the type of RRSP vehicle being deployed. D4 recently replaced tow vehicles with pickup trucks, a move that the practitioners believe lessens their effectiveness. D5 (Orlando) has made the change from a tow fleet to a pickup fleet, but they are in the process of testing “stinger” systems on some pickup trucks to maintain some tow capability. These systems are aftermarket wheel lifts that are a cost-effective alternative to tow trucks.

Discussion of how beats were configured presented challenges similar to inputs because of the length of time since those decisions were made, about 16 years ago. For the most part, the districts configured beats on simple division of roadways into somewhat equal segments in terms of length. Several districts indicated that they made some rough calculations of centerline miles to achieve a patrolling interval or ideal response time.

There was an understanding that RRSP played a significant role in planned special events and deployment should accommodate a “plus up” during those times. Several districts noted seasonal adjustments to beats/hours/trucks.

In D1 (Southwest), the roadway patrolled is I-75 and the divided highway is largely in rural areas with significant distance separating interchanges, most notably on Alligator Alley. The patrol beats are roughly 30 miles and 2 RRSP are assigned to patrol each of the 5 counties where I-75 passes. Recently there have been some tweaks to the interchange turnaround points or nodes.

These modifications were made after reviewing incident data for the roadway in order to improve coverage.

For D2 (Jacksonville), the idea was to create zones of about 15 centerline miles using convenient interchange locations as boundary nodes. The objective was to complete a bi-directional circuit every 30 minutes at normal driving speed. D2 uses a program called “safe tow” to supplement RRSP within beats and outside of those beats. Under safe tow, the FDOT/TMC will send a contract wrecker to remove a vehicle from travel lanes or to a safe location like an exit ramp. D2 believes that staffing RRSP on rural interstates might not be cost-effective, but the use of something like safe tow can cover those roads.

The rural area of I-10 in the Florida Panhandle is D3. RRSP have been in place on the first 31 miles of I-10, terminating at the Alabama State Line, for about 3 years. The section of I-10 near Tallahassee came on line in 2014. Between these bookend beats lies approximately 180 miles of rural, four lane divided Interstate which received RRSP coverage starting in 2016. The 180 mile segments was divided into 3 roughly equally 60 mile segments with the idea of hourly coverage at driving speed possible. The hours of operation were arrived at with a histogram of historical traffic volumes.

D4 in Ft. Lauderdale created the I-95 RRSP patrol zones by dividing the segment into 3 equal parts. I-595 is covered by a separate contract and that roadway is divided into two roughly equal segments. During meetings, the district eluded to an effort by Dr. Hadi at FIU to visit the RRSP deployment methodology, but they could not elaborate on the study. The I-595 beats are under a performance management system that requires the beat be covered every 30 minutes.

In D5 (Orlando), a simple plan was devised to establish zones. Patrolling 20 mile segments, the objective is to have a response time of 30 minutes or less. During peak periods, there are 2 trucks assigned to ostensibly cut response time to 15 minutes. All beats have an overlap segment of at least one interchange that ensures complete coverage and promotes units supporting each other. The 26-mile segment of I-4 that is part of the I-4 Ultimate project has been assumed by the construction contractor. Given performance requirements, the district has noted that the contractor sometimes has as many as a dozen trucks deployed because of the lack of shoulders and extreme congestion created by the road work. A 30-minute response is required of the contractor for all calls, regardless of the time, traffic, or conditions. Because the Ultimate deployment is a unique situation, the beats and coverage are not considered for this project.

D6 in Miami has one of the largest deployments of RRSP. Deployment was generally based on experience, historical crashes, and response times to determine where RRSP might be best suited. Part of the D6 expressway network is handled by Metro-Dade Transportation Authority (MDX), but still dispatched by the Miami TMC. D6 also has a unique RRSP deployment on the I-95 Express Lanes where in addition to express lane RRSP, flatbed wreckers are staged at each upstream end of the facility to expedite response to lane-blocking incidents. RRSP and wreckers are supplemented by 4 overtime troopers who respond to Express Lane incidents and effect hard closure of the lanes when necessary. D6 uses a SunGuide add on product called RRDIS to manage scheduling, drivers, and RRSP crashes.

In D7 (Tampa) the initial deployment was generally based on incidents and demand. According to the District RRSP Program Manager, they are currently tweaking a couple of beats to shift the boundary nodes/interchanges. D7 has awarded CUTR with a research project to optimize their RRSP patrol beats. Pei Sun Lin is the principal investigator.

The Florida Turnpike Enterprise has a comprehensive RRSP deployment, to include toll roads in the Orlando area and the Suncoast and Veterans Parkways north of Tampa.

Demand/incidents and funding were the determining factors for the configuration of beats, with a consideration of interchange spacing and median turnaround locations. The TPE considers input from RRSP operators for making beat modifications.

2.4. National Survey of Safety Service Patrol State Points of Contact

Nationally, forty-one states plus the District of Columbia and Puerto Rico use Freeway Service Patrols. To understand the state of the practice for warranting, allocating, and safety of SSP, the research team engaged state points of contact in each of those jurisdictions. Although there are more than one hundred individual SSP deployments in the US, state-level contacts at DOTs typically understand their respective deployments.

A web-based survey instrument was created, using a series of multiple choice, true-false, graphic rating scales, and open-ended questions. In addition to demographic information, items identified inputs that are beneficial to SSP deployment decisions, priorities for program expansion, and operator safety. The survey questions were similar to those presented to the eight Florida DOT RRSP/SSP Program Managers.

In the spring of 2016, state points of contact were identified and confirmed as the appropriate recipients of the SSP survey. Subsequently, those contacts were solicited via email and provided with a link to the online survey. From the 41 invitations that were ultimately sent (Florida was not included because of the in-person collection), 31 states responded for a response rate of 76 percent.

The following sections present the findings of the research team, generally following the format of the survey instrument. Tables and bulleted information accompany a narrative description by topic, and where possible information is categorized. A copy of the survey is attached as an appendix.

While SSP found their initial value and success in urban, freeway settings, increasingly they have been used on suburban and rural freeway segments. Exactly half of respondents to the SSP survey indicated that they have SSP deployed on what would be considered rural segments. An open-ended contingency question sought to understand the rationale for those cases where there was a rural application of SSP. In some cases the rural deployment was the product of the rural nature of the state and/or the emphasis on Interstate Highways. Although decidedly rural, some of the roadways experience high traffic volumes, while other deployments are designed to supplement scant coverage by other responders. The remoteness of some areas and lack of cellular phone coverage contributes to justification for assisting motorists. Figure 2-1 is a chart that depicts rural SSP deployment.

Q2 Do you have any FSP deployed on what would be considered rural freeways or Interstates?

Answered: 32 Skipped: 0

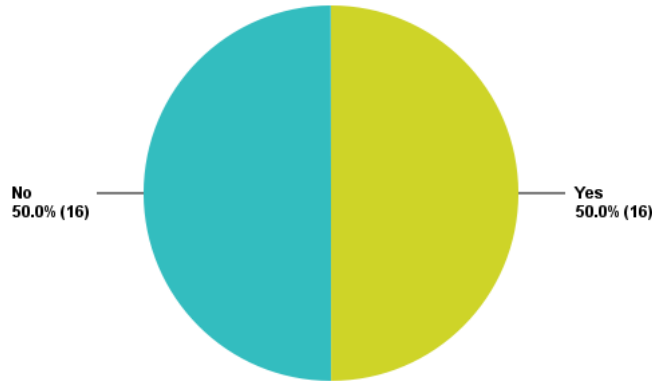


Figure 2-1 Rural FSP Deployment

Similar to rural deployments, there are some locations where SSP are deployed to accommodate seasonal traffic. One in four states indicated that they have some SSP deployments that are based on seasonal demands like tourism, holiday, or special events (Figure 2-2).

Q1 Do you have any FSP deployments/beats that are only seasonal to account for increased traffic on certain roadways?

Answered: 32 Skipped: 0

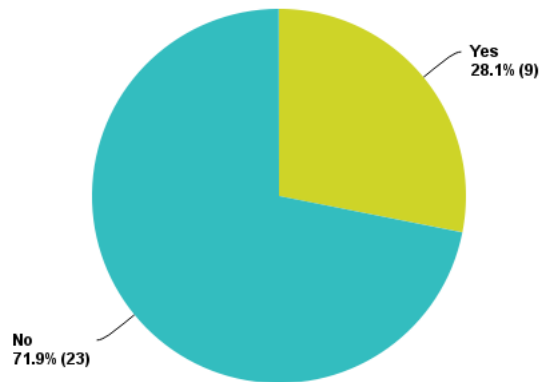


Figure 2-2 Seasonal FSP Deployment

Beyond those cases driven by seasonal factors, understanding factors that lead to deploying SSP is an important precursor to developing a decision support framework. The experience of the research team, a review of literature and conversations with stakeholders rendered a list of potential

inputs for survey participants to evaluate. The stem for the item asked respondents to rank the potential inputs on a continuum of “more important, important, less important, and would not consider”. Figure 2-3 is a graphic that depicts the responses to the question using a stacked bar graph.

A sensitivity to available funding was very pronounced in the results. Available funding is a constraint that likely precedes all deployment and expansion decisions, and all respondents listed this as important or more important. On a related question, more than 80 percent of participants noted that benefit-cost analysis should be an input, an acknowledgement that justifying expenditures is an important part of the decision process.

According to state points of contact, the second most prominent input for SSP decisions is traffic volume, with more than half of participants noting that traffic volume is “more important” and the others indicating it to be “important”. According to the Highway Capacity Manual, incidents reduce capacity, and higher volumes exacerbate their impact as evidenced in the familiar speed-flow curve. SSPs play a prominent role in safe, quick clearance and congestion mitigation.

Consideration of historical incidents (90%) and historical crashes (87%) were also noted as important or more important, demonstrating that demand is a strong factor for allocating SSP resources. Consideration for the type and severity of incidents also ranked highly, although only about 1 in 5 participants considered it as more important on the graphic rating scale.

Even though traffic incident management and SSP are typically linked with non-recurring congestion, their value at places where recurring congestion occurs was also noted as important by nearly 3 of every 4 participants. Where there are bottlenecks and recurring congestion, participants indicated that SSP can be of value.

An acknowledgment that traffic incident management is a multidisciplinary endeavor, more than 87 percent of survey participants noted that input from stakeholders is important or more important.

When asked specifically if they employed any type of mathematical formula, spreadsheet, or other computer programs to identify which roadways should be patrolled by SSP, only 4 survey participants answered affirmatively. For those four responses, the open-ended follow-up question helps elaborate. Two described how historical incidents were analyzed to define zones. One relied on traffic volume and incidents in a benefit-cost analysis. The Maryland CHART program noted that they relied upon the University of Maryland to aid in the process, citing their use of “formulas and algorithms,” but conversations with former CHART program managers indicated a reliance on historical incidents and institutional knowledge.

When one considers “warrants” for SSP, the tendency is to envision adding SSP to roadways not currently patrolled. Discussions with Florida SSP program managers actually helped the research team understand that expansion of SSP might also include expanding days or hours of service, increasing current beats, or changing the type of SSP vehicle. These ideas demonstrate the maturity of SSP in Florida and nationally and illuminated the topic for the benefit of the national survey.

State points of contact were asked to prioritize how they might expand their current program. Adding roadways and adding miles to current beats were both high priorities. Changing the type of SSP truck was noted by nearly 2/3 and slightly less than half sought to expand the days and/or hours of operation. Figure 2-4 is a stacked bar graph that depicts the ranking of expansion methods.

Q5 Please rank the following inputs on their scale of importance for deciding if FSP is warranted on a roadway.

Answered: 32 Skipped: 0

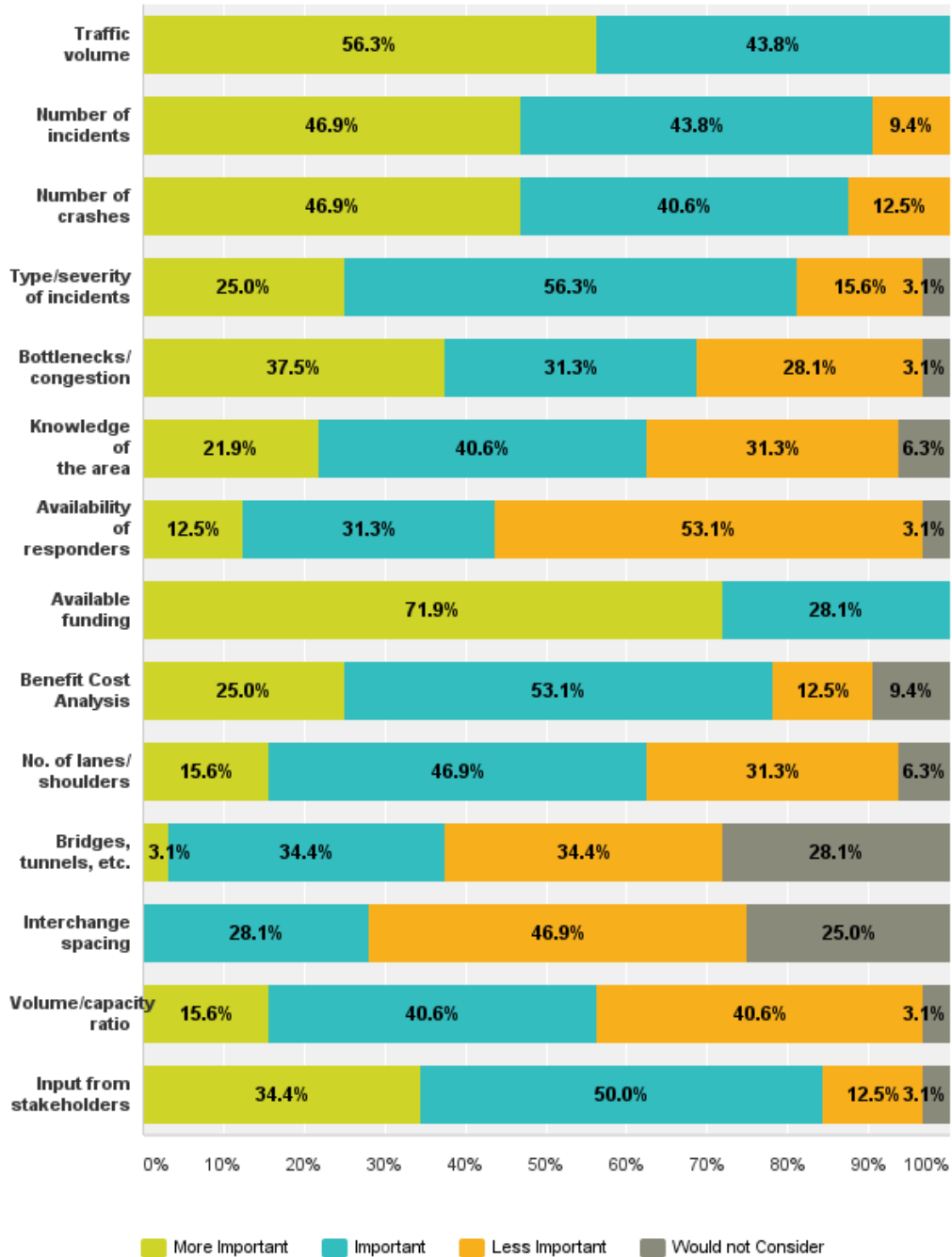


Figure 2-3 Ranking inputs for their importance in FSP deployment decisions

Q4 If you were to expand the current FSP program, please rank the order of priority you would attach to the following expansion methods.

Answered: 32 Skipped: 0

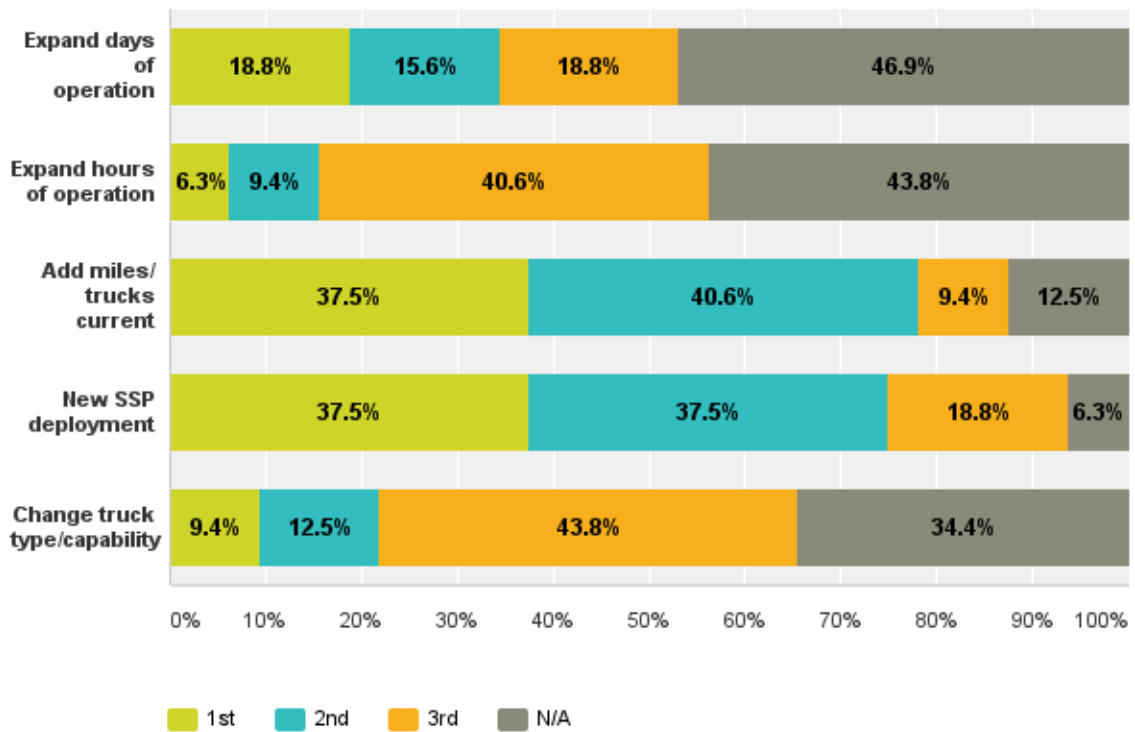


Figure 2-4 Ranking SSP expansion methods

The next survey questions focused respondents on SSP deployment and design. Design and performance measures are often intertwined. Nearly half of states use some type of performance measures in conjunction with SSP. Response time and clearance time were overwhelming performance measures among those responding to the open-ended contingency question. Benefit-cost was also noted as a way that SSP performance was measured.

When asked to describe how SSP are deployed (i.e., size of patrol area, number of trucks, etc.) all participants responded to the open-ended question. Similar to the warranting question described previously, the question stem included a request that mathematical formula be described if used. Most deployments were described by a spatio-temporal objective to cover a given area at a specified time interval. Roadway volumes and the number of incidents were also noted, along with benefit-cost consideration. There were several responses that the methodology was not known.

2.5. Planning Guideline - Defining the Purpose

The foundational question for this research asks if starting a new SSP program, or expanding the current SSP program is something that is needed. Therein lays the first step in developing planning guidance for SSP, identifying what that means and exploring variations for the concept of expansion.

Both the national survey of SSP state points of contact and meetings with Florida RRSSP program managers proved to be enlightening. At first glance, one might assume that the fundamental SSP deployment question would address which roads should have SSP. Engaging stakeholders however revealed that SSP expansion is actually more complex, based largely on the maturity of SSP programs and available funding. While new SSP beats are certainly an interest, for some locations expansion entails covering more hours of the day or days of the week.

Changing the type of SSP vehicles was identified in the qualitative research as an area where criteria might help decision-makers with the decision to use tow trucks or less expensive pickup trucks. Similarly, expansion might not involve new roads, hours, or days, but simply imply adding a few miles or another SSP vehicle to a current beat. While additional agency funding might allow for expanding the miles/trucks on current beats, or changing truck type, these are actually design issues rather than warranting decisions. For this reason, they will not be considered as candidates for guidelines, but they may be part of the process that designs the SSP beat in terms of size and number of SSP vehicles, beyond the scope of this project.

From the qualitative research mentioned previously, the importance attached to expansion methods is depicted in Table 2-4. The table shows the ranking of various expansion methods by individuals who were surveyed. Notice that since Florida has widespread SSP implementation, greater emphasis is on schedule rather than coverage area.

Table 2-4 Ranking of SSP Expansion Methods

	National Survey	Florida Program Managers
New SSP deployment / Add additional roadways	2	3
Expand days of operation to 7 days per week	3	1*
Expand hours of operation	5	1*
Add miles/trucks to current beats	1	5
Change truck type or capability	4	4

*indicates items were tied

With the benefit of input from nearly four dozen national FSP administrators/managers, the planning guidelines for SSP expansion is contained in this list, absent the aforementioned design considerations. There may be additional expansion methods, however these represent an initial consensus. From adding a news SSP deployment, expanding days of operation, and expanding hours of operation (weekday and weekend), four planning guidelines, formerly called “warrants,” are created.

2.6. Planning Guideline - Identification of Critical Factors

Just as engaging stakeholders helped refine the definition of purpose, identifying critical factors was also part of the qualitative research effort. Critical factors are those things that one

might consider in making a decision, inputs for lack of a better term. An initial list of potential SSP inputs was developed through a series of informal discussions with national stakeholders. The relative value of the inputs was captured using the national survey of SSP state points of contact. The result is the list of critical factors to be used in our guidance planning process.

There were several factors that were universally recognized as important to SSP deployment decisions. Traffic volume, number of incidents, number of crashes, and available funding were readily chosen by stakeholders as things they have or would consider in all types of SSP deployment decisions. Beyond those initial few, benefit-cost, the type/severity of incidents, input from stakeholders, and bottlenecks were well-represented inputs, though fewer considered them “more important”. The remaining items were viewed as important or less important; knowledge of the area, availability of other responders, and design/geometric attributes of the roadway.

To relate critical factors with SSP planning guidelines, a cross tabulation was performed for the national survey results. Table 2-5 shows the relationship between the expansion method and the corresponding weighted input selection. Survey responses were weighted among most important (3), important (2), or less important (1).

When cross tabulated and weighted, the critical factors for each defined purpose becomes clearer. Traffic volume, incidents, crashes, funding, benefit-cost, and stakeholder input are universal. The type/severity of incidents, bottlenecks, and knowledge of the roadway are selectively important among the purposes. The remaining five factors do not screen-in as sufficiently important for inclusion in the planning guidelines.

2.7. Planning Guideline – Planning Guideline Development

With the planning guidelines defined and the critical factors for each identified, the next step is translating critical factors into usable guidance. This involves determining how the critical factors affect the purpose and also establishing some threshold which will influence the decision. The fact that some critical factors are qualitative, while others are quantitative is complicating, as is the fact that there are multiple factors to be considered together.

Safety service patrols were founded in urban freeway settings, predominantly during peak traffic times. As the number of SSPs has grown, their value has prompted them to expand to non-peak hours and non-urban freeways. Where used in a rural setting, the nature of duties for the SSP is similar, yet different from that of their urban counterparts. On rural freeway segments, the SSP largely assist motorists in remote or isolated areas rather than reduce delay attributed to incidents (Li and Walton, 2013). The absolute volume of incidents is also quite different in the rural setting. Because the volume of traffic and the related number of incidents is quite different for the rural SSP, a distinction in the development of planning guidelines is necessary, most notably in the thresholds that are applied to the critical factors. The different operating environment posed by urban and rural segments create a need for different thresholds.

Table 2-5 Cross tabulation of expansion method and average of weighted input factors

Critical Factor	New SSP / New road	Expand Days	Expand Hours (Weekday and Weekend)
Traffic volume	2.6	2.6	2.6
Number of incidents	2.4	2.4	2.5
Number of traffic crashes	2.3	2.4	2.4
Type/severity of incidents	2.0	1.9	2.2
Bottlenecks/recurring congestion	2.1	2.1	1.9
Knowledge of the area/roadway	1.7	2.0	2.0
Availability of other responders	1.5	1.7	1.7
Available funding	2.8	2.8	2.8
Benefit-Cost Analysis	2.0	2.1	2.2
No. of lanes/presence of shoulders	1.8	1.9	1.7
Presence of bridges, tunnels, etc.	1.2	1.4	1.4
Distance between interchanges	1.0	1.2	1.1
Volume/capacity ratio (V/C)	1.7	1.6	1.8
Input from stakeholders	2.2	2.2	2.2

*Factors above 2.0 translate into important or more important

2.7.1 Historical Incident Analysis - Development of Incident Performance Functions

Understanding where SSP might be best used typically involves some examination of incidents on candidate roadway segments. This becomes somewhat problematic because minor incidents are generally under-reported when SSP are not present. Since these types of incidents make up a significant portion of the total, a simple count of incidents in police dispatch or even traffic management center (TMC) records fails to capture the full traffic incident picture for a given location without an SSP.

Using overall incident averages from one location (with SSP) to estimate traffic incidents in another locale (where SSP is being considered) is tricky given there are so many uncontrolled variables (such as traffic volumes, segment lengths, interchange spacing, and number of lanes). Similarly, using a reliable incident metric like crashes to create a crash-to-incident ratio from a current SSP location to a non-SSP location is equally problematic because of the uncontrolled variables. Fortunately a better means for estimating has been developed in recent years, albeit in a different context, traffic safety. The Highway Safety Manual provides predictive methods for traffic crash frequencies at locations using safety performance functions (SPF). Safety performance functions are equations that predict traffic crash frequencies as a function of average annual daily traffic (AADT) and roadway characteristics like the number of lanes and length of the segment.

For this research effort, the SPF methodology is replicated for the broader classification of traffic incidents using a rich data set of roadway characteristics, traffic counts, and incident history from the Florida Department of Transportation (FDOT). The FDOT Roadway Characteristics Inventory (RCI) contains geometric, cross section, and other relevant data for all state roadways,

some of which is required for the roadway characteristics portion of the methodology. Traffic counts are obtained by hundreds of portable traffic monitoring sites and telemetered traffic monitoring sites. Roadway inventory and traffic count data is stored in a geodatabase used by the research team. Finally, one dozen FDOT Traffic Management Centers (TMCs) use SunGuide software to document detailed information about traffic incidents on Florida freeways. The SunGuide incident database is easily related to the current FDOT SSP beats, hours, and days of operation to produce a subset of incident records where the SSP were deployed (Appendices A-G summarize characteristics of the SSP in each of Florida's districts). It is important to note that SunGuide documents all incidents (from minor debris removal to major crashes) irrespective of whether a Road Ranger assisted in clearing the event.

Variables describe incidents in the SunGuide database and a listing of variables is provided in Appendix H. Variables may be classified into four major categories, location data, date and time stamps, incident information, and performance data. Incidents can be mapped to GIS roadway layers to determine the characteristics of the roadway where the incident occurred. Timestamps for the events are critical for establishing reporting, response, and clearance activities. Time stamps can also be used to calculate the duration of incident activities like response time, time to clear travel lanes, and time to clear the scene. Incident information provides details concerning the nature of the incident such as the severity, lane blockage, and if an SSP assisted. In this study we consider incidents that involve one or more lane blocked that took more than 90 minutes to clear as "severe" incidents (more on this later). Performance measures were not a part of this project, but those incident variables capture the duration and secondary crashes.

For this project, each FDOT district provided SunGuide incident data in the form of CSV files.¹ While the overall data comprised more than 3.3 million records², the time periods of the data and the volume of data varied across the districts, as reflected in Table 2-6.

¹ The study team found that several records that caused error due to the illegal data entry (for example, text in numeric only field). Systematic problems are caused by the presence of comma (",") in the attributes [WRS_BLOCKAGE_DESC], [CONTACTS_DESC] and [CONDITION_DESC]. Where input contains ",", the CSV file interprets this as a new field. The study team corrected this problem by writing a macro, however, this error might be avoided if the output format is fixed-width instead of CSV.

² Even though the initial data query was for incidents on roadways with road ranger program, subsequent GIS analysis indicated that some of these incidents were not on roadways served by road rangers and these were excluded.

Table 2-6 FDOT SunGuide Historical Incident Data

FDOT District	Start Year	End Year	Total Record
1	2009	2016	302,672
2	2008	2016	272,110
3	2008	2016	17,972
4	2009	2016	700,000
5	2007	2016	400,156
6	2008	2016	382,405
7	2008	2016	443,596
Turnpike	2009	2016	784,760
Total			3,303,671

Data for FDOT District 3 begins in 2015 and some activities are included in the District 2 system/data. To ensure consistency, District 3 data from analysis, including the subset captured in the District 2 data. Overall, the data was restricted to calendar years 2010-2015, resulting in approximately 2.5 million valid incidents.

While the data set captures varying degrees of severity, for purposes of data reduction severe incidents were characterized as being lane blocking for 90 minutes, consistent with the Florida Open Roads Policy (Florida Department of Transportation and Florida Highway Patrol, 2014). A severe incident is one that satisfies the following two conditions.

- At least one lane must be blocked (WRS_BLK_TRAVELLANE_CNT, WRS_BLK_ENTRYLANE_CNT or WRS_BLK_EXITLANE_CNT must be >= 1)
- The total incident duration defined as the difference between time of event detection (DETECTED_DATE) and the time that lane was reopened (LANE_REOPEN_DATE) must be higher than 90 minute (note that Florida has a 90-minute open roads policy).

The incident data set was also classified based on day of the week (weekday and weekend day) and time of day (day and night). The data of the week classification was straightforward with Saturday and Sunday being weekend days and the remainder weekdays. It is important to note that incidents were classified as weekends only if there was a weekend Road Ranger program operational on that road segment. To classify based on time of day, 6 AM – 9 PM as the “day” and 9 PM to 6 AM as “night”. This decision was made based on the wide variety in hours of operation for SSP among the districts. The times corresponding to 6 AM – 9 PM is most representative of the day time beats. Since the night time programs are not of uniform durations, only beats that operated at least 6 hours within the period of 9P-6A will be considered to be night beat. Achieving an accurate, yet decidedly conservative, measure of daytime and nighttime SSP operations is important since two of the four planning guidelines are dependent upon that distinction.

A critical factor in the roadway layer is identification of homogeneous segments. The number of directional travel lanes, AADT, and truck factor are readily available in FDOT geodatabases. Using the intersection function in the ArcGIS software, homogeneous roadway segments were created. Additional roadway attributes such as shoulder width, median type and median width were included in the segmentation, but these attributes turned out to be statistically insignificant predictors of incident frequency. These roadway characteristics were ultimately excluded from the data set. The roadway network layers also included the location of interchanges. The method for analyzing freeways in the predictive model requires that no segments span across interchanges. The number of interchanges at the ends of each segment (0, 1, or 2) were added as

an attribute to each segment. It is useful to emphasize that the homogenous segments were created in this study. These are not the same as “segments” (defined by unique segment IDs) in the roadway network base maps maintained by FDOT.

The roadway segments were further classified as “urban” or “rural” by intersecting the roadway data with the urban area boundaries GIS layer. As shown in figure below, most of the current Road Ranger program coverage area is within urban areas.

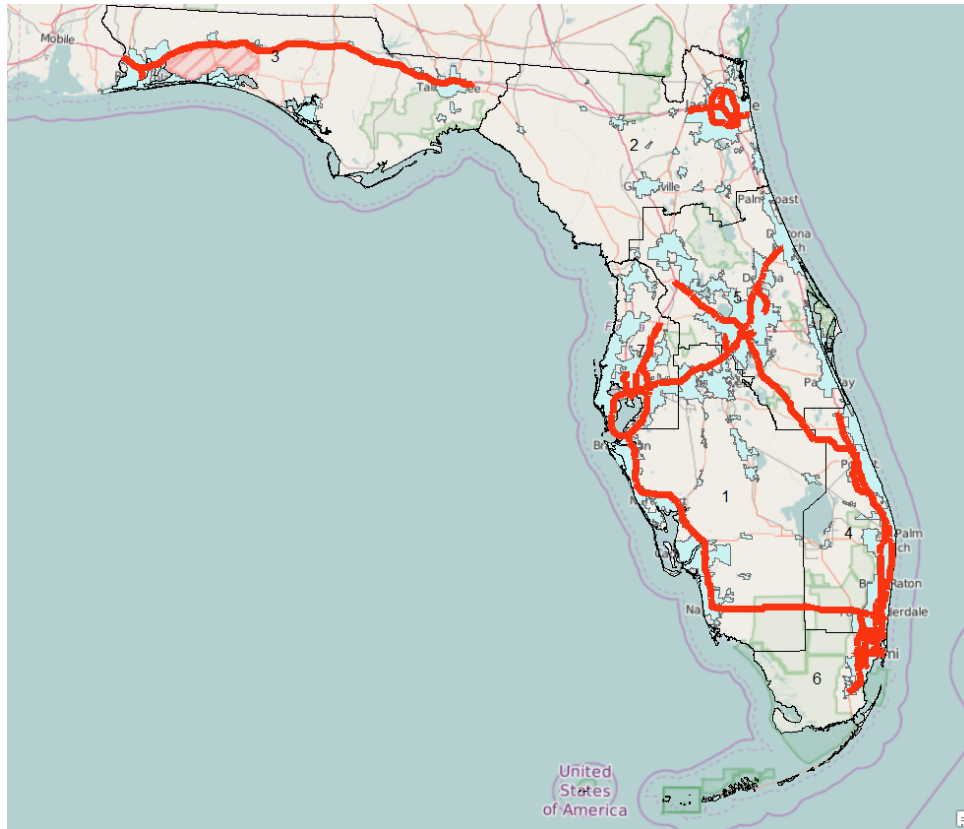


Figure 2-5 FDOT Statewide Coverage Map

Linking incident data to the roadway network is easily accomplished using a buffer around each around each segment and spatially joining all incidents within the buffer. Because the roadway network contains dual center lines with the roadway attributes were attached to one directional segment. The models and analysis will be developed for both directions together requiring incidents from both directions to be combined. In this context, a small buffer might exclude incidents from the opposite segments from being included while a large buffer potentially results in double counting of incidents at the edge of segments (especially if the segments are short). The following approach remedied this situation:

1. Use “select by location” to create subset of data that located within 200 feet from roadway in Road Ranger coverage area then create new feature from this new subset. (See footnote on how the original data did include some incidents that were not on Road Ranger service area)
2. Use “Snap” to snap the incident data to the closest roadway (this can be on the right or left segment).

3. Filter the data again for the data that happen on Road Ranger coverage link only. The use “select by location” to separate the left-hand side incidents from right hand side incidents.
4. Use “Snap” to snap left-hand side incidents to the right-handed side for each segment. Since the roadway characteristics data already attached to the right side, we now have a database which represents both directions of the roadway segment.
5. Aggregate the number of incidents by severity and time of day and day of the week to determine the incident frequencies for each segment.

The result of the data assembly procedure was four incident datasets representing a specific day of the week/time of the day period: (1) weekday day, (2) weekday night, (3) weekend day, and (4) weekend night. Given that the operational periods of the Road Ranger programs are different across the districts, the number of data points (segments) are different across these datasets. In all these datasets, each segment has data on total number of incidents, total number of severe incidents, segment length, AADT, truck factor, number of lanes, number of interchanges, and urban/rural location.

Negative-binomial regression models are the underpinning of estimating incidents. Using each of the four datasets, two models are estimated, one for total number of incidents and one for total number of severe incidents. Each of the eight models are estimated with the following type of equation:

$$N = \exp(\beta_0 + \beta_1 * \ln(\text{Length}) + \beta_2 * \ln(\text{AADT}) + \beta_3 * \ln(\text{TruckFactor}) + \beta_4 * (\text{Urban}) + \beta_5 * (\text{interchange0}) + \beta_6 * \ln(\text{number of lanes}))$$

Where

N=number of incidents (total or severe)

Length = segment length

AADT = Annual Average Daily Traffic

Truck Factor = % of trucks on roadway

Urban = 1 if the segment is in urban region and 0 otherwise

Interchange0 = 1 if the segment has no interchange at either end and 0 otherwise

Number of Lanes = number of bidirectional lanes in the segment

The following section describe the application of the models and the associated set of incident data.

Weekday-Daytime Model

The models for incident frequency (all incidents and severe incidents) for weekday day time were estimated using data from 2413 segments representing 1277 miles of roadway. A total of 2,135,724 incidents, including 28,755 severe incidents were reported on these roadways over the six year period. The models are presented in the table below and descriptive characteristics of the data used in estimation are presented in Appendix I.

As would be expected, both segment length and AADT have positive coefficients indicating increased number of incidents with increases exposure. The coefficient on number of lanes is negative indicating fewer incident with increasing number of lanes (assuming all else being constant). Segments that do no end of interchanges have fewer total incidents than those that have one/both ends as interchanges (no significant impact on severe incidents). Increased proportion of trucks increases the total number of incidents but does not impact the number of severe incidents. Segments in urban locations have fewer total incidents (after controlling for other factors such as

AADT) compared to segments in rural locations; however, the location has no impact on the frequency of severe incidents.

Table 2-7 Weekday-day Model Results

Weekday DAY				
	All Incidents		Severe Incidents	
	coeff	t stat	coeff	t stat
Constant	-4.71891	-3.14	-3.74285	-1.93
ln(AADT)	1.17972	8.04	0.93624	4.41
Ln(Length)	0.3409	11.68	0.30679	6.93
Ln(Num Lanes)	-0.87126	-3.08	-2.27143	-5.15
0 interchanges	-0.34552	-2.73	-	-
Ln(Truck Factor)	0.35791	2.43	-	-
Urban	-0.63856	-2.04	-	-
Dispersion parameter	0.1662		0.1981	

Weekday-Nighttime Model

The models for incident frequency (all incidents and severe incidents) for weekday-nighttime were estimated using data from 1,389 segments representing 494 miles of roadway. A total of 254,641 incidents, including 44,449 severe incidents, were reported on these roadways over the six-year period. The models are presented in Table 2-8, and descriptive characteristics of the data used in estimation are presented in Appendix J.

The models for incident frequency (all incidents and severe incidents) are presented in the table below. As would be expected, both segment length and AADT have positive coefficients indicating increased number of incidents with increased exposure. The coefficient on number of lanes is negative, indicating fewer incident with increasing number of lanes (assuming all else being constant). Segments that do not end on interchanges have fewer total incidents than those that have one/both ends as interchanges. However, this effect is not significant in the model for severe incidents. Increased proportion of trucks decreases the number of total incidents. Finally, the location (urban versus rural) has no impact on the frequency of incidents.

Table 2-8 Weekday-night Model Results

Weekday NIGHT				
	All Incidents		Severe Incidents	
	coeff	t stat	coeff	t stat
Constant	-1.48209	-0.80	-9.11686	-3.62
ln(AADT)	0.88433	5.03	1.5284	6.00
Ln(Length)	0.3	8.48	0.19952	3.67
Ln(Num Lanes)	-1.05403	-3.28	-2.71958	-5.73
0 interchanges	-0.33258	-2.26	-	-
Ln(Truck Factor)	-0.52841	-3.06	-	-
Urban	-	-	-	-
Dispersion parameter	0.1903		0.1716	

Weekend-Daytime Model

The models for incident frequency (all incidents and severe incidents) for weekend day time were estimated using data from 2,066 segments representing 1,084 miles of roadway. 499,944 total incidents and 4,249 severe incidents were reported on these roadways over the six year period. The models are presented in the table below and descriptive characteristics of the data used in estimation are presented in Appendix K.

The models for incident frequency (all incidents and severe incidents) are presented in the table below. As would be expected, both segment length and AADT have positive coefficients indicating increased number of incidents with increases exposure. The coefficient on number of lanes is negative indicating fewer incident with increasing number of lanes (assuming all else being constant). Segments that do no end of interchanges have fewer total incidents than those that have one/both ends as interchanges (this effect is insignificant in the model for severe incidents). Increased proportion of trucks increases the total number of incidents but does not impact the number of severe incidents. Finally segments in urban locations have fewer total incidents (after controlling for other factors such as AADT) compared to segments in rural locations. However, the location has no impact on the frequency of severe incidents.

Table 2-9 Weekend-day Model Results

Weekend DAY				
	All Incidents		Severe Incidents	
	coeff	t stat	coeff	t stat
Constant	-5.3359	-3.26	-8.26121	-3.75
ln(AADT)	1.14033	7.09	1.17403	4.80
Ln(Length)	0.35342	10.44	0.30754	5.77
Ln(Num Lanes)	-0.65593	-2.02	-2.25032	-4.34
0 interchanges	-0.35357	-2.44	-	-
Ln(Truck Factor)	0.34168	2.06	-	-
Urban	-1.2154	-3.43	-	-
Dispersion parameter	0.1827		0.1775	

Weekend-Nighttime Model

The models for incident frequency (all incidents and severe incidents) for weekend night time were estimated using data from 1,466 segments representing 522 miles of roadway. A total of 123,915 incidents, including 9,137 severe incidents were reported on these roadways over the six-year period. The models are presented in the table below and descriptive characteristics of the data used in estimation are presented in Appendix L.

The models for incident frequency (all incidents and severe incidents) are presented in the table below. As would be expected, both segment length and AADT have positive coefficients indicating increased number of incidents with increases exposure. The coefficient on number of lanes is negative indicating fewer severe incident with increasing number of lanes (assuming all else being constant). This effect is not significant for total incidents. Segments that do not end in interchanges have fewer severe incidents than those that have one/both ends as interchanges (this effect is insignificant in the model for total incidents). Increased proportion of trucks increases the number of total incidents but does not impact the number of severe incidents. Finally, the location has no impact on the frequency of severe incidents.

Table 2-10 Weekend-night Model Results

Weekend NIGHT				
	All Incidents		Severe Incidents	
	coeff	t stat	coeff	t stat
Constant	-5.2605	-2.12	-11.9385	-4.56
ln(AADT)	1.0774	4.53	1.612	6.00
Ln(Length)	0.29944	6.10	0.1771	3.29
Ln(Num Lanes)	-0.74348	-1.68	-2.6276	-5.31
0 interchanges	-0.38181	-1.89	-	-
Ln(Truck Factor)	-0.4473	-1.95	-	-
Urban	-	-	-	-
Dispersion parameter	0.2059		0.1803	

2.7.2 Thresholds for Critical Factors

If an SSP is being considered at a new location, the above equations are first applied to predict the expected number of total incidents and severe incidents. The predicted incident frequency can be compared to pre-determined thresholds to determine whether the number of incidents at that location is large enough to warrant a Road Ranger program.

Table 2-11 provides threshold values, in terms of the number of incidents per year per lane mile per 1000 units of AADT. Notice that the thresholds are provided separately for three levels of AADT (low, medium and high). Urban segments with higher AADTs are also generally shorter (because of closer interchange spacing and other geometry changes) whereas the rural segments with lower AADT are longer (greater interchange spacing). By stratifying AADTs into three bins and creating separate thresholds for each we ensure greater homogeneity in segments lengths and reduce the impact of systemic variations in segment lengths on the threshold estimate. In the current context, we notice that there is not much difference in the thresholds across the three different AADT levels.

In the case of all incidents the threshold is taken as the 50 percentile value of the number of incidents per year per lane mile per 1000 units of AADT within the appropriate AADT category and for the day of the week / time of the day period. These threshold values may be modified based on further feedback from subject matter experts.

The thresholds for severe incidents at the 50 percentile value is 0 for most cases (given that severe incidents are relatively rare). As most “severe incidents” are traffic crashes, historical data on crashes can also be used as an alternative to a predicted estimate of “severe incidents” from the models. Since police reporting provides a reliable tracking method, there is no need to predict traffic crashes using modeling. The University of Florida houses a robust traffic crash database for the FDOT, including 4.8 million Florida traffic crashes spanning the last decade. Using five years of traffic crashes (2011-2015) on Florida freeways provides the necessary basis for statistically evaluating the crash critical factor. Crashes are normalized to AADT and number of lanes and grouped according to segmentation for the different guidance types. Table 2-11 also provides thresholds on crashes.

The quantitative thresholds are accommodated by the data and the use of the SPF methodology. The thresholds for critical factors that are binary in nature are qualitative and represent feedback from national SSP stakeholders. Binary critical factors might best be viewed as questions considered in the decision-making process. For example, “have you engaged multi-discipline stakeholders in the SSP expansion decision?” or “is the estimated benefit-cost for the SSP expansion above 1.0?” Similarly, “do you and your superiors have a knowledge of the area that leads you to believe that the addition of SSP will improve safety?” and “are there bottlenecks or recurring congestion in the area considered that might benefit from SSP?” While it is true that the binary factors are somewhat subjective, when combined with other critical factors they have the ability to help in the decision-making process.

Table 2-11 Critical factor thresholds for low, medium, and high AADT roadways

LOW AADT				
AADT range	<714600	<105000	<76167	<106000
Critical Factor	Weekday Day	Weekend Day	Weekday Night	Weekend Night
All Incidents	0.2887	0.0551	0.0219	0.0072
Severe Incidents	0.0000	0.0000	0.0000	0.0000
Crashes	0.0228	0.0006	0.0058	0.0007
Stakeholder Engagement	Binary	Binary	Binary	Binary
Benefit-Cost	Binary	Binary	Binary	Binary
Knowledge of area	Binary	Binary	Binary	Binary
Bottlenecks	Binary	Binary	Binary	Binary
MEDIUM AADT				
AADT range	714600-130000	105000-162500	76167-141000	106000-162000
Critical Factor	Weekday Day	Weekend Day	Weekday Night	Weekend Night
All Incidents	0.2703	0.0603	0.0598	0.0297
Severe Incidents	0.0005	0.0000	0.0027	0.0001
Crashes	0.0309	0.0026	0.0077	0.0011
Stakeholder Engagement	Binary	Binary	Binary	Binary
Benefit-Cost	Binary	Binary	Binary	Binary
Knowledge of area	Binary	Binary	Binary	Binary
Bottlenecks	Binary	Binary	Binary	Binary
HIGH AADT				
AADT range	> 130000	> 162500	>141000	>162000
Critical Factor	Weekday Day	Weekend Day	Weekday Night	Weekend Night
All Incidents	0.2559	0.0598	0.0437	0.0215
Severe Incidents	0.0006	0.0000	0.0009	0.0000
Crashes	0.0448	0.0040	0.0067	0.0014
Stakeholder Engagement	Binary	Binary	Binary	Binary
Benefit-Cost	Binary	Binary	Binary	Binary
Knowledge of area	Binary	Binary	Binary	Binary
Bottlenecks	Binary	Binary	Binary	Binary

2.8. Planning Guideline - Preliminary Testing and Planning Guideline Adjustment

A decision support system is a method that considers inputs and then provides recommendations for action. The underpinnings of such a system might be represented as a decision table, where the broader inputs and actions are classified using rules. The representation of the conditions and actions with rules lends itself well to developing a planning guideline for SSP. With a decision table, the critical factors form the basis of the conditions. The options for each condition are represented as binary choices, “yes” or “no”, called rules. The number of rules for a decision table is typically represented in the combinations of conditions possible or arithmetically, 2 raised to the power of the number of conditions. For purposes of SSP planning guideline development, the “yes” or “no” binary choices for rules are driven by satisfaction of thresholds for that particular critical factor. Ultimately the decision table provides recommendations which are framed as actions. Table 2-12 is an example of how simple decision table as applied for these purposes.

Table 2-12 Example of a decision table

		Rules							
Conditions	Critical Factor 1	Y	Y	Y	Y	N	N	N	N
	Critical Factor 2	Y	Y	N	N	N	Y	N	Y
	Critical Factor 3	Y	N	N	Y	N	Y	Y	N
Actions	Proceed with planning guidance	X							
	Do not proceed with planning guidance					X			
	Alternative recommendation 1		X	X	X		X	X	X

Decision tables offer two features that are desirable for developing SSP planning guidance. First, they are scalable to the variety and number of critical factors that might be present. Secondly, rather than a simple “thumbs up/thumbs down” recommendation, they allow for multiple alternatives/actions. The second feature is important because it recognizes there is no one size fits all solution in SSP decisions. It provides flexibility to public policy decision-makers who must maximize taxpayer dollars while delivering public services that are not always easy to quantify, justify, or explain. This is an important because while testing and feedback showed great support for the Enterprise ITS Planning Guideline approach (Athey Creek Consultants, 2015), some practitioners noted guidelines might be “...too restrictive and local experts may understand a need for a device in locations where the guidelines do not support it.”

After defining the planning guidelines, establishing critical factors, and developing guidelines, the final step in the Enterprise model is preliminary testing and planning guideline adjustment. This implies constructing decision tables and establishes a vision for real-world application.

To implement those tables user inputs for homogenous segments and for qualitative factors are required so that decision table rules can be applied. For each homogeneous roadway segment, the length of the segment, number of directional lanes, AADT, and truck AADT are required.

These inputs feed the incident performance function modeling. The user is then required to answer the questions that relate to the binary critical factors that were mentioned previously.

Ultimately, all of the factors, both quantitative and qualitative are reduced to a series of Yes and No answers that makeup the decision table rules. In the case of the qualitative, they are already binary so they move directly into the tables. Quantitative thresholds at the 50th percentile are either satisfied (yes) or not (no) in the migration to the binary representation of the decision table rules.

Two critical factors that were identified by all survey respondents bear mentioning at this point. “Available funding” is foundational to the SSP expansion decision, and as such it would be too elementary to include in the decision tables. For this reason, available funding is assumed to be present, and if not, it is assumed that the SSP planning guidelines are being consulted as a “what if” proposition. Because of its importance, funding is part of the user input, but it does not influence the final action/recommendation.

Benefit-cost ratio is another critical element that is included in the user input and it is considered in the decision tables. A benefit-cost ratio of 1.0 or higher is typically sought to justify the expenditure associated with SSP expansion. Again, benefit-cost by itself will neither justify nor disqualify in the decision table process. Because the benefit-cost is a calculation of the estimated benefit of the SSP as it relates to the program cost, it is recommended that users consult an external tool to aid in the calculation. The FHWA (Federal Highway Administration, 2016) has a web-based TIM BENEFIT-COST (TIM-BC) TOOL that assists in determining the ratio.

A decision table was constructed for each expansion type with the corresponding inputs that came from the cross tabulation mentioned earlier. Actions were created by the research team, based on discussions with stakeholders, qualitative research results, and team expertise. The decision table approach considers multiple factors together and again, those subtle differences can be tweaked by management to represent the most important factors or current priorities of the agency.

Actions/recommendations include “proceed with planning guideline” and “do not proceed with planning guideline”. In addition, each planning guideline decision table has at least one alternative solution or recommendation. Two alternative towing program that are currently being used in Florida are worthy of consideration where there is need for an option. One is a program called “safe tow” that is being used in FDOT District 2 (Northeast Florida) where an on-call contract wrecker is dispatched immediately to remove vehicles from the roadway to a safe position on the shoulder. The FDOT pays a flat rate for removal, including a nominal fee for “dry runs”. Normal police rotation tow subsequently completes the tow away. The second alternative tow program in use in Florida is the Turnpike Enterprise Specialty Towing and Roadside Repair (STARR) Services Program. Light duty wreckers operate on a performance-based contractual basis for Florida Highway Patrol calls. The STARR program operates in lieu of the agency rotation wrecker system and is credited for significantly reducing time to clear the roadway and time to clear the scene TIM performance measures.

The following tables (Tables 2-13-2.16) represent each of the SSP planning guidelines, presented as decision tables.

Table 2-13 Decision table for new SSP service or new roadway

		Rules																																				
Conditions	Benefit-cost above 1.0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	
	Incidents above 50% thresholds	Y	Y	Y	Y	N	N	N	Y	N	N	N	Y	N	N	Y	Y	N	N	N	N	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	N	Y	Y	N	N	
	Severity above 50% thresholds	Y	Y	Y	N	N	N	Y	N	Y	N	Y	N	Y	N	N	Y	N	N	N	Y	Y	Y	N	Y	N	Y	N	Y	N	Y	N	Y	Y	N	Y	N	
	Bottlenecks	Y	Y	N	N	N	Y	Y	N	N	Y	Y	Y	N	N	Y	N	N	N	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	Y	N	Y
	Stakeholder engagement	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	Y	Y	N	N	N	N	N	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	N	N	N
Actions	Add SSP	✓	✓					✓				✓			✓	✓											✓				✓			✓	✓			
	Do not add SSP				✓	✓	✓			✓	✓			✓	✓			✓	✓	✓							✓				✓	✓			✓	✓		
	Consider alternative tow program			✓				✓				✓															✓	✓	✓	✓								

Table 2-14 Decision table for expanding days of operation to seven days per week

		Rules																																				
Conditions	Benefit-Cost above 1.0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N		
	Weekend incidents	Y	Y	Y	Y	N	N	N	Y	N	N	N	Y	N	N	Y	Y	N	N	N	N	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	N	Y	Y	N	N	
	Weekend severity	Y	Y	Y	N	N	N	Y	N	Y	N	Y	N	Y	N	N	Y	N	N	N	Y	Y	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	Y	N	N
	Bottlenecks	Y	Y	N	N	N	Y	Y	N	N	Y	Y	Y	N	N	Y	N	N	N	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	Y	N	Y
	Stakeholder engagement	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	N	Y	Y	N	N	N	N	N	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N
Actions	Implement weekend schedule	✓	✓	✓				✓								✓	✓														✓							
	Do not implement weekends				✓	✓	✓			✓	✓	✓	✓	✓				✓	✓	✓							✓	✓	✓			✓			✓	✓		
	Consider seasonal or special event adjustments in lieu							✓	✓																		✓	✓	✓			✓		✓	✓			

Table 2-15 Decision table for expanding hours of operation to weekday-nighttime hours

		Rules																																									
Conditions	Benefit-cost above 1.0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N							
	Weekday-nighttime incidents above 50% thresholds	Y	Y	Y	Y	N	N	N	Y	N	N	N	Y	N	N	Y	Y	N	N	N	N	Y	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	N	N							
	Weekday nighttime severity above 50% thresholds	Y	Y	Y	N	N	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	N	N	Y	Y	Y	N	Y	N	Y	N	Y	N	Y	N	Y	Y	N							
	Knowledge of the area	Y	Y	N	N	N	Y	Y	N	N	Y	Y	Y	N	N	Y	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	Y					
	Stakeholder engagement	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	N	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N			
Actions	Implement night coverage	✓	✓	✓					✓																													✓					
	Do not implement night coverage					✓	✓					✓	✓	✓	✓	✓									✓	✓	✓			✓	✓	✓					✓				✓	✓	
	Consider expanding hours but <24					✓					✓																		✓	✓											✓	✓	✓
	Consider alternative tow program					✓				✓	✓																		✓	✓	✓											✓	✓

Table 2-16 Decision table for expanding hours of operation to weekend-nighttime hours

		Rules																																												
Conditions	Benefit-cost above 1.0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N							
	Incidents during weekend- nighttime above 50% thresholds	Y	Y	Y	Y	N	N	N	Y	N	N	N	Y	N	N	Y	Y	N	N	N	N	Y	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	N					
	Weekend nighttime severity above 50% thresholds	Y	Y	Y	N	N	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	N	N	Y	Y	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	Y	N	Y	Y	N			
	Knowledge of the area	Y	Y	N	N	N	Y	Y	N	N	Y	Y	Y	N	N	Y	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	Y				
	Stakeholder engagement	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	N	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	N	N					
Actions	Implement night coverage	✓	✓	✓					✓																																✓					
	Do not implement night coverage					✓	✓					✓	✓	✓	✓	✓									✓	✓	✓			✓	✓	✓									✓			✓	✓	
	Consider expanding hours but <24					✓					✓																		✓	✓														✓	✓	✓
	Consider alternative tow program					✓				✓	✓																		✓	✓	✓														✓	✓

2.9. Summary and Conclusions

A survey of national state points of contact for SSP found that there is no generally accepted way to deploy SSP. When asked specifically if they employed any type of mathematical formula, spreadsheet, or other computer programs to identify which roadways should be patrolled by SSP, only 4 survey participants answered affirmatively. For those four responses, the open-ended follow-up question helps elaborate. Three described that historical incidents were analyzed to define zones. One relied on traffic volume and incidents in a benefit-cost analysis.

Using a proven framework for warranting ITS devices like closed-circuit television (CCTV), dynamic message signs (DMS), and road weather information systems (RWIS), this research provides a new method for deploying SSP. Given that SSP are often deployed alongside ITS investments, the framework is not only reliable, but relevant. Defining the purpose for SSP deployment, establishing critical factors needed, developing guidelines (thresholds), and testing/adjustment prove to be a worthy framework.

State and national SSP stakeholders provided the basis for identifying critical factors and thresholds, ensuring that the most important considerations were included in the guidelines. By using proven techniques for predictive modeling, the historic gap in estimating potential SSP incidents is resolved. By adding the use of decision tables, multiple criteria can be evaluated together to render recommendations. Strengths of the decision table approach are evidenced by scalability and flexibility in design and perhaps most importantly, the ability to consider alternatives beyond the simple “yes” or “no” that is typical of warrants.

The SSP guidelines developed herein were validated with an actual roadway segment in Florida, where SSP is envisioned, but not yet deployed. In meetings with stakeholders, the predictive models and decision tables worked effectively to recommend addition of SSP on the candidate segment. Evaluating each critical factor, the stakeholders were in agreement with the approach and recommendations. Coincidentally, another candidate roadway with much lower AADT did not result in a recommendation for addition.

The use of a quartile threshold for incidents and crashes provides significant flexibility going forward, as does the use of decision tables that can be easily adjusted through experience. The framework for the SSP guidance that is advanced herein is based on sound methodology and poised to be improved by its design.

Given there is no accepted method currently used to make SSP investment decisions, the guidance procedure developed by this research can be used by other states and jurisdictions. Should other states want to replicate the methodology in this research, the predictive models for incidents will require state/local calibration, as they would for HSM safety performance functions.

CHAPTER 3: DESIGN OF ROAD RANGER SERVICE PATROLS DEPLOYMENT

Safety service patrols (SSP), known in Florida as Road Ranger service patrols (RRSP), have long been proven as an efficient strategy to detect, respond, and prevent incidents across the United States. Two key decisions are central when designing the deployment strategy for such services. The first decision is related to the location or coverage of the patrol. In many cases, due to a limited budget and insufficient human resource, the SSP program cannot cover every mile of roadway in a district for 24 hours a day, 7 days a week. Therefore, factors including available funding, traffic conditions, incidents, and the trade-off between costs and benefits are crucial in determining the best locations for operating the SSP program. In Task 1 of this project, a set of recommendation criteria has been established, with illustrations on the procedure to certify an expansion on proposed roadways. The expansion of RRSP is specified into four types, namely adding a new RRSP deployment, expanding days of operation, and expanding hours of operation (weekday and weekend). For each expansion type, a planning guideline is created. The planning guidelines are applied in a decision support system to yield a recommendation action after considering the values of all critical factors. The universal critical factors concluded in Task 1 are *benefit-cost ratio above 1*, *number of incidents above 50% threshold*, *number of severe incidents above 50% threshold*, *existence of bottlenecks* and *stakeholders engagement*. Finally, the recommendation actions include “yes”, “no”, and “consider alternative programs”.

Given that a segment is recommended for SSP deployment, the next question for FDOT districts is how to cover and patrol the target segment efficiently, given finite resources. More specifically, an SSP program needs to be designed to cover a segment, which is usually divided into multiple beats, with a certain number of patrol vehicles/trucks assigned to each beat. Trucks patrol the beat and assist with small incidents, change tires, handle roadway debris, report and help manage crashes, as well as manage other necessary responsibilities. Operation hours can be flexible due to the variation of traffic situations.

In conjunction with this research, a national survey of state points of contact for SSP was conducted in Spring 2016. Nationally, the majority of deployments are operating according to a simple coverage of a certain area in a given amount of time. Traffic volume, the number of incidents, and a benefit-cost ratio are used as reference, though no location uses a computational method for deployment decisions. A comprehensive survey conducted in 2008 (Baird, 2008) provided a quantitative description of freeway service patrol deployment: the median number of vehicles owned by each SSP program is 11 (103 respondents), and the median number of vehicles patrolled on peak periods is 6 (101 respondents); the median number of SSP program travel miles during peak travel periods is 96 miles (92 respondents), and the median number of average headway, which is calculated by dividing route miles by the number of peak vehicles on patrol, is 14.8 miles. However, this survey didn't consider the lengths of beats in an SSP program.

In Florida, decisions on beat configuration were made two decades ago and mostly based on experience. In most of the existing RRSP deployments, the roadways are divided into roughly equal parts, with interchanges as the starting and ending points of each beat for patrol vehicles to turn around. The division is based on a certain target time for vehicles to make a bi-directional circuit. For example, beat lengths in District 2 are approximately 15 miles along the centerline, so that patrolling vehicles can make a circuit in 30 minutes at a normal driving speed; the I-95 RRSP in District 4 is also divided into 3 equal parts for vehicles to circulate the beat every 30 minutes. In District 3, since the 180 miles along I-10 are located in rural areas, the beats are selected to be 60 miles so that the vehicles can make one-hour coverage per direction.

Several districts also used historical data as a reference. District 1 recently modified the starting and ending points to improve beat coverage after reviewing incident data. In District 5, each beat is 20 miles long so that one patrolling vehicle can respond to incidents in 30 minutes or less. During peak periods, an additional truck is assigned to each beat so that a response time of 15 minutes can be achieved. The Regional Research and Development Information Service (RRDIS), an add-on product of the SunGuide-Florida Transportation Intelligence System, has been applied by District 6 to track historical crashes and response times as well as manage scheduling drivers and crashes. Several districts have also applied seasonal adjustments on beats, operation hours, and number of vehicles due to floating traffic volumes. For the Florida Turnpike Enterprise, funding is also a key decision variable for beat configuration.

In SSP deployment, there is always a fundamental trade-off between benefits and costs. On one hand, patrolling more miles per vehicle would decrease the number of required vehicles and lead to a reduction in costs. On the other hand, if more vehicles were assigned to a beat and beat lengths were shortened, a quicker response would be guaranteed, but it would also lead to significant increase in the total operation cost. In addition, deployments based on historical data do not necessarily improve the performance of an existing SSP program, and it is hard to decide the optimal plan for a new “warranted” roadway. In order to incorporate various decision variables into a planning process, researchers have developed mathematical models capable of addressing the trade-off between benefits and costs to better utilize limited funding and other resources. In this report, three different design models are proposed and solved in order to provide a recommendation for the deployment of an SSP program along the warranted segments. First, a fleet size minimization model is presented, which provides the minimum total number of patrol vehicles required to meet a target response time. The second model attempts to minimize the total average response time given that the fleet size is specified. This model will help achieve the minimum average response time over the whole corridor. Finally, the third model solves the deployment problem for corridors without any prior RRSP deployment, where the empirical data on fleet size and response time are not available. In addition, it is worth noting that these models do not specify the types of vehicles, since vehicle type is closely related to incident type and geometric conditions and thus needs to be further determined at the operations stage.

The remainder of this chapter is organized as follows: the next section reviews the available literature on the SSP planning followed by a detailed discussion of the models and their corresponding mathematical optimization formulations in Section 3. The fourth section discusses the heuristic algorithms proposed for solving the three proposed models. Finally, the appendix describes the integrated computer tool created in Excel VBA. A set of data is required for applying planning guidelines as well as optimization models for deployment. The model requires input data that are readily available from current practices of incident reporting and decision variables such as beat configuration, hours of operation, and the number of vehicles. A prototype computer-aided decision-support tool has been developed based on the model in Excel, which can be used by managers responsible for contracting and for RRSP operations.

3.1. Literature Review

To date, the literature on the design and deployment of an SSP program using mathematical modellings is limited. Since developing a patrolling strategy is a proactive form of incident management, the information about incident locations and duration is unknown to patrollers. Therefore, many deployments rely on historical and empirical data. In North Carolina, when

deciding the fleet size of a new corridor, a regression model calibrated from North Carolina IMAP data is applied. Simulation models have also been widely used to deploy new programs and make adjustments to existing programs.

Under the assumption that beat configuration is given, Petty (1997) and Yin (2006) addressed the fleet allocation problem using two distinct approaches. Petty developed a mathematical programming with an objective that maximizes profit given that the SSP is deployed. Delay reduction is regarded as a benefit, and the costs for the tow truck are regarded as the total operation cost. A fundamental queuing diagram is used to model traffic delay, and marginal benefit analysis is applied as the solution method. Since this model considers capacity, which may vary from one period of a day to another, the number of trucks assigned to each beat may vary within a day. Yin (2006) derived a min-max bi-level programming model to determine an optimal fleet allocation that minimizes the maximum system travel time that may result from incidents. A heuristic iterative solution algorithm was proposed to solve this non-convex model as well.

Lou et al. (2011) and Yin (2008) integrated beat configuration and fleet allocation problems into a single model, both in deterministic and stochastic cases. In the deterministic SSP Planning model (DFSP), travel time and incident frequency on each link are assumed to be deterministic parameters. A nonlinear mixed-integer programming model was developed to minimize the overall average incident response time. This model considers the existence of commercial tow trucks whose average response time is applied as the maximum response time for SSP trucks. The number of available tow trucks as well as an upper bound for the fleet size is also provided. Three heuristic algorithms were proposed to solve this model. The stochastic SSP Planning Model was extended from the DFSP model by allowing the number of incidents and response time to be stochastic. The model considered more than one scenario that can be generated from empirical distributions of incident occurrences by considering their impact on travel time. The DSFP can then be viewed as an average scenario. In order to eliminate over conservative solutions, the model focuses on high-consequence scenarios and attempts to minimize the expected response time incurred by high-consequence scenarios. The three heuristic algorithms mentioned above are still feasible in solving this stochastic model.

Contrary to the patrolling strategy, which is proactive incident management, the dispatching policy is a responsive management that traffic management centers directly dispatch tow trucks to incidents from a centralized depot, after incidents are detected or reported. There are extensive studies that concentrate on depot locations, fleet size, and vehicle routings.

In evaluating the benefits of a freeway service patrol in an urbanized area, the social benefits are mainly quantified by the monetary value of savings on traffic delays, fuel consumption and pollution emission, and secondary incidents. Comparing situations with and without SSP is a widely used evaluation approach first introduced by Sakabardonis et al. (1998). In this macroscopic analysis approach, incident delays are calculated based on queueing diagrams, where the relation of incident delays to all the other factors is linear. In rural areas where the traffic volume is low, the benefits derived from delay reduction are negligible, since no severe capacity reduction is experienced. Li and Walton (2013) indicated that the major function of SSP in low-traffic areas is to assist stalled vehicles, protect stranded drivers, and provide free road assistance services. Accordingly, the major benefit is calculated as the stranded driver's savings by using the free SSP service instead of a commercial towing or roadway assistance company.

3.2. Designing Models

Designing patrolling strategies involves three major tasks: beat configuration, operations scheduling, and assignment of patrol vehicles. The schedule for the operation hours was decided in Task 1 where time periods of operation were classified into weekday daytime, weekday nighttime, weekend daytime, and weekend nighttime. Therefore, the design models in Task 2 focus on beat configuration and vehicle assignment for a specific operation period.

The consecutive freeway corridor is assumed as a directed graph $G(N, A)$, where N is the set of nodes and A is the set of links in the graph. Each node $i \in N$ represents an interchange in reality where patrol vehicles can turn around. Each link $(i, j) \in A$ represents a freeway segment. For each link (i, j) , the freeway patrol time t_{ij} and incident frequency f_{ij} are predetermined. A beat b contains one or more continuous freeway segments that a total of $v_b (\geq 1)$ vehicles patrol. The freeway corridor G is covered by a total number of B beats and V patrol vehicles, with $V \geq B$. It is also assumed that no two adjacent beats overlap, although in practice there may be short segments commonly covered by two beats.

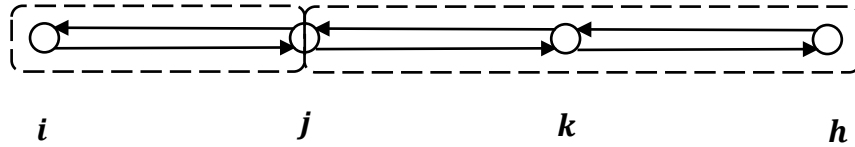


Figure 3-1 Freeway Corridor

In this section, three different models are presented as follows. The first model (**P1**) minimizes the total number of patrol vehicles of the corridor, if the target response time is given. Under the condition when the total fleet size is known, the second model (**P2**) attempts to minimize the total average response time. The third model (**P3**) solves the deployment problem for corridors if neither the fleet size nor the target response time is specified. The objective of **P3** is then to maximize total social benefits, which usually include benefits associated with delay savings, reduced fuel consumption, emission reduction, and reductions in secondary incidents.

3.2.1 Fleet Size Minimization

For districts with RRSP, incident response time is an important performance measure in evaluation. Given the target response time, the goal of the formulation is to minimize the total fleet size of the corridor in order to achieve the lowest operations cost. Model P1 provides the details of the mathematical formulation in below:

Model P1:

$$\text{Min } \sum_b v_b \quad (1)$$

$$\text{s. t. } \sum_{ij \in A} \frac{t_{ij} x_{ij}^b}{2v_b} \leq \bar{t} \quad \forall b \in \{1, 2, \dots, B\} \quad (2)$$

$$\sum_{ij \in A} t_{ij} x_{ij}^b \leq \hat{t} \quad \forall b \in \{1, 2, \dots, B\} \quad (3)$$

$$\sum_b x_{ij}^b = 1 \quad \forall (i, j) \in A \quad (4)$$

$$\sum_{ij \in A} x_{ij}^b \geq 2 \quad \forall b \in \{1, 2, \dots, B\} \quad (5)$$

$$x_{ij}^b = x_{ji}^b \quad \forall (i, j) \in A, b \in \{1, 2, \dots, B\} \quad (6)$$

$$y_i^b \leq \sum_{j, ij \in A} x_{ij}^b \leq M y_i^b \quad \forall i \in N, b \in \{1, 2, \dots, B\} \quad (7)$$

$$\sum_{i \in N} O_i^b y_i^b = 1 \quad \forall b \in \{1, 2, \dots, B\} \quad (8)$$

The goal of the mathematical formulation P1 is to minimize the fleet size (equation 1). Constraint (2) ensures that the average response time does not exceed the target response time \bar{t} . x_{ij}^b is a binary variable, which is equal to 1 if link (i, j) belongs to beat b and takes 0 otherwise. Under the assumption that the incidents happen uniformly over the corridor, the average response time to an incident is half of the headway between patrol vehicles. Constraint (3) bounds the beat length within the beat circulation time. Constraints (4) – (8) specify network characteristics. In particular, constraints (4) – (6) indicate that one link can only be assigned to one beat, and the same beat must contain both directions of a road segment. Constraints (7) and (8) ensure each beat has no disjointed segment. y_i^b and O_i^b are binary variables. y_i^b indicates whether or not node i belongs to beat b . M is a sufficiently large number. If $y_i^b = 0$, no link starting from or ending with node i is covered by beat b ; otherwise, at least one segment (both directions) starting from or ending with node i is covered by beat b . Constraint (8) defines the starting node of a beat b ; O_i^b equals 1 if i is the starting node of beat b . Since the network is a bi-directional linear structure, each beat would have only one starting node. Constraints (7) and (8) are generated based on flow balance equations (Ahuja et al. 1993).

3.2.2. Total Average Response Time Minimization

If the total amount of budget is available, a well-designed patrolling strategy can help achieve the highest margins of efficiency. The number of available patrol vehicles can be used to represent the budget, and the efficiency is largely represented by average response time. The second model, P2, configures the beat design and allocates the vehicles such that the minimum total average response time is achieved.

Model P2:

$$\text{Min} \sum_b \left(\sum_{ij \in A} \frac{t_{ij} x_{ij}^b}{2v_b} \sum_{i, j \in A} f_{ij} x_{ij}^b \right) \quad (9)$$

s. t. Constraints (3) – (8)

$$\sum_b v_b \leq V \quad \forall b \in \{1, 2, \dots, B\} \quad (10)$$

Where \bar{t} is target response time, \hat{t} beat is circulation time and V is the fleet budget.

In the above formulation, $\sum_{ij \in A} \frac{t_{ij} x_{ij}^b}{2v_b}$ in the objective function is the average response time for an incident on beat b , and $\sum_{i, j \in A} f_{ij} x_{ij}^b$ is the total incident frequency on beat b . The overall

objective function determines the total average response time to all incidents along the corridor. In addition, the constraints regarding the circulation time requirement and network characteristic constraints still hold in this case. In this model, the total number of vehicles is constrained by fleet budget.

3.2.3 Social Benefit Maximization

The third model deals with the situation in which both budget and efficiency target are unclear. In this case, neither minimizing the total average response time nor minimizing the total fleet size is feasible. Therefore, the third model that maximizes the social benefit is proposed.

In urban areas, the main benefits that can be identified are from delay savings, fuel consumption reduction, and emission reduction. The Freeway Service Patrol Evaluation Model proposed by Sakabardonis et al. (1998) can be applied to calculate such benefits. In rural or low-traffic volume areas, when an incident doesn't cause a delay, the benefits of a real-time response to an incident can be viewed as the savings in waiting time for the drivers, compared to a situation in which drivers are serviced by commercial tow companies. In the formulation below, the closed-form of these benefits are analytically derived.

Model P3:

$$\text{Max} \sum_{b,k} B_b^{d,k} TTV_b + B_b^{f,k} F_b + B_b^{e,k} E_b^e + B_b^{s,k} S_b^k + \sum_b B_b^{w,k} WTC_b - c * \sum_b v_b \quad (11)$$

s.t. Constraints (3) – (8)

In the above, the objective function maximizes the total social benefits minus the total cost. Incidents are classified into K categories by the number of lanes the incident blocked and the total number of lanes before the incident. For the k th type of incidents on beat b , the social benefits include delay savings, waiting time savings, fuel consumption reduction, and emission reduction. The benefit of secondary incident reduction is also counted as a type of social benefit, but it is not quantified in this model. More specifically,

$$B_b^{d,k} = \sum_{ij \in A} (\tilde{t}^2 - t_b^2) \frac{(v_{ij} - c_{ij}^k)(c_{ij} - c_{ij}^k)}{2(c_{ij} - v_{ij})} (\sum_{ij \in A} f_{ij}^k x_{ij}^b), \quad \text{if } v_{ij} - c_{ij}^k > 0, \forall k \in \{1, 2, \dots, K\}, b \in \{1, 2, \dots, B\}$$

Where \tilde{t} is the average response time to an incident by commercial companies, which is applied here as a reference to the longest response time. v_{ij} is the traffic volume on link ij , c_{ij} is the original capacity before the incident, c_{ij}^k is the remaining capacity after the k type of incident happens, and f_{ij}^k is the incident frequency of type k . The equation is derived as per Figure 2 and the impacts of incident on capacity can be found in Table 1.

$B_b^{f,k} = B_b^{d,k} e_f$ is the benefit of fuel consumption reduction, where e_f is the fuel factor.

$B_b^{e,k} = B_b^{d,k} e_p$ is the benefit of emission reduction.

TTV_b represents the value of travel time which converges benefits in a time unit into monetary value.

$B_b^{w,k} = \tilde{t} - t_b$ represents savings on waiting time, when $v_{ij} - c_{ij}^k < 0$, which means that the incident caused no traffic delay, in which case the major benefits would be the time savings of the stranded driver.

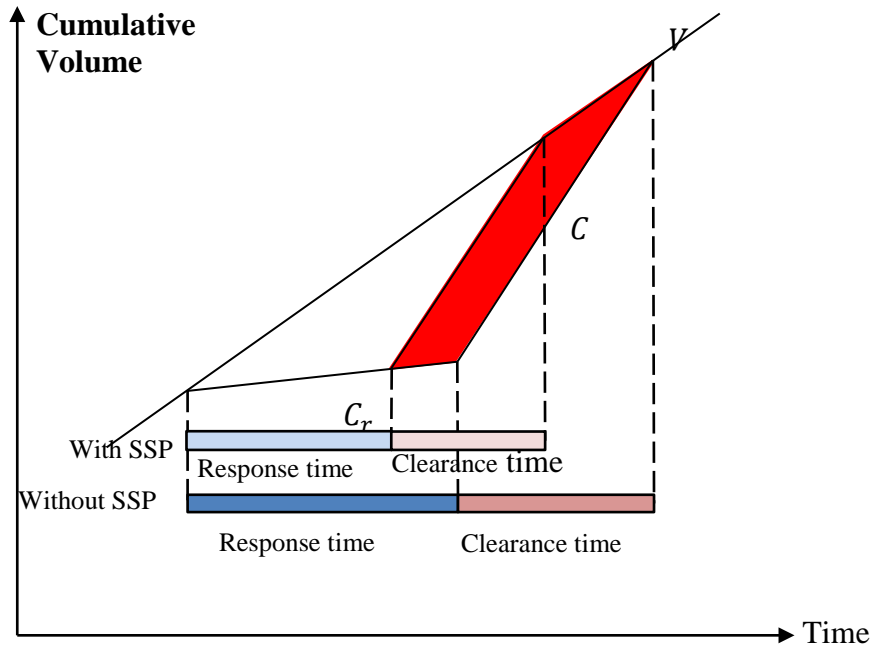


Figure 3-2 Fundamental Queueing Diagram

Table 3-1 Residual Freeway Capacity in Incident Zones per the HCM

Number of Lanes (One Direction) Before Incident	Shoulder Disablement	Shoulder Accident	One Lane Blocked	Two Lanes Blocked	Three Lanes Blocked
2	0.95	0.81	0.35	0	N/A
3	0.99	0.83	0.49	0.17	0
4	0.99	0.85	0.58	0.25	0.13
5	0.99	0.87	0.65	0.4	0.2
6	0.99	0.89	0.71	0.5	0.26
7	0.99	0.91	0.75	0.57	0.36
8	0.99	0.93	0.78	0.63	0.41

3.3. Data Collection

In the implementation of design models, several parameters must be adjusted in order to reflect real world conditions. In particular, incident frequencies play an important part in designing models. However, the historical data alone cannot capture a full picture of the traffic incidents. For example, in places where RRSP has not been deployed, minor incidents tend to be under-reported. Incident Performance Functions, following the methodology of safety performance functions found in the Highway Safety Manual, are generated based on the data from the Florida SunGuide and FDOT Roadway Characteristics Inventory (RCI). The total number of incidents generated captures a broad range, from minor incidents to severe crashes. For deployment purposes, the percentage of incidents assisted by RRSP to the total number of incidents is calculated by studying historical data. Incident data sets are classified into four time periods: weekday daytime, weekday nighttime, weekend daytime, and weekend nighttime, corresponding to the four operation time

periods. In order to capture a more accurate value of total benefits, the incident data sets are also classified by location: no lane blocked, shoulder incidents, one lane blocked, two lanes blocked, and other. Incident performance function has a form:

$$N = \exp(\beta_0 + \beta_1 * \ln(\text{Length}) + \beta_2 * \ln(\text{AADT}) + \beta_3 * \ln(\text{TruckFactor}) + \beta_4 * (\text{Urban}) + \beta_5 * (\text{interchange0}) + \beta_6 * \ln(\text{number of lanes}))$$

Refer to the technical memorandum of Task 1 for more details.

The value of travel time can be estimated by studying the local hourly salary, truck percentage on roadways, and average vehicle occupancy/truck rate. A review on RRSP cost-benefit analysis conducted by Lin et al. (2012b) listed the value of travel time in Florida per operation zone, and is used as the reference in this work.

However, when converting waiting time into monetary value, there is no study that accurately estimates the value of the waiting time. Therefore, the value of waiting time, WTC_b is estimated based on the average price of towing or assistance services provided by commercial companies. The value of waiting time should be greater than the value of travel time.

Travel speed is used to capture the travel time of each beat. In normal conditions, the travel speed applied here is based on posted travel speed. If the candidate corridor is located in an urban area, and the deployment is designed for weekday day time, the average speed during peak hours needs to be adopted.

3.4. Solution Algorithms - Neighborhood Search Techniques

In this work, three heuristic algorithms based on neighborhood search methods are applied in order to solve the proposed mathematical programming formulations. A neighborhood search, also known as a local search, is a heuristic method for solving computationally hard combinatorial optimization problems. A neighborhood search starts with a feasible solution, and by applying local changes, the algorithm moves from solution to solution in the space of candidate solutions, stopping when a certain criterion is reached or a time limit is elapsed. In this problem, the initial solution is generated by considering each segment as a beat. Then, by combining its adjacent segments, or links, and adjusting the number of vehicles assigned to each beat under different requirements, the algorithm will improve the initial solution until no improvement is achieved. In this case, the algorithm will converge to a local minimum.

Consider the freeway as a horizontal bi-directional linear structure consisting of multiple consecutive links. Here, a “link” refers to a segment with both directions. One or more connected links are assigned to one beat, indicated by b_s . Each beat is identified by its left link ID, l_b , and right link ID, r_b , which determines the starting and ending points together, and the number of patrol vehicles assigned to the beat, v_b .

3.4.1. Fleet Size Minimization

When a beat design is given, the original problem degenerates into a linear program:

$$\begin{aligned} & \text{Min } \sum_b v_b & (12) \\ \text{s. t. } & \frac{t_b}{2v_b} \leq \tilde{t} & \forall b \in \{1, 2, \dots, B\} & (13) \end{aligned}$$

Thus, the optimal solution would be $\sum_b \lceil \frac{t_b}{2\tilde{t}} \rceil + 1$, meaning that we can solve the sub-problem in a greedy search procedure.

As previously mentioned, the neighborhood search algorithm is applied to find feasible beat designs. Starting from a feasible beat design, for each beat b , the algorithm will add adjacent links r_{b-1} and l_{b+1} to beat b and check whether the new beat design satisfies constraint $\sum_{ij \in A} t_{ij} x_{ij}^b \leq \hat{t}$. If the constraint is satisfied, the beat index will be updated to meet constraints (2) – (6), in which one link (two directions) is only assigned to one beat, and beats are continuous. There are two possible scenarios for updating the solution:

Scenario 1: if the adjacent beats $b - 1$ or $b + 1$ contain only one link, adding link r_{b-1} or l_{b+1} to beat b , the number of beats will decrease by 1, and the beat index will decrease by 1.

Scenario 2: if the adjacent beats $b - 1$ or $b + 1$ contain more than one link, only the beat index of the newly added link, the left or right link of beat b , will be updated.

Algorithm 1

1. **Begin**, generate an initial solution $(\mathbf{b}, \mathbf{l}, \mathbf{r}, \mathbf{v})$
 2. **Set** a binary variable flag equal to true
 3. **While** flag = true
 4. Add boundary links to adjacent beats and update beat configuration to $(\mathbf{b}', \mathbf{l}', \mathbf{r}')$
 5. Update fleet size in the greedy search manner to \mathbf{v}'
 6. **If** the circulation time requirement is satisfied, **then**
 7. **Update** the beat configuration by scenario 1 or scenario 2
 8. $(\mathbf{b}, \mathbf{l}, \mathbf{r}, \mathbf{v}) \leftarrow (\mathbf{b}', \mathbf{l}', \mathbf{r}', \mathbf{v}')$
 9. Flag = false
 10. **End if**
 11. **End While**
 12. **End**
-

3.4.2. Minimum Response Time

When a beat design is given, the problem degenerates into

$$\min \sum \frac{t_b}{2v_b} \quad (14)$$

$$s. t \sum v_b \leq V \quad (15)$$

The objective function decreases when the number of vehicles increases. Therefore, the optimal solution of the sub problem can be written as

$$\min \sum \frac{t_b}{2v_b} \quad (16)$$

$$s. t \sum v_b = V \quad (17)$$

Starting from a feasible initial solution, the overall procedure will first improve the beat design by using neighborhood search algorithm; then, with a fixed fleet size, the number of vehicles are allocated to each beat to decrease the total average response time until no improvement

in objective function is achieved. The initial solution is generated by marking each segment as one beat and assigning one patrolling vehicle to each beat. However, this initial solution may not be feasible since the fleet budget constraint cannot always be satisfied. In order to generate a feasible initial solution, two cases are considered:

Case 1: The fleet size is greater than the fleet budget. Starting from the first beat b that satisfied the circulation time requirement, merge beat $b + 1$ to beat b , and assign one patrol vehicle to the new beat. If the new beat satisfies the beat circulation time requirement, update the beat design. As a result, the beat size and fleet size will decrease. Repeat the procedure until the fleet budget constraint is satisfied.

Case 2: The fleet size is less than the fleet budget. In this case, extra patrol vehicles can be assigned to the beat, which results in more patrol vehicles. Consider the beat b_m that has the maximum value of beat length multiplying incident frequency. Assigning the vehicles to this beat, the fleet budget constraint is satisfied, and a feasible solution is obtained. However, the feasible solution may not be an optimal one. Transporting one patrol vehicle from one beat to another can help decrease the total incident response time in order to generate a better feasible solution.

Algorithm 2

1. **Begin**, generate an initial solution (b, l, r, v)
 2. **While** fleet size \neq fleet budget
 3. Generate a feasible solution (b', l', r', v')
 4. End While
 5. **Update** beat design by adding boundary links to adjacent beat b , the new beat configuration to (b', l', r') :
 6. **If** scenario 1 is met
 7. Fleet size of beat b equals to $v_b + v_{b+1}$ or $v_b + v_{b-1}$, the number of beats decreases by 1, the new fleet allocation is v'
 8. **If** the circulation time requirement is satisfied, **then**
 9. Update the beat configuration $(b, l, r, v) \leftarrow (b', l', r', v')$
 10. **End if**
 11. End if
 12. **If** scenario 2 is met
 13. The fleet size of each beat remains unchanged
 14. **If** the circulation time requirement is satisfied, **then**
 15. Update the beat configuration $(b, l, r, v) \leftarrow (b', l', r', v)$
 16. **End if**
 17. End if
 18. **Improve** the feasible solution by allocating patrol vehicles
 19. End
-

3.4.3. Social Benefit Maximization Model

The overall algorithm is similar to the fleet size minimization model. However, for every given beat design, the assignments of vehicles are not based on target response time. Instead, the assignment of vehicles that yields the maximum social benefits is accepted.

When assigning the number of trucks to each beat, there is no constraint to follow. Therefore, a depth-first search is applied. We set an upper bound of the number of trucks that can be assigned to each beat, then choose the value that can help achieve the maximum social benefits among all as the candidate solution.

Algorithm 3

1. **Begin**, generate an initial solution (b, l, r, v)
 2. **Set** a binary variable flag equal to true
 3. **While** flag = true
 4. Add boundary links to adjacent beats and update beat configuration to (b', l', r')
 5. Update the fleet size by depth-first search to v'
 6. **If** the circulation time requirement is satisfied, **then**
 7. **Update the** beat configuration by scenario 1 or scenario 2
 8. $(b, l, r, v) \leftarrow (b', l', r', v')$
 9. Flag = false
 10. **End if**
 11. **End While**
 12. **End**
-

3.5. Numerical Example

For illustrative purposes, all three models were applied to a 72-mile stretch of freeway on I-95 in Brevard County. Note that this was done irrespective of evaluating SSP warranting in order to demonstrate how deployment/design might be approached using a diverse roadway with multiple segments. The geometric and traffic information are shown in Table 2. For the Total Average Response Time Minimization, we set the available fleet size as 8 vehicles. Operation cost per truck is set at 56 dollars per hour, which is recommended by RRSP project managers. Other parameters including fuel factors, emission factors, and value of travel time used are taken from a benefit analysis report of RRSP by Lin et al. (2012). The value of waiting time is estimated as 70 dollars per hour. Beat design and truck assignment are shown in Table 3, while evaluation and comparison are shown in Table 4. The deployment is designated for weekday daytime, 5 am to 9 pm.

Table 3-2 I-95 Brevard County

Starting	Ending	Mile Marker		Lanes	AADT	Truck AADT
Indian River Line	Malabar	160	173	3	40563	6504
Malabar	Palm Bay Rd	173	176	3	59590	8628
Palm Bay Rd	US 192	176	180	3	72000	11952
US 192	518	180	183	3	43500	2915
518	Pine Pkwy	183	188	3	81000	18306
Pine Pkwy	Wickham	188	191	3	60500	4054
Wickham	Fiske	191	195	3	56000	4054
Fiske	520	195	201	3	52500	6328
520	524	201	202	3	40000	5560
524	528	202	205	3	57000	8322
528	Port SJ	205	208	2	24500	3406
Port SJ	407	208	212	2	42000	7812
407	50	212	215	2	25700	3572
50	406	215	220	2	39500	7700
406	46	220	223	2	34000	4726
46	5A	223	231	3	25500	3545
5A	Volusia Line	231	232	3	36000	5004

Table 3-3 Deployment Schedule from Three Models

Fleet Size Minimization					Total Average Response Time Minimization					Social Benefits Maximization				
b	l_b	v_b	Start Mile Mark	End Mile Mark	b	l_b	v_b	Start Mile Mark	End Mile Mark	b	l_b	v_b	Start Mile Mark	End Mile Mark
1	1-2	1	160	176	1	1-2	1	160	176	1	1-5	2	160	188
2	3-8	1	176	201	2	3-9	2	176	202	2	6-13	2	188	215
3	9-13	1	201	215	3	10-17	2	202	232	3	14-17	1	215	232
4	14-17	1	215	232					215					

Table 3-4 Model Evaluation

	Fleet Size Minimization	Average Response Time Minimization	Social Benefits Minimization
Total fleet size	4	5	5
Average response time (mins)	16.86	12.17	12.30
Truck Cost per Year	\$873600	\$1092000	\$1092000

Comparing the results of the three models, it is shown that all three models have provided the outcomes according to their objectives. In particular, Model P1, which attempts to minimize the fleet size, would assign only 4 vehicles to cover the entire area, which is the minimum number of vehicles considered by all three models. Similarly, the total average response time of Model P2 is the minimum of the three models, as the goal of this model is to achieve the minimum response time for SSP. The comparison of social benefits shows that Model P3 produces the highest social benefits, as we expected. However, the social benefits here are only a measurement to show that Model P3 conducts as we desired. Since we only capture a few types of measurable benefits, and the monetary value vary from one place to another, the social benefits showed here has no physical meaning in practice.

CHAPTER 4: A USER MANUAL FOR THE SPREADSHEET TOOL

RRSP Integrated Interface is an Excel tool that provides planning guidelines and patrolling beat design for safety service patrols. The interface has been embedded with expansion decision tables, incident performance functions, and design algorithms.

It is important to note that the RRSP Integrated Interface is designed and intended for use by knowledgeable practitioners who need to evaluate roadways where there are currently no RRSP assigned. Adding RRSP typically implies deploying trucks on weekdays during daytime hours. Realizing that most Florida freeways already have some form of RRSP, the tool also has the capability to evaluate additional days of the week (weekends) and additional hours (extended nighttime hours). Addition of weekday-daytime patrols necessarily precludes all other planning guidelines. The use of the tool and particularly planning guidelines and beat design are not substitutes for engineering and/or managerial judgement. Results and recommendations produced by the tool are guidance to assist managers and practitioners with RRSP deployment decisions. The user assumes all risk associated with use of the tool. Users are cautioned that the tool is based on historical data from the state of Florida and like the predictive methodologies found in the Highway Safety Manual, should be calibrated accordingly if used outside of the state.

This user interface is developed on Excel 2016 Visual Basic Editor, but is accessible from earlier versions as well. Seven reference libraries contained necessary methods and properties are built into the interface. These reference libraries include:

- Visual Basic For Applications
- OLE Automation
- Ref Edit Control
- Microsoft Excel 16.0 Object Library
- Microsoft Forms 2.0 Object Library
- Microsoft Office 16.0 Object Library
- Printer Extension 1.0 Type Library
- From these Libraries, Microsoft Excel 16.0 Object Library, Microsoft 2.0 Forms Object Library and Microsoft Office 16.0 Object Library may be substituted by their earlier versions if an earlier version of Excel is used to operate the user interface. Those changes will not affect the normal functioning of user interface.

If an error “Can’t project or library” shows, users need to check their reference library to see if there is any library missing. To work around this problem, uncheck the missing library in the VBA project. To do this, follow these steps:

In the **VBA editor**, click **References** on the **Tools** menu. The **References - VBAProject** dialog box appears.

1. Click to clear the library starting with “**MISSING:**” check box.
2. Click **OK**, and then run the project.

Users start by opening the RRSP Integrated Interface which begins with the main form (Figure 4-1). Users decide whether to create a new project and start by inputting required data, or to choose to open and run an existing project (Figure 4-2). Projects are saved as Excel workbooks using the file names created by the user with the .xlsx extension, in the program directory.

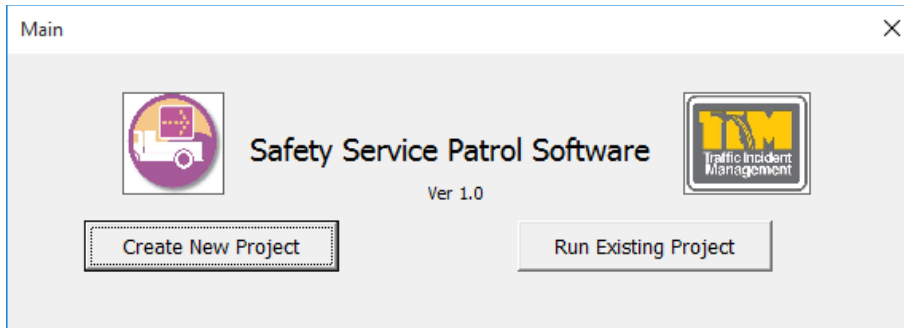


Figure 4-1 Main Form

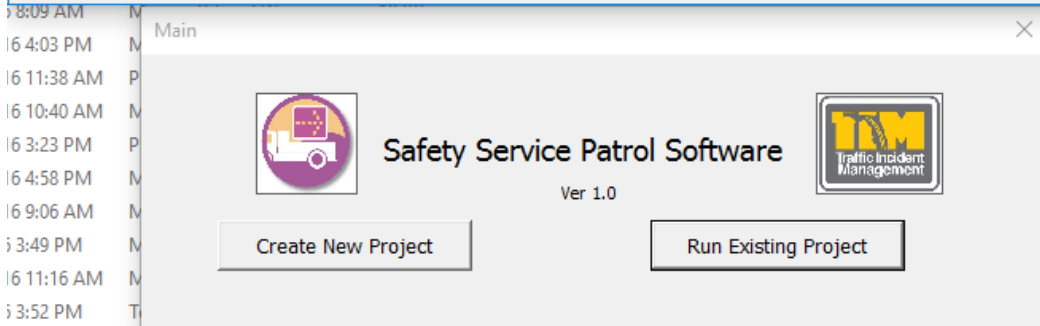
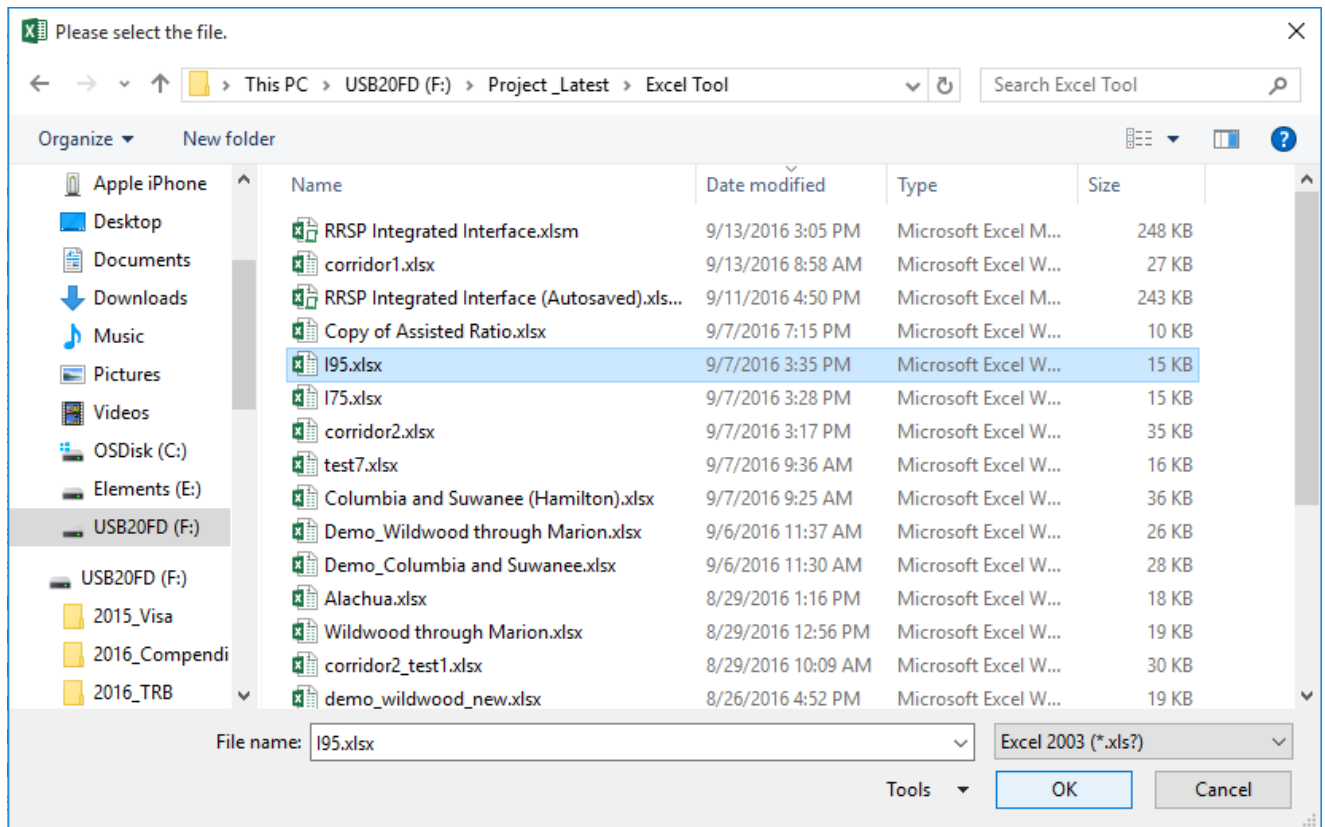


Figure 4-2 Open existing project file

The **Data Entry Form** has two tabs. The first tab records project information, and the second tab records segment information.

The screenshot shows a window titled "Road Ranger Data Entry" with a close button (X) in the top right corner. At the top, there are two tabs: "Project Info" (which is selected) and "Segment Info". Below the tabs is a section titled "Basic Information" containing a text input field labeled "Corridor Name". Underneath this is a heading: "Answer each of the following questions, checking only those items that are appropriate." There are five questions, each preceded by a blue square icon containing a white question mark. Each question has a "Yes" checkbox to its right. The questions are: 1. "Have you engaged stakeholders about SSP expansion?" 2. "Do you and district supervisors have experience with the roadway segment(s) and incident history that leads you to believe that SSP expansion will be beneficial?" 3. "Are there any bottlenecks or other points of recurring congestion on the segment(s) under consideration?" 4. "Do you currently have funding for the proposed SSP expansion?" 5. "Is the calculated Benefit-Cost ratio for the proposed expansion 1.0 or higher?" At the bottom center of the form is a "Clear All" button, and at the bottom right is a "Next" button.

Figure 4-3 Data Entry Form – Project Info

For the **Project Information** tab (Figure 4-3), users must create a corridor name. Users will also need to respond to the five “yes” or “no” questions. They are important qualitative factors used by decision tables, which are part of the underlying logic of the tool. An explanation of each question is displayed using the “?” icon located to the left of each question. The “**Clear All**” button is a shortcut key to clear input data on the data entry form when a large amount of information needs to be revised. The “**Next**” button directs users to the Segment Info tab and saves the data automatically in an Excel file which uses the corridor name as the file name. The directory of the newly created Excel file is the same as the RRSP Integrated Interface. If the input name has

already been used, a dialog window will prompt the user to choose a different name or to replace the existing one.

The screenshot shows a software window titled "Road Ranger Data Entry" with a close button (X) in the top right corner. It has two tabs: "Project Info" and "Segment Info", with "Segment Info" being the active tab. At the top right of the main area, there is a "Segment Number" label and a text box containing the number "1". Below this, there are two main sections: "Segment Geometric Information" and "Segment Traffic Information".

Segment Geometric Information

Segments are homogeneous stretches of roadway with the same traffic volume and number of lanes, usually between interchanges. If there is a change in number of lanes, a segment may end between interchanges.

Start Mile Marker	<input type="text"/>	<input type="checkbox"/> Interchange?	<input type="button" value="?"/>
End Mile Marker	<input type="text"/>	<input type="checkbox"/> Interchange?	<input type="button" value="?"/>
Number of Lanes	<input type="text"/>	per direction	<input type="button" value="?"/>
Is this segment prodominantly rural?	<input type="checkbox"/> Yes		<input type="button" value="?"/>

Segment Traffic Information

AADT	<input type="text"/>	vehicles	<input type="button" value="?"/>
Truck AADT	<input type="text"/>	vehicles	<input type="button" value="?"/>
Average Speed in Peak Hours	<input type="text"/>	miles per hour	<input type="button" value="?"/>
Posted Speed Limit	<input type="text"/>	miles per hour	<input type="button" value="?"/>

At the bottom of the window, there are five buttons: "Add Segment", "Clear All", "Remove Last Segment", "Previous", and "Next".

Figure 4-4 Data Entry Form – Segment Info

In the **Segment Info** tab (Figure 4-4), users can input data for a homogenous segment (refer to the technical memorandum for the definition of homogenous segment). “**Segment Number**” indicates the number of the segment that users are recording (This is NOT the segment IDs already available in FDOT base maps). Geometric information includes start and end mile markers, the number of lanes, and the option for rural/urban areas. The start and end mile markers define the starting and ending points of a homogenous segment. Users must specify whether there is an interchange at the starting and ending points for the design purpose. Again, “?” icons to the left of items are buttons providing an explanation for each input. For traffic information, users are asked to provide AADT, truck AADT, average speed in peak hours, posted speed. When all information

has been entered, click **“Add Segment”** to record the information into the Excel worksheet that was opened in the preceding section. Once the **“Add Segment”** button has been clicked, values in checkboxes indicating the start and end mile markers, the rural/urban areas, and values of peak hour speed and speed limit will remain on the data entry form, becoming default values for subsequent segments. Others values will be cleared, creating the need to input new values for each segment. Users are allowed to change any values for individual segments where necessary. For the purpose of quick input, **“Clear All”** button and **“Remove Last Segment”** button are provided. **“Clear All”** clears the input on the data entry form. **“Remove Last Segment”** (Figure 4-5) removes wrong input which has been added to the Excel worksheet. All input will be saved into the Excel sheet named **“Segment Information”**.

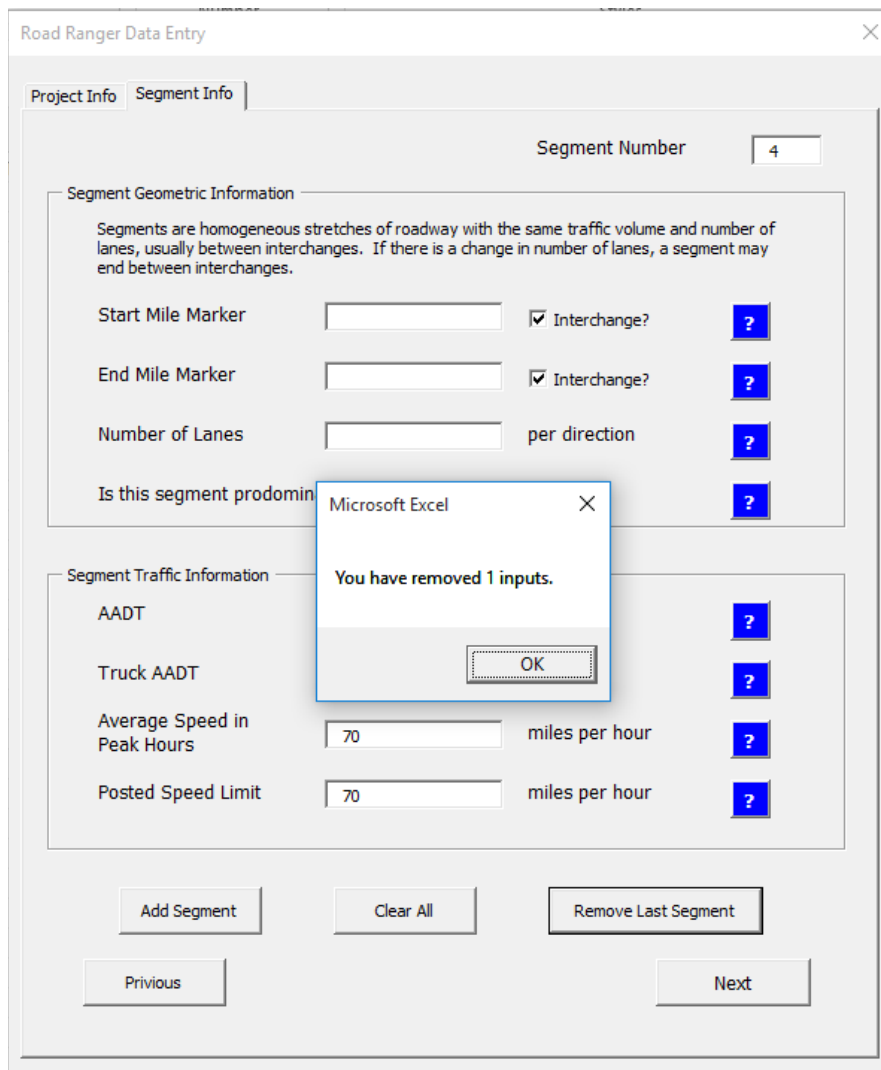


Figure 4-5 Performance of “Remove Last Segment” Button

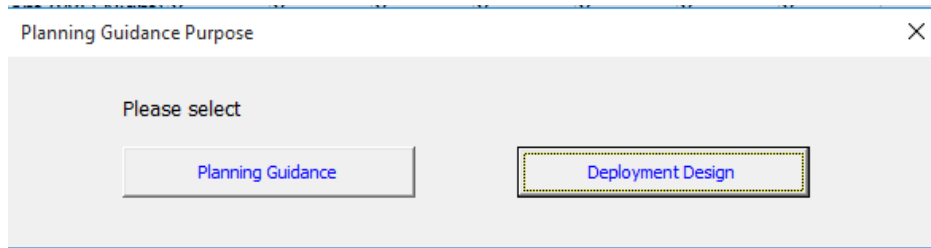


Figure 4-6 Planning Guidance Purpose

During segment information data entry, users can always view information on “**Project Info**” tab by clicking “**Previous**” button. However, users are only allowed to click “**Next**” button for planning evaluation and deployment design after they have input data for all continuous segments. In the newly created project, when “**Next**” button is clicked, users will be directed to **Planning Guidance Purpose** window (Figure 4-6). If users open an existed project file from **Main Form**, a worksheet named “**Warrants**” will be presented where users can find a button named “**Back to the Planning Guidance Window**”. This is simply another way to open **Planning Guidance Purpose** window. Two independent options represent the top level user actions, one **Planning Guidance** for all four types of expansion, and the other is **Deployment Design** for the recorded freeway corridor.

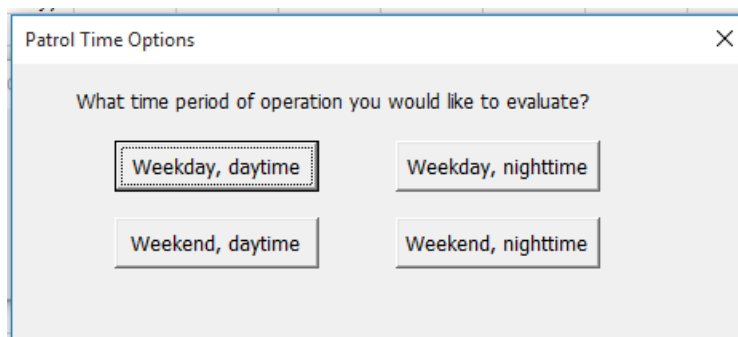


Figure 4-7 Patrol Time Options

The tool relies on the predicted number of incidents, severe incidents, and the various qualitative questions from the project tab form the basis for the underlying decision logics. These combination of inputs vary from weekday to weekend and from daytime to nighttime. Consequently, when **Planning Guidance** is chosen, users are required to select one of the four patrol time periods in the newly opened “**Patrol Time Options**” window (Figure 4-7).

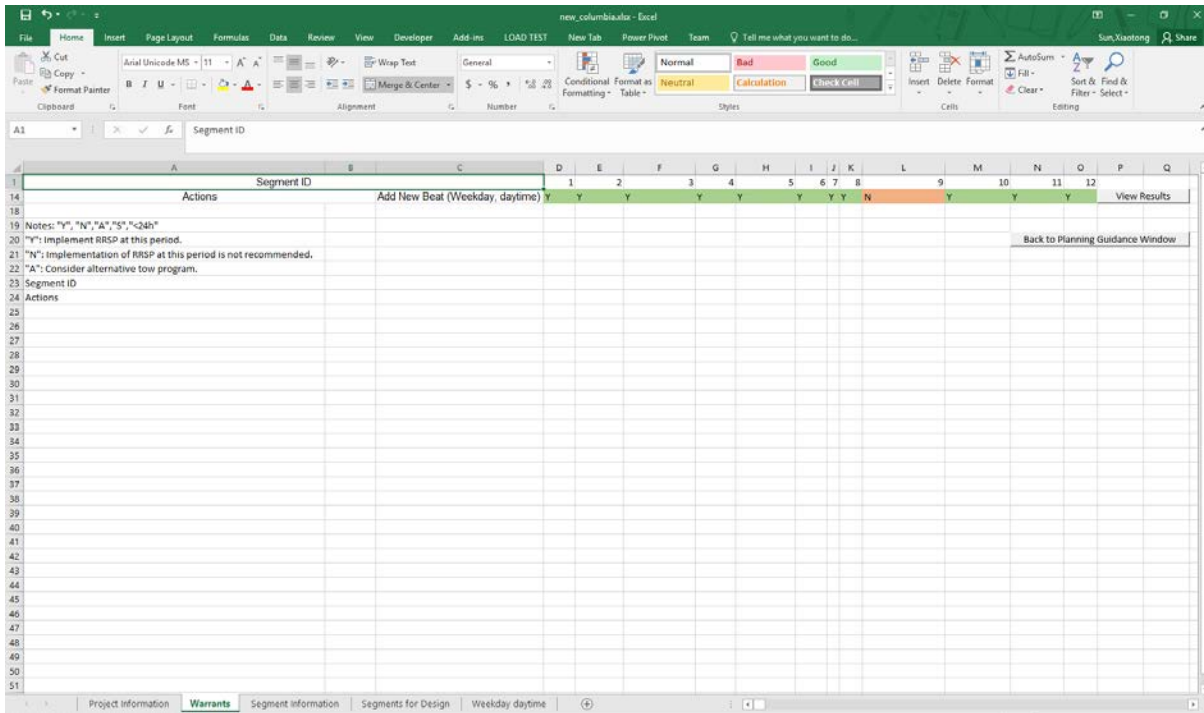




Figure 4-8 Planning Guidance and Analysis

Figure 4-8 presents a planning guidance for a new corridor. The result presented in the “**Warrants**” sheet will automatically pop out when one of the patrol time period is chosen. Decision logic is performed for each segment, and under the segment ID, both the color and the letter indicate the recommended action for that particular segment. Explanations of each letter are provided in **Notes**. The width of each column indicates relative length of each segment. The overall decision is performed by considering the total length of freeway corridor, as well as the number of segments. Users thus can view the overall recommendation from the straightforward view by colors and letters, or click the “**View Results**” button for a written description in a **RRSP Report** form.

RRSP Report

 **Florida Road Ranger Software** 
Planning Guidance Report

Date: 09/27/16

Project Name: new_columbia

Type of Analysis: Planning Guidance

Time Period: Weekday, daytime

Design Target:

The planning guidance for the above project is based on the qualitative and quantitative information provided. The box below is a graphic representation of the segments provided and they color and key is provided at the bottom of this report.

1	2	3	4	5	6	7	8	9	10	11	12
Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y

Using the decision logic built into the Road Ranger Software Tool, the following boxes summarize the findings and recommendations for the project, based on the segment information and other data supplied.

84.5 % of the total length is warranted.
 0 % of the total length is recommended to apply alternative programs.
 15.5 % of the total length is not recommended.

91.67 % of the segments are warranted.
 0 % of the segments are recommended to apply alternative programs.
 8.33 % of the segments are not recommended.

Print Close Results Window

Figure 4-9 Report for Planning Guidance

In the printable report (Figure 4-9), a final recommendation of the selected analysis is recorded. Basic information is provided, including date of analysis, project name, type of analysis, time period and recommendation for each segment. The overall analysis of the corridor includes two parts. First is the percentages of total length that is recommended, not recommended or recommended to apply alternative programs. Second is the absolute number of segments that are recommended, not recommended or recommended to apply alternative programs. These two results allow managers flexibility in decision making, given rural freeway segments may be unusually long while those segments passing near more populated areas might be shorter.

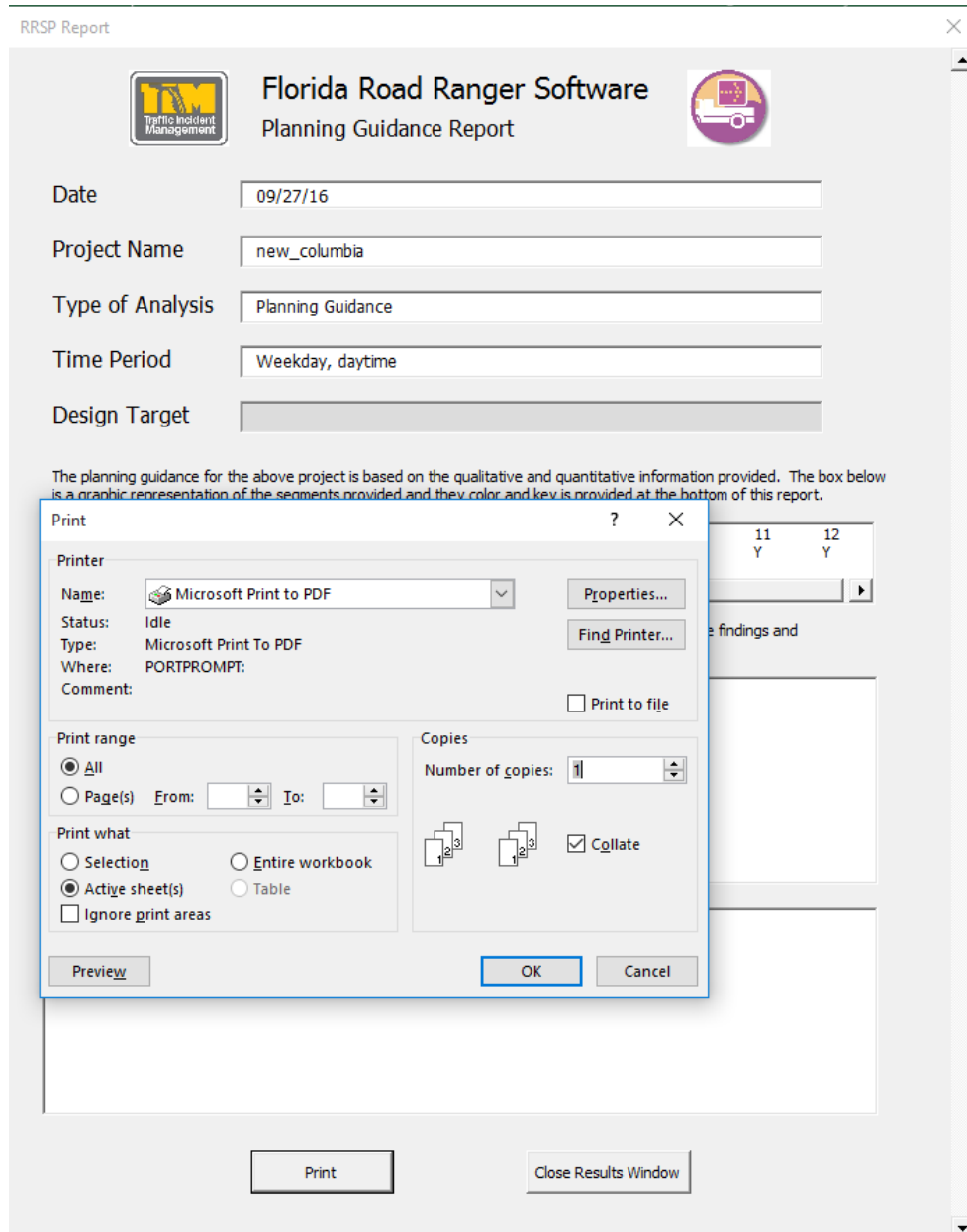


Figure 4-10 Printable Report Form

Users can save this report for further use by clicking “**Print**” button (Figure 4-10). The default printer is PDF viewer so that users can save this report as PDF file. Users also have the option to change the printer and print out the report directly. Click the “**Close Results Window**”, report will be closed and “Warrants” sheet will be presented. Click “**Back to the Planning Guidance Window**” and then planning guidance window will be shown again. When users proceed to beat configuration and vehicle assignment by clicking “**Deployment Design**”, the Design Requirement window is presented. According to their own demands, users can choose one of the three targets to perform the corresponding designing model. For the patrol time period, users are required to specify one of the four aforementioned time periods. When the design target is to

Minimize Fleet Size, users are required to enter the maximum allowable circulation time for each beat and the target response time to incidents (Figure 4-11). When the design target is to Minimize Total Response Time, users are required to enter the maximum allowable circulation time and the total fleet size (Figure 4-12). When Maximize Social Benefits is chosen, users are only required to provide the maximum allowed circulation time (Figure 4-13).

The image shows a software dialog box titled "Design Requirement". It contains three main sections:

- Design Target:** Three radio buttons are present: "Minimize Fleet Size" (selected), "Minimize Total Response Time", and "Maximize Social Benefit".
- Patrol Time:** A heading "Specify one or more time periods for beat design optimization:" is followed by four radio buttons: "Weekday, daytime", "Weekday, nighttime" (selected), "Weekend, daytime", and "Weekend, nighttime".
- Parameters:** Three rows of settings:
 - Checked checkbox "Maximum Circulation Time" with a text input field containing "40" and a blue question mark button.
 - Checked checkbox "Target Response Time" with a text input field containing "30" and a blue question mark button.
 - Unchecked checkbox "Total Fleet Size" with a greyed-out text input field and a blue question mark button.

At the bottom, there are three buttons: "Design", "View Results", and "Save and Exit".

Figure 4-11 Design to Minimize Fleet Size

Design Requirement X

Design Target

Minimize Fleet Size Minimize Total Response Time Maximize Social Benefit

Patrol Time

Specify one or more time periods for beat design optimization:

Weekday, daytime Weekday, nighttime
 Weekend, daytime Weekend, nighttime

Maximum Circulation Time

Target Response Time

Total Fleet Size

Figure 4-12 Design to Minimize Total Response Time

Design Requirement ✕

Design Target

Minimize Fleet Size Minimize Total Response Time Maximize Social Benefit

Patrol Time

Specify one or more time periods for beat design optimization:

Weekday, daytime Weekday, nighttime

Weekend, daytime Weekend, nighttime

Maximum Circulation Time

Target Response Time

Total Fleet Size

Figure 4-13 Design to Maximize Social Benefit

Design Requirement

Design Target

Minimize Fleet Size Minimize Total Response Time Maximize Social Benefit

Patrol Time

Specify one or more time periods for beat design optimization:

Weekday, daytime Weekday, nighttime

Please Input:

K Factor %

D Factor %

Total Fleet Size

Figure 4-14 K Factor and D Factor


When the design target is to Maximize Social Benefits, parameters including **K Factor** and **D Factor** are required (Figure 4-14). Unlike the traditional meaning of K factor which indicate the proportion of AADT in the peak hour, here K factor is used to imply the proportion of maximum hourly traffic volume over the total volume in the selected time period. D factor is still used as the proportion of design hourly volume in the heaviest direction. Once the input is ready, users can click “**Return**” button to go back to the **Design Requirement Form**.

	A	B	C	D	E	F	G	H
1	Open Design Input Window				View Results			
2	Fleet Size Minimization Model							
3	Beat ID	Link ID	Number of	Start Mile	End Mile Mark			
4	1	1, 2	1	160	176			
5	2	3, 4, 5, 6, 7	1	176	201			
6	3	9, 10, 11, 1	1	201	215			
7	4	14, 15, 16,	1	215	232			
8	Total Average	16.8598						
9	Truck Cost	873600						
10								
11								
12								

Figure 4-15 Design Outputs


Beat configuration and vehicle assignment are performed by clicking “**Design**” button. By clicking the “**View Results**” button, the deployment results of the chosen model will be presented in a new worksheet. The title of the worksheet is consistent with the chosen time period. For each design, the results will include the starting and ending mile mark of each beat and the number of patrol vehicles assigned to that beat. In this worksheet, two buttons are provided. “**Open Design Input Window**” can lead users to the previous user form, users can then perform other design types or save and exit the tool. “**View Results**” can lead users to RRSP Report form for deployment design.

RRSP Report



Florida Road Ranger Software

Planning Guidance Report



Date: 09/30/16

Project Name: I95BySevereIncidents

Type of Analysis: Deployment design

Time Period: Weekday, daytime

Design Target: Fleet size minimization

The planning guidance for the above project is based on the qualitative and quantitative information provided. The box below is a graphic representation of the segments provided and they color and key is provided at the bottom of this report.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	Y	A	A	A	A	A	A	Y	Y	Y	Y	Y	Y	Y	A	Y

Using the decision logic built into the Road Ranger Software Tool, the following box summarizes the findings and recommendations for the project, based on the segment information and other data supplied.

Beat ID	Link ID	Number of Trucks	Start Mile Mark	End Mile Mark
1	1, 2	1	160	176
2	3, 4, 5, 6, 7, 8	1	176	201
3	9, 10, 11, 12, 13	1	201	215
4	14, 15, 16, 17	1	215	232
Total Average Response Time		16.85979932		
Truck Cost per Year		873600		

Print
Close Results Window

Figure 4-16 Report for Deployment Design

CHAPTER 5: SAFETY OF ROAD RANGERS

There are significant hazards associated with working near moving traffic. Whether on an urban freeway or a rural local street, traffic incident responders are among the most vulnerable road users, challenged with working in dynamic and dangerous conditions that are neither designed nor intended for pedestrians.

While there is no national reporting system for incident responders who are killed while working at roadside, some insight can be obtained from industry sources. According to the National Law Enforcement Memorial Foundation, 134 police officers were killed in struck by incidents between 2005 and 2014, or about 13 per year.¹ The National Fire Protection Association completed a study of fire personnel who were struck and killed by vehicles in 2014 and found that in the most recent ten years, a total of 28 personnel were struck and killed by non-fire vehicles, or about 3 each year². The towing profession loses “about 40 to 50” operators per year, and it is estimated that about ¾ of those deaths involve struck by incidents.³

The number of transportation workers killed on the job is difficult to pin down because in addition to government employees, there are many private industry contractors involved. In the work zone setting, more than 100 workers lose their life annual, with nearly one quarter of those being struck or run over by non-construction vehicles.⁴

There is no published number of deaths involving safety service patrol operators. In conjunction with this project, a survey of national point of contact for safety service patrols, and a search of media accounts revealed that at least 19 service patrol operators have been killed in the line of duty since their inception. Their mention herein represents the first documentation of their occurrence and the sacrifice made by these operators. Table 5-1 is an accounting of service patrol operator deaths by state.

¹ <http://www.nleomf.org/facts/officer-fatalities-data/causes.html>

² <http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/the-fire-service/fatalities-and-injuries/firefighter-fatalities-in-the-united-states>

³ <http://gazette.com/towing-cars-dangerous-even-on-a-good-day/article/113414>

⁴ http://www.ops.fhwa.dot.gov/wz/resources/facts_stats/injuries_fatalities.htm

Table 5-1 Safety Service Patrol Deaths

State	SSP Deaths
California	1
Florida	4
Georgia	2
Illinois	3
Louisiana	1
Missouri	2
New Jersey	1
North Carolina	1
Tennessee	1
Texas	1
Virginia	1
West Virginia	1
Total	19

Safety Service Patrols have proven to be an effective means by which traffic incidents can be managed and congestion mitigated, saving lives and money. The job of SSP is dangerous, and it is important to gain insight into the things that present risk for SSP operators. This research has the objective to understand the characteristics of Florida Road Ranger crashes and related safety concerns to help identify countermeasures.

5.1. Literature Review

Safety service patrols have been in existence since the 1960's, though they really just gained in popularity in the past two decades. (Service patrol handbook) Though there are several government publications that guide implementation of SSP, there are no published studies regarding safety service patrol crash experience. There are however, related studies for other types of traffic incident responders that establish examples of how safety might be evaluated.

Carrick, et al. (2010) examined more than 31,000 law enforcement vehicle collisions occurring in Florida from 2005 through 2008. The study found that most law enforcement crash are low-speed events on local streets. The law enforcement vehicle commonly were often stopped or parked when it crashed. Rear-end crashes were common, but on freeway shoulders not prominent. Most crashes occurred during the daytime, under favorable driving conditions, and during routine operating mode. The environmental conditions for emergency mode were not significantly different than for other crashes.

The US Fire Administration studied emergency vehicle markings, designed to increase visibility and promote safety of responders at highway incidents (2009). Though the study points out that there is no national standard from marking responder vehicles, marking vehicles is a passive treatment that can ultimately prevent them from being struck while stationary at incident scene. Making emergency vehicles conspicuous involves using contrasting colors, fluorescent for daytime, and retro-reflective for nighttime. The study encouraged the use of conspicuity markings, focused primarily on the rear of the vehicle.

Grant and Merrifield (2011) performed research for the Fire Protection Research Foundation, examining the sources of traffic crash report data that is related to ambulances. Ambulance traffic crash data was noted as fairly robust at the national and state level, though not

a lot of analysis has been done. Model Minimum Uniform Crash Criteria (MMUCC) contain guidance for state crash reporting systems related to vehicle types and purposes that make finding ambulance crashes fairly easy.

Maistros and Schneider (2015) examined fatal law enforcement vehicle traffic crashes using Fatality Analysis and Reporting System (FARS) data for a three-year period. A regression model found several factors to be significant, among which are the use of seat belts by officers, the presence of more than one person in the vehicle, and speed.

Savolainen (2009) examined emergency vehicle crashes in Wisconsin using state traffic crash report records. The research found that about 28% of crashes involved emergency operation. Intersections were well represented, and severity was greatly reduced where speeds were lower. The need to further differentiate police, fire, and ambulance vehicles was noted.

5.2. Methodology

Since no research has ever evaluated SSP safety, the approach herein relies on SSP program managers, individual operators, and official traffic crash reports to understand safety. Program managers, both in Florida and nationally, have experience with program elements like equipment, training, and procedures that contribute to understanding SSP safety. Surveying individual Road Ranger drivers can provide insight from their “boots on the ground” experience associated with working around moving traffic. Finally, examining historical traffic crashes can illuminate the characteristics of those events to complement the understanding of safety. With an understanding of safety through research, countermeasures can be recommended for improvement.

5.2.1 Engaging Program Managers

A series of in-person discussions were conducted in all FDOT districts and the Florida Turnpike Enterprise (FTE) to better understand Road Ranger Service Patrol deployment in Florida. The research team arranged meetings at each Traffic Management Center (TMC) location with a combination of interested individuals selected by the district. Some combination or subset of District ITS Engineers, RRSP Program Managers, TIM Program Managers, TMC Managers, District Consultants, and partnering local transportation agencies were the typical participants. Meetings typically lasted approximately 2 hours.

Since overarching concepts related to TIM are an important part of RRSP, topical expertise by the research team was invaluable. To facilitate discussion, the research team developed a discussion outline which was provided to participants prior to each meeting. The district meetings enjoyed a conversational tone that allowed for the free exchange of information and ideas. The research team benefited immensely from each visit, as each host/participant provided a wealth of information about RRSP.

The research team used a structured question to elicit information about safety, “**What do you think are the most compelling safety issues for Road Ranger operators?**” The open-ended question generated responses that are presented in a bulleted format below:

- A good inventory of necessary equipment is needed.
- The use of median turnarounds and the safety implications of their use should be included in policy guidance and training.
- There is a need for a standardized training program that covers minimum training required of contractors.

- SHRP 2 Responder Training should be required of all operators as part of the contract language.
- A handbook for operators is needed.
- The ability to use the vehicle-mounted arrow board while on the shoulder (the MUTCD specifies the caution mode when on the shoulder)
- Communications via SLERS and cell phone promote safety.
- Continuous training is needed to remain current and proficient.
- Tabletops and after action reviews are an excellent way to learn and training operators.
- Construction that limits shoulders creates vulnerabilities; need for safety zones; crash sites.
- PPE and visibility of operators. (The D3 contractor requires PPE pants, shirts, helmets, and safety glasses)
- “D” Drivers (Drunk, drugged, distracted, drowsy, dangerous)
- Unwilling motorists that don’t want help or may be involved in criminal activity.
- FHP response to support (this was isolated to D3 where the new program may not be understood by law enforcement).
- Debris procedures and the need for a blocking vehicle.
- Lack of move over compliance for RRSP.
- The value of digital message boards versus arrow boards.
- Many motorists do not know who RRSP are when they stop/approach.
- Emergency vehicle lighting on RRSP may not be sufficient. Need to standardize lighting and conspicuity markings.
- Communications dead spots (SLERS and cellular)
- Dash cams may improve safety and training.
- FHP tow and owner request system causes delay that increases exposure.
- RRSP orientation should be part of FHP Academy training.
- Need for additional resources on overpasses, bridges, curves, etc. for advance warning and block.
- Roadway re-entry from shoulder.
- Push bumper liability.
- Tire change procedures where limited lateral clearance makes use of a floor jack difficult.
- Concern that performance measures may push operators to leave incidents/other responders when they might provide safety with advance warning or vehicle block.

Nationally, forty-one states plus the District of Columbia and Puerto Rico use Freeway Service Patrols. To understand the state of the practice for warranting, allocating, and safety of FSP, the research team engaged state points of contact in each of those jurisdictions. Although there are more than one hundred individual FSP deployments in the US, state-level contacts at DOTs typically understand their respective deployments.

A web-based survey instrument was created, using a series of multiple choice, true-false, graphic rating scales, and open-ended questions. In addition to demographic information, items identified inputs that are beneficial to FSP deployment decisions, priorities for program expansion, and operator safety. The survey questions were similar to those presented to the eight Florida DOT FSP Program Managers.

In the spring of 2016, state points of contact were identified and confirmed as the appropriate recipients of the FSP survey. Subsequently, those contacts were solicited via email

and provided with a link to the online survey. From the 41 invitations that were ultimately sent, 31 states responded for a response rate of 76 percent.

Safety related questions began with understanding staffing models for SSP. The majority of programs continue to be staffed by employees of state or local governments (61.3%), though privatization has accounts for 45.2 percent. A small number of states (6.5%) use law enforcement for SSP staffing, and at least one state uses volunteers. Percentages do not total 100 due to multiple approaches in some states.

SSP operators and vehicles are not captured as a data element in most statewide traffic crash reporting forms and they are not part of the Minimum Model Uniform Crash Criteria (MMUCC) (NHTSA, 2012). Consequently, safety analysis for FSP has been limited. Locally, SSP programs sometimes track crashes, particularly where there is a private vendor model, ostensibly to facilitate insurance claims. According to the survey, just over half of states (54.8%) track SSP crashes, and only 29 percent do any type of evaluation on that data. For those that do analysis, they indicated that SSP vehicles are typically struck while parked at incident scenes by inattentive, speeding, or impaired drivers. Where the SSP vehicle is at fault, low speed backing and striking fixed objects at roadside are prominent, typical of fleet operations. Several states indicated that they have experienced fatal crashes where the SSP operator was killed in the line of duty, either as a vehicle operator or pedestrian at the scene of an incident.

Training for SSP operators can promote safe operations, particularly when crash experience provides guidance. To gauge the state of the practice with respect to FSP training, a multiple choice items was used to identify the approximate number of hours of training prior to “solo duties”. Figure 5-1 is a graphic representation of survey responses for hours of FSP operator training. The majority of states require 40 hours or less of training, about one quarter requiring between 40 and 110 hours, and slightly more than 1 in 5 states requiring more than 110 hours of operator training.

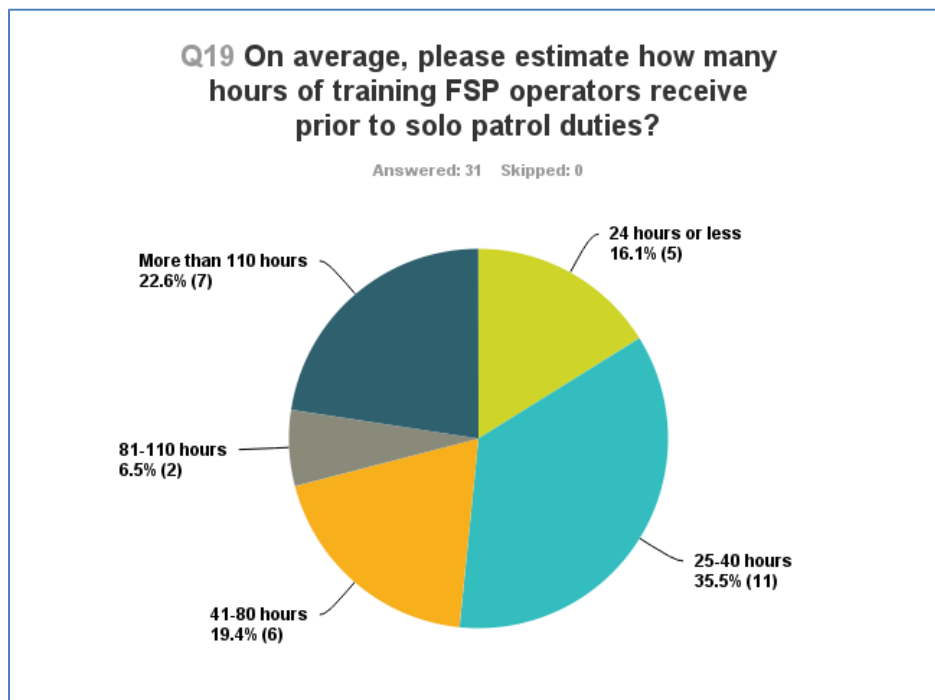


Figure 5-1 Hours of FSP operator training from US points of contact

5.2.2 Florida Traffic Crash Data

The research team also obtained traffic crash report information for RRSP-involved incidents. During the course of normal operations, RRSP vehicles are sometime involved in traffic collisions, most notably when they are struck while stopped at an incident scene. In rare cases, the RRSP operator may be involved in a vehicular collision while a pedestrian on or near the roadway, which are also captured as a traffic crash. With the date, time, and location of a traffic crash, the research team can retrieve crash information utilizing the Signal 4 Analytics database which is housed at the University of Florida¹. Signal 4 Analytics is a repository of more than 4.6 million historical Florida Traffic Crash Report forms. Each crash record contains the more than 100 data elements from the individual crash report as well as an image of the actual form.

Individual FDOT districts and their RRSP contractors were polled to identify crashes involving RRSP for calendar year 2014-2015. FDOT's SunGuide Traffic Management Center (TMC) software contained a record of most incidents and RRSP contractors verified and supplemented the TMC list. Given that they maintain a complete accounting of crashes involving their vehicles/personnel for insurance purposes the combination of these sources accounted for all RRSP crashes.

For the two-year period, 2014-2015, there were 119 RRSP crashes in Florida, resulting in 59 injuries and two fatalities. This represents an average of just over 1 per week.

Most traffic crash report data is presented as nominal/categorical data, readily lending it to presentation using descriptive techniques like frequency distributions. Since RRSP operate only on freeways, a comparison with other freeway traffic collisions seems like a logical approach. For the same 2-year period, there were 115,167 traffic crashes on Florida freeways. Comparing the frequencies for RRSP and all freeway crashes has the potential to show how they differ, though tests for statistical strength of the comparison are not appropriate given the relatively small number of RRSP crashes. Clear distinctions are readily apparent when comparing frequencies for the two sets.

Time of day and day of the week are fundamental traffic crash attributes. Figure 5-2 is a graphic that shows the day of week comparison for RRSP crashes as compared to all freeway crashes. The day of week is fairly consistent between the two sets of data with the noticeable exception of Monday where fewer RRSP crashes occur and Wednesday where just over 1 in 5 RRSP crashes happen. There does not appear to be any explanation for these differences.

¹ <https://s4.geoplan.ufl.edu/>.

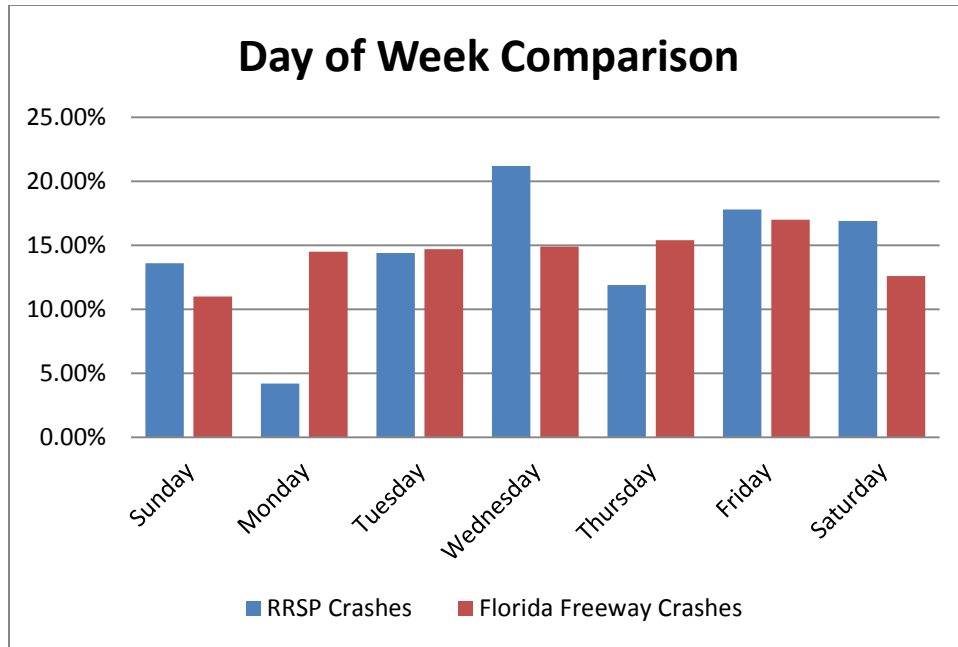


Figure 5-2 Day of week comparison between RRSP crashes and all freeway crashes in Florida

In Figure 5-3, one can see that the time of day differences show that early morning hours tend to be more dangerous for RRSP, as compared to the larger data set. The highest number of RRSP crashes are observed at 5 am, 1 pm, 3 pm, and 10 pm, perhaps coinciding with greater exposure associated with RRSP shift changes.

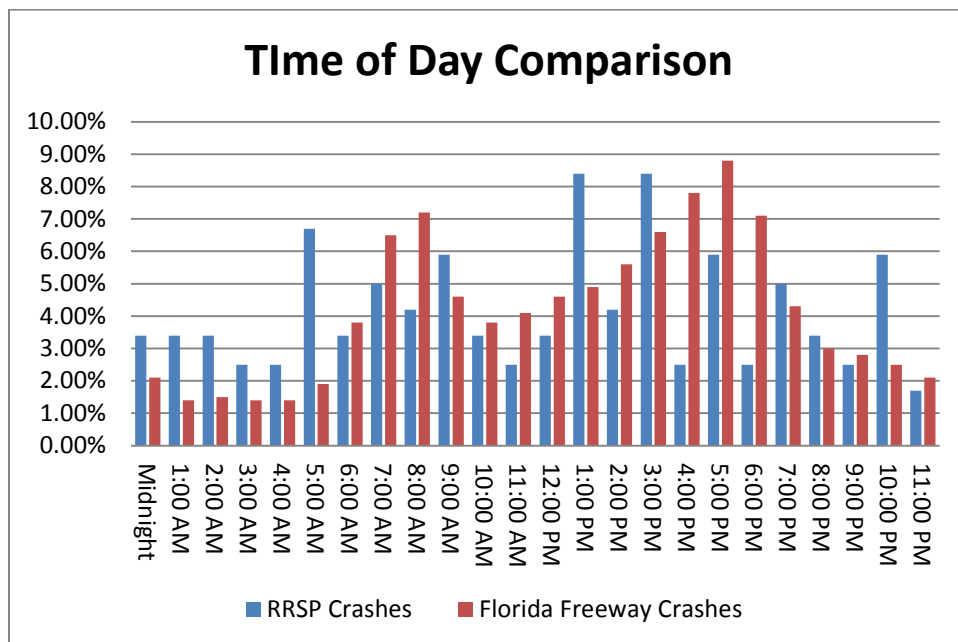


Figure 5-3 Time of day comparison between RRSP crashes and all freeway crashes in Florida

The type of crash data element is a variable to explain the manner of collision, typically between vehicles. Like most freeway incidents, the rear end crash is very common for RRSP. Run off road crashes are 3 times more likely among generic freeway crashes, and “other” types are twice as likely for RRSP crashes, probably explained by the varied duties of the job. Because the RRSP operator is almost always out of their vehicle at some point during their duties, pedestrian crashes involving RRSP account for 3.4 percent of crashes while in the typical freeway incident they are quite rare (.2%). This is even more pronounced where “non-motorists” are counted in 9.2 percent of RRSP crashes and only .4 percent of the generic freeway crash.

The detailed crash type is equally illuminating. Again, run off road and single vehicle crashes are much higher in the freeway crash set. Rear-end crashes occur at a similar rate, but nearly 1 in 5 RRSP crashes involve a parked vehicle where they are quite rare (.9%) in the larger data set. Same direction sideswipe and rear-end types are fairly similar.

Where 1 in every 4 freeway crashes is a single vehicle event, more than 95% of RRSP crashes involve two vehicles or more vehicles. The frequency of crashes involving three or more vehicles are fairly consistent between the data sets. Table 5-2 represents selected data elements that describe the collision event. Note that variable attributes are truncated so small frequency values are not listed, consequently percentages do not always total 100%.

Table 5-2 Event Characteristics Compared

		Florida Freeway Crashes	RRSP Crashes
Crash Type	Angle	0.60%	2.50%
	Head On	0.40%	0.80%
	Left Turn	0.60%	1.70%
	Off Road	17.20%	5.00%
	Other	12.70%	24.40%
	Pedestrian	0.20%	4.20%
	Rear End	46.90%	44.50%
	Sideswipe	16.10%	14.30%
Vehicles	1	26.10%	4.20%
	2	62.30%	79.80%
	3+	11.60%	16.00%
Non Motorists	0	99.60%	90.80%
	1	0.40%	7.60%
	2	0.00%	1.70%
Crash Type Detailed	Backed Into	0.50%	0.80%
	Head On	0.40%	0.80%
	Left Entering	0.30%	1.70%
	Off Road	17.20%	5.00%
	Opposing Sideswipe	0.30%	0.80%
	Other	4.10%	3.40%
	Parked Vehicle	0.90%	19.30%
	Pedestrian	0.20%	4.20%
	Rear End	46.90%	44.50%
	Right Angle	0.60%	2.50%
	Same Direction Sideswipe	15.80%	13.40%
	Single Vehicle	7.30%	0.80%
Crash Severity	Fatality	0.50%	1.70%
	Injury	26.50%	37.00%
	Property Damage Only	73.00%	61.30%
Manner of Collision	Angle	5.80%	8.40%
	Front to Rear	45.40%	52.90%
	Other	30.20%	16.00%
	Rear to Rear	0.10%	0.80%
	Sideswipe; Opposite Direction	0.20%	0.80%
	Sideswipe; Same Direction	15.70%	18.50%

Weather plays a less significant role in the RRSP crash. While rain is noted in 17.1 percent of freeway crashes, it is only present in 10.1 percent of RRSP crashes. Similarly, wet roads account for more than 1 in 4 freeway crashes (26.5%), but only 18.5 percent of those involving RRSP. Weather contributes in 8.4 percent of freeway crashes versus only 5 percent of RRSP events.

Lighting conditions are another common explanatory crash characteristic. Freeway crashes are more likely to occur during daylight hours (68.8% versus 58%), but RRSP crashes are more likely to occur on dark roadways with artificial lighting (27.7% versus 17.7%). Periods of dusk and dawn are represented slightly higher for RRSP crashes.

Road Ranger crashes are more than twice as likely to occur in or near a work zone (13.4% versus 5.4%) and the type of work generally occurring in lane closures and on the shoulder. The proportion occurring in the activity area, advance warning area, and transition area are similar between the two data sets. Despite the higher presence of road work, the road itself does not contribute differently. Table 5-3 depicts the environmental conditions for Road Ranger crashes as compared to statewide freeway crashes.

Table 5-3 Environmental Characteristics Compared

		Florida Freeway Crashes	RRSP Crashes
Weather Condition	Clear	58.30%	68.10%
	Cloudy	24.00%	21.00%
	Rain	17.10%	10.10%
Light Condition	Dark - Lighted	17.70%	27.70%
	Dark - Not Lighted	7.10%	2.50%
	Dawn	2.20%	3.40%
	Daylight	68.80%	58.00%
	Dusk	3.90%	7.60%
Road Surface Condition	Dry	73.10%	80.70%
	Wet	26.50%	18.50%
Contributing Roadway Characteristics	Debris	1.30%	0.80%
	None	88.70%	88.20%
	Obstruction in Roadway	0.60%	2.50%
	Road Surface Condition	7.40%	5.00%
	Work Zone	1.20%	2.50%
Contributing Environmental Characteristics	None	90.20%	94.10%
	Weather Conditions	8.40%	5.00%
Work Zone Related	No	94.50%	85.70%
	Yes	5.40%	13.40%

Injuries are more likely when RRSP are involved. Thirty-seven percent of RRSP crashes result in at least one injury, where only 27 percent of Florida freeway crashes cause injury. Because of the small sample size, fatalities are difficult to compare, but there were 2 fatal RRSP crashes during the period representing 1.7 percent. Fatal freeway crashes account for just .4 percent of the more than 115 thousand crashes in that set.

Drugs, alcohol, and distraction are all increase with RRSP crashes. Driver distraction is 80% more likely to be present in the RRSP crash. Alcohol is nearly 3 times more prominent, and the use of drugs 5 times more common in RRSP crashes. The FHWA National Responder Training Program¹ notes the dangers of “D” drivers (drunk, drugged, drowsy, distracted), and that is confirmed in the Florida crash data. Table 5-4 shows selective data elements and attributes for persons involved in crashes.

Table 5-4 Persons Characteristics Compared

		Florida Freeway Crashes	RRSP Crashes
Fatalities	0	99.50%	98.30%
	1	0.40%	1.70%
Injuries	0	73.30%	63.00%
	1	17.70%	25.20%
	2	5.50%	10.90%
	3	1.90%	0.80%
Alcohol Related	N	98.00%	94.10%
	Y	2.00%	5.90%
Distraction Related	N	87.40%	77.30%
	Y	12.60%	22.70%
Drug Related	N	99.40%	96.60%
	Y	0.60%	3.40%

Motor vehicle in transport is typically the first harmful event 80.7 percent of the time for RRSP crashes and parked motor vehicles 10.1 percent. Again, parked motor vehicles are uncommon among general freeway crashes. The first harmful event occurs on the roadway at about the same rate, but as expected, shoulder incidents are more common for RRSP (11.8% versus 7.1%). Table 5-5 shows selected variables and attributes for harmful events.

¹ FHWA. Training for safer, faster, stronger, more integrated incident response. https://www.fhwa.dot.gov/goshrp2/Solutions/Reliability/L12_L32A_L32B/National_Traffic_Incident_Management_Responder_Training_Program. Accessed November 27, 2016.

Table 5-5 Harmful Event Comparison

		Florida Freeway Crashes	RRSP Crashes
First Harmful Event	Motor Vehicle in Transport	70.10%	80.70%
	Parked Motor Vehicle	0.60%	10.10%
	Pedestrian	0.20%	4.20%
First HE Location	Median	3.30%	1.70%
	Off Roadway	6.60%	5.90%
	On Roadway	82.20%	79.00%
	Shoulder	7.10%	11.80%
First HE Relation to Junction	Acceleration/Deceleration Lane	0.10%	0.80%
	Driveway/Alley Access Related	0.10%	0.80%
	Entrance/Exit Ramp	12.30%	10.90%
	Non-Junction	80.40%	77.30%
First HE Within Interchange	N	90.60%	90.80%
	Y	8.80%	8.40%

5.2.3 Driver Survey – Frequency Distributions

Road Ranger operators have the potential to shed light on safety, from the perspective of the individual doing the job. With the safety information obtained in the aforementioned meetings with FDOT program managers, candidate survey items were developed by the research team. Potential survey questions were circulated to the program managers for review and comment, and changes were incorporated into the final product. The final survey instrument was reviewed and approved by the FDOT statewide TIM Program Manager.

FDOT program managers indicated that a paper-based survey would likely be the easiest for drivers to complete, so both the Web-based and paper format were provided with the request that drivers complete the survey. The survey instrument was distributed as both a PDF file and Web link to FDOT RRSP Program Managers, who in turn solicited their RRSP contractors to have drivers complete the survey. Surveys were collected by the FDOT RRSP Program Manager and then returned to the research team. The paper format proved to be the best option for the audience, who completed just 4 percent using the Web link. The participation in the survey was exceptional with 217 drivers participating, which is likely well above 90% given there are 105 unique RRSP beats. Paper surveys were transferred to an electronic format for analysis by the research team.

While survey items were constructed and grouped in a way that easily flowed, presenting them in this report requires different grouping, hence the question numbers left of each item are ordered differently. In the sections that follow, demographic information, vehicle and equipment, training, operations and procedures, and perceptions and opinions make up the grouping of survey responses.

5.2.3.1 Demographic information

To reduce any anxiety drivers might have about taking a survey and potentially offending either their employing subcontractor or FDOT, a decision was made to allow surveys to be

completed anonymously. Demographic information about the driver taking the survey captures the FDOT District where they work, which type of RRSP vehicle they drive, how many years they have been working, and whether the work mostly during daytime or nighttime hours.

All FDOT districts currently use Road Rangers and all participated in the survey. Figure 5-4 is a chart that depicts the district which respondents noted. There were some instances where District 5, District 7, and Turnpike personnel were unsure of their affiliation because of toll roads that pass through the district and/or contracting arrangements with the same RRSP provider. For the most part these were resolved by identifying those drivers with the affiliation of the FDOT program manager who collected the survey.

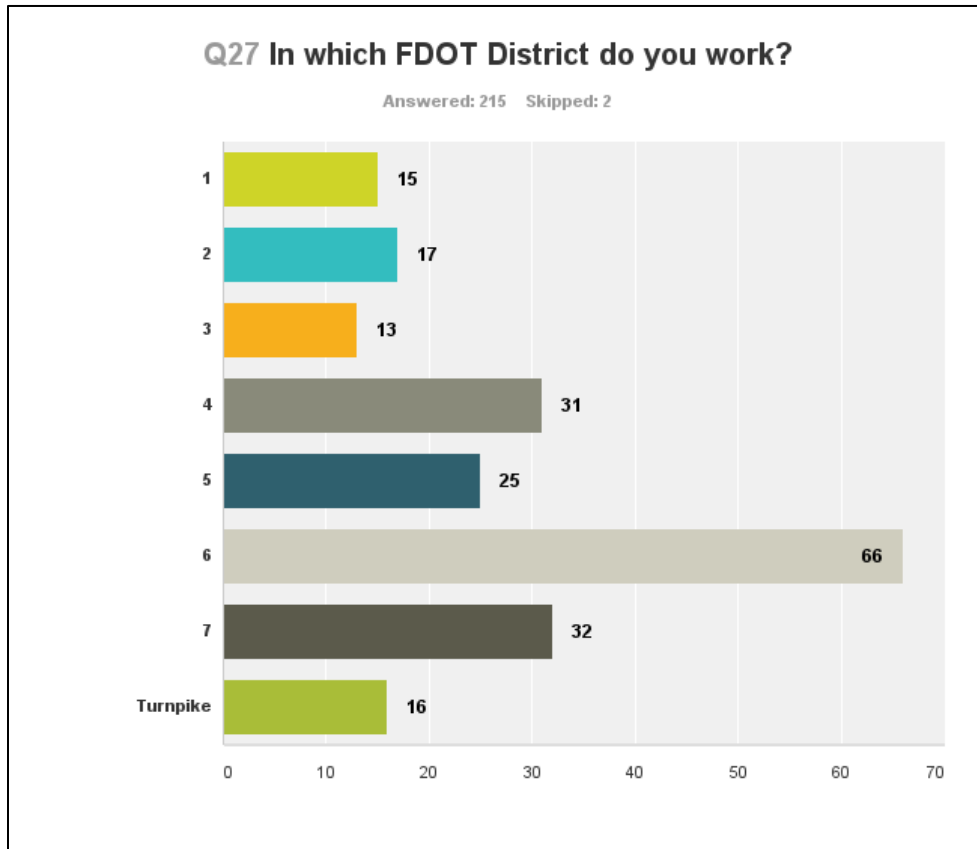


Figure 5-4 Survey Responses by FDOT District

According to survey responses, many RRSP drivers have been on the job for more than five years (45%). On the opposite end of the continuum, 26 percent have been on the job for one year or less. This interesting dichotomy of experience has potential to be enlightening, and will be explored with a series of cross tabulations in the analysis section later in this report. Figure 5-5 is a chart that presents the years of experience in absolute numbers.

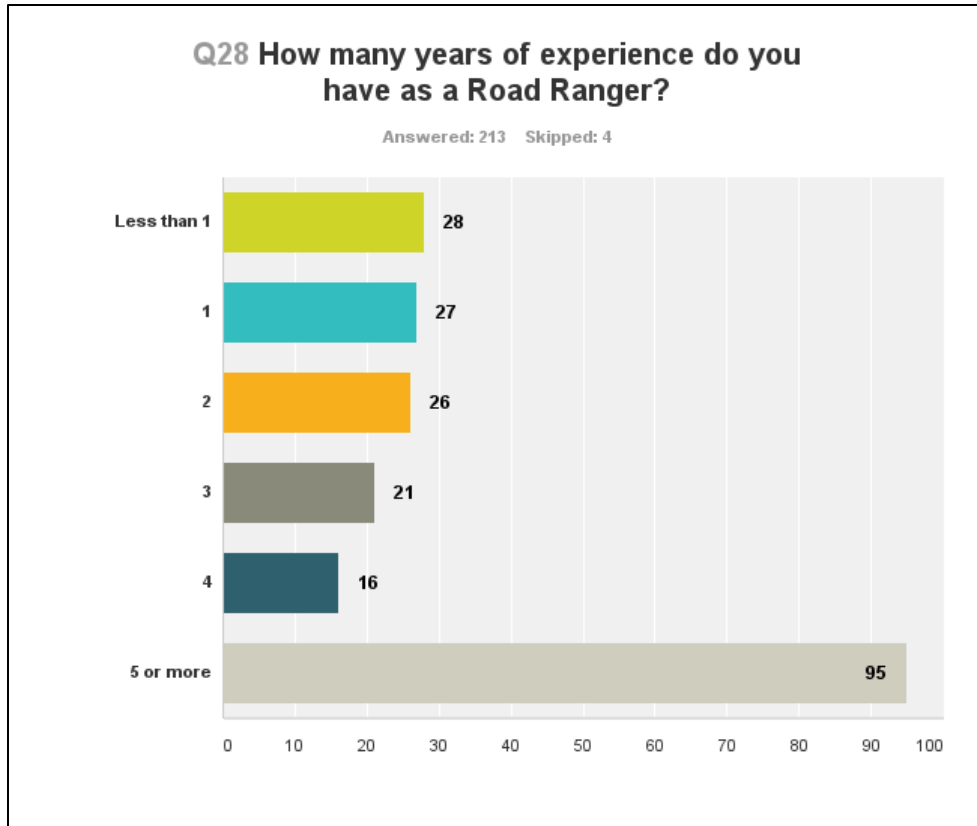


Figure 5-5 RRSP Operator Years of Experience – Absolute Numbers

A number of FDOT RRSP Program Managers indicated that tow-capable vehicles are a valuable resource. Unfortunately, budget constraints have created circumstances where towing vehicles were replaced with less expensive pickup trucks. When operated as a RRSP, tow trucks are dedicated and marked as full-time Road Rangers. Figure 5-6 is a chart that represents the type of RRSP vehicle typically used by the driver completing the survey. Several drivers indicated that they use both pickup truck and tow truck, in which case the tow truck was recorded since it represented the higher level of capability.

Safety Service Patrols were created to deal with rush hour traffic on urban freeways, typically daytime hours. Over time, the value of SSP has spread to off-peak hours and even 24 hour coverage. Days and hours of operation are dictated at the District level, particularly in contracting agreements. Asking drivers if they work mostly during daytime or nighttime hours has value since darkness presents unique safety challenges. Figure 5-7 is a chart that provides the split between daytime and nighttime operators. As is the case with years of experience, the value of know when an operator works comes when that information is related to other factors in cross tabs. Daytime/nighttime operations are evaluated further in the analysis sections that follows.

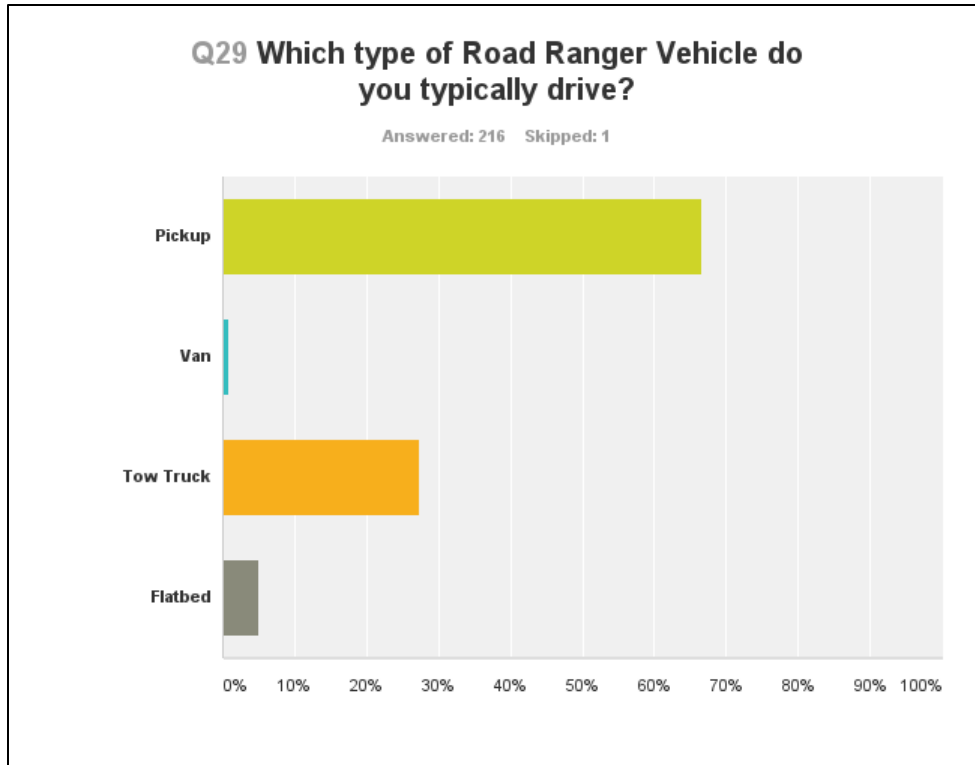


Figure 5-6 RRSP Type of Vehicle

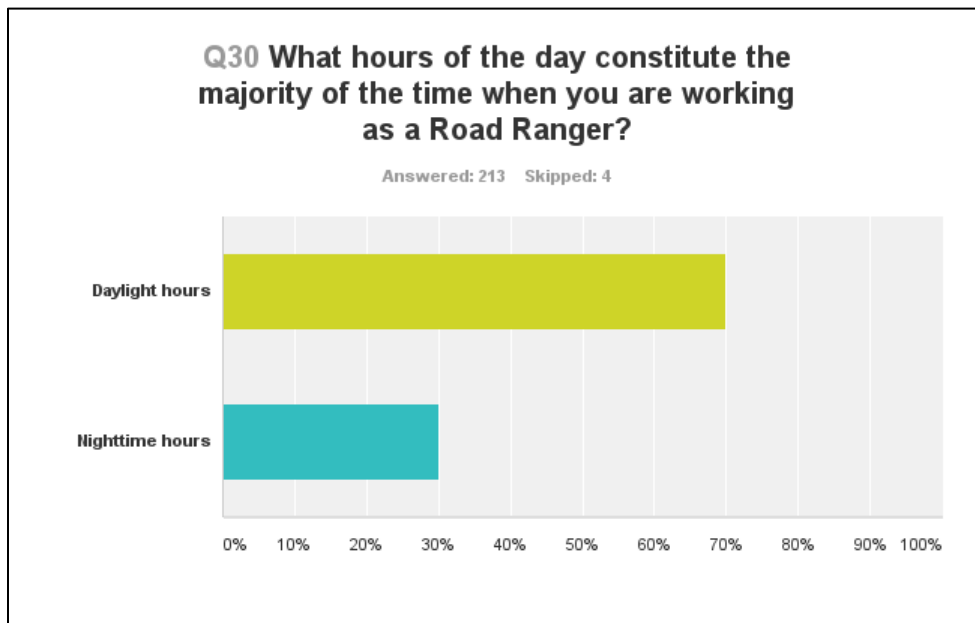


Figure 5-7 RRSP Operator Dominant Operating Hours, Lighting

5.2.3.2 Vehicle and equipment

Vehicles and equipment were evaluated using several survey items. Minimum equipment required for RRSP contractors is set forth by contract, so querying details about those items is not of value. The objective of the questions about vehicles and equipment is to consider vehicle markings, lighting, arrow boards, advance warning and high visibility safety apparel (HVSA) sufficiency.

The sufficiency of RRSP vehicle conspicuity markings and emergency lighting were captured using a graphic rating scale. Survey respondents were asked to rate these items as “excellent”, “good”, or “needs improvement”. Most drivers viewed conspicuity markings on the rear of the RRSP vehicle as “excellent”, and nearly 9 in 10 felt them to be “excellent or good”. Figure 5-8 is a chart that depicts responses to the conspicuity/vehicle markings question.

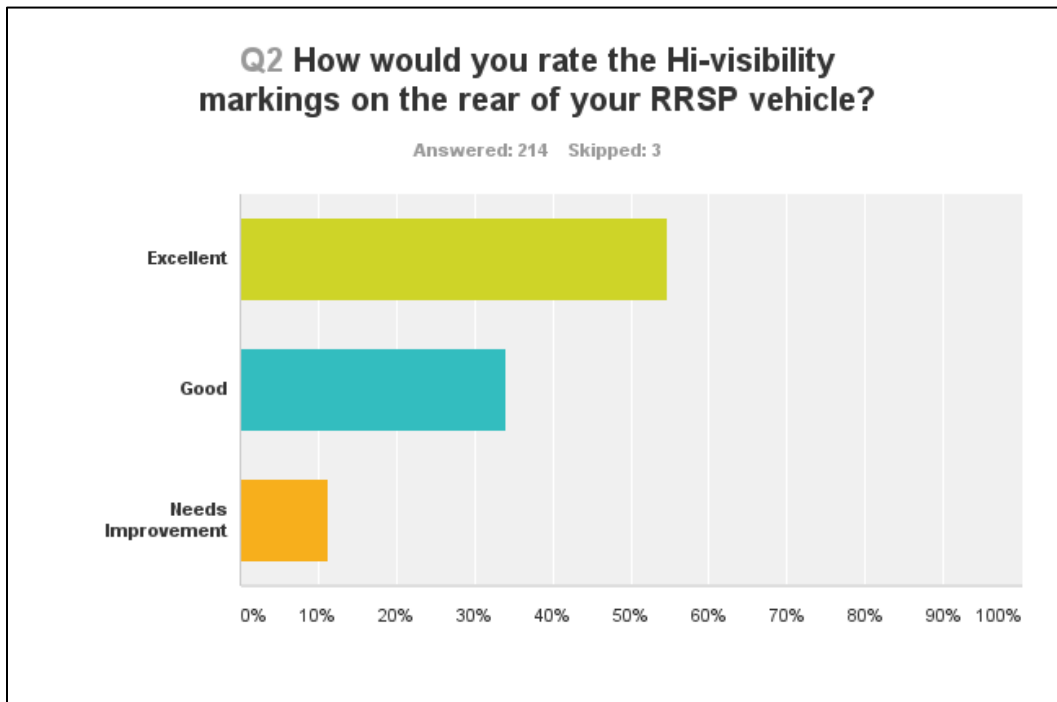


Figure 5-8 RRSP Operator Rating High Visibility Markings on RRSP Vehicle

A similar question about emergency lighting was answered quite differently, with nearly 1/3 of drivers indicating that was an area that required improvement. Figure 5-9 is a chart representing responses to the lighting question. Emergency vehicle lighting is a topic that is further evaluated with an opinion question to be presented later. A large number of drivers actually commented on vehicle emergency lighting in responses to open-ended questions about equipment and safety. Presentation of those survey items is forthcoming and discussion will follow in the analysis section.

The Manual on Uniform Traffic Control Devices (MUTCD) designates that a fluorescent pink advance warning sign can be used for traffic incident management applications. Though not required by FDOT contract, many RRSP carry these signs on their vehicle to augment arrow boards and other temporary traffic control devices. Figure 5-10 shows how many operators carry the MUTCD fluorescent pink advance warning sign.

Florida RRSP are unique when compared to most of their National counterparts in that they can use and monitor the Florida State Law Enforcement Radio System (SLERS). The SLERS is an 800 Mhz radio system used by 11 state law enforcement agencies, dispatched by the Florida Highway Patrol (FHP). The use of SLERS is beneficial given the FHP is responsible for incidents on most Florida freeways and also since FHP dispatch is co-located with FDOT Traffic Management Centers (TMC). Drivers can communicate with the TMC and other responders regarding incidents, but many of them monitor FHP dispatch to respond pre-emptively to assist with incident management. In most districts RRSP contractors are required to provide SLERS to drivers, who are required to be trained and certified in the use of the equipment. Figure 5-11 is a chart that depicts how many drivers have SLERS and Figure 5-12 shows how many monitor the radio during routine patrols.

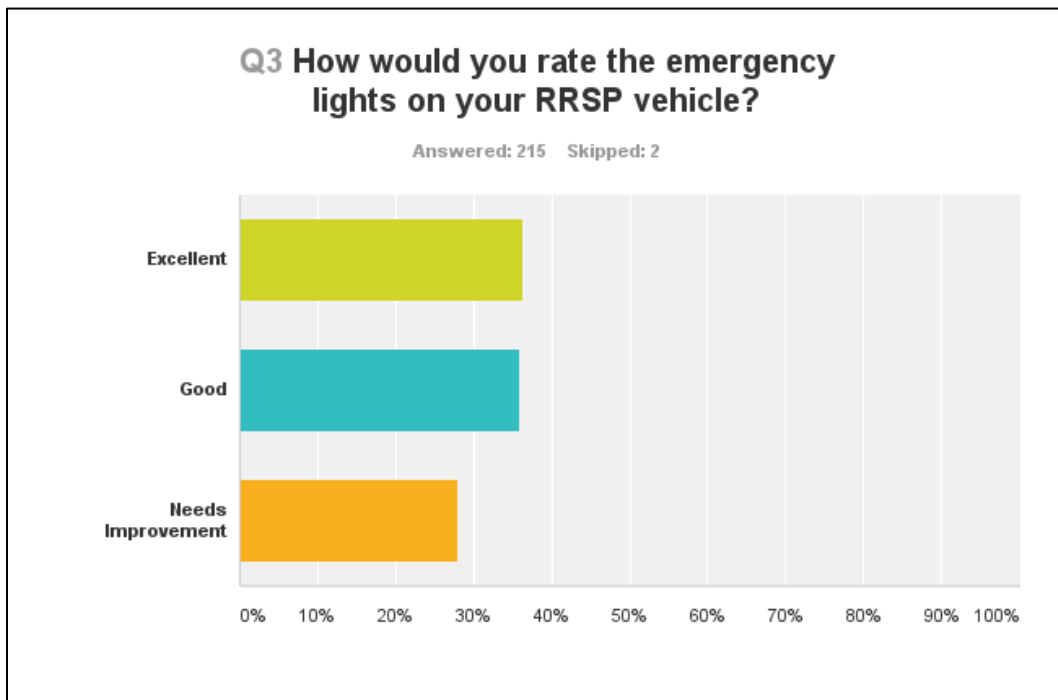


Figure 5-9 RRSP Response to Emergency Vehicle Lighting Sufficiency

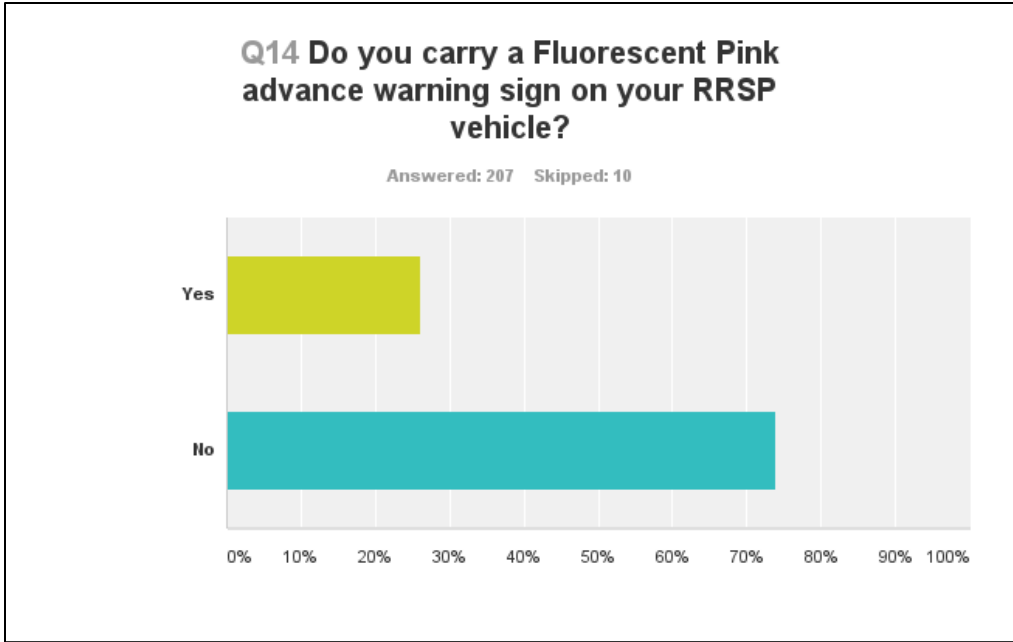


Figure 5-10 RRSP that carry advance warning sign

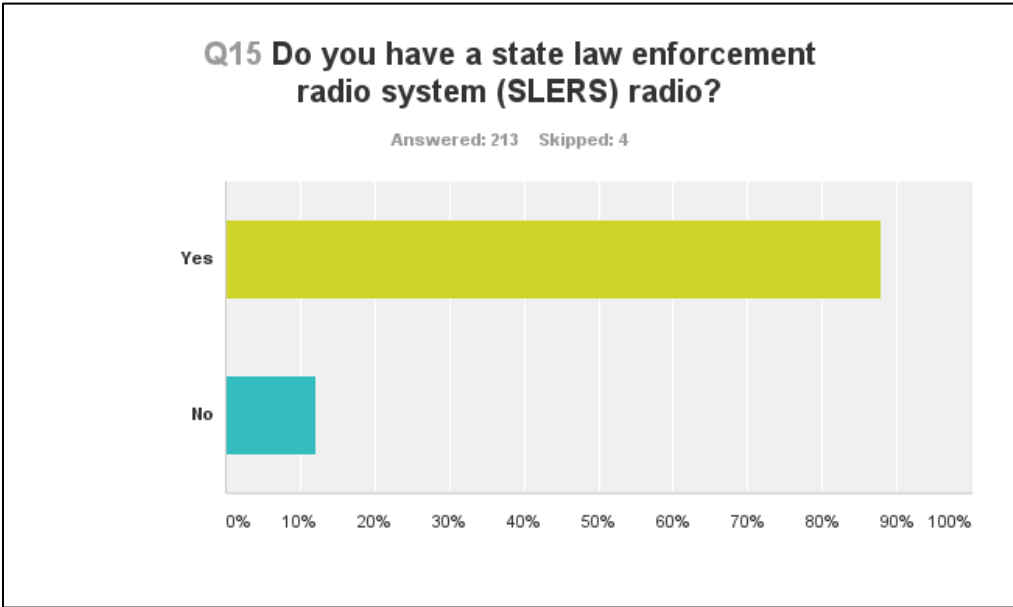


Figure 5-11 RRSP Response to have SLERS

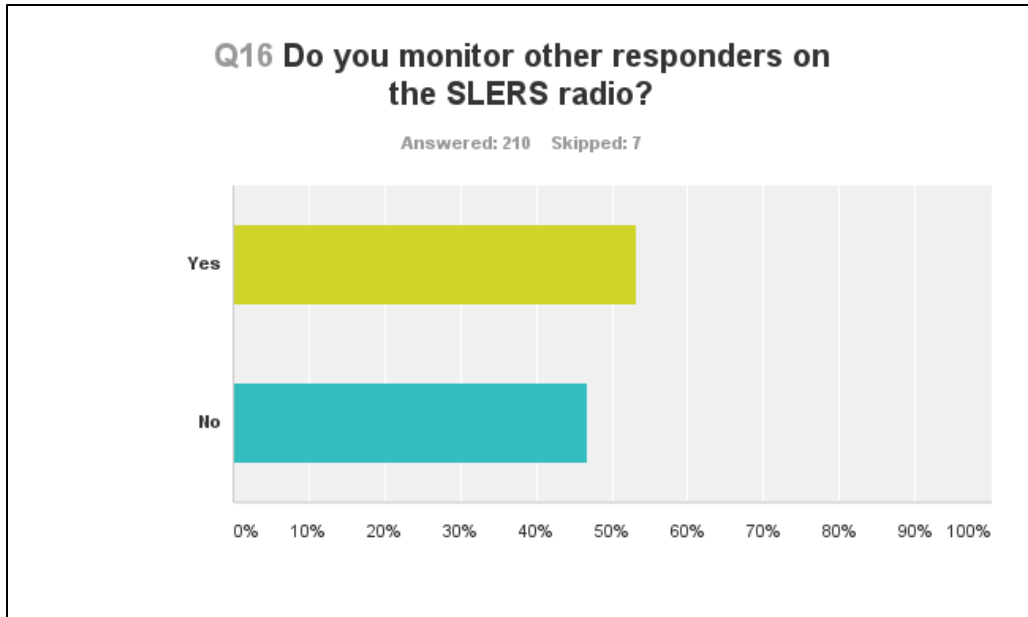


Figure 5-12 RRSP Response to monitoring SLERS

The value of SLERS is enhanced because many rural RRSP beats are on rural freeway segments where cellular coverage might be suspect. Where the SLERS is a portable radio, as opposed to a vehicle mounted radio, coverage might be diminished in rural areas as well. Drivers were asked if communications coverage was ever a problem and just over 70% responded affirmatively as depicted in Figure 5-13.

High visibility safety apparel (HVSA), commonly known as high visibility traffic vests, are required by the MUTCD, and FDOT RRSP contracts. The Secretary of FDOT has issued directives to affirm the requirements for employees and contractors to use hi-vis vests. Every RRSP is required to use a traffic vest at all times. Drivers were questioned about the potential value of other HVSA, like pants, to improve responder safety. Figure 5-14 is a chart that depicts driver views on HVSA pants. As a related note, many drivers mentioned traffic vests in open-ended questions which will be covered separately.

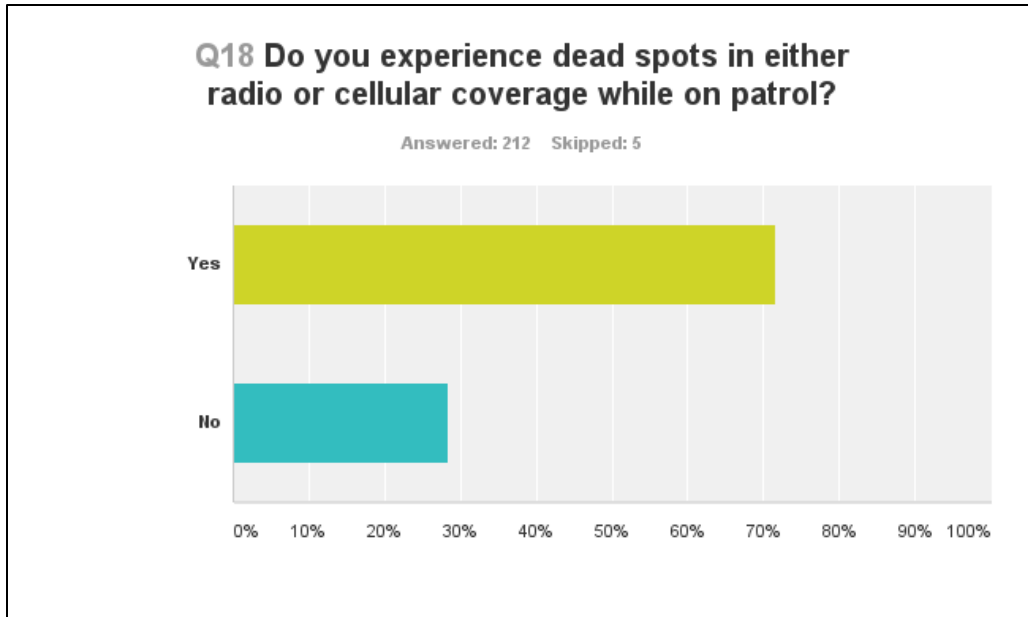


Figure 5-13 RRSP Radio or Cellular Coverage Issues

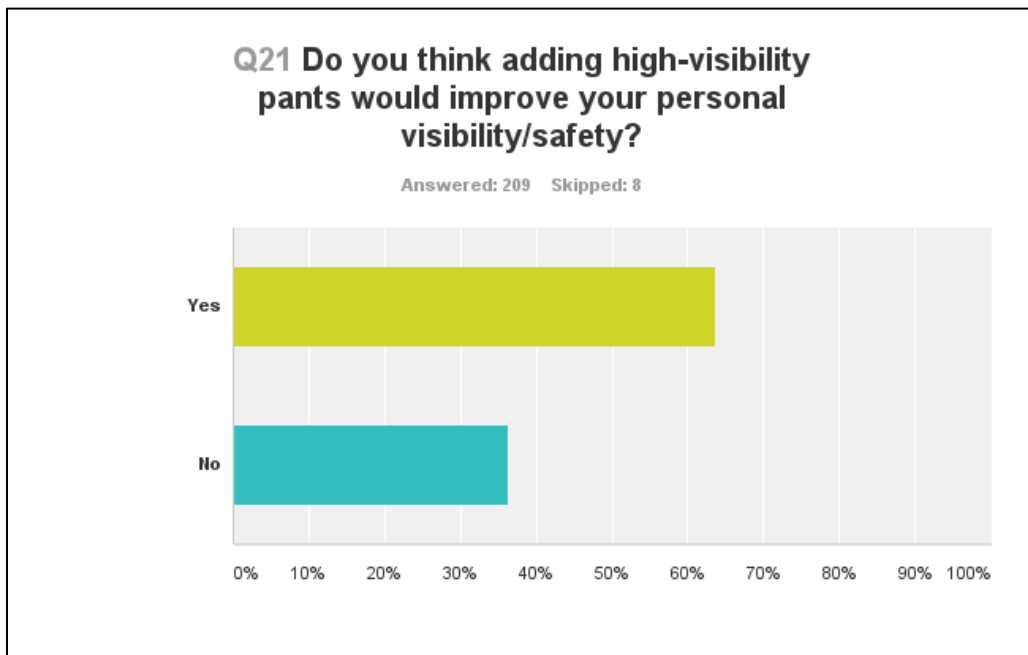


Figure 5-14 RRSP High Visibility Pants Option

5.2.3.3 Training

Road Ranger contractors bear the responsibility for training RRSP driver/operators. FDOT procedures specify basic first aid, CPR, Intermediate MOT, and SLERS radio as the minimum training for operators. Clearly there are many competencies required of the job, so additional training is required. The national survey of SSP state points of contact indicated that more than half of responding states require less than 40 hours of training (Figure 1). For Florida, contractor

training varies in terms of hours, so questions focusing on topical competencies are a better gauge of sufficiency. Using a graphic rating scale, drivers were asked to rate their training in several common areas as “excellent, good, or needs improvement.” Figure 5-16 is a graph that depicts responses from drivers.

More than half of drivers rated their training in all topical areas as “excellent,” a good indication that the current contractor delivery is useful to drivers. Push bumper procedures, debris procedures, and handling spills were areas where drivers indicated there was a need for improvement, but by fewer than 1 in 10 survey participants. Another encouraging sign about training was a question that asked if they had “all of the training and equipment needed to do their job,” 97% of respondents answered affirmatively (Figure 5-15).

Recurring training is important to drivers remaining current. Since many drivers have years of experience, continuous training is important. In district meetings, many indicated that they have short training meetings/briefings on a monthly basis. To identify how widespread monthly training was, drivers were asked if they participated in some type of monthly training. Approximately half of drivers have monthly training, as presented in Figure 5-17.

The national standard for incident management training is the FHWA National Traffic Incident Management Responder Training Program. Developed under the second Strategic Highway Research Program (SHRP2), more than 200,000 police, fire, EMS, transportation, and towing professionals have attended the 4-hour in-person class or taken the equivalent online program. A total of 59% of Florida RRSP operators have taken the training, as depicted in Figure 18.

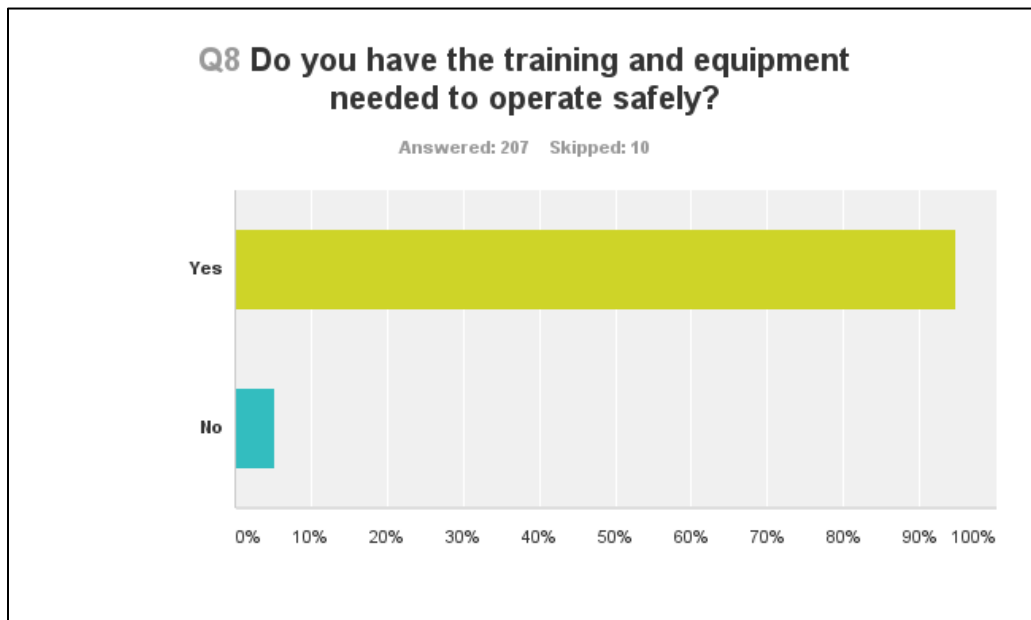


Figure 5-15 RRSP Training Sufficiency by Topic

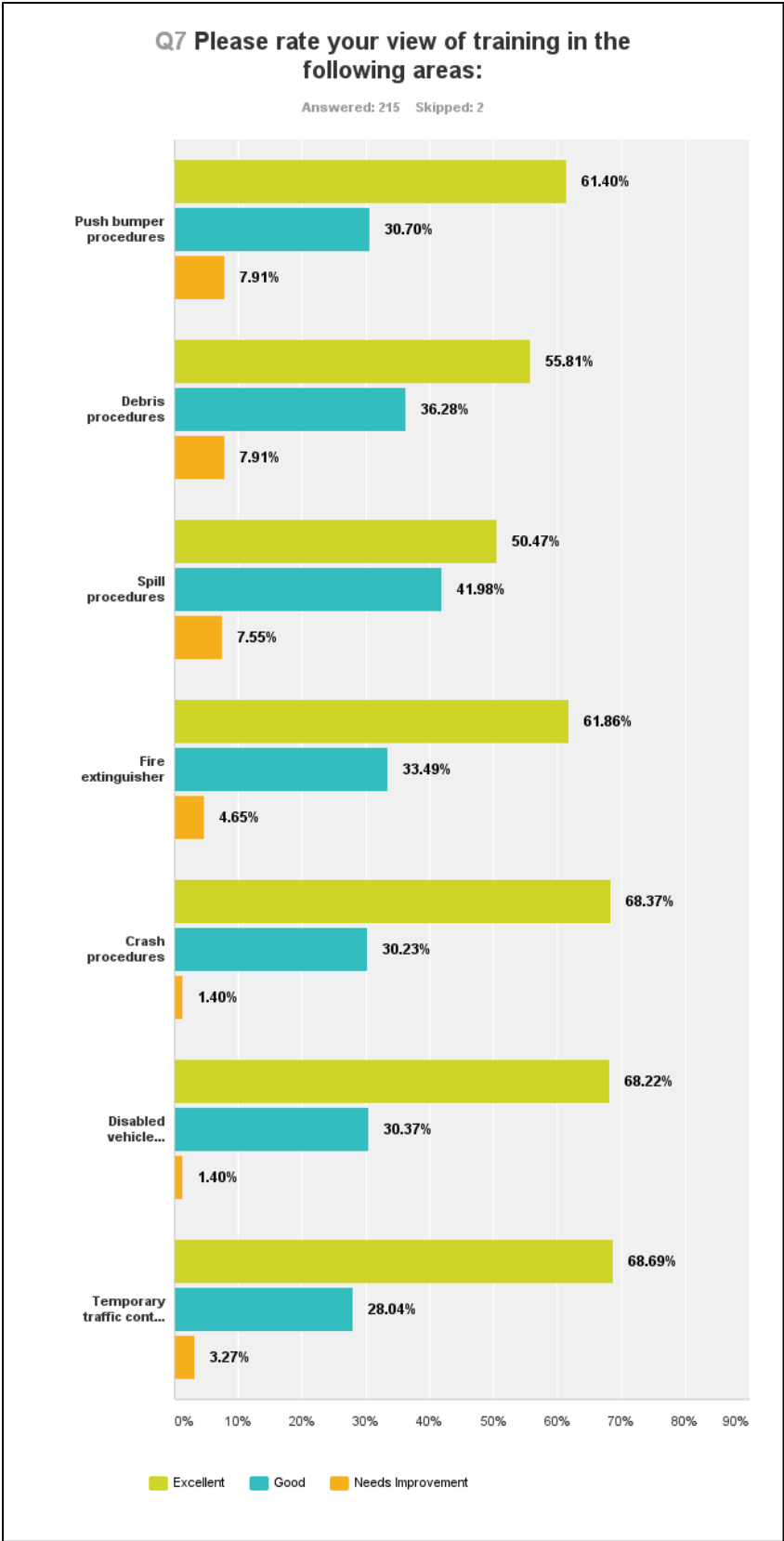


Figure 5-16 RRSP Training Sufficiency by Topic
81

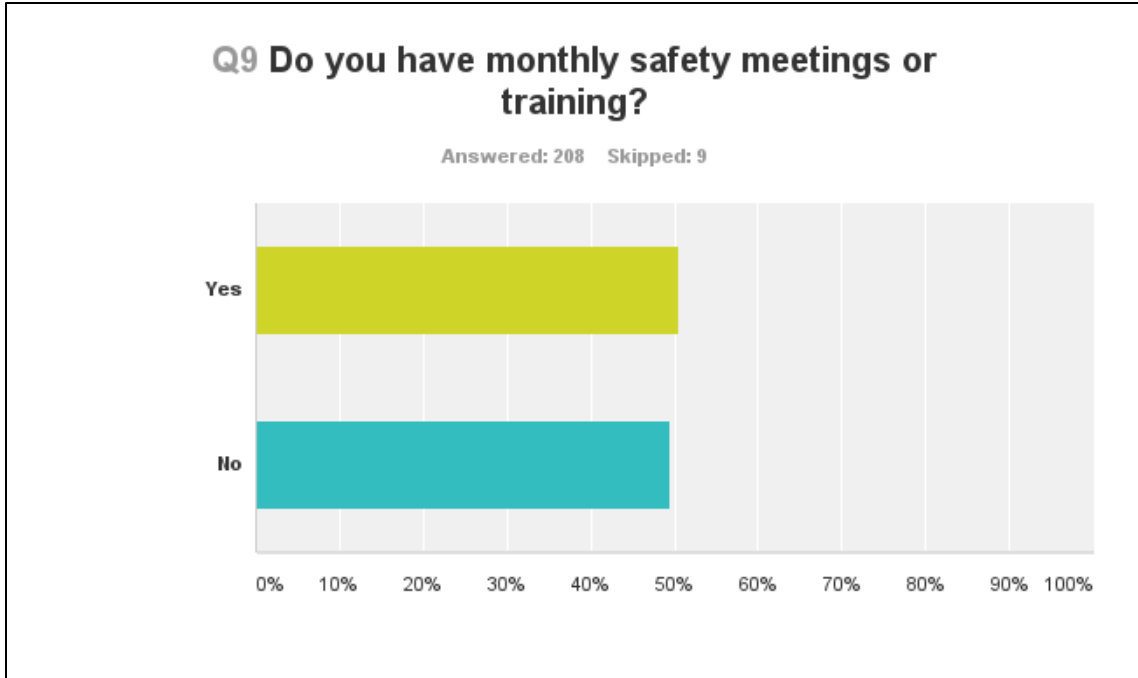


Figure 5-17 Monthly Training Meetings

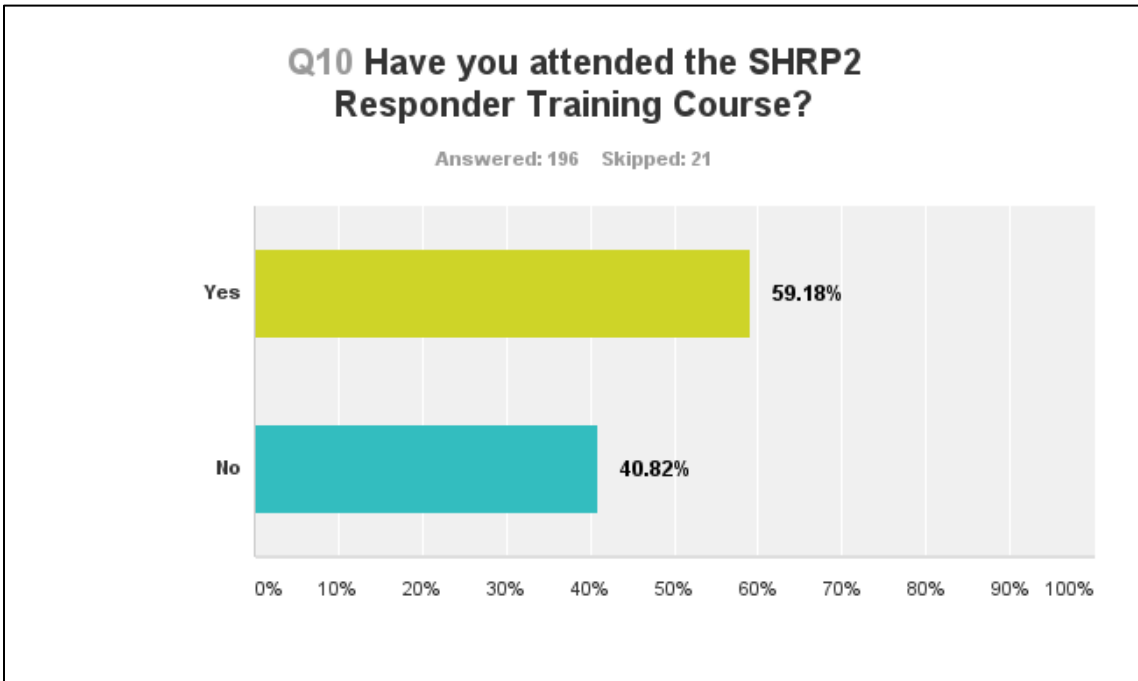


Figure 5-18 National Responder Training Program Attendance

5.2.3.4 Operations and Procedures

Vehicle operation is an area where risk for RRSP operators is increased. Under authority granted in Florida Statute 316.003(1), the FDOT has designated RRSP vehicles as authorized

emergency vehicles. This allows drivers to RRSP vehicles to disregard regulations governing parking, direction, turning, movement, etc. under certain circumstances. Despite the legal authority, some RRSP contractors may impose company policies that restrict the use of shoulders and median openings for insurance reasons. To gain insight into these aspects of vehicle operations, three questions were presented to drivers. Figures 5-19, 5-20, and 5-21 show how drivers use median turnarounds and shoulders in their duties.

While the majority of drivers do not use median openings and official turnarounds, driving on the shoulder is a common practice that is necessary to pass incident delays and respond to incidents.

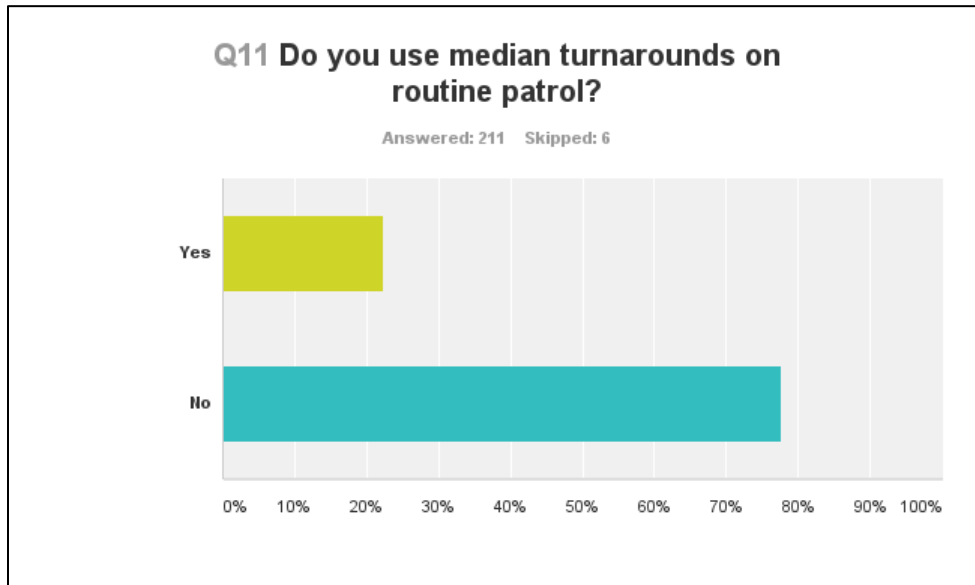


Figure 5-19 Use of Median Turnarounds on Patrol

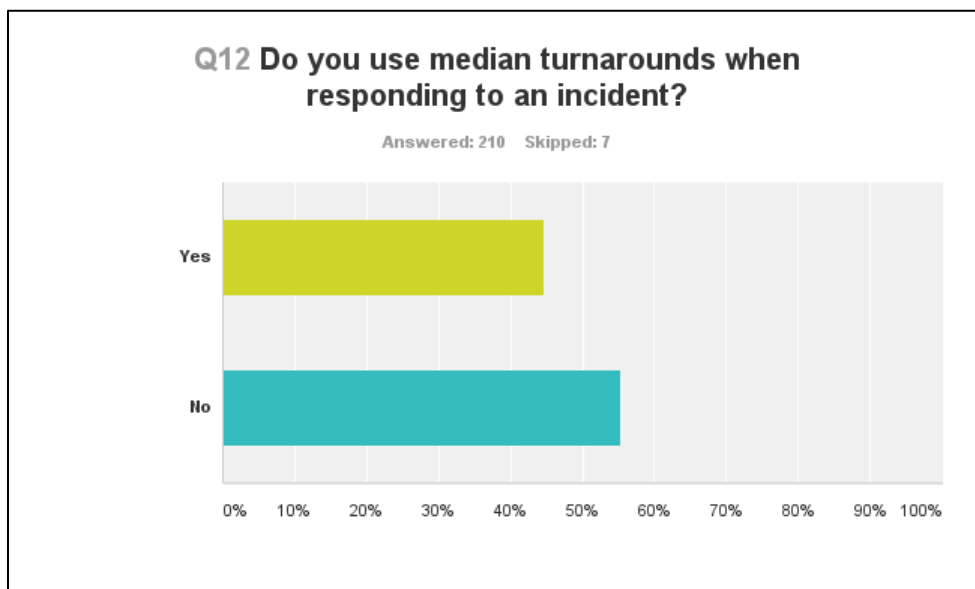


Figure 5-20 Use of Median Turnarounds in Response to Calls

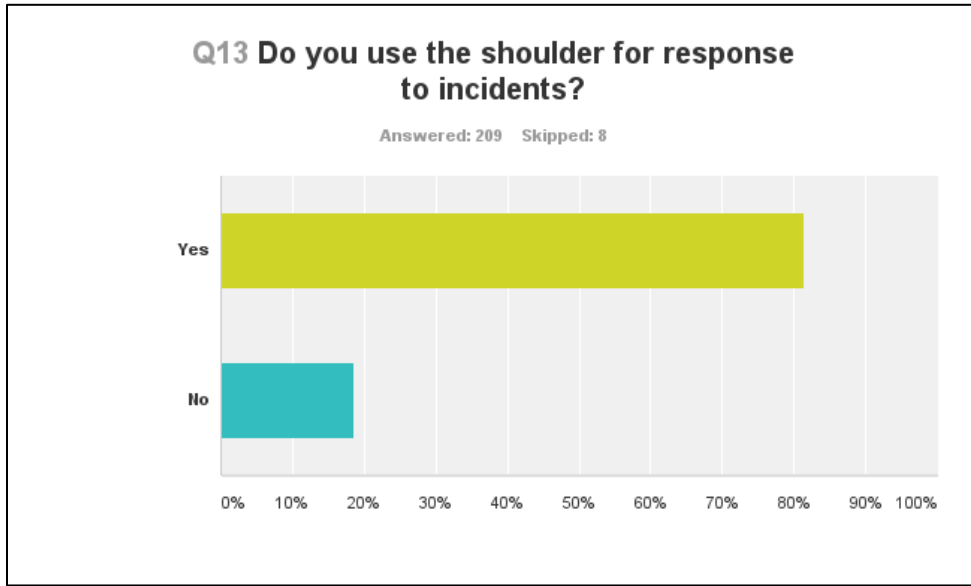


Figure 5-21 Use of Shoulder in Response to Calls

A series of questions sought to understand exposure that RRSP operators have in hazardous situations. RRSP operators indicated that they often (47%) or sometimes (41%) work on bridges or elevated roadways where there is limited space. A follow-up question sought to see if they had assistance from other responders in those situations, providing advance warning or a blocking vehicle. When operating in those conditions, 37 percent of drivers “often” had help, 34 percent “sometimes”, and 29 percent “rarely” (Figures 5-22 and 5-23).

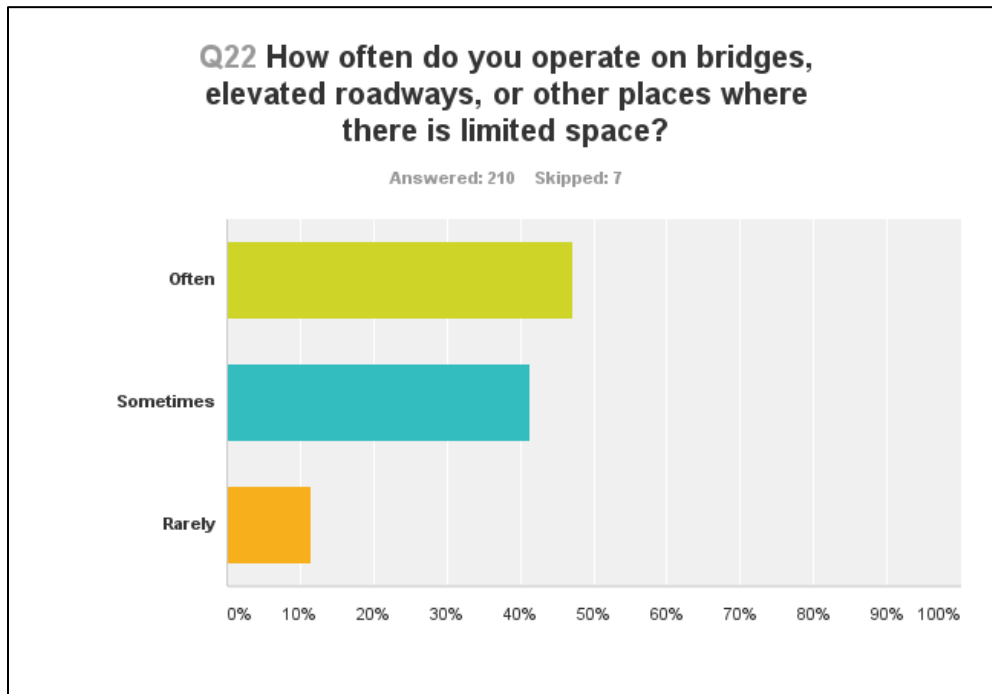


Figure 5-22 Operating on Bridges and Overpasses

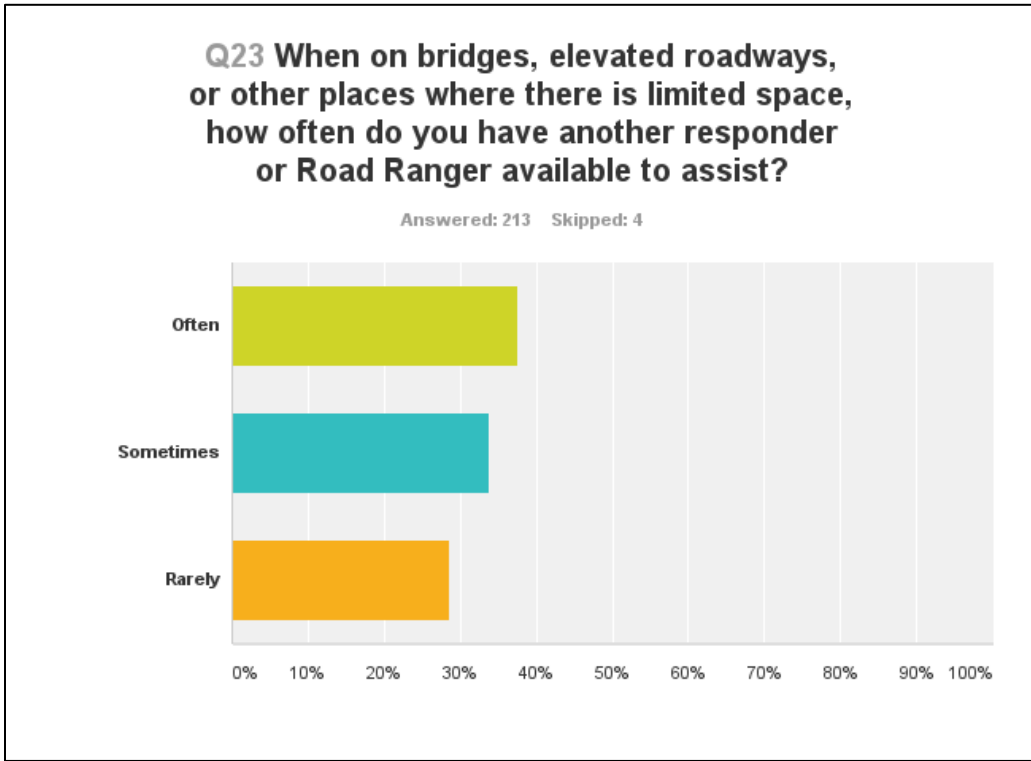


Figure 5-23 Operating on Bridges or Overpasses with Help

A basic principle of responder safety is avoiding standing near active lanes of traffic. Drivers were asked if they use a technique called an “off side approach” when engaging disabled motorists or others. In this technique, the RRSP operator would approach stand for example on the right side of a car on the right shoulder, speaking with the occupant(s) through the passenger window. Nine out of ten RRSP drivers indicated that they “often” use this technique when making initial contact, 6 percent “sometimes”, and 4 percent “rarely”. Figure 5-24 shows those responses.

A follow-up question sought to understand exposure in situations where the RRSP operator may be confronted with working near moving traffic. When asked how often they provide fuel or change tires on the traffic side of a disabled vehicle, 66 percent said “often”, 22 percent “sometimes”, and 12 percent “rarely”, as depicted in the chart in Figure 5-25.

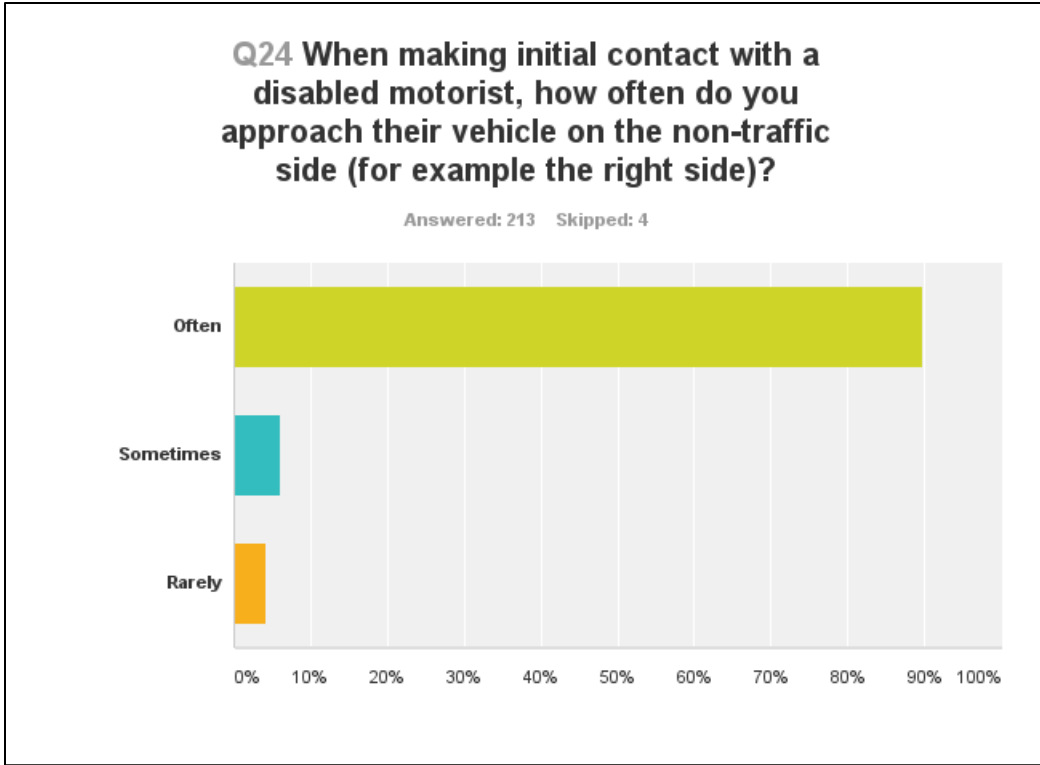


Figure 5-24 Use of Non-Traffic Side Approach

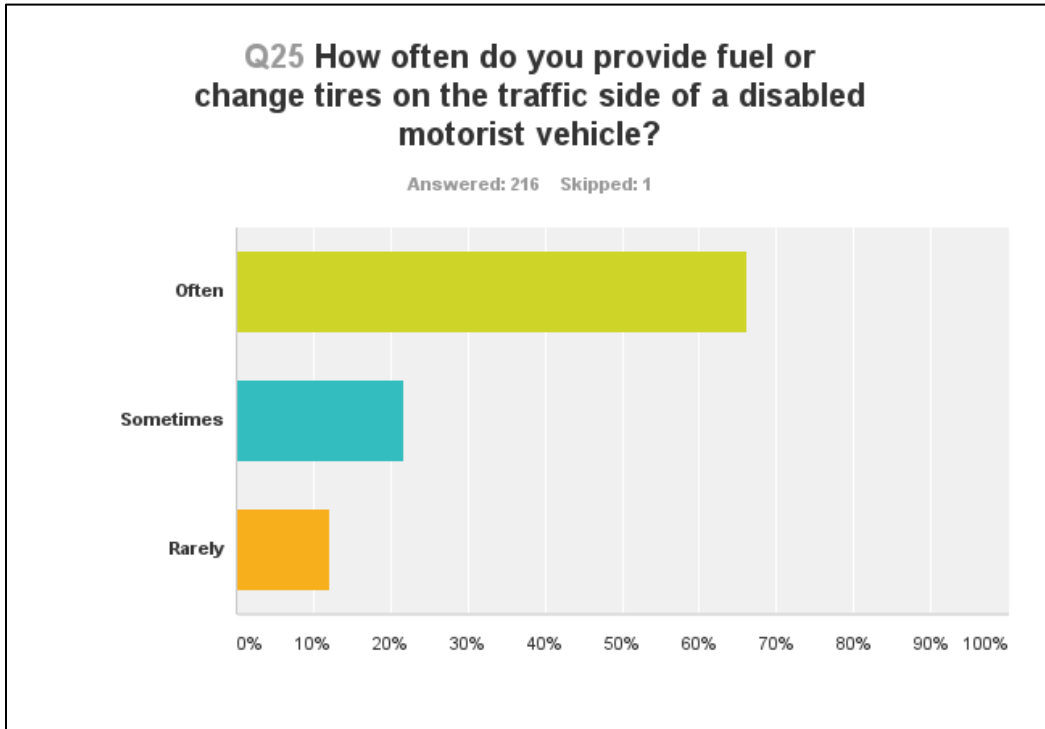


Figure 5-25 Working on the Traffic Side of a Disabled Vehicle

5.2.3.5 Perceptions and Opinions

Drivers were asked a series of questions that were based more on opinion than fact. Driver opinions and perceptions are a valuable part of safety analysis.

In open-ended questions, drivers were noticeably concerned about “move over” behavior among drivers who pass their incident scenes. The drivers commented that more enforcement was needed to improve compliance, but also wrote that additional emergency lights and/or different color lights would improve move over. When asked if additional emergency lights on the RRSP vehicle would improve compliance, 70 percent of drivers indicated they felt they would. An additional 17 percent were not sure, and only 13 percent felt they would not improve move over. Figure 5-26 is a chart for the additional lighting question.

A related question centered on the use of vehicle mounted arrow boards while on the shoulder. The MUTCD specifies that while on the shoulder, arrow boards should be placed in the “caution” mode, where their lights on the board simply display a dot in each of the 4 corners of the display. Incident responders have often desired to use an arrow on the display board to promote move over behavior. Drivers were asked if they felt using the arrow would improve move over compliance and 72 percent said “yes”, with an additional 11 percent “not sure”, and the remaining 17 percent indicating “no”. Figure 5-27 is a chart that depicts responses to the question about arrow boards to support move over.

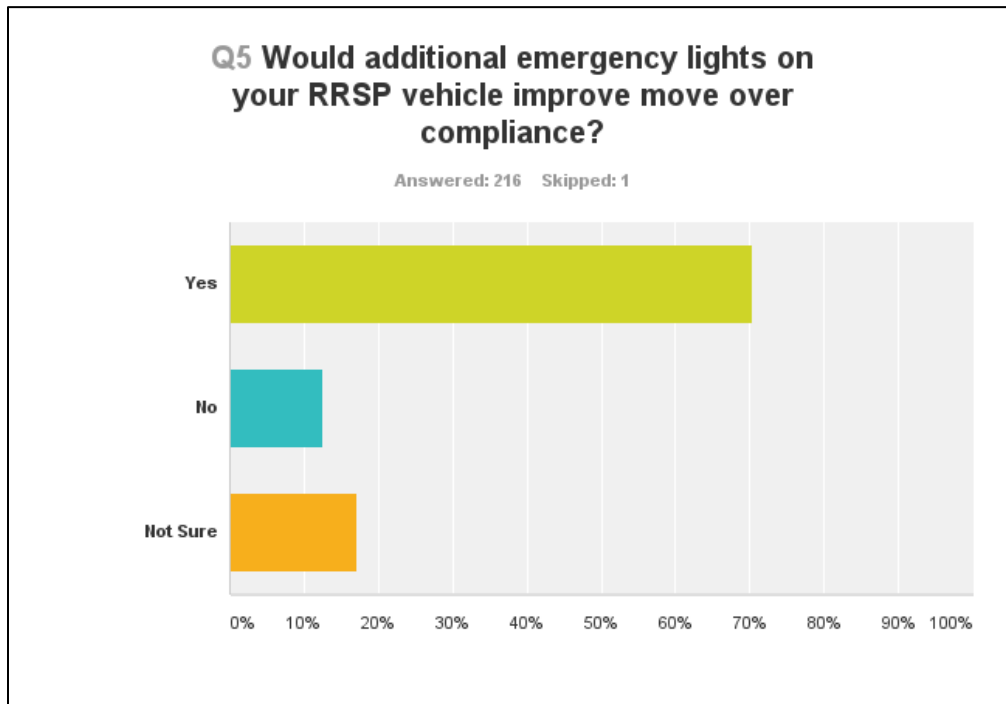


Figure 5-26 Additional Lights

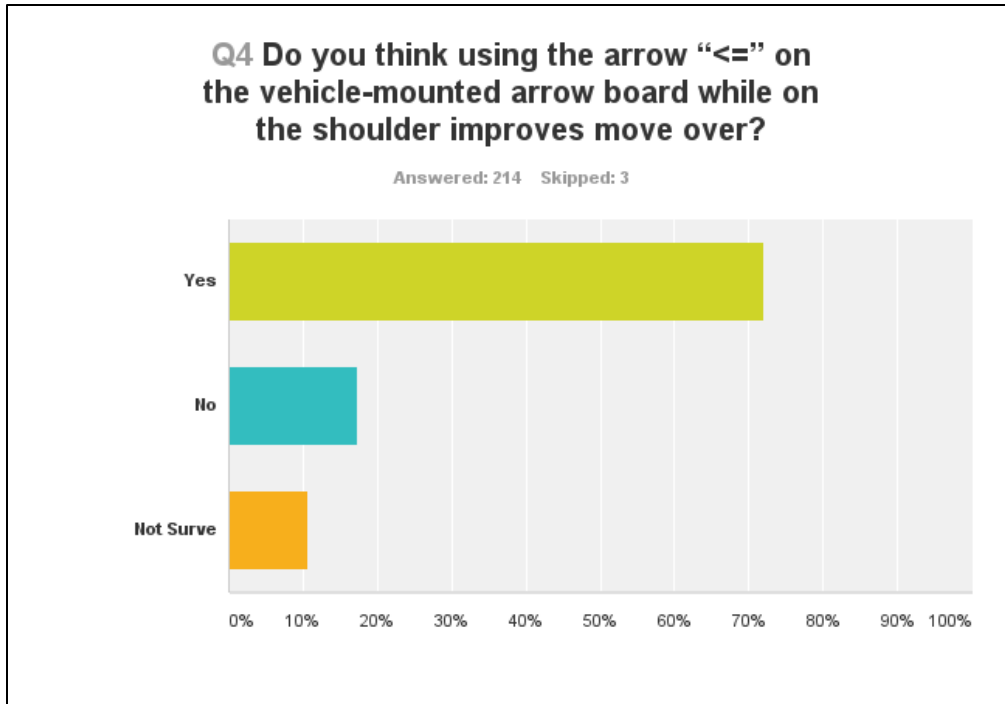


Figure 5-27 Use of Arrow Board to Promote Move Over

Vehicle-mounted digital message boards are an alternative to the vehicle-mounted arrow board on most RRSP. Digital message boards, sometimes called changeable message boards, allow the operator to display text messages and/or graphics like an arrow. RRSP drivers were asked if they thought message boards were superior to simple arrow boards and 47 percent indicated “yes”, 31 percent “no”, and the remaining 22 percent “not sure”. Figure 5-28 is a chart of responses.

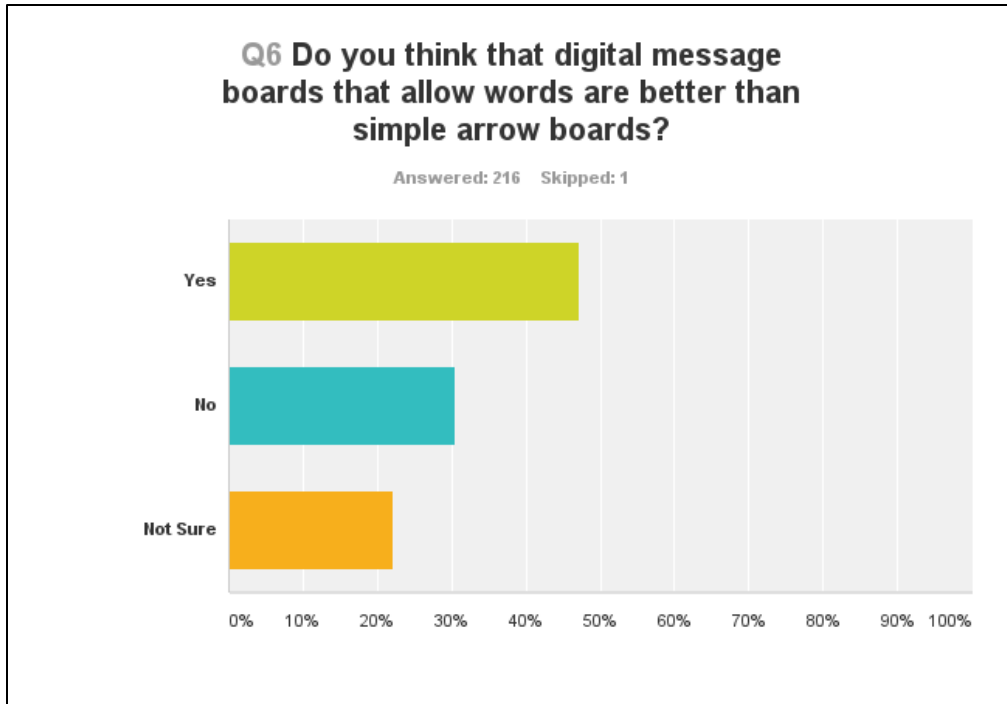


Figure 5-28 Digital Message Boards

Most RRSP have SLERS available and 88 percent felt they were important to safety. Figure 5-28 depicts a chart of SLERS radio.

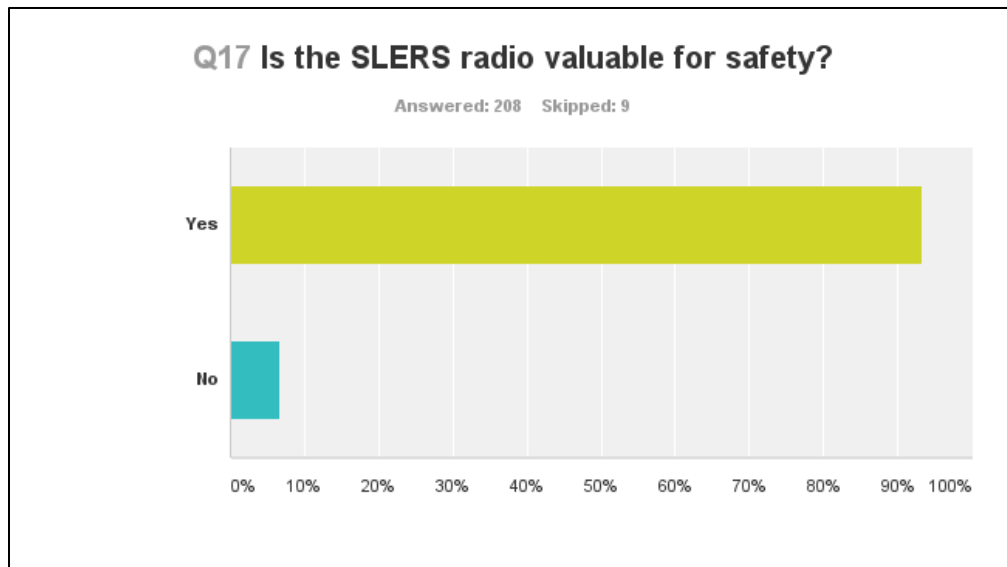


Figure 5-29 Value of SLERS

During interviews with FDOT RRSP Program Managers, several voiced concern over shoulders in work zones. Drivers were asked to rate the importance of “shoulders or crash investigation sites in work zones”. All drivers thought they were “important” or “very important”.

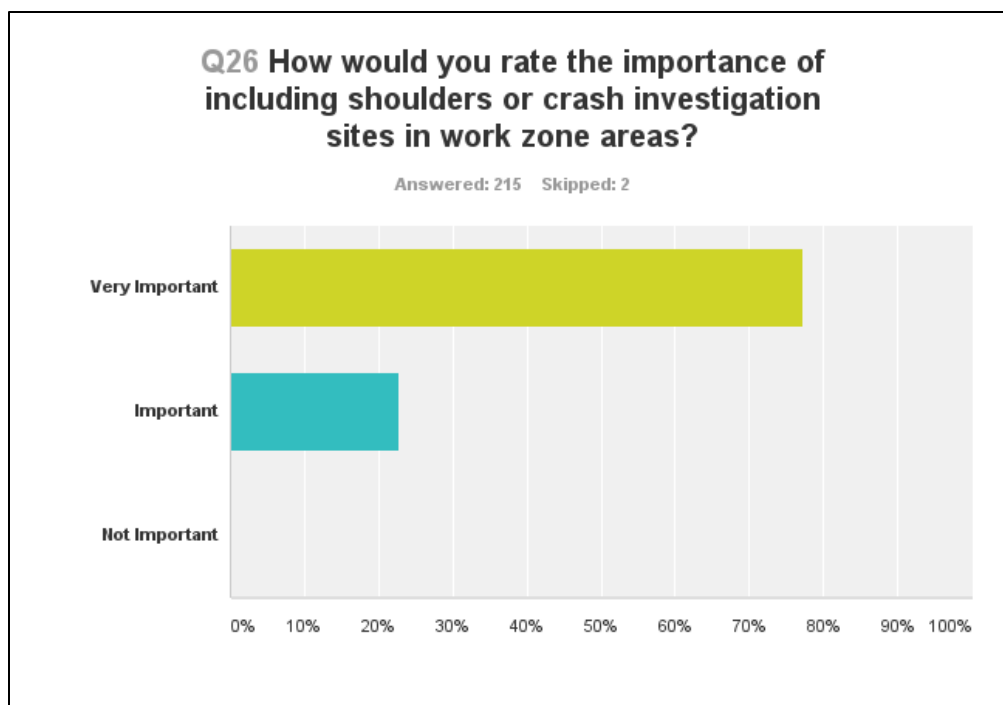


Figure 5-30 Including Shoulders in Work Zones

5.2.3.6 Open-Ended Questions

Because the RRSP driver survey seeks to learn about safety, two open-ended questions were included. With open-ended questions, emergent information can be gleaned from survey participants.

Is there any equipment that you feel that you need that is not available to you right now?

- Lights were mentioned 30 times and specifically red 17 times and strobe 8 times
- Jump box or similar 6 times
- PPE (vests, gloves, shirts, boots, eye protection) mentioned 11 times
- Impact or cordless tools were mentioned 4 times

The following items had multiple mentions

- Need for radios; better rain gear; traffic wands/flashlights; water for drivers
- Tow trucks and/or wheel lifts
- Arrow boards and message boards

Additional comments: What do you feel is unsafe, what do you have to add about Road Ranger safety, what might be done to improve safety?

- Light and lights were mentioned 41 times and red specifically 21 times
- Move over was mentioned 31 times (Enforcement and Public Awareness)
- TMC (5) and dispatch (9) issues were mentioned
- Training was mentioned 4 times

The following items were mentioned multiple times

- Debris; push bumper; paperwork/SPARR; Personal protective equipment; driver breaks

5.2.4 Driver Survey – Contingency Tables

Contingency tables, also called cross tabulations, relate variables to further explain data descriptively. The demographic variables presented earlier lend themselves well to cross tabulation. Using statistical software a wide range of cross tabulations were created using driver experience, type of responder vehicle, and night/day work. For driver experience, those with greater than 5 years are grouped in the binary “yes” which is represented by the value 1, and all others are grouped using the value 0. For type of responder vehicle, those who operate a tow truck are grouped as 1, and all others 0. Finally, drivers who work at night are grouped as 1, and all others (daytime) 0.

When exploring the impact that lighting might have on move over compliance, more experienced operators tended to be less optimistic about potential for improvement. As depicted in table 5-6, more experienced operators did not feel that additional emergency lighting would improve move over. Similarly, experienced drivers did not believe that using the arrow while on the shoulder would improve move over either, table 5-7. There was also less certainty that the message board is superior to the simple arrow board as seen in table 5-8. More years of experience also apparently create comfortable habits as seen in non-traffic side approaches. More experienced officers tend to use the non-traffic side approach as seen in table 5-9.

Table 5-6 Cross Tabulation Experience and Additional Lighting
LIGHTARROW * EXP5PLUS Crosstabulation

% within EXP5PLUS

		EXP5PLUS		Total
		.00	1.00	
LIGHTARROW				
	No	9.0%	16.8%	12.4%
	Not Sure	14.8%	20.0%	17.1%
	Yes	76.2%	62.1%	70.0%
Total		100.0%	100.0%	100.0%

Table 5-7 Cross Tabulation Experience and Use of Arrow Board
USEARROW * EXP5PLUS Crosstabulation

% within EXP5PLUS

		EXP5PLUS		Total
		.00	1.00	
USEARROW				
	No	0.8%	2.1%	1.4%
	Not Sure	13.1%	22.1%	17.1%
	Yes	9.0%	12.6%	10.6%
Total		77.0%	63.2%	71.0%
		100.0%	100.0%	100.0%

Table 5-8 Cross Tabulation Experience and Message Board
DMBORARROW * EXP5PLUS Crosstabulation

% within EXP5PLUS

		EXP5PLUS		Total
		.00	1.00	
DMBORARROW				
	No	26.2%	35.8%	30.4%
	Not Sure	23.0%	21.1%	22.1%
	Yes	50.8%	42.1%	47.0%
Total		100.0%	100.0%	100.0%

Table 5-9 Cross Tabulation Experience and Non-Traffic Side Approach

APPROACH_RIGHT * EXP5PLUS Crosstabulation

% within EXP5PLUS

		EXP5PLUS		Total
		.00	1.00	
APPROACH_RIGHT		3.3%		1.8%
	Often	91.8%	83.2%	88.0%
	Rarely	1.6%	7.4%	4.1%
	Sometimes	3.3%	9.5%	6.0%
Total		100.0%	100.0%	100.0%

Working in nighttime conditions present special hazards of RRSP drivers. Nighttime evidently has an impact of opportunities for responders to interact. Drivers who work mostly at night were more likely to indicate that relationships with other responders “need improvement”. Table 5-10 shows that nighttime RRSP operators are about 3 times more likely to cite a need for improvement.

Table 5-10 Cross Tabulation Nighttime RRSP and Relationship with Other Responders

RATEO * NIGHT Crosstabulation

% within NIGHT

		NIGHT		Total
		.00	1.00	
RATEO		1.3%		0.9%
	Excellent	54.9%	51.6%	53.9%
	Good	41.2%	40.6%	41.0%
	Needs Improvement	2.6%	7.8%	4.1%
Total		100.0%	100.0%	100.0%

High Visibility Safety Apparel (HVSA) makes incident responders more visible at night, most notably making them visible from farther away under low beam headlights. At highway speeds, this is critically important because of stopping distances. Drivers who work at night are more inclined to think that enhancing HVSA with pants is a good idea. Table 5-11 depicts the optimism of increased visibility.

Table 5-11 Cross Tabulation Nighttime RRSP and High Visibility Safety Apparel

HIVISPANTS * NIGHT Crosstabulation

% within NIGHT

		NIGHT		Total
		.00	1.00	
HIVISPANTS		3.3%	4.7%	3.7%
	No	37.3%	29.7%	35.0%
	Yes	59.5%	65.6%	61.3%
Total		100.0%	100.0%	100.0%

Vehicle-mounted message boards and arrow boards have a different light intensity at night. Drivers who work at night appear to be “not sure” if they are superior to arrow boards, as depicted in table 5-12. The logistics of working at night make training meetings more challenging. Table 5-13 shows that nighttime operators are less likely to have recurring training meetings. Finally, nighttime drivers are highly sensitive to being in travel lanes, ostensibly due to reduced visibility. Table 5-14 shows that more nighttime drivers rate having shoulders in work zone settings as “very important”.

Table 5-12 Cross Tabulation Nighttime RRSP and Message Boards

DMBORARROW * NIGHT Crosstabulation

% within NIGHT

		NIGHT		Total
		.00	1.00	
DMBORARROW		0.7%		0.5%
	No	32.7%	25.0%	30.4%
	Not Sure	15.7%	37.5%	22.1%
	Yes	51.0%	37.5%	47.0%
Total		100.0%	100.0%	100.0%

Table 5-13 Cross Tabulation Nighttime RRSP and Monthly Training

HAVEMEET * NIGHT Crosstabulation

% within NIGHT

		NIGHT		Total
		.00	1.00	
HAVEMEET		3.9%	4.7%	4.1%
	No	43.8%	56.3%	47.5%
	Yes	52.3%	39.1%	48.4%
Total		100.0%	100.0%	100.0%

Table 5-14 Cross Tabulation Nighttime and Work Zone
INCL_WZ * NIGHT Crosstabulation

% within NIGHT

		NIGHT		Total
		.00	1.00	
INCL_WZ		1.3%		0.9%
	Important	26.1%	14.1%	22.6%
	Very Important	72.5%	85.9%	76.5%
Total		100.0%	100.0%	100.0%

The advantage of tow trucks as RRSP vehicles has been espoused by drivers and FDOT Program Managers. When asked about fueling vehicles or changing tires on the traffic side of a disabled vehicle, the operator of a tow truck is clearly less likely to engage in that activity. A tow truck can remove a vehicle to a safer location and not place the operator in danger. Table 5-15 shows that tow truck RRSP drivers are far less likely to engage in hazardous traffic side activities.

Table 5-15 Cross Tabulation Tow Truck and Assisting Disabled on Traffic Side
FREQ_DISABLE * TOWTRUCK Crosstabulation

% within TOWTRUCK

		TOWTRUCK		Total
		.00	1.00	
FREQ_DISABLE		0.6%		0.5%
	Often	72.8%	47.5%	65.9%
	Rarely	7.0%	25.4%	12.0%
	Sometimes	19.6%	27.1%	21.7%
Total		100.0%	100.0%	100.0%

5.3. Conclusions and Recommendations

Research has indicated rear-end collisions are common for RRSP vehicles, and they are struck while parked and on the shoulder at a higher rate than the larger population of freeway crashes. Vehicle conspicuity is very important to mitigate these crash hazards. Passive treatments like rear-facing markings on vehicles that including contrasting, fluorescent, and retro-reflective materials complement emergency lighting.

Compliance with Florida’s move over law has the potential to improve safety. Public information, coupled with proactive high visibility enforcement by law enforcement are needed to reinforce the move over requirements where RRSP are involved. Emergency vehicle lighting and the use of vehicle-mounted arrow boards have the potential to improve move over compliance, but these treatments need to be studied further.

RRSP operators are more likely to be struck as pedestrians, making situational awareness and the use of high visibility safety apparel (HVSA) more important. Drivers have indicated that the use of “traffic vests” might be replaced with newer uniform technologies that incorporate

MUTCD compliant ANSI standards in shirts and pants. Additionally, rain gear, traffic gloves, and safety glasses should be examined further.

RRSP operator training appears to be adequate, from the driver point of view, however the required training is very minimal and should be examined. A formal training needs assessment would identify competencies and guide contractor training, potentially improving safety.

The following recommendations are made for policy changes:

- Conduct a training needs assessment and create a set of basic competencies for operators to guide contractor training
- Create a requirement for operators to attend the 4-hour FHWA National TIM Responder Training course
- Create a requirement for recurring training to ensure operators are current
- Engage law enforcement to do move over enforcement involving RRSP
- Creation of a systematic reporting system for all RRSP crashes
- Evaluate RRSP equipment to consider inclusion of jump boxes and tools to speed tire changes

The following recommendations are made for additional research:

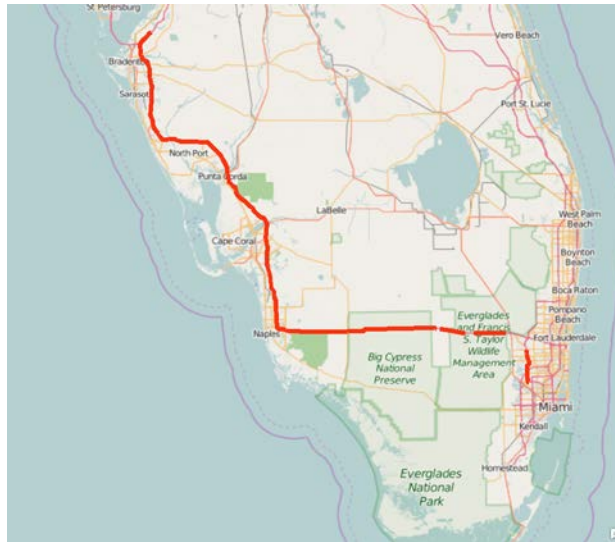
- Efficacy of rear-facing red strobes to promote move over
- Efficacy of shoulder arrow and message board use to promote move over
- RRSP HVSA and uniform standards to include rain gear and eye protection

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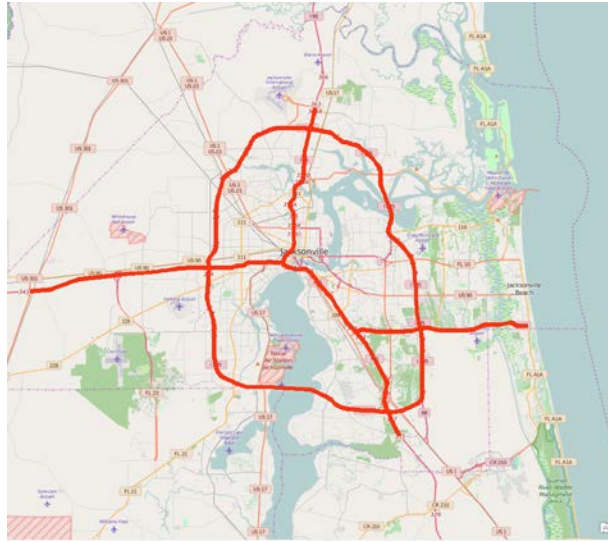
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APPENDIX A: ROAD RANGER PROGRAM IN D1



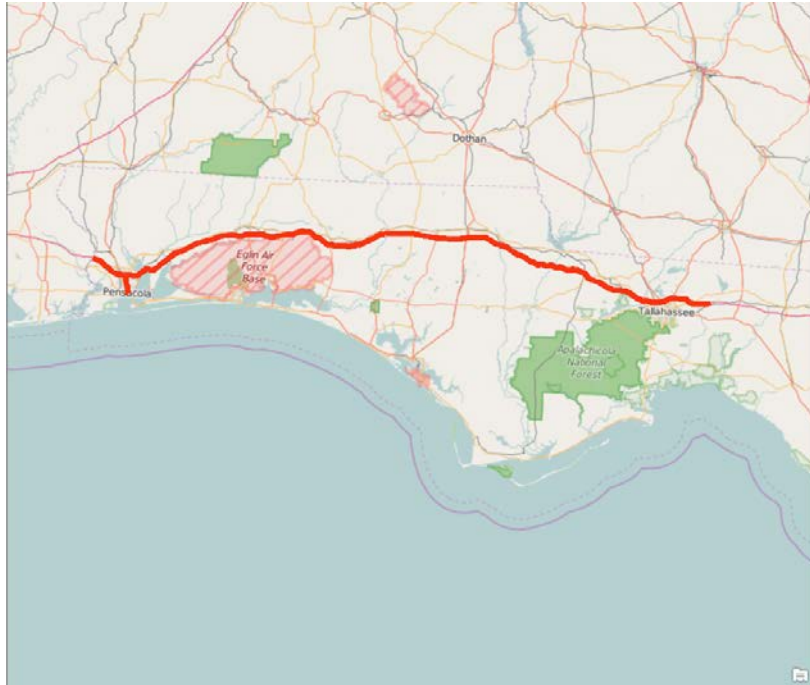
Segment				Patrol Time		Number of Truck
Segment	Route	Start	END	MON-THU	FRI-SAT	
1	I75	MM49	MM80	7AM-11PM	9AM-9AM	1
2	I75	MM80	MM105	5AM-9PM	8AM-3.30AM	1
3	I75	MM105	MM123	7AM-7PM	7AM-7PM	1
4	I75	MM116	MM138	6AM-6PM	7AM-7PM	1
5	I75	MM136	MM158	6AM-6PM	9AM-9PM	1
6	I75	MM143	MM170	7AM-7PM	9AM-9PM	1
7	I75	MM167	MM193	7AM-7PM	9AM-9PM	1
8	I75	MM191	MM213	6AM-6PM	9AM-9PM	1
9	I75	MM210	MM234	7AM-7PM	9AM-9PM	1
10	I275	MM0	MM13	9AM-7PM	9AM-7PM	1

APPENDIX B: ROAD RANGER PROGRAM IN D2



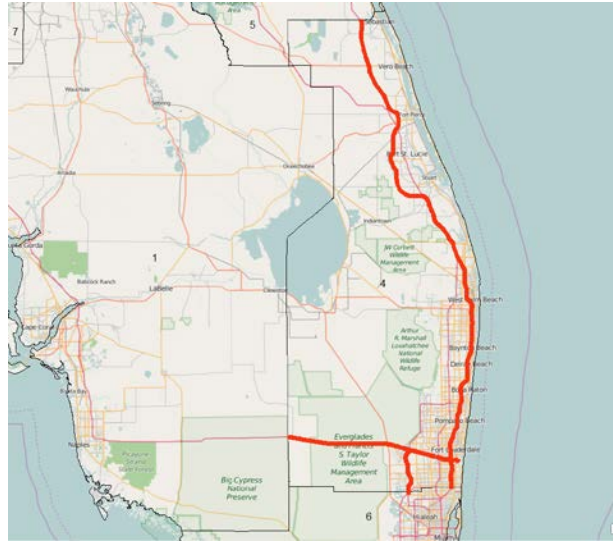
Segment				Patrol Time		Number of Truck
Seg.	Route	Start MM	END MM	MON-THU	FRI-SAT	
1	I95	San Marco Road north	Pecan Park Rd	6.30AM - 6.30PM	-	1
2	I95	Old St. Augustine Rd.	College St.	6.30AM - 6.30PM	-	1
3	I295	East Beltway	West Beltway	6.30AM - 6.30PM	-	1
4	J. Turner Blvd	San Marco Blvd	SR.200	6.30AM - 6.30PM	-	1
5	SR.202	I-95	SR.A1A	6.30AM - 6.30PM	-	1

APPENDIX C: ROAD RANGER PROGRAM IN D3



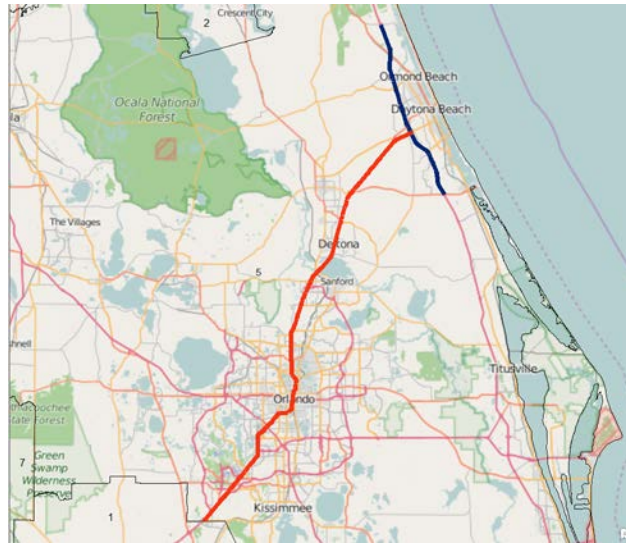
Segment				Patrol Time		Number of Truck
Segment	Route	Start	END	MON-THU	FRI-SAT	
1	I-10	MM.0	MM.33	24/7		1
2	I-110	MM.0	MM.6	24/7		1
3	I-10	MM33	MM96	M-F 6-6		1
4	I-10	MM96	MM152	M-F 6-6		1
5	I-10	MM152	MM196	M-F 6-6		1
6	I-10	MM196	MM217	M-F 5-9		1

APPENDIX D: ROAD RANGER PROGRAM IN D4



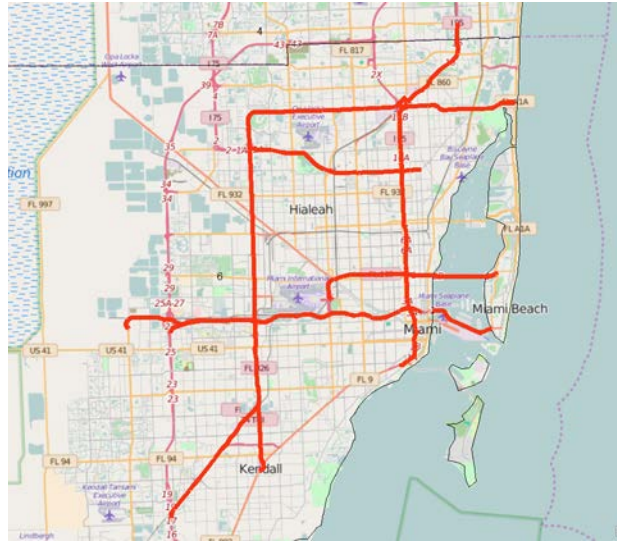
Segment				Patrol Time		Number of Truck
Segment	Route	Start MM	END MM	MON-THU	FRI-SAT	
1	I-95	Ives Dairy Road	Davie Road.	24/7		3
2	I-95	SR 84	Cypress Creek Rd.	24/7		3
3	I-95	Commercial Blvd	Palmetto Park Rd.	24/7		3
4	I-595	Eller Dr.	University Dr.	24/7		3
5	I-595	U.S. 441	SW 136th Ave	24/7		3
6	I-75	Indian Trace	MM35	24/7		3
7	I-75	Griffin Rd.	Flamingo Rd.	24/7		3
8	I-75	Miami Garden Dr.	Griffin Rd.	24/7		3
9	I-95	Northlake Blvd.	Indian Town Rd.	24/7		1
10	I-95	Palm Beach Lake Blvd.	PGA Blvd.	24/7		1
11	I-95	Lantana Rd.	45th St.	24/7		1
12	I-95	Linton Blvd.	6th Ave.	24/7		1
13	I-95	Hillsboro Blvd.	Atlantic Ave.	24/7		1
14	I-95	Donald Ross Rd.	CR 708	6AM - 9PM	-	1
15	I-95	CR 708	High Meadows Ave.	6AM - 9PM	-	1
16	I-95	SR 75	Martin Hwy.	6AM - 9PM	-	1
17	I-95	Martin Hwy.	St. Lucie Blvd.	6AM - 9PM	-	1
18	I-95	Gatlin Blvd.	Okeechobee Rd.	6AM - 9PM	-	1
19	I-95	Midway Rd.	Indrio Rd.	6AM - 9PM	-	1
20	I-95	Indrio Rd.	Osceola Blvvd.	6AM - 9PM	-	1
21	I-95	Osceola Blvd.	Fellsmere Rd.	6AM - 9PM	-	1

APPENDIX E: ROAD RANGER PROGRAM IN D5



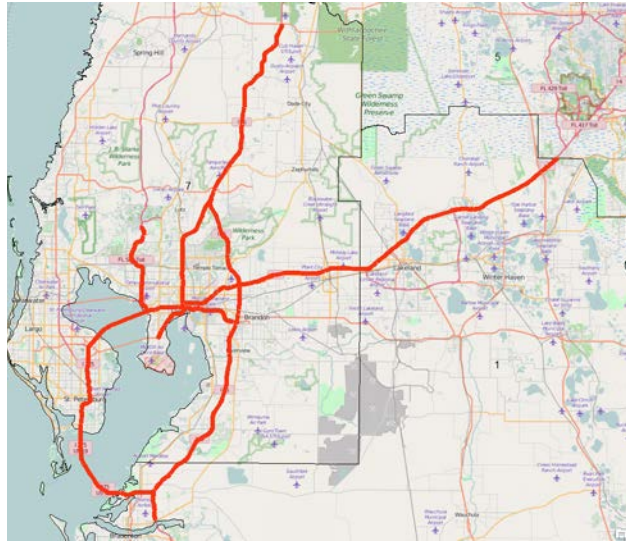
Segment				Patrol Time		Number of Truck
Segment	Route	Start MM	END MM	MON-THU	FRI-SAT	
1	I4	111	132	8AM-12AM	8AM-3.30AM	2
2	I4	98	118	8AM-12AM	8AM-3.30AM	
3	I4	83	98	Coverage Only		-
4	I4	72	85	Coverage Only		-
5	I4	62	72	8AM-12AM	8AM-3.30AM	2
6	I4	58	68	8AM-12AM	8AM-3.30AM	
7	I4	118	132	Special Event Only		1
	I95	260	265	Special Event Only		
8	I95	265	258	Special Event Only		
	I4	118	132	Special Event Only		2
9	I95	260	278	Special Event Only		
10	I95	249	261	Special Event Only		

APPENDIX F: ROAD RANGER PROGRAM IN D6



Segment				Patrol Time		Number of Truck	Remark
Segment	Route	Start MM	END MM	MON-THU	FRI-SAT		
1	I-75	SR 826 N	County Line	24/7		1	
2	I-95	US 1	Miami/Broward	24/7		1	
3	I-195	I-95 E	Alton Rd.	24/7		1	
4	I-395	I-95 E	Alton Rd.	24/7		1	
5	SR 826	US 1	Golden Glades	24/7		1	
6	SR 112	LeJeune Rd.	I-95	24/7		1	MDX
7	SR 836	Turnpike	I-95	24/7		1	MDX
8	SR 874	Turnpike	SR 826	24/7		1	MDX
9	SR 878	SR 874	US 1	24/7		1	MDX
10	SR 924	SR -826	Indian Town Rd.	24/7		1	MDX

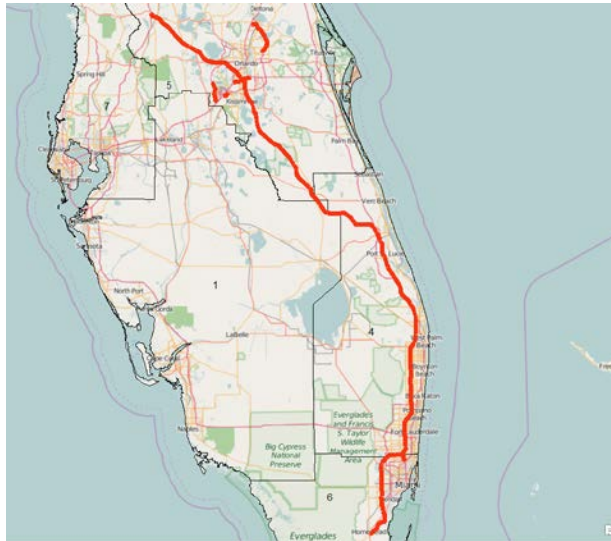
APPENDIX G: ROAD RANGER PROGRAM IN D7



Segment				Patrol Time		Number of Truck	Remark
Segment	Route	Start	END	MON-THU	FRI-SAT		
1	I-275	North Rest Area	54th Ave.	6:30AM-6:30P	24/7	1	Tow Truck
2	I-275	Roosevelt Blvd.	Lois Ave.	7:30A-7:30P	24/7	1	Tow Truck
3	I-275	Westshore Blvd.	MLK Blvd.	7:30A-7:30P	24/7	1	
4	I-275/I-4	Bearss Ave.	22nd St.	5:30A-9:30P	24/7	1	
5	I-275/I-4	Ashley Dr.	Mcintosh Rd.	5:30A-9:30P	24/7	1	Tow Truck
6	I-75	Gibsonson Dr.	Bruce B. Down Blvd.	5:30A-9:30P	5:30A-9:30P	1	
7	SR 60/ I-4	Rocky Point Dr.	US 41	5:30A-9:30P	24/7	1	
8	I-4	Mcintosh Rd.	County Line	5:30A-9:30P	24/7	1	
9	I-75	SR 56	CR 41	5:30A-9:30P	24/7	1	
10	I-275	Bearss Ave.	Bruce B. Down Blvd.	5:30A-9:30P	24/7	1	
11	I-75	Gibsonson Dr.	Moccasin Wallow Rd.	5:30A-9:30P	24/7	1	
12	I-275	54th Avenue North	Kennedy Boulevard	5:30A-9:30P	24/7	1	
13	I-75	SR 52	SR 50	5:30A-9:30P	24/7	1	Const. Zone/ Tow Truck
14	I-4/Leeroy Selmon Expressway Connector			6:30A-10:30P	24/7	1	
15	I-275	North Rest Area	Roosevelt Blvd.	7:30P-7:30A	24/7	1	Tow Truck
16	I-275	Roosevelt Blvd.	Lois Ave.	7:30P-7:30A	24/7	1	Tow Truck

17	I-75	SR 52	SR 50	6:30P-6:30A	6:30P-6:30A	1	Construction Zone/Tow Truck
18	I-275	SR 60	CR 579	6:30P-6:30A	24/7	1	Tow Truck
19	SR 60	Rocky Point Dr.	Bearss Ave.	6:30P-6:30A	24/7	1	Tow Truck
20	I-4	County Line	Exit 38 (SR 33)	6:00A-6:00P	9:00A-9:00P	1	D1 manage by D7
21	I-4	SR 33	Champions Gate	6:00A-6:00P	9:00A-9:00P	1	D1 manage by D7
22	I-275	Moccasin Wallow Road	SR 301	6:00A-6:00P	11:00A-7:00P	1	D1 manage by D7
23	SR 589	0MM	12.8MM	6:30A-6:30P	-	1	D1 manage by D7
24	Leroy Selmon Expressway	Gandy Blvd.	I-75	6:30A-6:30P	-	1	D1 manage by D7

APPENDIX H: ROAD RANGER PROGRAM IN D8 (TURNPIKE AND FLORIDA EXPRESS WAY)



Segment				Patrol Time		Number of Truck	Remark
Segment	Route	Start	END	MON-THU	FRI-SAT		
1	Florida Turnpike	I-75	MM272	6A-10P	6A-10P	1	Pickup
2	Florida Turnpike	MM272	MM259	24/7	24/7	1	Tow
3	Florida Turnpike	MM259	MM229	6A-10P	6A-10P	1	Tow
4	Florida Turnpike	MM229	MM184	6A-10P	6A-10P	1	IRT
5	Florida Turnpike	MM184	MM144	6A-10P	6A-10P	1	Pickup
6	Florida Turnpike	MM144	MM100.	6A-10P	6A-10P	1	Tow
7	Florida Turnpike	MM100	MM75	24/7	24/7	1	Tow
8	Florida Turnpike	MM75	MM69	24/7	24/7	1	Pickup
9	Florida Turnpike	MM69	MM53	24/7	24/7	1	Tow
10	Florida Turnpike	MM53	MM0x	6A-10P	6A-10P	1	Pickup
11	Florida Turnpike	MM49	MM29	24/7	24/7	1	IRT
12	Florida Turnpike	MM35	MM11	24/7	24/7	1	TOW
13	Florida Turnpike	MM16	MM0	6A-10P	6A-10P	1	TOW
14	Veteran' Exp	MM1	MM16	6A-8P	-	1	Pickup
15	SR 429	MM0	MM12	6A-8P	6A-8P	1	Pickup
16	SR 428	MM0	MM1	6A-8P	6A-8P	1	Pickup
17	SR 528	MM0	MM8	6A-8P	6A-8P	1	Pickup
18	SR 417	MM38	MM55	6A-8P	6A-8P	1	Pickup
19	SR 417	MM0	MM69	6A-8P	6A-8P	1	Pickup

APPENDIX I ATTRIBUTES FROM THE SUNGUIDE DATABASE

Field Name	Explanation	Type
EVENT_ID	Event ID	ID
IS_PERFMEASD	??? (but doesn't matter cause everything is 1)	binary
LAST_MODIFIED_DATE	Last revision date	timestamp
LAST_MODIFIED_BY	The person who last modified	timestamp
LAST_EVENT_AUDID	Time of last checking	timestamp
DETECTED_DATE	Timestamp of the first detection of event	timestamp
KNOWLEDGE_DATE	??? Possibly the time that event is input to system	timestamp
CLOSED_DATE	??? Possibly the time that case was closed	timestamp
INITIAL_CONFIRMED_DATE	??? Possibly the time confirm that event happen in the coverage	timestamp
INITIAL_OWNED_DATE	???	timestamp
FIRST_RESPONDER_ARRIVAL_DATE	Time that first responder arrival at the scene	timestamp
FIRST_RESPONDER_NOTIFIED_DATE	Time that first responder arrival have been notified. Either seem as arrival or earlier	timestamp
LAST_RESPONDER_DEPARTURE_DATE	Time that first responder leave the the scene	timestamp
FIRST_DSPHVEH_DISPATCHED_DATE	Time that Towing vehicle? Leave the station.	timestamp
FIRST_DSPHVEH_ARRIVAL_DATE	Time that Towing vehicle? Arrival at the scene.	timestamp
LAST_DSPHVEH_DEPARTURE_DATE	Time that last Towing vehicle? Arrival at the scene.	timestamp
FIRST_LANE_BLOCKED_DATE	Time that first lane have been blocked	timestamp
LANES_REOPENED_DATE	Time that lane are reopened	timestamp
WRS_BLOCKAGE_DATE	Most are same as first lane blocked	timestamp
WRS_BLOCKAGE_DESC	Descriptive of lane blocking	Text
WRS_BLK_TRAVELLANE_CNT	Number of travel lane blocked	integer
WRS_BLK_ENTRYLANE_CNT	Number of entry lane blocked	integer
WRS_BLK_EXITLANE_CNT	Number of exit lane blocked	integer
WRS_BLK_SHOULDERLANE_CNT	number of shoulder blocked	integer
WRS_BLK_SHOULDERONLY	event is blocking shoulder only	binary
WRS_FULLCLOSURE	event require full road closure	binary
LAST_EVENT_RESPONSEPLAN_ID	the id of response plan	integer
FIRST_RSPNSPLAN_ACTIVATED_DATE	Timestamp at the beginning of response plan	timestamp
LAST_RSPNSPLAN_TERMINATED_DATE	Timestamp at the termination of response plan	timestamp
IS_SEVERITY_OTHER	??? Is the event cause severity to other	binary
SEVERITY_ID	Severity type - Need clarification from FDOT	integer

CONDITIONS_DESC	Descriptive of weather	text
CONTACTS_DESC	Contact of people involved	text
INVOLVEDVEHICLES_DESC	Descriptive of involved vehicle	text
DSPHVEH_ASSISTED	Assisted by DSPHVEH?	binary
DSPHVEH_CNT	Number of DSPHVEH help managing the event	integer
USERERROR_CNT	Number of user error	integer
ACTIVITY_CNT	DSPHVEH Number of activity	integer
ROADRANGER_ASSISTED	Assisted by Road Ranger?	binary
ROADRANGER_CNT	Number of Road Ranger help managing event	integer
RR_USERERROR_CNT	Road Ranger Opinion : Number of user error	integer
RR_ACTIVITY_CNT	Road Ranger Number of activity	integer
SIRV_ASSISTED	Assisted by SIRV?	binary
SIRV_CNT	Number of SIRV help managing event	integer
SIRV_USERERROR_CNT	Road Ranger Opinion : Number of user error	integer
SIRV_ACTIVITY_CNT	Road Ranger Number of activity	integer
DSPHVEH_DISPATCH_MNT_AVGOF	DSPHVEH : Average dispatch time (minute)	double
DSPHVEH_RESPONSE_MNT_AVGOF	DSPHVEH : Average response time (minute)	double
DSPHVEH_ONSCENE_MNT_AVGOF	DSPHVEH : Average time on scene (minute)	double
RR_DISPATCH_MNT_AVGOF	Road Ranger : Average dispatch time (minute)	double
RR_RESPONSE_MNT_AVGOF	Road Ranger : Average response time (minute)	double
RR_ONSCENE_MNT_AVGOF	Road Ranger : Average time on scene (minute)	double
SIRV_DISPATCH_MNT_AVGOF	SIRV : Average dispatch time (minute)	double
SIRV_RESPONSE_MNT_AVGOF	SIRV : Average response time (minute)	double
SIRV_ONSCENE_MNT_AVGOF	SIRV : Average time on scene (minute)	double
RESPONDER_NOTIFIED_MNT_AVGOF	Responder : Average notified time (minute)	double
RESPONDER_RESPONSE_MNT_AVGOF	Responder : Average response time (minute)	double
RESPONDER_ONSCENE_MNT_AVGOF	Responder : Average time on scene (minute)	double
EVENT_LATITUDE	Latitude	double
EVENT_LONGITUDE	Longitude	double

APPENDIX J SUMMARY OF DATA USED FOR ESTIMATING WEEKDAY DAYTIME MODELS

		Total	Incidents (crashes)/Lane-Mile/1000AADT					
			Mean	P10	P25	P50	P75	P90
AADT>=71460	all	548985	23.19	0.00	0.00	0.29	1.26	10.39
796 segments	severe	9412	0.30	0.00	0.00	0.00	0.02	0.14
675.27 miles	crashes	17576	0.32	0.00	0.01	0.02	0.07	0.26
71460<AADT<=130000	all	680015	7.98	0.00	0.00	0.27	1.26	10.25
810 segments	severe	11767	0.28	0.00	0.00	0.00	0.01	0.12
377.88 miles	crashes	30828	1.04	0.00	0.01	0.03	0.07	0.25
AADT>130000	all	906724	19.00	0.00	0.00	0.26	1.29	8.56
807 segments	severe	7576	0.06	0.00	0.00	0.00	0.01	0.05
224.08 miles	crashes	60876	0.91	0.01	0.02	0.04	0.11	0.41
Overall	all	2135724	16.68	0.00	0.00	0.27	1.27	9.60
2413 segments	severe	28755	0.21	0.00	0.00	0.00	0.01	0.09
1277.23 miles	crashes	109280	0.76	0.00	0.01	0.03	0.08	0.30

segment length	average	0.529314	
	min	7.15E-06	
	25	0.019005	
	50	0.150721	
	75	0.512947	
	max	25.84736	
AADT	average	110321.5	
	min	8900	
	25	60000	
	50	100000	
	75	151000	
	max	319000	
0 interchanges		1248	51.72%
1 interchange		1117	46.29%
2 interchanges		48	1.99%
number of lanes (both directions)	<4	37	1.53%
	4	570	23.90%
	5	145	7.98%
	6	840	50.08%
	7	209	24.74%
	8	358	55.29%
	9	65	18.77%
	10	148	52.60%
	>10	41	30.74%
Truck Factor (TFCTR)	average	8.761583	
	min	2.1	
	25	5.6	
	50	7.4	
	75	11.6	
	max	56.9	

APPENDIX K SUMMARY OF DATA USED FOR ESTIMATING WEEKDAY NIGHTTIME MODELS

		Total	Incidents (crashes)/Lane-Mile/1000AADT					
			Mean	P10	P25	P50	P75	P90
AADT>=105000	all	59901	7.61	0.00	0.00	0.02	0.19	1.22
462 segments	severe	7930	0.92	0.00	0.00	0.00	0.02	0.11
233.84 miles	crashes	2826	0.27	0.00	0.00	0.01	0.02	0.08
105000<AADT<=162500	all	67777	6.10	0.00	0.00	0.06	0.29	1.72
463 segments	severe	14460	3.38	0.00	0.00	0.00	0.04	0.35
137.23 miles	crashes	4305	0.12	0.00	0.00	0.01	0.02	0.07
AADT>162500	all	126963	5.53	0.00	0.00	0.04	0.23	1.73
464 segments	severe	22059	0.57	0.00	0.00	0.00	0.02	0.21
123.36 miles	crashes	8110	0.06	0.00	0.00	0.01	0.02	0.08
Overall	all	254641	6.42	0.00	0.00	0.05	0.23	1.61
1389 segments	severe	44449	1.62	0.00	0.00	0.00	0.03	0.22
494.43 miles	crashes	15241	0.15	0.00	0.00	0.01	0.02	0.08

segment length	average	0.355964	
	min	7.65E-06	
	25	0.019954	
	50	0.14162	
	75	0.442747	
	max	25.84736	
AADT	average	137805	
	min	12000	
	25	91000	
	50	138000	
	75	186390	
	max	319000	
0 interchanges		742	53.42%
1 interchange		616	44.35%
2 interchanges		31	2.23%
number of lanes (both directions)	<4	20	1.44%
	4	156	11.23%
	5	83	5.98%
	6	449	32.33%
	7	140	10.08%
	8	296	21.31%
	9	59	4.25%
	10	145	10.44%
	>10	41	2.95%
Truck Factor (TFCTR)	average	7.544852	
	min	2.5	
	25	4.9	
	50	6.2	
	75	8.2	
	max	56.9	

APPENDIX L SUMMARY OF DATA USED FOR ESTIMATING WEEKEND DAYTIME MODELS

		Total	Incidents (crashes)/Lane-Mile/1000AADT					
			Mean	P10	P25	P50	P75	P90
AADT>=76167	all	149512	9.19	0.00	0.00	0.06	0.36	3.43
686 segments	severe	1379	0.04	0.00	0.00	0.00	0.00	0.02
585.64 miles	crashes	2127	0.03	0.00	0.00	0.00	0.01	0.02
76167<AADT<=141000	all	153105	1.93	0.00	0.00	0.06	0.27	2.03
679 segments	severe	1223	0.04	0.00	0.00	0.00	0.00	0.01
314.25 miles	crashes	3387	0.11	0.00	0.00	0.00	0.01	0.03
AADT>141000	all	197327	4.67	0.00	0.00	0.06	0.32	2.47
701 segments	severe	1647	0.03	0.00	0.00	0.00	0.00	0.01
184.46 miles	crashes	6236	0.06	0.00	0.00	0.00	0.01	0.05
Overall	all	499944	5.27	0.00	0.00	0.06	0.33	2.53
2066 segments	severe	4249	0.04	0.00	0.00	0.00	0.00	0.01
1084.35 miles	crashes	11750	0.07	0.00	0.00	0.00	0.01	0.03

segment length	average	0.524853	
	min	7.15E-06	
	25	0.019909	
	50	0.15495	
	75	0.505021	
	max	25.84736	
AADT	average	114511.4	
	min	8900	
	25	61500	
	50	107000	
	75	159500	
	max	319000	
0 interchanges		1097	53.10%
1 interchange		930	45.01%
2 interchanges		39	1.89%
number of lanes (both directions)	<4	35	1.69%
	4	477	23.09%
	5	124	6.00%
	6	666	32.24%
	7	178	8.62%
	8	336	16.26%
	9	64	3.10%
	10	145	7.02%
	>10	41	1.98%
Truck Factor (TFCTR)	average	8.612052	
	min	2.1	
	25	5.6	
	50	7.4	
	75	10.675	
	max	56.9	

**APPENDIX M SUMMARY OF DATA USED FOR ESTIMATING WEEKEND
NIGHTTIME MODELS**

		Total	Incidents (crashes)/Lane-Mile/1000AADT					
			Mean	P10	P25	P50	P75	P90
AADT>=106000	all	26637.00	3.41	0.00	0.00	0.01	0.08	0.57
487 segments	severe	1539.00	0.19	0.00	0.00	0.00	0.00	0.01
238.51 miles	crashes	750.00	0.01	0.00	0.00	0.00	0.00	0.02
106000<AADT<=162000	all	31727.00	2.16	0.00	0.00	0.03	0.12	0.79
487 segments	severe	2758.00	0.85	0.00	0.00	0.00	0.01	0.05
158.15 miles	crashes	1171.00	0.01	0.00	0.00	0.00	0.00	0.01
AADT>162000	all	65551.00	3.05	0.00	0.00	0.02	0.13	1.00
492 segments	severe	4840.00	0.23	0.00	0.00	0.00	0.01	0.05
125.74 miles	crashes	2296.00	0.02	0.00	0.00	0.00	0.00	0.02
Overall	all	123915.00	2.88	0.00	0.00	0.02	0.11	0.79
1466 segments	severe	9137.00	0.42	0.00	0.00	0.00	0.00	0.04
522.39 miles	crashes	4217.00	0.01	0.00	0.00	0.00	0.00	0.02

segment length	average	0.356338	
	min	7.65E-06	
	25	0.018929	
	50	0.141797	
	75	0.43597	
	max	25.84736	
AADT	average	136722.9	
	min	8900	
	25	91500	
	50	136500	
	75	184500	
	max	319000	
0 interchanges		782	53.34%
1 interchange		651	44.41%
2 interchanges		33	2.25%
number of lanes (both directions)	<4	24	1.64%
	4	162	11.05%
	5	85	5.80%
	6	491	33.49%
	7	151	10.30%
	8	308	21.01%
	9	59	4.02%
	10	145	9.89%
	>10	41	2.80%
Truck Factor (TFCTR)	average	7.647476	
	min	2.1	
	25	5	
	50	6.3	
	75	8.3	
	max	56.9	

APPENDIX N FREEWAY SAFETY PATROL ALLOCATION AND SAFETY SURVEY

Freeway/Safety Service Patrol Allocation and Safety Survey

Welcome

The Florida Department of Transportation Research Office has enlisted the University of Florida in a research project entitled Warrants, Design, and Safety of Road Ranger Service Patrols. As part of the project, this survey will help the research team understand practices nationally. For purposes of this survey, the terms safety service patrol, freeway service patrol, motorist assist, and incident response are interchangeable and will be referred to as freeway service patrol (FSP) for simplicity. Since there are likely multiple FSP deployments in each state, think about the program generally in the state when answering questions.

This survey should take about 8 to 10 minutes and questions center on service allocation and safety of FSP operators. Thank you for your time and contribution to this important research. If you have any questions, please contact Dr. Grady Carrick at gcarrick@ufl.edu or (904) 705-8046.

* 1. Do you have any FSP deployments/beats that are only seasonal to account for increased traffic on certain roadways?

- Yes
 No

* 2. Do you have any FSP deployed on what would be considered rural freeways or Interstates?

- Yes
 No

3. Please describe the primary reasons/justifications for staffing FSP on rural roadways

* 4. If you were to expand the current FSP program, please rank the order of priority you would attach to the following expansion methods.

	1st	2nd	3rd	N/A
Expand days of operation to 7 days a week	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Expand hours of operation to 24/7	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Add additional miles to current beats/roadways	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Add additional roadways, beats/trucks	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Change truck type/capability (pickup, van, tow truck, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

* 5. Please rank the following inputs on their scale of importance for deciding if FSP is warranted on a roadway. (Rank the importance of inputs or indicate if the input would not be considered)

	More Important	Important	Less Important	Would not Consider
Traffic volume	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Number of historical incidents in general	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Number of historical traffic crashes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Type/severity of historical incidents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Bottlenecks/recurring congestion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Knowledge of the area/roadway considered	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Availability of other responders (law enforcement, fire, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Available funding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Benefit Cost Analysis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Number of lanes and/or presence of shoulders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Presence of bridges, tunnels, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Distance between interchanges	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Volume/capacity ratio (V/C ratio)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Input from stakeholders (law enforcement, TMC operators)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

* 6. Do you use a mathematical formula, spreadsheet or other computer programs to identify which roadways should be patrolled by FSP?

Yes

No

* 7. Briefly describe how you determine FSP deployment is warranted or justified for a roadway. If you use a mathematical formula, a spreadsheet, or a computer program, please describe it. If you base deployment on other factors, please describe them.

8. As part of the design in any FSP deployments, are there performance measures or performance targets attached, i.e., response time, patrol beat coverage intervals, etc.?

Yes

No

Not Sure

9. Please describe the performance measures used for FSP:

* 10. Briefly describe how you deploy FSP (i.e., size of patrol area, number of trucks, etc.) – If you use a mathematical formula, a spreadsheet, or a computer program, please describe it. If you base allocation on past experience, knowledge etc. please give an example.

11. Provide an estimate as to what is the largest single FSP patrol zone in your state based on centerline miles?

12. Provide an estimate as to what is the smallest single FSP patrol zone in your state based on centerline miles?

* 13. Please describe the type of staffing used for FSP in your state (check all that apply)

- State/local government employees
- Private contractors including towers
- Employees of another organization type (MPO, planning council, etc.)
- Volunteers
- Other (please specify)

* 14. Do you have a tracking system for crashes involving FSP vehicles and/or operators?

- Yes
- No
- Not Sure

15. Have you ever evaluated FSP crashes to determine common characteristics?

- Yes
- No
- Not Sure

16. Please describe the findings regarding common characteristics of FSP crashes:

* 17. Since the inception of FSP programs in your state, have you had any FSP operators killed while working (either in an FSP vehicle collision or struck as a pedestrian)?

- Yes
- No
- Not Sure

* 18. Could you provide a copy of the traffic crash report to the research team or otherwise provide some details like date, time, location, and operator name?

* 19. On average, please estimate how many hours of training FSP operators receive prior to solo patrol duties?

- 24 hours or less
- 25-40 hours
- 41-80 hours
- 81-110 hours
- More than 110 hours

* 20. Are FSP operators required to attend the FHWA National Traffic Incident Management Responder Training Course (SHRP 2)? (including the online or e-learning version)

- Yes
- No
- Not Sure

* 21. Contact Information:

Name	<input type="text"/>
Agency/Organization	<input type="text"/>
State/Province	<input type="text"/>
Email Address	<input type="text"/>
Phone Number	<input type="text"/>

Freeway/Safety Service Patrol Allocation and Safety Survey

Thank you!

Thank you very much for your participation in the FDOT/UF Research project "Warrants, Design, and Safety of Road Ranger Service Patrols". The results of the project will be published later in the year.

APPENDIX O ROAD RANGER DRIVER SAFETY SURVEY

Road Ranger Driver Safety Survey

The Florida Department of Transportation Research Office is conducting a survey of Road Ranger drivers to better understand safety. This survey can be completed anonymously. If you are taking the survey electronically, your responses will be saved automatically. If you are taking the survey with pen and paper, please return the survey to your supervisor who will provide them to the FDOT District Program Manager. Please only complete one survey for each driver.

Thank you for taking the time to complete this survey. If you have any questions, please contact your supervisor.

1. Overall, how would you rate the relationships between Road Rangers and other responders?

Excellent Good Needs Improvement

2. How would you rate the Hi-visibility markings on the rear of your RRSP vehicle?

Excellent Good Needs Improvement

3. How would you rate the emergency lights on your RRSP vehicle?

Excellent Good Needs Improvement

4. Do you think using the arrow “<=” on the vehicle-mounted arrow board while on the shoulder improves move over?

Yes No Not Sure

5. Would additional emergency lights on your RRSP vehicle improve move over compliance?

Yes No Not Sure

6. Do you think that digital message boards that allow words are better than simple arrow boards?

Yes No Not Sure

7. Please rate your view of training in the following areas:

	Excellent	Good	Needs Improvement
Push bumper procedures			
Debris procedures			
Spill procedures			
Fire extinguisher			
Crash procedures			
Disabled vehicle procedures			
Temporary traffic control/MOT			

8. Do you have the training and equipment needed to operate safely? Yes No
9. Do you have monthly safety meetings or training? Yes No
10. Have you attended the SHRP2 Responder Training Course? Yes No
11. Do you use median turnarounds on routine patrol? Yes No
12. Do you use median turnarounds when responding to an incident? Yes No
13. Do you use the shoulder for response to incidents? Yes No
14. Do you carry a Fluorescent Pink advance warning sign on your RRSP vehicle? Yes No
15. Do you have a state law enforcement radio system (SLERS) radio? Yes No
16. Do you monitor other responders on the SLERS radio? Yes No
17. Is the SLERS radio valuable for safety? Yes No
18. Do you experience dead spots in either radio or cellular coverage while on patrol? Yes No
19. Do you think that bad weather has an impact on Road Ranger safety? Yes No
20. Do you ever work special hours or beats for special events? Yes No
21. Do you think adding high-visibility pants would improve your personal visibility/safety?
 Yes No
22. How often do you operate on bridges, elevated roadways, or other places where there is limited space?
 Often Sometimes Rarely
23. When on bridges, elevated roadways, or other places where there is limited space, how often do you have another responder or Road Ranger available to assist?
 Often Sometimes Rarely

24. When making initial contact with a disabled motorist, how often do you approach their vehicle on the non-traffic side (for example the right side)?

_____ Often _____ Sometimes _____ Rarely

25. How often do you provide fuel or change tires on the traffic side of a disabled motorist vehicle?

_____ Often _____ Sometimes _____ Rarely

26. How would you rate the importance of including shoulders or crash investigation sites in work zone areas?

_____ Very Important _____ Important _____ Not Important

27. In which FDOT District do you work? (circle)

1 2 3 4 5 6 7 Turnpike

28. How many years of experience do you have as a Road Ranger? (circle)

<1 1 2 3 4 5 or more

29. Which type of Road Ranger Vehicle do you typically drive? (circle)

Pickup Van Tow Truck Flatbed

30. What hours of the day constitute the majority of the time when you are working as a Road Ranger?

_____ Daylight hours _____ Nighttime hours

31. Is there any equipment that you feel that you need that is not available to you right now? (write answer below)

32. Additional comments: What do you feel is unsafe, what do you have to add about Road Ranger safety, what might be done to improve safety? (write answer below)