
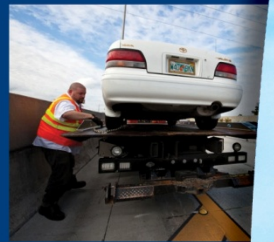
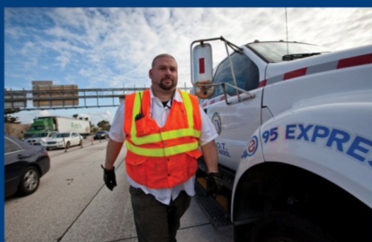



REVIEW and UPDATE of ROAD RANGER COST BENEFIT ANALYSIS

FINAL REPORT ■ BDK 84 977-15

January 2012

CUTR

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

REVIEW AND UPDATE OF ROAD RANGER COST BENEFIT ANALYSIS

BDK84 977-15

Final Report

Prepared for:

Florida Department of Transportation
Research Center
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January 2012

DISCLAIMER

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

METRIC CONVERSION TABLE

Approximate Conversions to SI Units

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

Approximate Conversions to SI Units

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
Review and Update of Road Ranger Cost Benefit Analysis

5. Report Date
January, 2012

6. Performing Organization Code

7. Author(s)
Pei-Sung Lin, Aldo Fabregas, Hongyun Chen, Huaguo Zhou, Qing Wang

8. Performing Organization Report No.

9. Performing Organization Name and Address
Center for Urban Transportation Research
4202 E. Fowler Avenue, CUT 100
Tampa FL 33620-5735

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
BDK84 977-15

12. Sponsoring Agency Name and Address
Research Center
Florida Department of Transportation
605 Suwannee Street, MS 30
Tallahassee, FL 32399-0450

13. Type of Report and Period Covered Final Report
February 1, 2011 – January 31, 2012

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract
This study provides district- and state-level evaluation of the Road Ranger program and recommendations for future evaluations of the program. The major benefits of the Road Ranger program include delay savings, reduced fuel consumption and emissions, improved traffic flow, and reduced secondary incidents. The Freeway Service Patrol Evaluation (FSPE) model was used for the analysis phase to quantify the amount of savings due to reductions in delay, fuel, emissions, administrative, and contract costs of the Road Ranger program. A total of 200 scenarios were completed using the FSPE model. Road Ranger service coverage data were compiled for Districts 1, 2, 4, 5, 6, 7, and Florida's Turnpike Enterprise (FTE). Road Rangers cover a total of 1,321 centerline miles of interstates and toll roads in Florida. The calculated benefits (delay and fuel saving) of the Road Ranger program were about $134 million in total, and the costs (contract) were about $20 million. Overall, the program achieved a benefit-to-cost ratio of 6.68 in 2010. The benefits of the Road Ranger program are actually much greater than calculated by the FSPE model, as only lane blockage incidents are included in the analysis.

17. Key Words: Freeway Service Patrol, Safety , Benefit Cost Analysis, Road Ranger

18. Distribution Statement
No restriction

19. Security Class if. (of this report) Unclassified

20. Security Class if. (of this page) Unclassified

21. No. of Pages
89

22. Price

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

ACKNOWLEDGEMENT

Many people contributed to this research project and this final report could not have been completed without their assistance and support. The authors would like to express their gratitude to FDOT project manager Paul Clark and to the following FDOT District Road Ranger Managers and Supervisors:

William Fuller (FDOT District 1)
Donna Danson (FDOT District 2)
Gaetano Francese (FDOT District 4)
Nathan Ruckert (FDOT District 5)
Javier Rodriguez (FDOT District 6)
Rossi Gaudio (FDOT District 6)
Terry Hensley (FDOT District 7)
Michael Washburn (Florida's Turnpike Enterprise)

The researchers would also like to thank Mr. Brian Ritchson from Montgomery Consulting Group, as well as Mr. Clay Packard and Mr. David Chang from Atkins North America, consultants to the Florida Department of Transportation (FDOT) Traffic Engineering and Operations Office, for their support and guidance in all aspects of the SunGuide® Software. Special thanks to Jared Roso of Lucent Group in the FDOT D7 Traffic Management Center for his contributions on D7 data. Thanks to Neena Soans and Jacques Dupuy of IBI Group in FDOT D4 for their input.

Special thanks go to David Soniat and George Donaghy from the USF IT office for their diligence and support with all the aspects of Oracle database account set-up and data importing from the SunGuide® database. Special thanks also to Sisinnio Concas in CUTR for his valuable advice and insights on emissions modeling.

The research team would also like to express their gratitude to Mr. Michael Mauch of DKS and Associates for his valuable input and insight on the use of the FSPE model.

EXECUTIVE SUMMARY

The Road Ranger program is one of the most effective elements of the Florida Department of Transportation's (FDOT) Traffic Incident Management (TIM) Program, providing direct assistance to motorists by quickly responding, assisting, and clearing primary incidents from the travel lanes in close coordination with the Florida Highway Patrol (FHP) and other law enforcement agencies. Road Rangers also assist disabled motorists with basic services, such as furnishing limited amounts of fuel, assisting with tire changes, and helping with other types of minor vehicle repairs.

The major benefits of the Road Ranger program include reduced incident duration and consequent reduction of secondary incidents delay savings, reduced fuel consumption and emissions, and improved traffic flow. The main objective of this study was to perform a benefit-cost analysis of the Road Ranger program in the different transportation districts in Florida through:

- Selection of a widely recognized methodology for the evaluation of Freeway Service Patrols;
- Obtaining and processing the required traffic volume and incident data;
- Performing a benefit-cost analysis of the program using the selected methodology.

The Freeway Service Patrol Evaluation (FSPE) model was used to quantify the amount of savings due to reductions in traffic delay, fuel, and emissions; the contract costs of the Road Ranger program were used in this model. The FSPE model calculates the benefits by considering average daily traffic volume and distributing incidents on the selected beat segment proportionally to vehicle miles traveled (VMT). The main input parameters for the FSPE model include service description, roadway design characteristics, traffic characteristics, and incident data. Only those incidents which caused lane blockage, right shoulder blockage, or left shoulder blockage, were included in the FSPE model. Incidents were grouped into nine categories under three incident types (accident, breakdown, and debris) and three types of lane-blockage (one lane blockage[1], left shoulder, and right shoulder). SunGuide® software was used as the data resource to collect the Road Ranger operations data, mean time spent per incident type, mean response time without Road Ranger service, traffic profile (weekday, Saturday, and Sunday), geometric profile, and field speed.

Road Ranger service coverage data were compiled for FDOT Districts 1, 2, 4, 5, 6, 7, and the Florida's Turnpike Enterprise (FTE). The service was divided into zones, and each zone was assigned a Road Ranger truck with a service schedule by weekends and weekdays respectively. Road Rangers cover a total of 1,321 centerline miles of the interstates and toll roads in Florida. To effectively generate the models, the research team developed the FSPE

[1] It should be noted that one of the limitations of the FSPE model is that it does not allow for input of multiple lanes being blocked. In these multiple lane blocking events the default of one lane blocked is applied, affecting the overall benefit-to-cost ratio.

model generator, scenario generator, and model runner software which can systematically, automatically, and effectively run the FSPE model. A total of 200 scenarios were completed in the final database.

The benefits (delay and fuel saving) for the Road Ranger program were about $134 million in total and the costs (contract) were about $20 million. Overall, the statewide combined Road Ranger program achieved a benefit-to-cost ratio of 6.68 in 2010.

While the primary goal of this research is to identify the benefit-to-cost ratio of Florida's Road Ranger program, it cannot be ignored that some benefits have not been quantified in this document. Often, Road Rangers are the first to arrive at an incident and provide assistance before law enforcement or other responders are able to reach the location. Their prompt arrival to the incident scene provides reassurance to the traveler, emergency assistance when needed and allows for placement of advance warning devices to notify approaching drivers of the hazard ahead. Due to their quick response and life saving actions it is difficult to quantify their total benefit to emergency responders and the traveling public.

Among other recommendations, the research team suggested that similar reviews should be conducted annually to effectively manage the program based on the up-to-date benefit-cost (B/C) ratios.

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1 INTRODUCTION

One of the main goals of today's transportation systems is to provide a safe and reliable travel experience to road users. To achieve this goal, transportation agencies strive to implement initiatives to mitigate congestion effects. In 2010, congestion caused road users to spend 4.8 billion hours of extra time in traffic, wasting 1.9 billion gallons of fuel. In monetary terms, this was equivalent to $101 billion [1]. Factors such as crashes, special events, and hazardous weather affect the network, causing non-recurring congestion and diminishing the reliability of the transportation network. These unforeseen delays account for almost half of the congestion on the nation's roadway [2].

Traffic incidents are random, capacity-reducing events that range from minor debris to major vehicle crashes. Capacity reductions are not directly proportional to the number of blocked lanes. According to the Highway Capacity Manual (HCM) [3], blockage of one lane on a three-lane freeway causes more than a 50 percent reduction in capacity instead of only 33 percent, as might be expected. Even an incident on the shoulder causes a reduction in capacity because curiosity leads to driver distraction and speed reduction [4].

In order to reduce non-recurring delays caused by incidents, many states run freeway service patrols (FSP). FSPs are a special incident response initiative designed to alleviate non-recurrent congestion through quick detection, verification, and removal of freeway incidents [5]. FSP services have existed since 1960 and there are currently over 50 freeway service patrols in the United States [6].

FSP vehicles vary from agency to agency, and include pickup trucks, vans, tow trucks, cars, and utility vehicles. Some agencies have special on-call support vehicles such as variable message sign (VMS) trailers, crash-cushion trailers, dump trucks, and sanders. Patrols vary greatly in their temporal and spatial extent. The service time span may be 24 hours, or just during peak periods. The number of patrol vehicles and service hours depends upon the frequency of incidents, traffic on the freeway, and available budget.

In Florida, the FSP service is provided under the Road Ranger program funded by the Florida Department of Transportation (FDOT). The Road Ranger program consists of roving vehicles providing primary incident response and assistance to disabled vehicles on interstate corridors and construction zones. FDOT began funding the program in 1999 and by 2010 the number of assists grew to more than 3.1 million, constituting a proof of the program’s success. The Road Ranger program is one of the most effective elements of the FDOT’s Traffic Incident Management (TIM) Program [7]. Road Ranger service patrols provide direct assistance to motorists by quickly clearing primary incidents from the travel lanes in close coordination with the Florida Highway Patrol (FHP) and other law enforcement agencies. Road Ranger patrols are equipped to assist other incident responders in lane clearance and traffic control during major incidents. They also provide additional services to stranded motorists by providing limited amounts of fuel, tire changing assistance, cell phone calls for car service, and other types of minor emergency repairs to disabled vehicles. The number of assists provided by the Road Ranger program since its inception is listed in Table 1.

Table 1: Number of assists by Road Rangers in year 2000-2010

Year	Assists
2010	351,941
2009	296,041
2008	320,217
2007	383,584
2006	277,537
2005	298,776
2004	342,895
2003	316,883
2002	279,525
2001	198,372
2000	112,000

One benefit of FSPs, compared to other services, such as private tow companies, is faster response time. The reduced response time not only gets the travel lanes open quicker, but it also reduces the delays for other drivers passing through the incident areas. This, in turn, translates into a reduction of fuel and emissions. In addition to these quantifiable benefits, Road Rangers receive positive comments from the public through comment cards distributed at each service call.

The main objective of this study was to review and update the benefit-cost analysis of the Road Ranger program in the different transportation districts in Florida through:

- Selection of a widely recognized methodology for the evaluation of Freeway Service Patrols;
- Obtaining and processing the required traffic volume and incident data;
- Performing a benefit-cost analysis of the program using the selected methodology.

In this study, the Freeway Service Patrol Evaluation (FSPE) model, developed by the University of California, Berkeley, was used for the analysis phase to quantify the amount of savings, due to reductions in traffic delay, fuel, and emissions, by the Road Ranger program. This study provides district- and state-level evaluations of the program for 2010, and provides supplemental tools and recommendations for future evaluations of the program.

2 RELATED CONCEPTS AND LITERATURE REVIEW

This section introduces the main concepts involved in the evaluation of FSP programs, such as the Road Ranger program in Florida. In addition, it provides a review of FSP benefit-cost evaluations in other states.

2.1 Benefits of FSP

The Road Ranger program is a highly customer-oriented service program offered by the FDOT. The program offers many benefits, but only some can be quantified for evaluation. Road Ranger benefits can be classified into two major categories: individual benefits and general public benefits. At the individual level, the benefits include increased safety at the incident scene, reduced incident duration, and reduced cost of towing/assistance for the motorist being serviced. Benefits for the general public include increased safety at incident scenes, reduced traffic delay, reduced emissions, and reduced fuel consumption. Since the general public benefits are applied to a much greater number of motorists, these benefits are preferred to quantify the impact of freeway service programs, such as the Road Rangers. Delay savings and reduced fuel consumption compose the majority of total benefits in terms of dollar value. The different components of the benefits calculations of FSP programs are described in the following subsections.

2.1.1 Capacity reduction

Freeway incidents, such as accidents, vehicle breakdowns, or debris, may cause blockage and reductions in capacity. The severity of the capacity reduction depends mainly on the incident type (e.g., crash, breakdowns, or debris), lateral distribution (e.g., median, in-lane, or shoulder), and number of lanes. Estimates of capacity reduction factors are important in the calculation of benefits for FSP programs. Increased delays occur when the traffic demand exceeds the remaining freeway capacity during an incident, which translates into monetary terms when performing benefit-cost calculations.

Capacity reductions during incidents have been an area for recurrent research and review. The first efforts in calculating the effective capacity during incidents were performed by Goolsby [8]. The Highway Capacity Manual (HCM) [3] reports capacity reduction by incident types and lateral distribution. A study in Virginia [9] obtained empirical values related to a 63 percent capacity reduction for one lane blocked out of three, and 77 percent for two lanes blocked out of three. The same study reported a 21 percent reduction for shoulder blockages. A review of capacity reduction models before 2005 is presented in Hagen and Zhou [10]. For this project, the FSP evaluation methodology proposed by Skabardonis and Mauch [11] is used. The selected methodology uses the capacity reduction factors suggested by the HCM. These factors are presented in Table 2. It can be observed that lane blockage incidents have a significant effect on capacity reduction. It is also observed that breakdowns and debris on the right-hand shoulder do not cause significant capacity reductions. In general, FSP service benefits are significant on freeway segments with narrow or no shoulders, operating near or at full capacity, with a high number of vehicle disablements. On the other hand, FSP benefits, with respect to delay savings and reduced fuel consumption, will be limited on uncongested freeways with wide shoulders [5].

Table 2: Remaining freeway capacity (percentage) recommended by HCM

Incident Type	Location	No. of Freeway Lanes/Direction			
		2	3	4	5+
Accident	Right Shoulder	81.00	83.00	85.00	87.00
	Median	81.00	83.00	85.00	87.00
	1-Lane	35.00	49.00	58.00	65.00
Breakdown	Right Shoulder	95.00	98.00	98.00	98.00
	Median	95.00	98.00	98.00	98.00
	1-Lane	35.00	49.00	58.00	65.00
Debris	Right Shoulder	95.00	98.00	98.00	98.00
	Median	95.00	98.00	98.00	98.00
	1-Lane	35.00	49.00	58.00	65.00

2.1.2 Delay savings

Delay savings is one of the major benefits of a freeway service patrol program. The difference in delay with and without an FSP is one of the main components of the net benefit calculations of the program. The delay savings by an FSP consists mainly of reduced response and clearance time in incidents involving FSP assistance.

The primary reasoning behind the delay savings modeling of FSP programs, such as the Road Rangers in Florida, is presented in Figure 1. The horizontal axis represents the time and the vertical axis represents the cumulative volume for a freeway segment. The line represents the volume through the segment (demand). The slope of this line is the vehicle throughput rate of the freeway in the absence of incidents (based on the demand). The figures assume that the freeway is working at or near full capacity. When an incident occurs, the capacity is reduced to C_r. During this period of reduced capacity, the incident is detected and reported and a responder is dispatched. Once the responder arrives at the location, the incident is cleared as quickly as possible. The area between the normal condition line and the reduced capacity line is a measure of the delay experienced by the general public due to the incident. Part A of Figure 1 presents the delay without Road Rangers and part B presents the same incident with the assistance of Road Rangers. Since Road Rangers are patrolling the freeway, the detection and arrival times in part B (assisted by Road Rangers) are less than in part A (without Road Rangers assistance). When the incident is cleared, capacity is restored to its normal value of C. Since there was additional volume during the incident, it takes some time to recover and return to the initial conditions. The calculated delay can be translated into monetary terms for the purpose of benefit-cost evaluation. These delay saving models require capacity reduction factors as inputs.

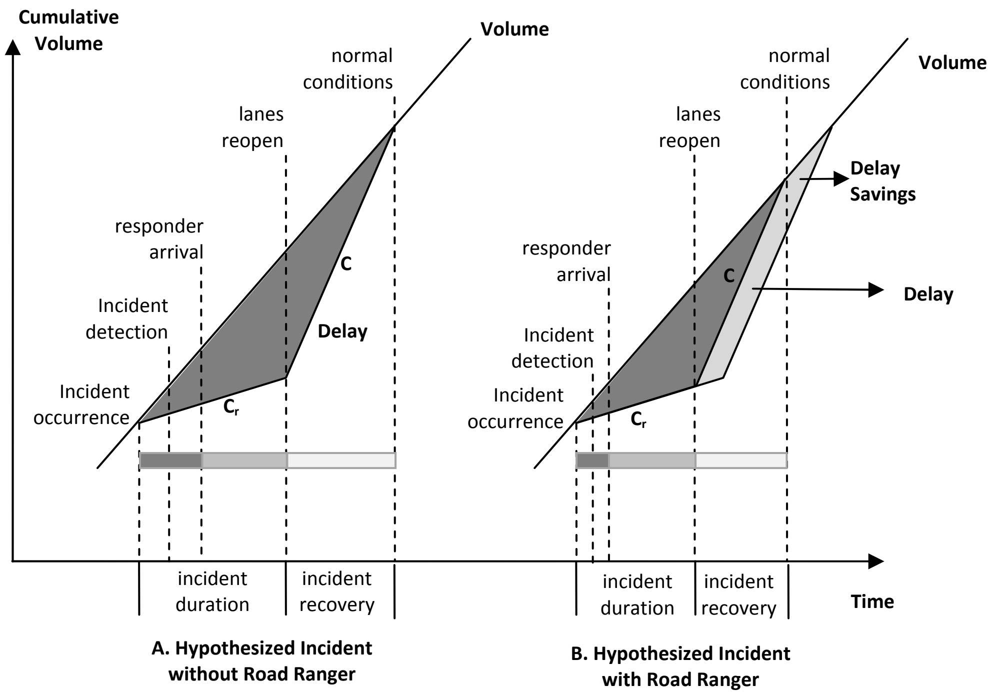

Figure 1: Delay savings modeling

When reliable and detailed information is available, direct measurements of delay can be performed (based on speed). For instance, data mining procedures can be implemented to determine the true baseline operating conditions by time of day/day of week. When an incident occurs, the speed, volume, and occupancy data of detectors can be used to calculate delay values based on the baseline conditions. These procedures can be implemented on existing ITS information systems, such as SunGuide®, and can be run in the background, triggered by incident detection or on demand, by the Traffic Management Center operator.

A study by Chou [13] summarizes the methodologies for benefit-cost analyses of FSPs. Three types of models are often used to estimate the delay savings by FSPs: mathematical models based on field data, deterministic queuing models, and computer simulation models. Additional literature reviews on delay savings calculations for freeway evaluation models are provided by Hagen and Zhou in [10]. In this project, the delay saving methodology proposed by Skarbardonis et.al. [11] is used. This methodology was part of a series of studies realized in California. Two of those studies were conducted to estimate the delays due to incidents on I-880 in San Francisco by Skarbardonis et al. [14] and Garib et al. [15]. Loop detectors were used to measure the speed of vehicles, and probe vehicles were used to detect incidents. Skarbardonis et al. [14] developed a general equation which calculated delay as a function of traffic volume, time of congestion, length of impacted freeway segments, average travel speed, and travel speed during an incident. Garib et al. [15] conducted a regression analysis of I-880 incident data to develop two models to predict incident-induced delays. The first model used four variables that included the number of lanes involved, the number of vehicles involved, incident duration, and traffic demand upstream of the incident. Skabardonis in [11] recommended the use of a 30 minute mean response time without FSP. The study also suggested calculating the response time with freeway service patrols based on patrol size, beat characteristics, patrol vehicle speeds, and time of day (peak, off-peak, and midday).

2.1.3 Emissions and fuel consumption

Wasted fuel and excess of emissions occur during incident-induced delays. For measuring fuel and emission savings, the selected evaluation methodology uses the EMissions FACtor (EMFAC) model with the mobile source emission rates published by the California Air Resource Board (CARB). Emissions rates and fuel consumption rates in the selected model were implemented as lookup tables based on average speed. The air pollutant emissions and fuel consumption are calculated based on the following formula [11]:

$$F_i = D \times e_{vi}$$

where,

i=1: fuel consumption in gallons

i=2: HC emissions in Kg

i=3: CO emission in Kg

i=4: NOx emission in Kg

F_i: Fuel consumption or emissions

D: incident-induced total delay

e_i: fuels or emission factor for speed *v*

Three pollutants are modeled in the FSPE model using the EMFAC emission rates in the form of a lookup table. Such pollutants are: Reactive Organic Gases (ROG) which are equivalent to Volatile Organic Compounds (VOC), Carbon Monoxide (CO), and Nitrogen Oxides (NOx). Figure 2 presents a plot of the emissions factors in grams per mile (gr/mi) for the emissions model in the FSPE model. It can be observed that VOC and CO emission rates decrease as the operating speed increases up to moderate speeds nearby 60 mph. At higher speeds, the emissions for VOC and CO present an increasing behavior.

The parabolic shape of the pollutants in Figure 2 is typical of a steady state scenario where the acceleration effects are smoothed out. Such a parabolic shape indicates that at lower speeds a vehicle has reduced emissions in grams per second, but takes more time to traverse a mile of roadway and therefore its emission rate per mile (gr/mi) is high. At higher speeds, the engine is forced to work more and the emissions rate in grams per second is significantly increased. In this latter scenario, even though the vehicle can traverse a mile of road in less time, the increase in the grams per second emissions rate is the dominant effect and the overall grams per miles emission rates in increased [12].

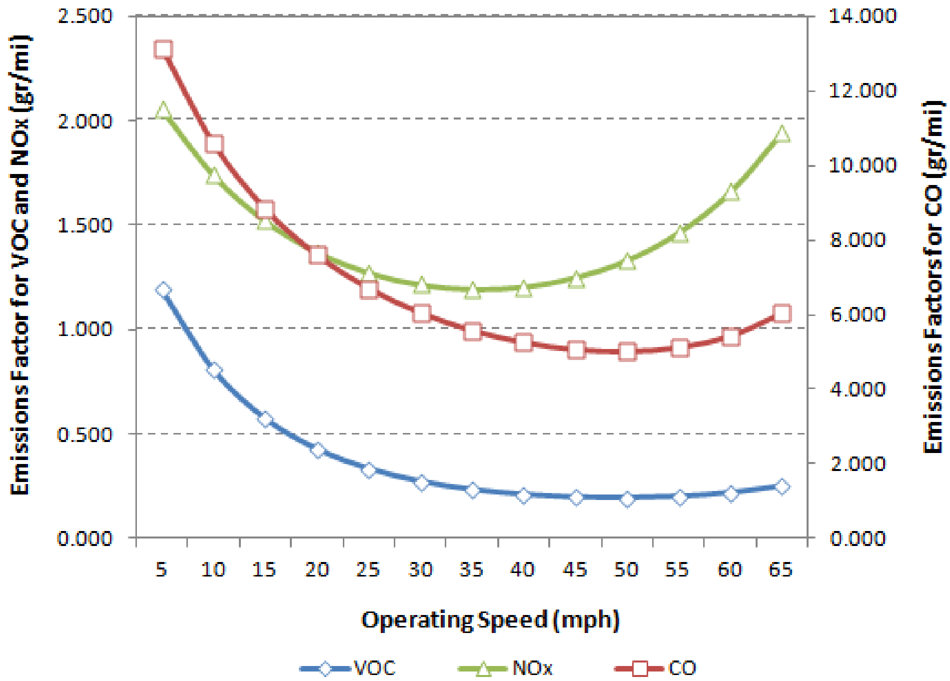

Figure 2: Pollutants look-up values in the FSPE model

In an urban scenario, an improvement in the operating conditions will produce, in general, a decrease in emissions. For example, in Figure 2, going from 20 mph to 40 mph will reduce emissions for the three trace pollutants. On the other hand, for freeways (40 mph and above), VOC and CO emissions rates increase at higher speeds than NOx. Reductions in NOx at higher speed can be obtained by technological improvements.

It is important to highlight that these emission curves encompass a series of assumptions for vehicle types, meteorological conditions etc. These are very general estimations and a more detailed emissions table with parameters specific to Florida for each segment is recommendable. The use of customized emissions lookup tables based on the Motor Vehicles Emissions Simulator (MOVES) developed by the Environmental Protection Agency (EPA) [16] model is recommended as a further enhancement for this benefits evaluation.

Another important aspect of the emissions model pertains to the evaluation of capacity reduction scenarios using steady-state emission curves. When an incident occurs, there could be fluctuations in speed, causing the freeway segment to go from a steady state scenario to a congested scenario and return, after the Road Ranger clears the incident. If the disruption is evaluated with a curve derived from congested scenario, as opposed to the same steady state curve, the effects of speed fluctuations are accounted for more accurately. Barth, Scora, and Younglove [12] derived curves for estimating emissions and fuel consumption for different levels of freeway congestion and different vehicle types.

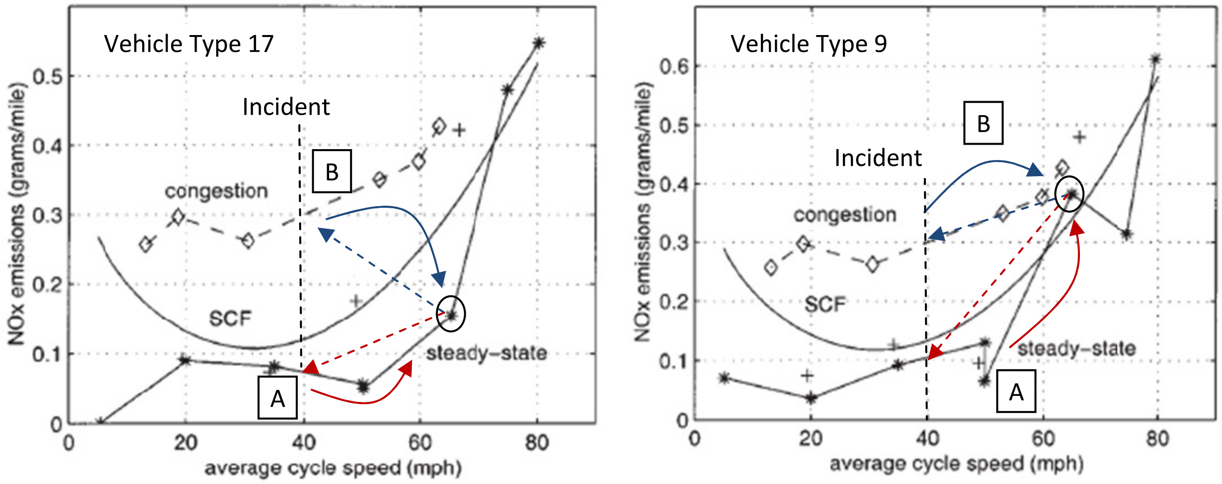

Figure 3: Example of congested emission curves for different vehicle types [12]

Figure 3 shows that the emissions rates differ in congested scenarios with respect to the steady state curve and vehicle type [12] . In scenario A for vehicle type 17, during an incident, speed can drop to 40 mph in congested conditions (dashed line). If the steady state curve is used, returning to normal conditions implies an increase in emissions. In scenario B, for the same vehicle type, the speed drops to a congested curve, which is more representative of a disruption in a traffic pattern due to an accident. When scenario B is back to normal, there is a reduction in emissions for NOx. Emissions rates for this pollutant are heavily dependent upon vehicle type as observed on the right portion of Figure 3. In general, a freeway segment goes from a steady state condition to a congested condition during an accident and is brought back to normal conditions with the assistance of the FSP. If a congested emissions curve is used, then the impacts for some pollutants are better assessed than when only the steady state curve is used.

2.2 Costs of Freeway Service Patrol

The main cost components of a service patrol program are capital, operating costs, and administrative costs. The latter costs are minimized when the FSP is entirely contracted out and charged on a per-truck-hour basis. The annual cost of an FSP depends upon the number of centerline miles covered, hours of operation, and number of vehicles maintained. The hours of operation may range from 24 hours to peak service hours only, depending on congestion and budget. Examples of budget and fleet considerations can be found in Hagen, Zhou, and Singh [10].

Over 70 percent of FSP programs are funded by state DOTs and they operate the FSP either on their own or on a contractual basis. About 90 percent of the FSP programs are funded by combining two sources, at most, of funding [18]. Funding sources include motor fuel taxes, Department of Motor Vehicle fees, tolls, and sponsorship. Federal dollars frequently come from congestion mitigation and air quality (CMAQ) funds, construction funds, or highway safety funds. In some cases, the funding is sponsored exclusively by private agencies. An example of this is the Samaritan patrol program. Samaritan patrols operate in 11 northeastern United States metropolitan areas. The patrols are operated by Samaritan, Inc. and funded by large corporations, such as CVS Pharmacy [19]. Some privately operated programs get their funding from turnpike authorities, which use collected tolls to support the program.

2.3 Benefit-Cost Analysis

The benefits of FSPs for the general public mainly include delay savings through quick incident response. FSPs perform similar duties as a private assistance service (PAS). When estimating the benefits to the general public from FSPs, many studies have used the reduced response time by FSPs compared with PASs. A study [20] investigated the factors that might influence people to choose an FSP over a PAS. The data employed are from a stated preference survey, which provides individuals' evaluations of the FSP based on many different scenarios when vehicle breakdowns occur. These scenarios reflect comparisons of the FSP with PASs and incorporate important factors, including time of vehicle breakdown (morning/midnight/regular hours), cost of assistance based upon different quality of service, and time of waiting for assistance. Because the sample size is large, this study further takes into account demographic factors, including sex, age, income, auto age, maintenance expenses, commute, ownership of cell phone, and towing coverage.

2.4 Benefit-Cost for FSP in Other States

Many states have carried out evaluations of their FSP using different methods. The results showed greater benefit value than cost. A nationwide survey of 19 agencies showed that the benefit-to-cost ratios for FSP programs ranged from 4.6:1 to 42:1 (see Table 3). The average benefit-cost ratio was 12.4:1 and the median was 9.45:1 [18]. It is important to notice that past benefit-cost studies may need to be upgraded to incorporate data from new sources. For instance, in Florida, the previous benefit-cost evaluation was performed before the implementation of SunGuide® (ITS database). In general, values of benefit-to-cost ratios may vary between and within agencies, depending on the benefit and cost components. Interagency comparisons are usually discouraged due to the number of factors affecting such quantities. Benefit-to-cost ratios are sensitive to the percentage of trucks, passenger vehicle occupancy, incident costs, etc.

Table 3: Results of service patrol benefit-cost studies

Patrol Location	Patrol Name	Year Performed	Results
Alabama	Service and Assistance Patrol	2009	1.7:1 to 23.4:1
Charlotte, NC	Incident Management Assistance Patrol	1993	3:1 to 7:1
Chicago, IL	Emergency Traffic Patrol	1990	17:1
Dallas, TX	Courtesy Patrol	1995	3.3:1 to 36.2:1
Denver, CO	Mile High Courtesy Patrol	1996	20:1 to 23:1
Detroit, MI	Freeway Courtesy Patrol	1995	14:1
Fresno, CA	Freeway Service Patrol	1995	12.5:1
FDOT, FL	Road Ranger Program	2005	2:1 to 40:1
Houston, TX	Motorist Assistance Program	1994	6.6:1 to 23.3:1
Los Angeles, CA	Metro Freeway Service Patrol	1993	11:1
Minneapolis, MN	Highway Helper	1995	5:1
New York, NY	Highway Emergency Local Patrol	1995	23.5:1
Norfolk, VA	Safety Service Patrol	1995	2:1 to 2.5:1
Oakland, CA	Freeway Service Patrol	1991	3.5:1
Orange Co., CA	Freeway Service Patrol	1995	3:1
Riverside Co., CA	Freeway Service Patrol	1995	3:1
Sacramento, CA	Freeway Service Patrol	1995	5.5:1

3 METHODOLOGY

This section describes the tools used for FSP evaluation. An overview of the data collection and processing is also provided. Details of the automation framework adopted for model generation, data input, evaluation, and data gathering are presented.

3.1 FSP Evaluation Tool

The Freeway Service Patrol Evaluation (FSPE) Version 12.1 developed by the University of California, Berkeley, was the methodology selected to perform the evaluation of the Road Ranger program. The FSPE model uses Microsoft Excel workbooks for all inputs and outputs. The MS Excel interface makes the model user-friendly, convenient, and simple in terms of entering the data and obtaining the results [11]. The inputs are used by FSPE's internal Visual Basic for Applications (VBA) program to estimate hourly traffic flow that is then used to estimate the incident-induced vehicular delays and delay reductions due to FSP service. The FSPE model uses a queuing model for calculating the delay. The FSPE delay model uses VBA code implemented as an add-in module to accommodate the more detailed queuing model. The model estimates delay saving benefits based on geometric and traffic characteristics, and the frequency and type of FSP-assisted incidents.

The FSPE methodology uses nine types of incidents, based on the type and location, to estimate the benefits of an FSP program. These incident types include: accident (right shoulder, in lane, left shoulder), breakdown (right shoulder, in lane, left shoulder), and debris (right shoulder, in lane, left shoulder). The FSPE model distributes the various incident types over the study segment during the service period proportional to the Vehicle Miles Traveled (VMT) in that segment during different periods of the day. The model uses traffic profiles of the study area and AADT volumes on the study segments to calculate VMT during different times of the day and assigns incidents accordingly. It calculates the benefits for one average day, using the input information, and multiplies it by the number of days of service to give the total benefit. Besides California, the FSPE has been used by Virginia [21] and Florida [10] to evaluate their FSP programs.

To apply the FSPE model to evaluate the Florida Road Ranger program, the model has to be calibrated to suit Florida traffic, roadway conditions, and information availability. It should also be noted that the FSPE model does not address multi-lane incidents. For the FSPE model these multi-lane incidents are modeled as a single lane blocking incident.

3.2 Data Collection

The main input parameters for the FSPE model and the data sources used in this study are listed in Table 4.

Table 4: Data inputs and data sources

Data Sheet	Variables	Type	Data Source
Service Description	District and Beat Name, Date, Hours of Operation, Number of Trucks;	Input	District Road Ranger Manager
	Cost of Service	Input	District Road Ranger Manager
Design Characteristics	Direction, Geometric Design, Number of Lanes, Length, Number of Mixed Flow Lanes, HOV lane (if any), Presence of Right Shoulders/Median	Input	SunGuide® system, Florida Traffic Information DVD (2010), District Road Ranger Manager, Aerial View
Traffic Characteristics	Average Annual Daily Traffic, percentage of trucks, directionality Factors (AM, Midday, and PM peak periods)	Input	SunGuide® system, Florida Traffic Information DVD (2010)
Incident Characteristics	Mean Time and Percentage of Incidents at Right Shoulder, Median and In-lane by Each Type (Accidents, Breakdowns, and Debris), response time without Road Ranger	Input	SunGuide® system
Additional Parameters	Capacity Values	Default	Model
	Remaining Freeway Capacity Factors	Default	Highway Capacity Manual
	Fuel/emission Base Rates	Default	CARB 2003
	Delay and Fuel Costs	Input	Average gas price in Florida for 2010 and value of time from TTI Urban Mobility Report 2009
	Occupancy Rates	Input	Updated to 2009 National Household Travel Survey (NHTS)
Traffic Profiles (Field Data, Directional Factors)	Percentage of Hourly Volume (in a 24hr day without incidents)	Optional Input	SunGuide® system, Florida Traffic Information DVD (2010)
	Percentage of Hourly Volumes by Directions	Optional Input	SunGuide® system, Florida Traffic Information DVD (2010)

Currently, the information collected on Road Ranger operations is handled in a standardized reporting format in the SunGuide® system. SunGuide® is a statewide Advanced Traffic Management System Software (ATMS) that allows the centralized control, monitoring, and management of ITS equipment and incidents [22]. The main functions of the SunGuide® System are:

- Facilitate traffic incident management
- Disseminate traveler information to the motoring public
- Exchange critical information among agencies
- Collect and report data regarding the operation and performance of Florida's roadways

It should be noted that although all FDOT districts utilize SunGuide® software in their Traffic Management Centers (TMC) there may be variations in data collection and terminology. These variations could affect the benefit-cost calculations and not provide a totally accurate comparison from district to district.

An overview of the architecture of the SunGuide® system is presented in Figure 4. It can be observed that Road Ranger data are reported and stored in the SunGuide® database. Each FDOT district has an instance of the SunGuide® database; however, the underlying data structure/schema are the same across all districts.

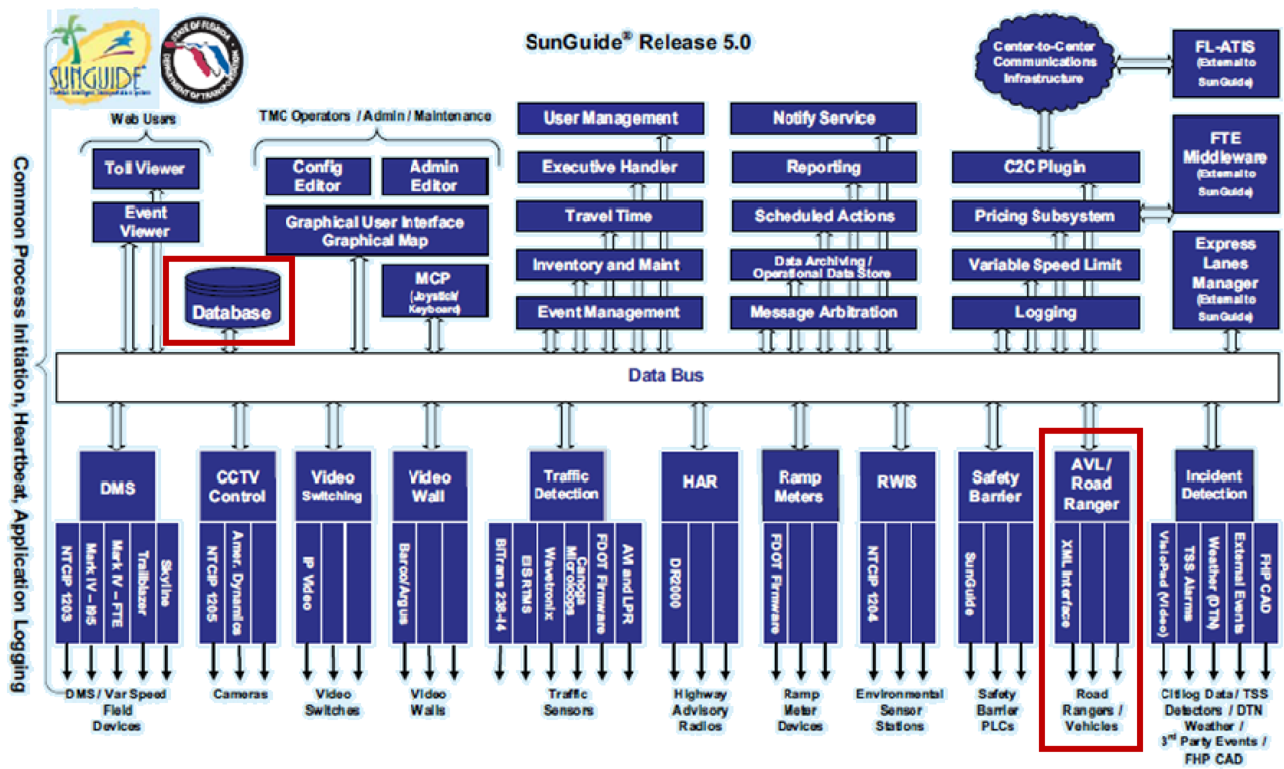

Figure 4: SunGuide® system architecture

A copy of the SunGuide® data was provided to the research team to perform the analysis and extraction of the required data. The data, as of the time of this report, consisted of approximately 400 GB of data stored in an Oracle database with over 250 tables per district.

3.2.1 FSPE data requirements

The data requirements for the FSPE model are listed as follows:

1. The FSPE model requires traffic parameters to be the default values used by the model to estimate hourly traffic volumes, delay, and fuel consumption savings. The model provides default values for various parameters in the PARAMS worksheet. The default values were adjusted to reflect each FDOT district characteristic. An example of traffic parameters is presented in Figure 5.

B. Beat Design Characteristics

Beat Length (miles)	12.50											
#Segments	12											
DIRECTION-1	NB											
Segment#	1	2	3	4	5	6	7	8	9	10	11	12
Length (mi)	2.60	1.90	1.30	0.40	0.60	1.00	0.30	0.50	0.60	0.50	1.30	1.50
# Mixed-Flow Lanes	2	2	2	2	2	2	2	2	2	2	2	2
HOV Lane	N	N	N	N	N	N	N	N	N	N	N	N
Rt Shdr	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lt Shdr (Median)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

C. Beat Traffic Characteristics

Segment #	1	2	3	4	5	6	7	8	9	10	11	12
AADT	53756	48592	87721	74838	65789	82363	77163	75752	72836	76162	73628	76715
AM PEAK Dir.	NB	SB	SB	NB	SB	NB	SB	NB	NB	NB	SB	SB
D factor (%)	57.00	50.00	42.00	56.00	44.00	54.00	46.00	51.00	50.00	51.00	50.00	57.00
MD PEAK Dir.	NB	SB	SB	NB	SB	SB	SB	SB	SB	SB	NB	SB
D factor (%)	51.91	50.00	39.86	52.79	42.60	49.85	46.58	49.94	49.83	48.92	50.09	48.95
PM PEAK Dir.	NB	SB	SB	NB	SB	SB	SB	SB	SB	SB	NB	SB
D factor (%)	50.40	50.00	40.03	50.94	41.31	48.05	48.38	49.91	49.75	49.70	50.05	48.78

Figure 5: Example of district traffic parameters in the FSPE model

2. The freeway capacity for mixed-use lanes was taken from the HCM. According to the HCM, the speed of passenger cars at flow rates that represent capacity is about 55 mph, and the flow rate corresponding to this speed could be approximated as about 2,250 pcphpl (passenger cars per hour per lane). However, for actual analysis, a lower capacity of 2,100 pcphpl is typically used in the analysis due to the mix use of passenger cars, vans, trucks, and motorcycles. An example of the FSPE requirement for freeway capacity is presented in Figure 6.

FREEWAY CAPACITY VALUES

"Ideal" Value (Mix Use)	2,100	vphl
"Ideal" Value (HOV)	1,800	vphl

Figure 6: Example of default freeway parameters in the FSPE model

3. The reduction values in the HCM will be used to estimate the remaining capacity on the freeway due to various incidents. An example of remaining freeway capacity in the FSPE model is presented in Figure 7.

REMAINING FREEWAY CAPACITY DUE TO INCIDENTS (%)

Incident		No of Freeway Lanes/Direction			
Type	Location	2	3	4	5+
Accident	Rt Shdr	81.00	83.00	85.00	87.00
	Median	81.00	83.00	85.00	87.00
	1-Lane	35.00	49.00	58.00	65.00
Breakdown	Rt Shdr	95.00	98.00	98.00	98.00
	Median	95.00	98.00	98.00	98.00
	1-Lane	35.00	49.00	58.00	65.00
Debris	Rt Shdr	95.00	98.00	98.00	98.00
	Median	95.00	98.00	98.00	98.00
	1-Lane	35.00	49.00	58.00	65.00

Figure 7: Remaining freeway capacity parameters in the FSPE model

4. Response time without freeway patrol and the mean time spent per incident type/location are required for the FSPE model. These parameters were extracted from the SunGuide® system based on the timeline presented in Figure 8. First, the incident occurs, usually this time is unknown, and then the incident is detected. Once it is confirmed, an emergency responder is dispatched. The arrival time of the responder is time-stamped in the SunGuide® system, as well as the time when the lanes are clear. At the end of the incident, the departure time of the responder is time-stamped in the system and the incident is closed by the TMC. Each incident is tagged in the system indicating whether the incident was assisted by a Road Ranger or not. The response time was considered as the difference between the arrival to the incident scene and the detection time of the incident. The time spent was considered as the time difference between the departure time and the arrival time. The response time without a Road Ranger can be calculated as the response time for those events tagged as unassisted by Road Rangers. Some districts, such as the Turnpike, offer additional incentives to incident responders to provide traffic control and clear incident scenes as quickly as possible. This is also part of the open roads policy promoted by FDOT, whose goal is to provide traffic control within 30 minutes of notification during working hours and 60 minutes for after-hours. It was observed that different agencies have different implementation of the open roads policies for incident responders. To level out those differences for the analysis, the same response time without Road Rangers was used. This time will be set at 30 minutes based on studies developed by California [11] and the open roads policy by FDOT [23].

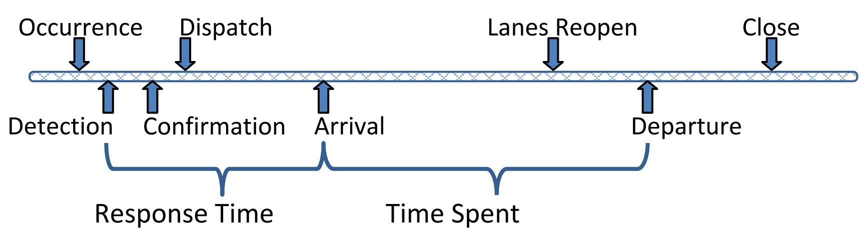

Figure 8: Approximate timeline of an incident report

5. Event type and its lateral distribution are required by the FSPE model. The SunGuide® system considers the following event types:

- Evacuation
- Flooding
- Pedestrian
- PSA
- Crash
- Disabled Vehicle
- Abandoned Vehicle
- Debris on Roadway
- Congestion
- Scheduled Road Work
- Emergency Road Work
- Bridge Work
- Police Activity
- Special Event
- Vehicle Alert
- Other
- Emergency Vehicles
- Vehicle Fire
- Off Ramp Backup
- Weather
- Visibility
- Interagency Coordination

For this study, the following incident types were considered, which covered the vast majority of incidents:

- Crash
- Disabled Vehicle
- Debris on Roadway
- Vehicle Fire

Vehicle fires were mapped into the accidents category. In addition to incident types, the SunGuide® system records lateral distribution of incidents that caused lane blockage or shoulder blockage. This is also consistent with the assumptions of the FSPE model regarding capacity reduction. In this study, only those incidents that caused blockages were considered in the evaluation of the Road Ranger benefits. This helps to keep consistency between the FSPE model assumptions, capacity reductions, and data availability.

6. The average fuel cost per gallon in Florida is shown in Figure 9 [24]. An example of the values used in the model for Florida is presented in Figure 10 .

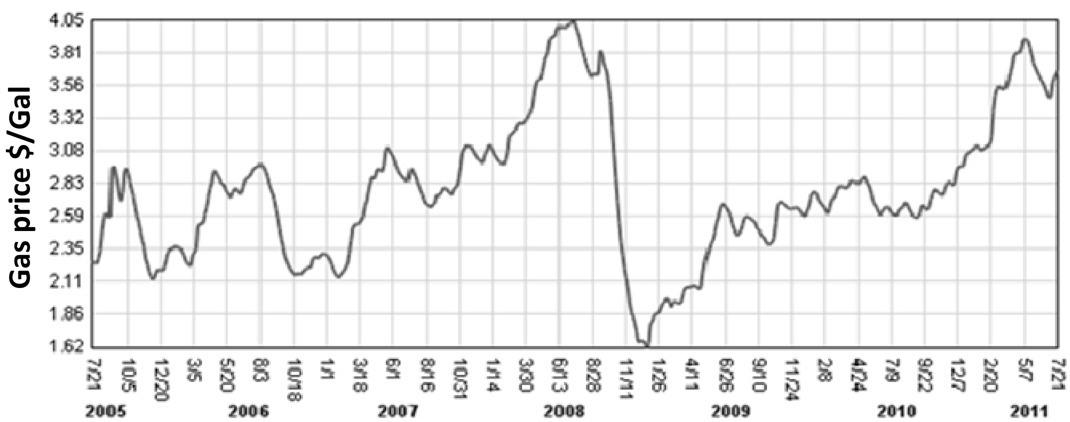

Figure 9: Historical gas prices in Florida

7. A study performed in Alabama [25] summarized the average values of travel time used for FSP benefit and cost analysis in Table 5. The travel time values for each person hour of travel and truck hour were obtained from the Urban Mobility Report 2009. Average vehicle occupancy can be found from NHTS (National Household Travel Survey). The percentage of trucks in total traffic can be found in the FDOT Traffic Information CD. An example of the values used in the model for Florida is presented in Figure 10. The detailed calculations for each district/zone can be found in Appendix A. The travel time value for the FSPE model can be calculated as:

   Travel Time Value = $ per person hour*average occupancy *(1-truck percentage) + $ per truck hour*truck percentage.

Table 5: Reviewed average values of travel time

Study	Citation	Year	Passenger Car ($/hr)	Truck ($/hr)
Florida	Hagen	2005	13.75	72.65
Northern Virginia	Dougald	2006	13.45	71.05
Gary, IN	Latoski et al.	1999	8.03	30.38
Hudson Valley, NY	Haghani et al.	2006	15	15
Atlanta, GA	GDOT	2006	19.14	32.15
Minneapolis, MN	MnDOT	2004	10.04	18.61
North Carolina	Khattak et al.	2005	10.00	-
Puget Sound	Nee, et al.	2001	12.40	-

RESPONSE TIME REDUCTION DATA

Beat Length (miles)	12.50
FSP Tow-Truck Average Speed (mph)	55.00
Mean Response time W/O FSP (minutes)	25.00
AM Response Time Reduction (minutes)	11.46
MD Response Time Reduction (minutes)	11.46
PM Response Time Reduction (minutes)	11.46
Delay Cost ($/veh-hr)	$ 28.89
Fuel Cost ($/gal)	$ 2.83

Figure 10: Example of the FSPE response time reduction data and other costs

3.2.2 Zone data

Service coverage data was compiled for FDOT Districts and Florida's Turnpike Enterprise (FTE). The service is divided into zones and each zone is assigned one or more Road Ranger trucks with a service schedule. Tables and maps for each district are presented in Appendix B.

4 RESULTS OF INCIDENT DATA ANALYSIS

Incident data were compiled, filtered, and analyzed for each district prior to performing the benefit-cost evaluation of the Road Ranger program. The results are presented in this section. It should be noted that in the following Figures 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, and 39 that lane blocking can refer to single or multi-lane blocking incidents.

4.1 District 1 Incident Data

Figure 11 presents the lateral distribution per incident type for District 1 during weekdays. It can be observed that right shoulder blockage due to vehicle breakdowns constitute the majority of the cases, followed by right shoulder blockages caused by debris.

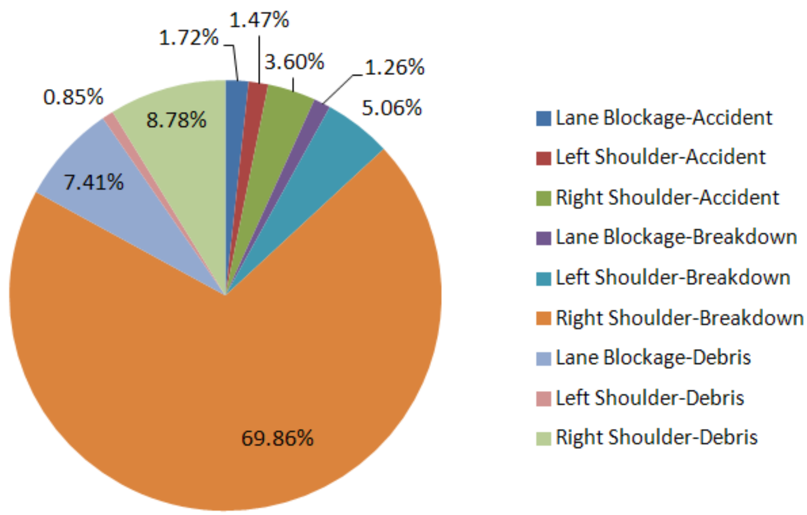

Figure 11: Lateral distribution of incidents for weekdays in District 1

Figure 12 shows the mean time spent by lateral distribution and incident type. It can be observed that accident-related blockages are the most demanding incidents in terms of mean time spent at the scene. With respect to frequency, lane blockages due to accidents are less frequent.

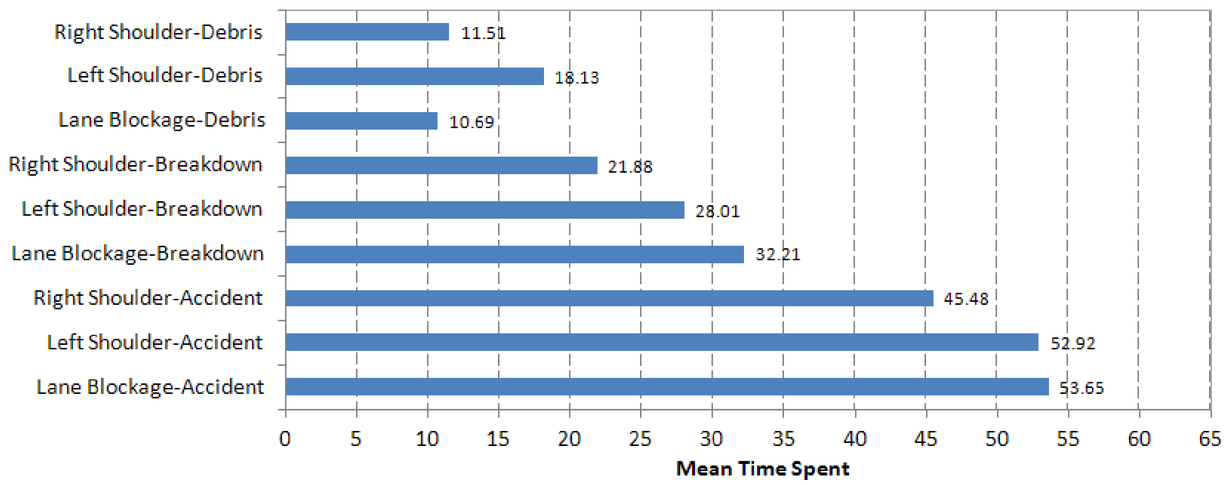

Figure 12: Mean time spent for Road Ranger assisted incidents during weekdays in District 1

The lateral distribution per incident type and the mean time spent are presented in Figures 13 and Figure 14 respectively. The predominant incident type is breakdown on the right shoulder having a mean time spent of 23 minutes.

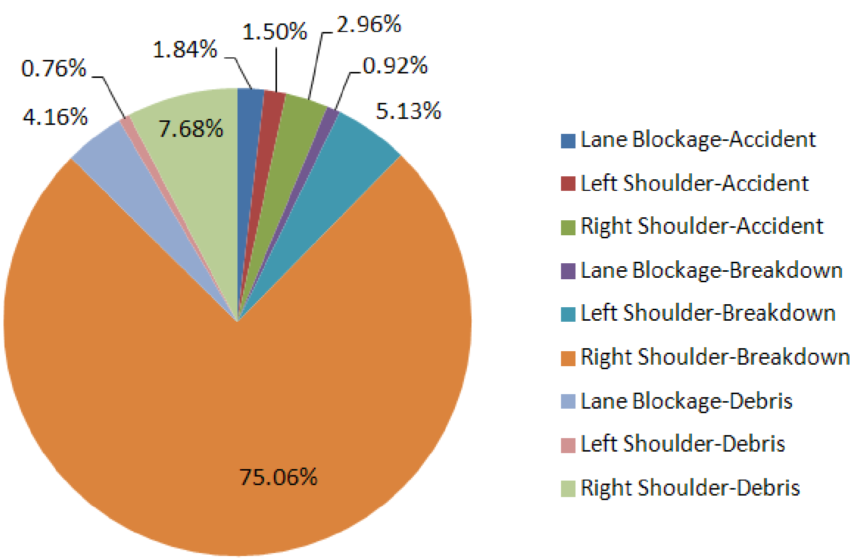

Figure 13 : Lateral distribution of incidents for weekends in District 1

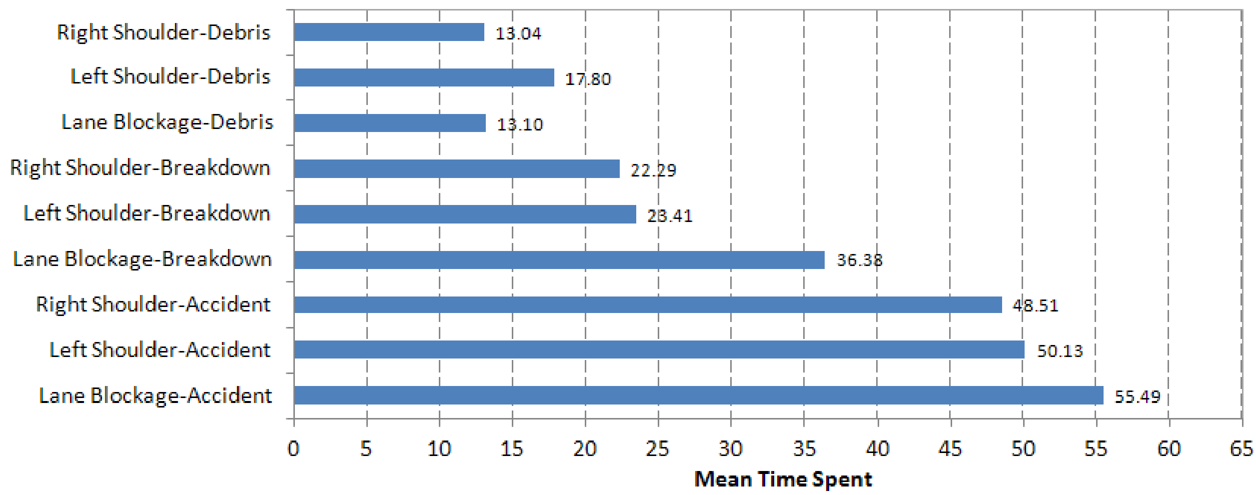

Figure 14 : Mean time spent for Road Ranger assisted incidents during weekends in District 1

4.2 District 2 Incident Data

Figure 15 presents the weekday lateral distribution per incident type for District 2. It can be observed that lane blockage due to accidents constitute the majority of the cases, followed by lane blockages caused by vehicle breakdowns.

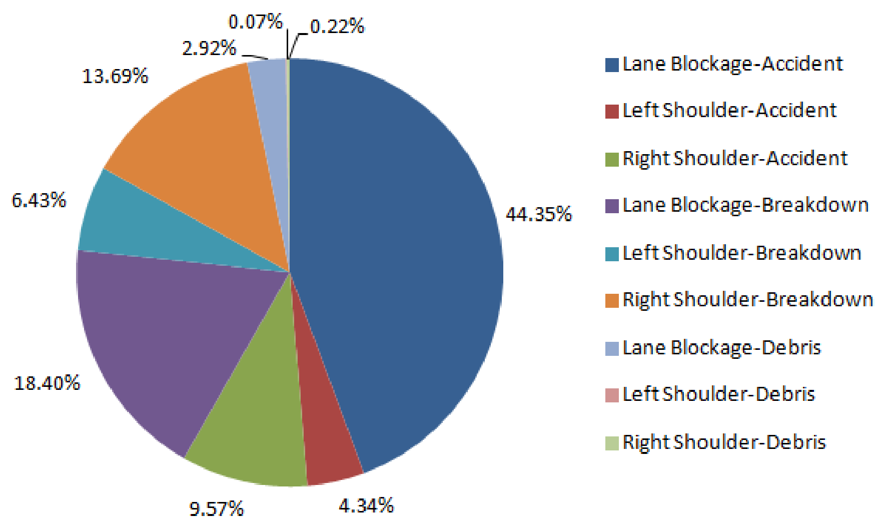

Figure 15: Lateral distribution of incidents for weekdays in District 2

Figure 16 shows the weekday mean time spent by lateral distribution and incident type. It can be observed that accident-related blockages are the most demanding incident types. Since this incident type and lateral distribution combination causes the greatest capacity reduction, it is expected that District 2 presents a relatively high benefit-cost ratio. It should be noted that there is no weekend Road Ranger service in District 2.

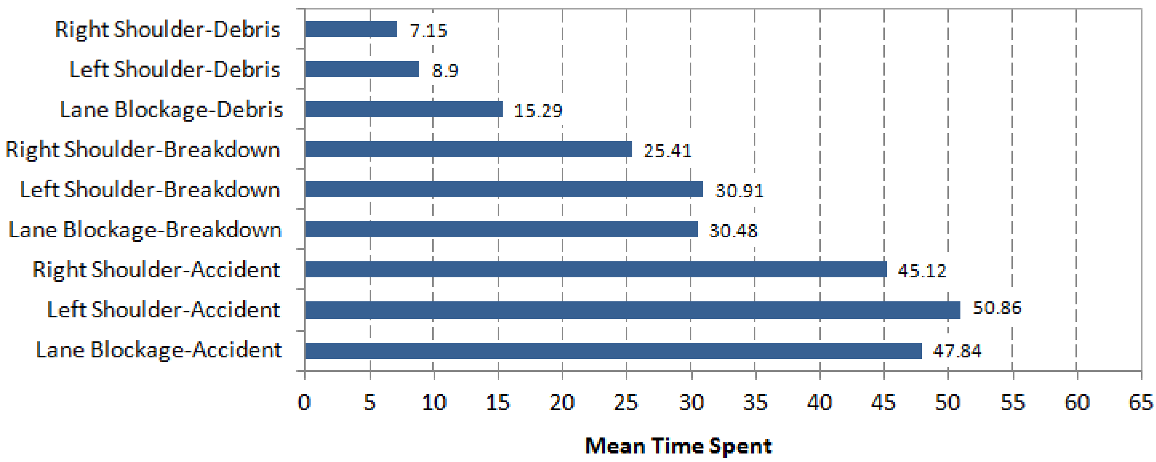

Figure 16: Mean time spent for Road Ranger assisted incidents during weekdays in District 2

4.3 District 4 Incident Data

Figure 17 and Figure 19 present the lateral distribution per incident type during weekdays and weekends for District 4. The right shoulder blockage due to vehicle breakdowns constitute the majority of the cases, followed by left shoulder breakdowns.

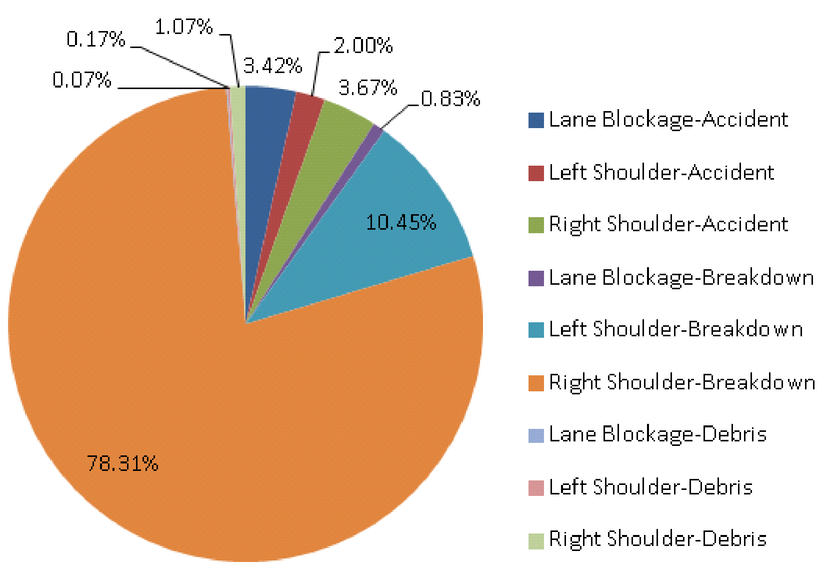

Figure 17: Lateral distribution of incidents for weekdays in District 4

Figure 18 shows the mean time spent for incidents based on their lateral distribution during weekdays for District 4. Right shoulder breakdowns take nearly 16 minutes to clear and makes up over 75 percent of the incidents for District 4.

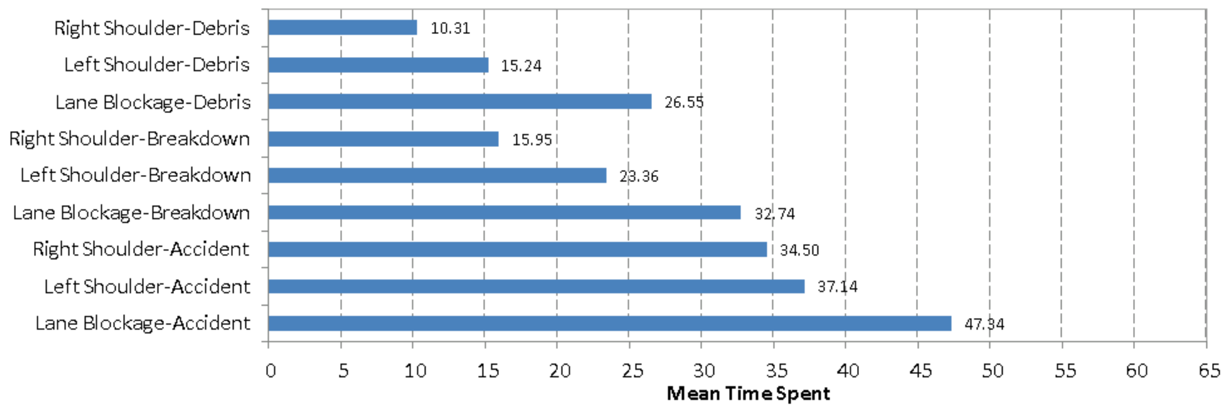

Figure 18: Mean time spent for Road Ranger assisted incidents during weekdays in District 4

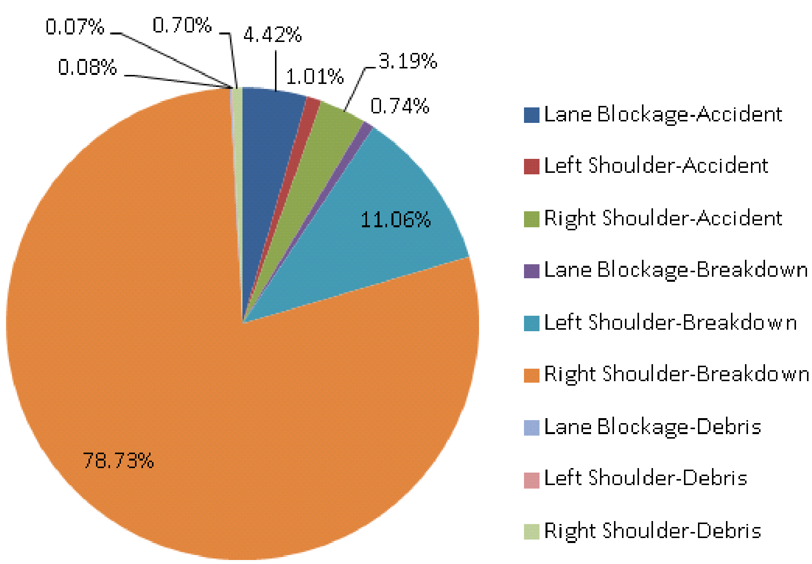

Figure 19 : Lateral distribution of incidents for weekends in District 4

Figure 20 shows the mean time spent by lateral distribution and incident type during weekends. The distributions for the weekends are close to those during the weekdays in Figure 18.

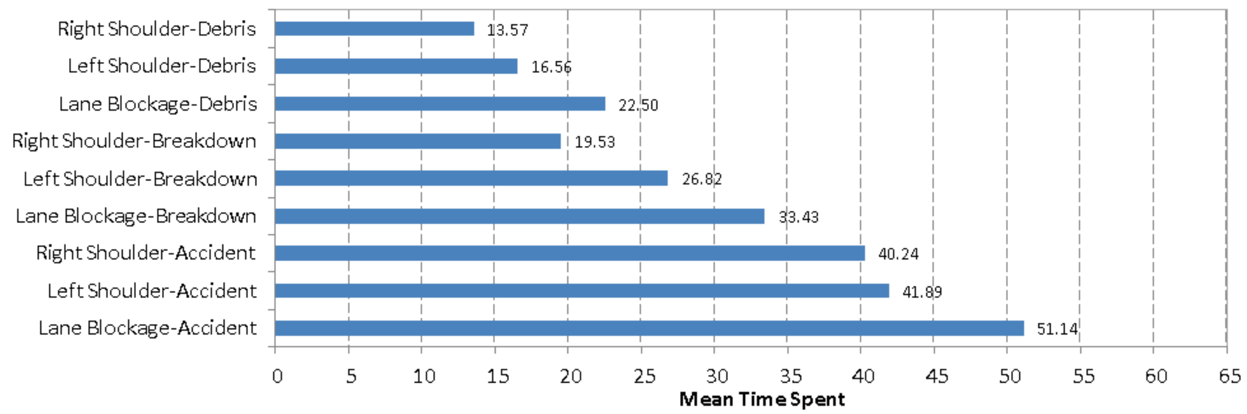

Figure 20 : Mean time spent for Road Ranger assisted incidents during weekends in District 4

4.4 District 5 Incident Data

The lateral distribution of incident data for weekdays in District 5 is presented in Figure 21. It can be observed that lane and shoulder blockages due to accidents are the dominant incident types with over 75 percent of occurrences.

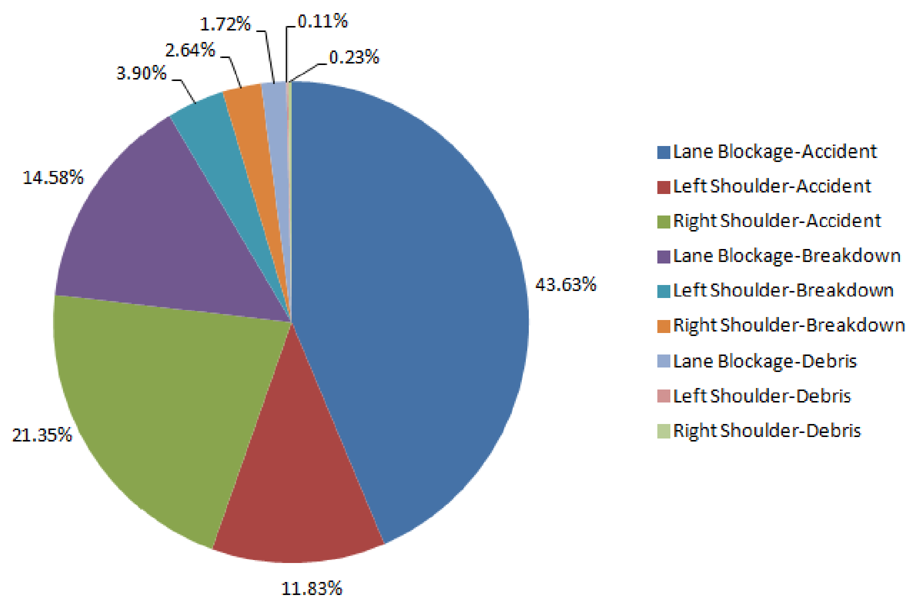

Figure 21: Lateral distribution of incidents for weekdays in District 5

The weekday mean time spent by lateral distribution and incident type is presented in Figure 22. Accidents on the right or left shoulders (median) and lane blockages take between 44 and 52 minutes to clear from arrival to departure.

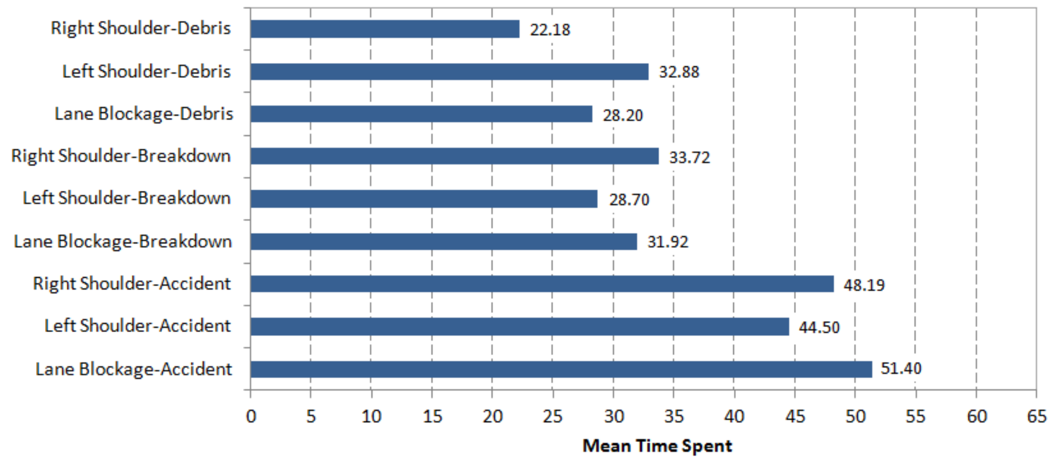

Figure 22: Mean time spent for Road Ranger assisted incidents during weekdays in District 5

The lateral distribution for incidents occurring during the weekend is presented in Figure 23. Accidents (lane blockage, left shoulder, right shoulder) cover the majority of cases, similar to the weekday distribution (over 80 percent of the cases).

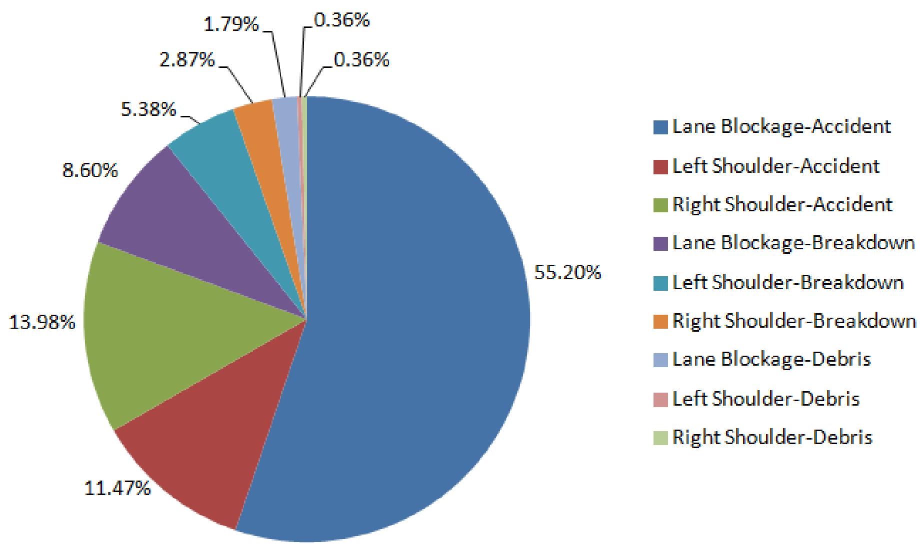

Figure 23: Lateral distribution of incidents for weekends in District 5

Figure 24 shows the distribution of the mean time spent for weekend incidents. It can be observed that for lane blocking incidents the meant time spent very similar for both weekends and weekdays.

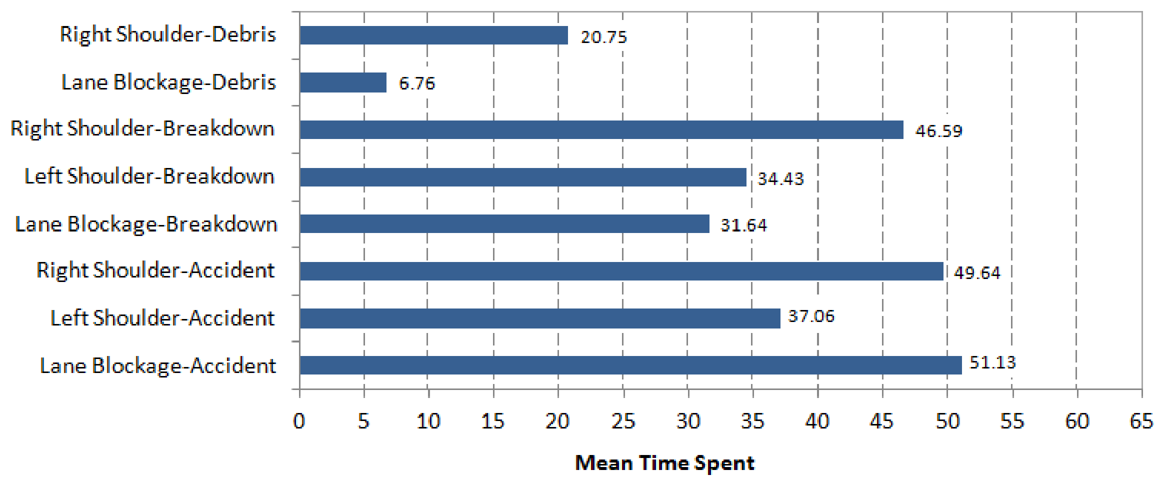

Figure 24: Mean time spent for Road Ranger assisted incidents during weekends in District 5

4.5 District 6 Incident Data

Figure 25 shows the lateral distribution by incident type in District 6. It can be observed that vehicle breakdown is the major cause of freeway incidents, accounting for 80 percent of the occurrences. Accident-related blockages constitute 18.47 percent of all the incidents.

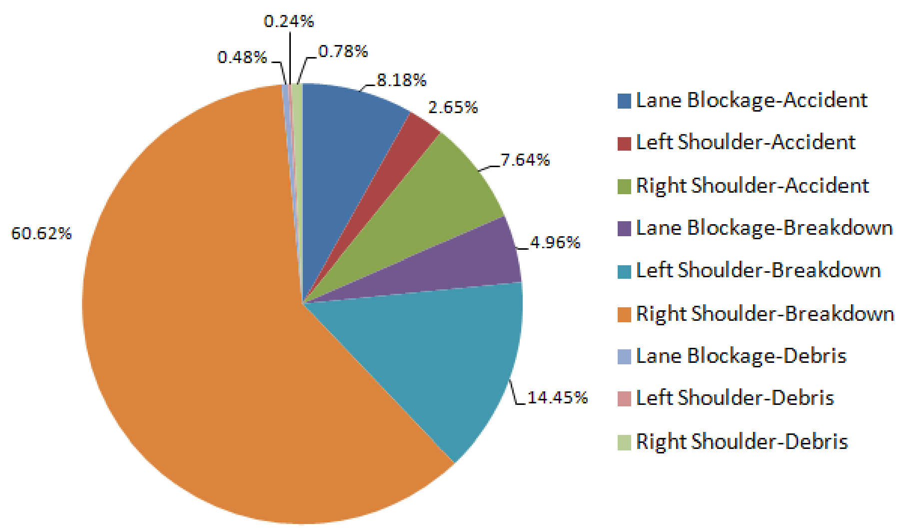

Figure 25: Lateral distribution of incidents for weekdays in District 6

For District 6 it can be observed that the mean time spent for breakdowns varies between 17 and 33 minutes, the mean time for accident varies between 39 and 53 minutes (see Figure 26).

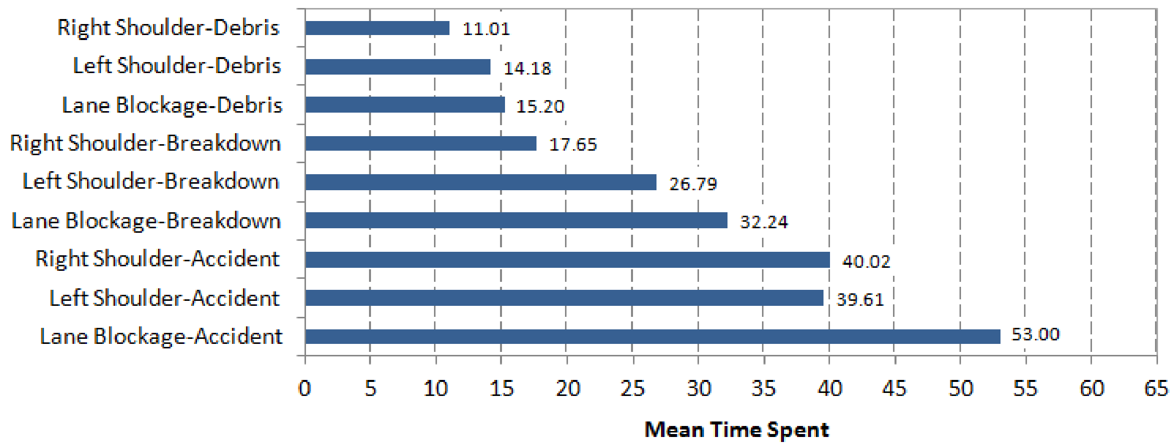

Figure 26: Mean time spent for Road Ranger assisted incidents during weekdays in District 6

The lateral distribution of incidents during the weekend is very similar to that of weekdays for District 6. Just over 80 percent of the cases are due to vehicle breakdown while 17.23 percent are due to accidents (Figure 27).

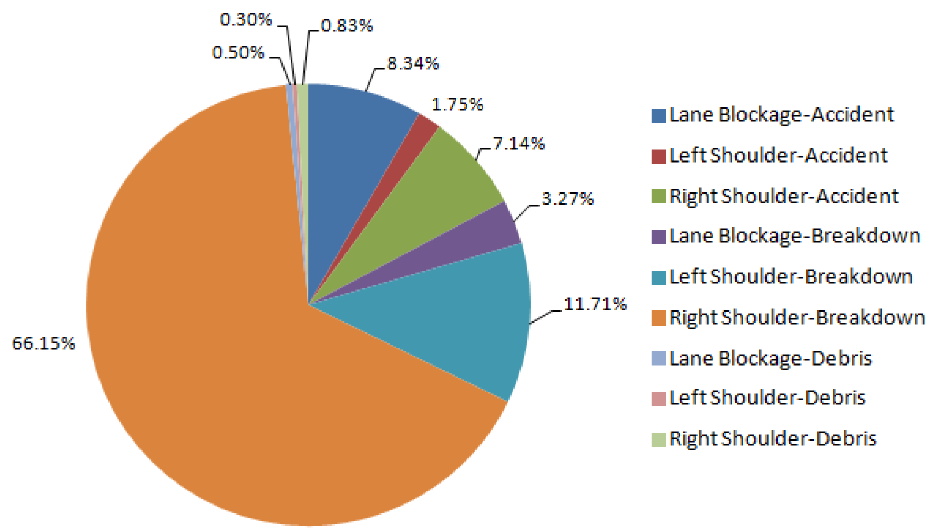

Figure 27: Lateral distribution of incidents for weekends in District 6

Figure 28 presents the mean time spent for weekend incidents in District 6. It can be observed that breakdowns range between 17 and 32 minutes whereas the mean time spent in accidents varies from 35 to 50 minutes.

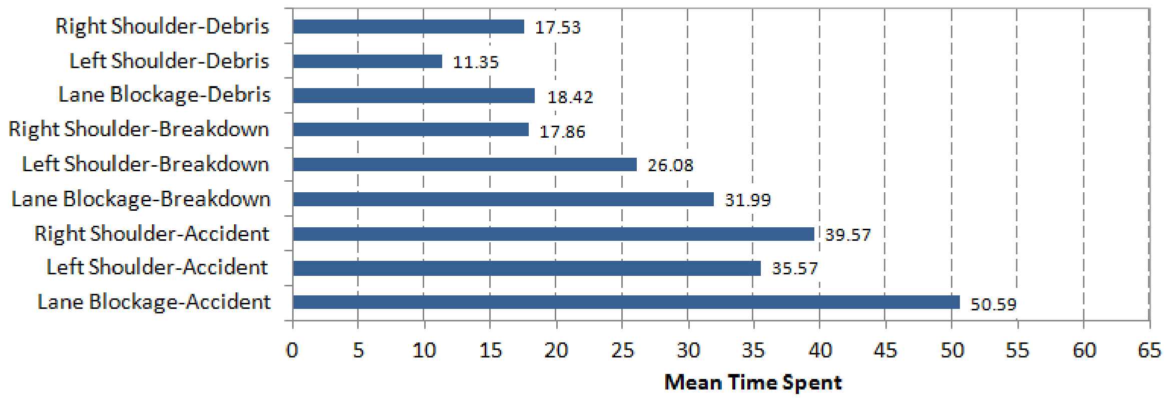

Figure 28: Mean time spent for Road Ranger assisted incidents during weekends in District 6

4.6 District 7 Incident Data

Figure 29 shows the weekday lateral distribution of incidents by incident type in District 7. It can be observed that lane blockage accidents account for over half of the incidents in District 7. Breakdowns blocking the left shoulder or median are the second most frequent incident, followed by breakdowns blocking one lane.

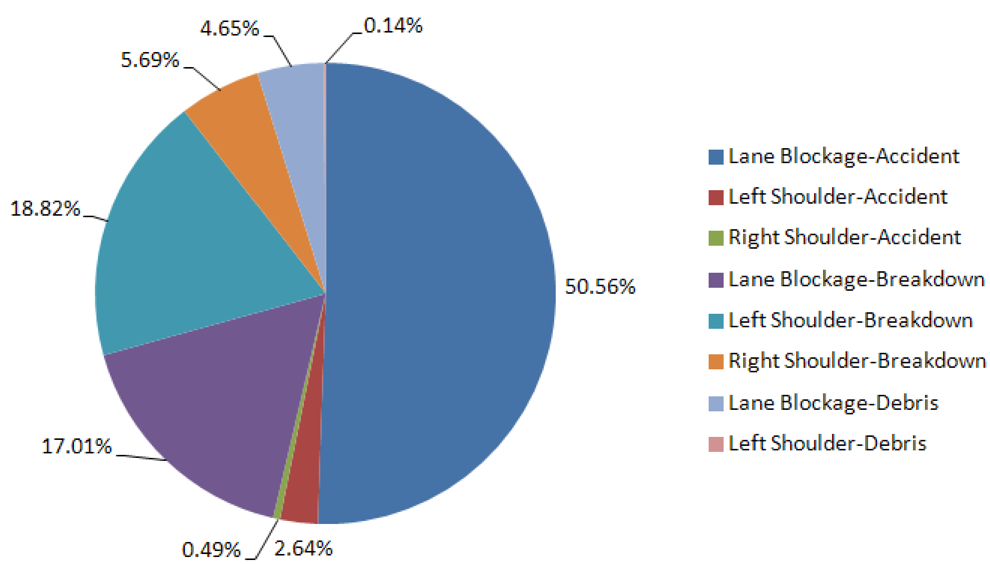

Figure 29: Lateral distribution of incidents for weekdays in District 7

The weekday mean time spent by lateral distribution and incident type for District 7 is presented in Figure 30. Accidents are the most demanding incident types, ranging from 42 to 58 minutes. All types of breakdowns have a similar mean time spent, ranging between 33 and 34 minutes.

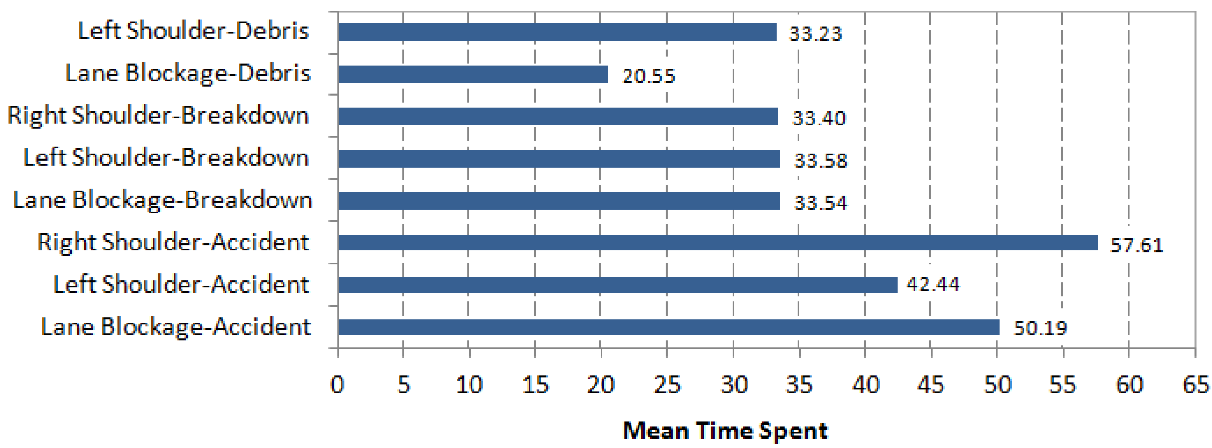

Figure 30: Mean time spent for Road Ranger assisted incidents during weekdays in District 7

The lateral distribution of incidents for weekends is presented in Figure 31. The distribution is very similar to that of the weekdays. The top category is lane blocking accidents, followed by left shoulder breakdowns and lane blocking breakdowns.

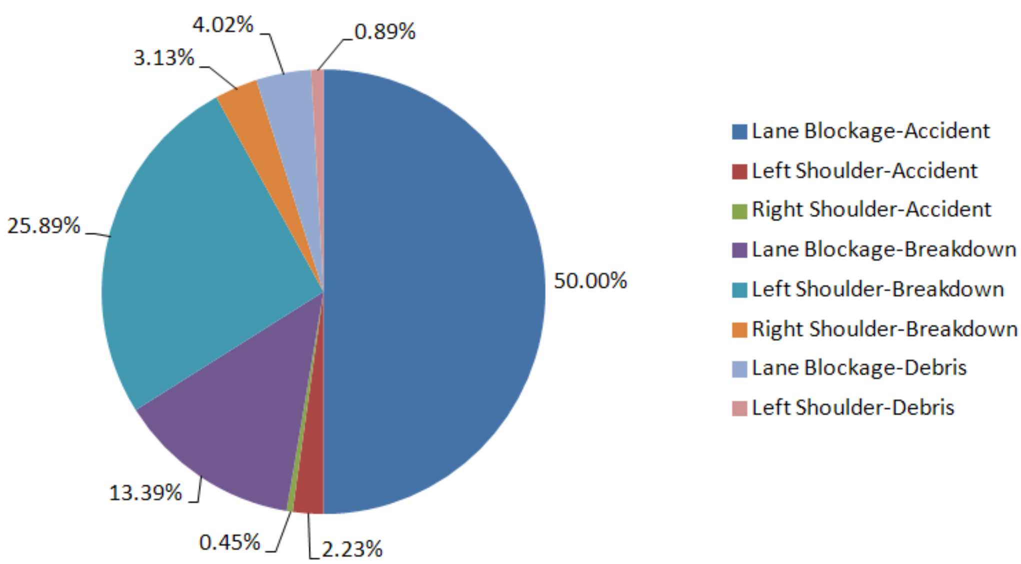

Figure 31: Lateral distribution of incidents for weekends in District 7

The mean time spent for weekend incidents in District 7 is presented in Figure 32. Lane blocking accidents and left shoulder accidents are the most demanding categories. Also, left shoulder breakdowns and lane-blocking breakdowns are among the top four most time consuming incidents.

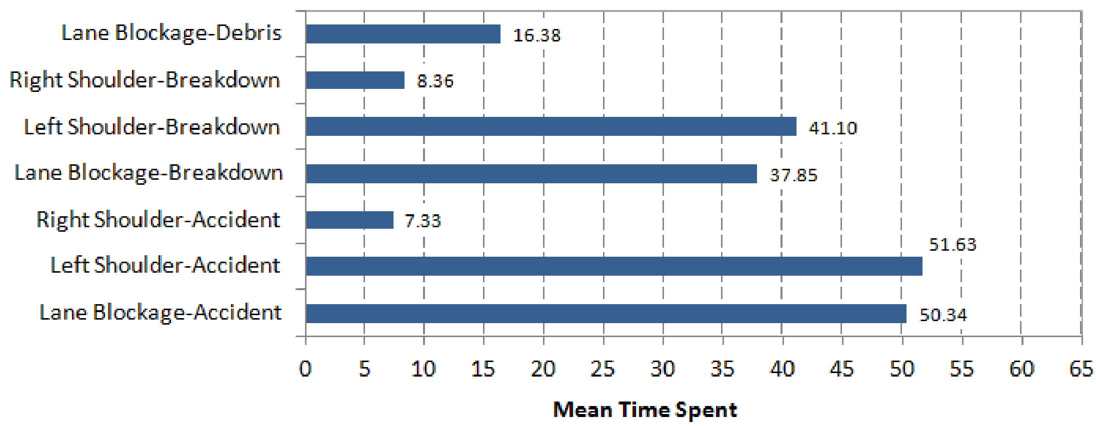

Figure 32: Mean time spent for Road Ranger assisted incidents during weekends in District 7

4.7 Florida's Turnpike Incident Data

The lateral distribution of incidents for weekdays in the Florida's Turnpike is presented in Figure 33. It can be observed that the most frequent incident types are breakdowns on the right shoulder (31%), right shoulder accidents (23%), and lane blocking accidents (20%).

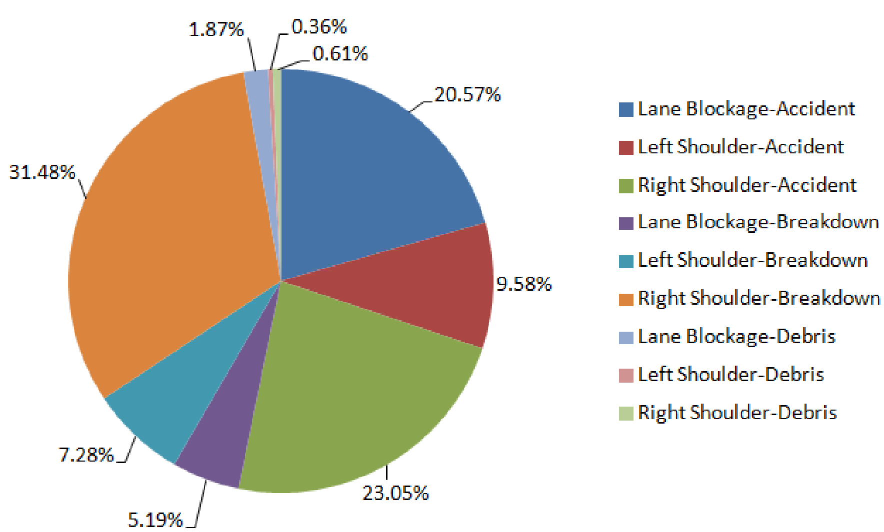

Figure 33: Lateral distribution of incidents for weekdays on the Florida's Turnpike

Figure 34 shows the mean time spent for weekday incidents on Florida's Turnpike. From the lateral distribution, the top three categories are: right shoulder breakdowns, right shoulder accidents, and lane blocking accidents, taking 40.66, 57.27, and 62.68 minutes respectively.

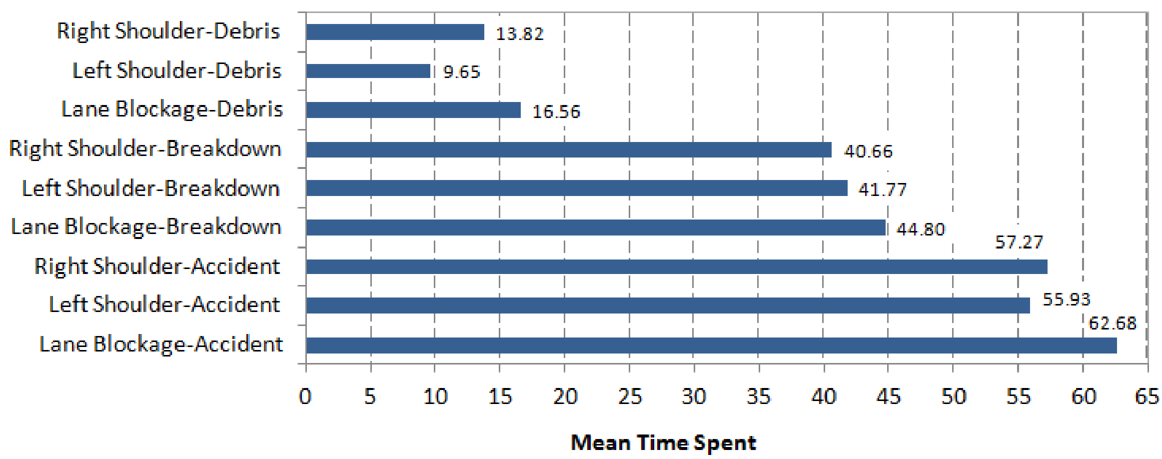

Figure 34: Mean time spent for Road Ranger assisted incidents during weekdays on Florida's Turnpike

Figure 35 shows the lateral distribution of incidents for the weekend in Florida's Turnpike. The distribution is very similar to that of the weekdays for the top three incident categories. The top category is the right shoulder accident, followed by lane blocking accidents, and then by right shoulder breakdowns.

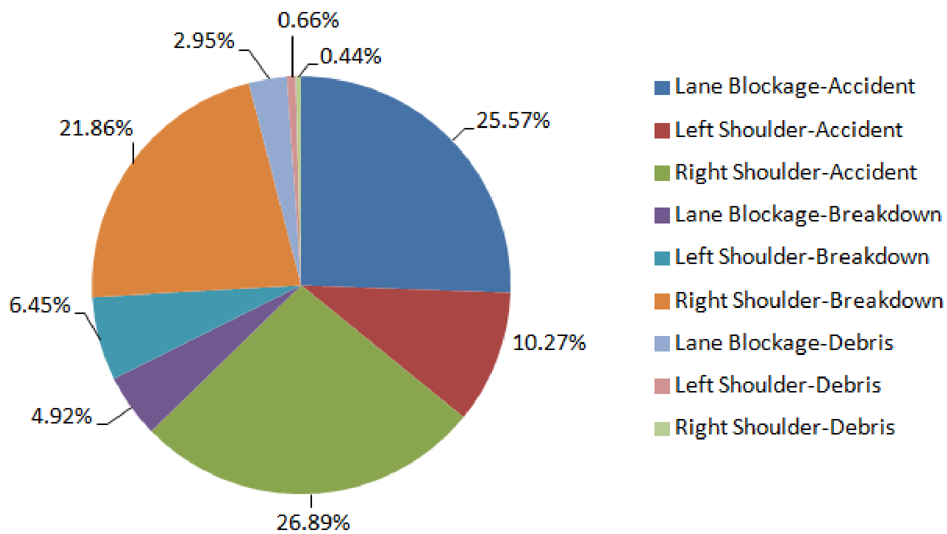

Figure 35: Lateral distribution of incidents for weekends on the Florida's Turnpike

The corresponding weekend mean time spent for the top three categories of lane blocking accidents, right shoulder accidents, and right shoulders breakdowns are 62.81, 54.67, and 35.48 minutes respectively as can be observed in Figure 36.

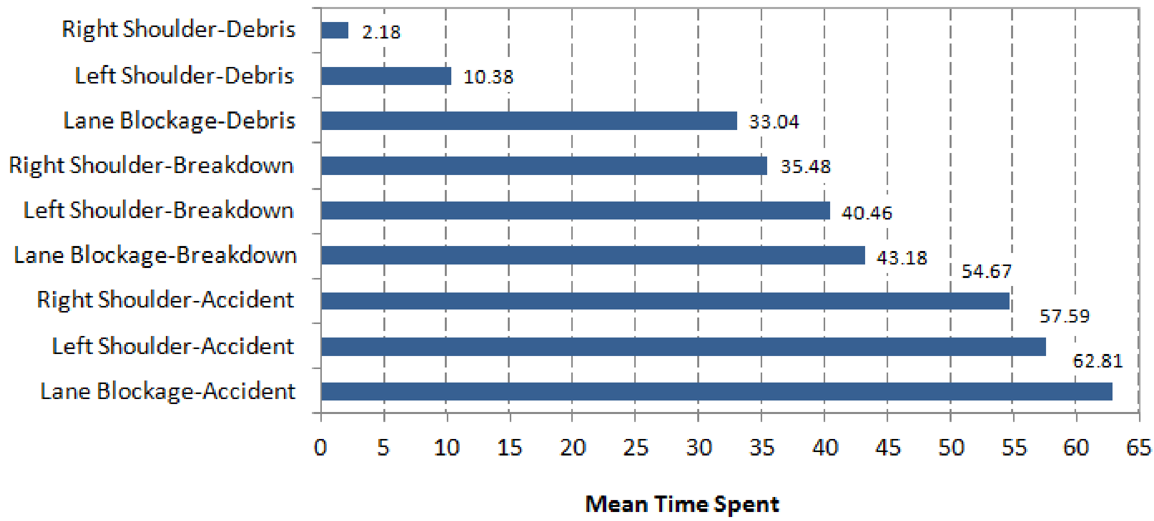

Figure 36: Mean time spent for Road Ranger assisted incidents during weekends on Florida's Turnpike

4.8 Florida Incident Data

Data for Florida were compiled and summarized in Figure 37 for lateral distribution by incident type for weekdays and in Figure 38 for mean time spent.

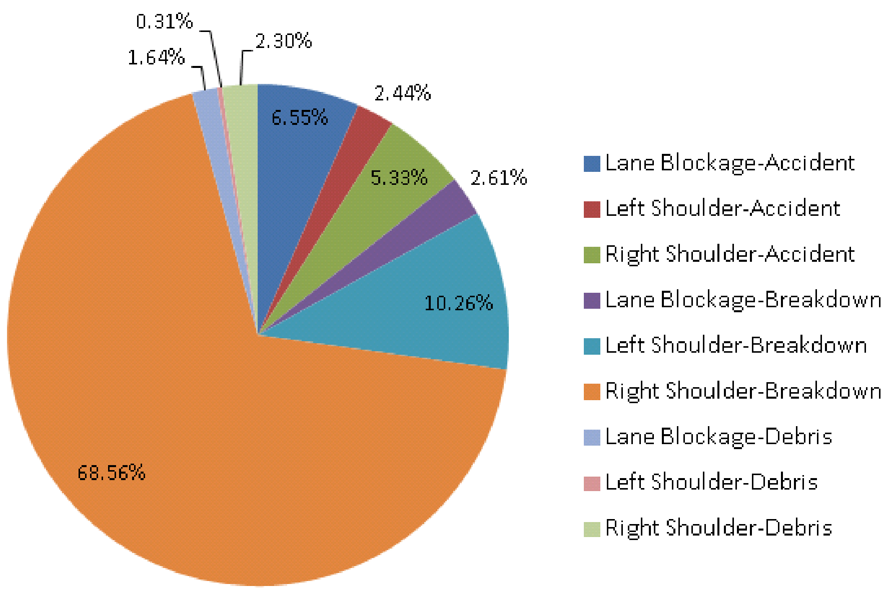

Figure 37: Lateral distribution of incidents for weekdays in Florida

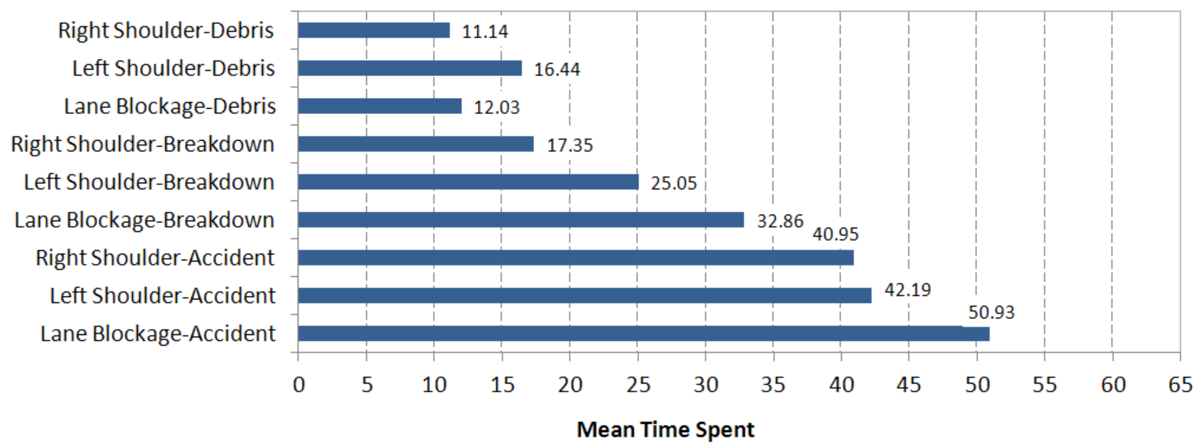

Figure 38: Mean time spent for Road Ranger assisted incidents during weekdays in Florida

Data for Florida were compiled and summarized in Figure 39 for lateral distribution by incident type for weekends and in Figure 40 for mean time spent.

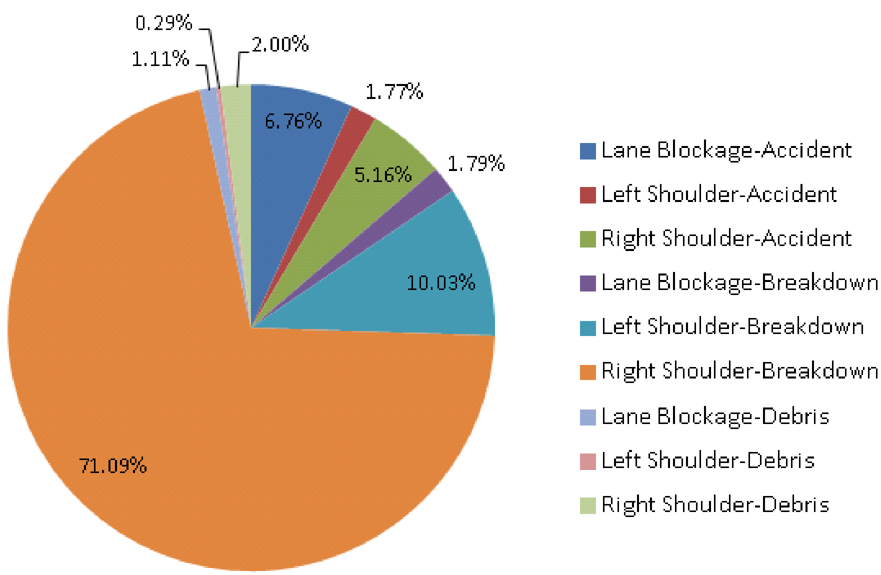

Figure 39: Lateral distribution of incidents for weekends in Florida

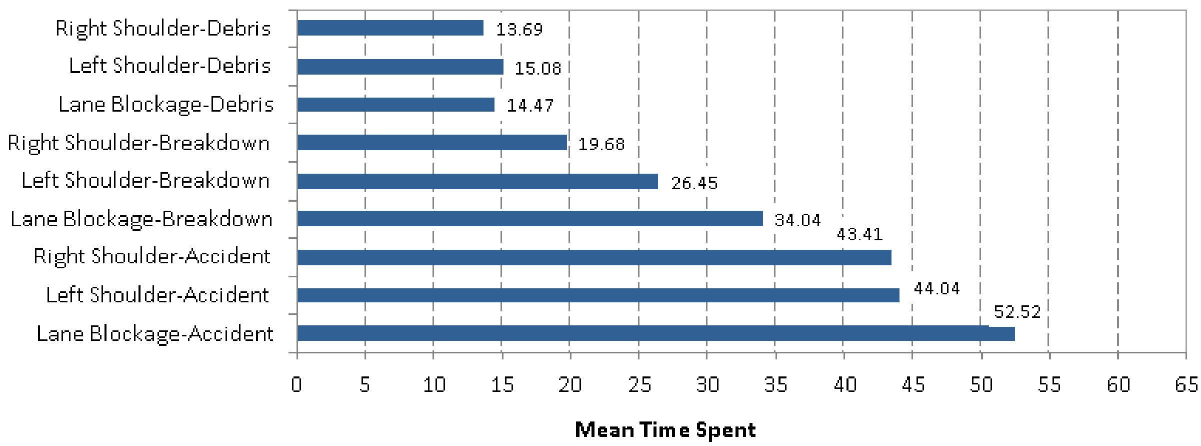

Figure 40: Mean time spent for Road Ranger assisted incidents during weekends in Florida

Figure 41 presents a radar chart of the capacity reduction factors suggested by HCM and used in the evaluation of the benefits of the Road Ranger program in Florida. The outer polygon represents the full capacity of the freeway, and capacity decreases towards the center of the chart. Lane blockages and shoulder incidents account for the majority of capacity reductions. The chart also presents a series based on the number of lanes from two to five. Capacity reductions are more critical with two lanes. Right shoulder breakdowns have a slight effect on the capacity of the freeway. The effect of an incident on the right shoulder decreases for freeways with wide shoulders, where disabled vehicles can be moved out of the travel lanes without obstructing the traffic.

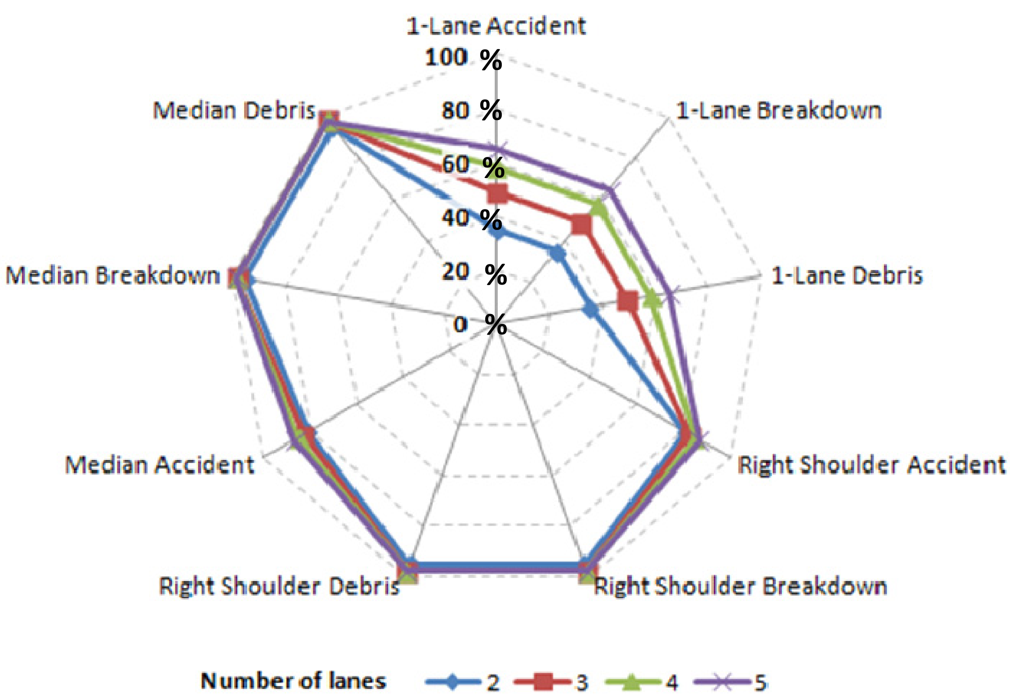

Figure 41: Visual representation of HCM capacity reduction factors

5 BENEFIT COST ANALYSIS

This section presents the results of the model evaluation for benefit-cost analysis for each FDOT District Road Ranger program in Florida. It is important to highlight that the benefit-cost analysis tool used to evaluate the program calculates high benefits for freeway segments with narrow or no shoulders with high number of vehicle disablements. For uncongested freeways with wide shoulders, the benefits tend to be lower [5]. Even if the Road Rangers perform a great number of assists per year, only those causing blockage will induce a quantifiable delay. Therefore, the benefits of the Road Ranger program are much greater than those calculated by the FSPE model. It is expected that during weekends and after hours (and combinations) when volumes are low, the FSPE model will tend to calculate lower B/C ratios, in many cases below one. On the other hand, during daytime hours on congested segments, B/C ratios will tend to be significantly higher. The overall operation is balanced to a moderate district-wide B/C ratio that helps road users during peak and off-peak, and after hours, increasing safety and public acceptance of the program.

5.1 Benefit-Cost Results District 1

District 1 has Road Ranger service on both weekdays and weekends. The predominant incident type was breakdowns on the right shoulder. The overall B/C ratio for District 1 was calculated at 3.82:1, indicating a favorable effect of the service in reducing congestion and delay due to incidents. For every dollar spent on the Road Ranger program, $3.82 is returned in delay and fuel savings.

Table 6: District 1 Road Ranger program B/C ratio summary

Zone	Profile	Delay Saving ($)	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
101&102	WE	353,966.04	10,963.42	364,929.46	149,518.80	2.44
101&102	WD	1,575,844	48,809	1,624,653	410,783	3.96
103	WE	265,619	9,290	274,909	69,585	3.95
103	WD	952,669	33,321	985,991	349,265	2.82
104	WE	170,526	5,964	176,490	104,378	1.69
104	WD	644,638	22,547	667,186	349,265	1.91
106	WE	146,424	5,144	151,568	79,103	1.92
106	WD	838,146	29,443	867,588	198,519	4.37
107	WE	103,965	3,652	107,617	79,103	1.36
107	WD	919,813	32,312	952,125	198,519	4.80
108	WE	56,535	1,690	58,225	78,711	0.74
108	WD	607,664	18,163	625,827	197,535	3.17
109	WE	494,379	14,777	509,155	78,711	6.47
109	WD	518,111	15,486	533,597	197,535	2.70
112	WE	401,649	12,826	414,474	74,785	5.54
112	WD	2,320,733	74,107	2,394,839	187,682	12.76
Overall		10,370,679	338,493	10,709,172	2,803,000	**3.82**

5.2 Benefit-Cost Results District 2

District 2 provides Road Ranger coverage only on weekdays. Lane blockage accidents and lane blockage breakdowns account for 63 percent of the incidents. The interaction of the number of incidents, incident types, and traffic profiles was performed by the FSPE model. One model (workbook) was built per beat. The FSPE model results per zone are presented in Table 7. The overall B/C ratio for District 2 was 7.53:1, indicating that there is a $7.53 return in fuel and time savings for each dollar invested in the Road Ranger program.

Table 7: District 2 Road Ranger program B/C ratio summary

Zone	Profile	Delay Saving ($)	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
201	WD	2,285,585	64,231	2,349,816	159,607	14.72
202	WD	881,952	33,981	915,933	158,511	5.78
203	WD	1,828,920	60,970	1,889,890	156,099	12.11
204	WD	942,235	29,560	971,795	154,251	6.30
205	WD	866,073	40,872	906,945	156,318	5.80
208	WD	56,875	2,275	59,150	156,913	0.38
Overall		6,861,641	231,888	7,093,529	941,698	**7.53**

5.3 Benefit-Cost Results District 4

District 4 presents three major areas, Broward County, Palm Beach County, and the Treasure Coast (Indian River, St. Lucie, and Martin counties). From the analysis, Broward and Palm Beach counties are characterized by a higher number of incidents, especially right shoulder breakdowns, while the Treasure Coast presents a lower number of incidents. The FSPE model was used to calculate the B/C ratios based on the interaction of the number of incidents, incident types, and traffic profiles. The FSPE model results per zone are presented in Table 10 and Table 9.

Table 8: District 4 Road Ranger program B/C ratio summary

Zone	Profile	Delay Saving ($)	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
B1	WE	1,131,012	46,452	1,177,463	168,131	7.00
B1&B8	WD	5,252,340	215,718	5,468,057	493,979	11.07
B1*&B8*	WE	608,811	25,938	634,749	190,145	3.34
B1*&B8*	WD	1,163,667	49,578	1,213,245	477,192	2.54
B2	WE	2,812,958	115,029	2,927,987	165,668	17.67
B2&B9	WD	10,136,444	414,506	10,550,950	487,799	21.63
B3	WE	1,525,128	65,086	1,590,214	197,117	8.07
B3&B10	WD	12,079,645	515,504	12,595,149	566,725	22.22
B4	WE	334,784	13,256	348,040	92,003	3.78
B4	WD	75,377	2,984	78,361	230,891	0.34
B5	WE	509,600	18,540	528,140	89,656	5.89
B5&B11	WD	1,884,432	68,557	1,952,990	297,039	6.57

Zone	Profile	Delay Saving ($)	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
B6&B12	WD	375,949	16,303	392,252	284,093	1.38
PB1	WE	786,427	28,387	814,814	81,469	10.00
PB1	WD	2,578,001	93,054	2,671,056	204,457	13.06
PB2	WE	802,238	31,764	834,002	86,328	9.66
PB2	WD	1,785,386	70,691	1,856,077	216,651	8.57
PB3	WE	383,475	15,095	398,570	87,044	4.58
PB3	WD	1,473,533	58,005	1,531,538	218,447	7.01
PB4	WD	1,353,907	53,296	1,407,203	204,875	6.87
PB5	WD	141,343	5,564	146,907	207,965	0.71
PBE1	WE	2,588	102	2,689	26,208	0.10
sPBE1	WD	23,660	929	24,590	65,772	0.37
PBE2	WE	25,014	990	26,005	26,208	0.99
PBE2	WD	60,395	2,391	62,787	65,772	0.95
PBE3	WE	16,422	646	17,068	26,208	0.65
PBE3	WD	170,660	6,718	177,378	65,772	2.70
PBE4	WD	3,025	119	3,144	65,772	0.05
TC1	WD	623,799	22,230	646,029	223,124	2.90
TC2	WD	54,091	1,761	55,852	207,130	0.27
TC3	WD	52,748	1,717	54,465	195,687	0.28
TC4	WD	22,583	789	23,373	199,070	0.12
TC5	WD	16,133	585	16,718	199,320	0.08
TC6	WD	160,833	5,048	165,881	201,158	0.82
TC7	WD	18,721	588	19,309	195,353	0.10
TC8	WD	58,023	1,821	59,844	195,061	0.31
Overall		48,503,153	1,969,742	50,472,895	7,005,288	**7.20**

The overall B/C ratio for District 4 was 7.20:1, indicating that there is a $7.20 return in fuel and time savings for each dollar invested in the Road Ranger program.

5.4 Benefit-Cost Results District 5

District 5 has Road Ranger service on weekdays and weekends as presented in previous sections. The majority of the incident types are accidents with lane blockage and breakdowns with right shoulder blockage (65%, weekdays). The results of the FSPE model runs are presented in Table 9. It can be observed that District 5 has an overall B/C ratio of 4.52:1, indicating a positive effect of the Road Ranger program in producing delay and fuel savings to motorists.

Table 9: District 5 Road Ranger program B/C ratio summary

Zone	Profile	Delay Saving (s)	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
5/6	WE	521,310	21,715	543,025	53,136	10.22
5/6	WD	241,821	10,073	251,894	128,556	1.96
3.4.5	WD	73,932	2,817	76,749	48,773	1.57
4/5	WE	32,083	1,293	33,376	32,515	1.03
4/5	WD	583,720	23,519	607,239	81,621	7.44
3/4	WE	45,925	1,699	47,624	29,948	1.59
3/4	WD	457,048	16,911	473,959	128,843	3.68
2/3	WE	128,220	4,767	132,988	16,258	8.18
2/3	WD	755,907	28,106	784,013	122,830	6.38
1/2/3	WD	118,186	4,293	122,479	32,515	3.77
1/2	WE	208,000	7,595	215,595	38,134	5.65
1/2	WD	327,846	11,971	339,817	90,333	3.76
Overall		3,493,999	134,760	3,628,759	803,462	**4.52**

5.5 Benefit-Cost Results District 6

District 6 has both weekend and weekday Road Ranger service. Right shoulder breakdowns and left shoulder breakdowns constitute over 75 percent of all the incidents occurring during weekdays. The results of the FSPE model are presented in Table 10.

Table 10: District 6 Road Ranger program B/C ratio summary

Zone	Profile	Delay Saving (s)	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
101	WD	1,127,616	44,764	1,172,380	170,016	6.90
102	WD	331,450	13,739	345,189	170,016	2.03
103	WD	1,266,339	58,174	1,324,513	170,016	7.79
104,105	District wide					
8261	WD	957,225	38,289	995,514	170,016	5.86
8262	WD	3,083,531	116,404	3,199,935	170,016	18.82
8263	WE	2,251,631	90,065	2,341,696	131,360	17.83
8263	WD	66,683	2,667	69,351	138,475	0.50
8264	WE	237,278	8,957	246,236	111,301	2.21
8264	WD	48,891	1,846	50,737	134,091	0.38
8266	WD	1,949,290	77,205	2,026,494	190,256	10.65
951	WD	4,135,599	179,793	4,315,391	170,016	25.38
952	WD	1,511,562	69,082	1,580,644	170,016	9.30
953,957	WD	1,433,887	66,213	1,500,100	380,512	3.94
954	WE	1,882,717	81,850	1,964,567	96,447	20.37
954	WD	96,705	4,204	100,909	101,691	0.99
955	WE	1,108,987	48,213	1,157,199	107,963	10.72
955	WD	14,016	609	14,626	113,811	0.13
956	WE	477,147	22,033	499,181	93,890	5.32
956	WD	32,350	1,494	33,844	98,975	0.34

Zone	Profile	Delay Saving (s)	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
Overall		22,012,905	925,600	22,938,504	2,888,883	**7.94**

Beats 104 and 105 in Table 10 are district wide beats using a flatbed truck. These trucks support the Road Rangers by providing quick towing truck response and thus helping in the reduction of incident clearance times. The effect of these trucks is reflected in the calculated mean time spent. The costs for these trucks were prorated and distributed countywide since these trucks can be used on any beat.

It can be observed that the overall B/C ratio for District 6 is 7.94:1. This B/C ratio is the result of the interaction of the incident distribution, mean time spent, and traffic profiles. For the case of District 6, the dominant incident type was breakdowns on the right shoulder, which requires approximately half the time to clear as compared to accidents with lane blockages. The current B/C ratio shows that for an event without a significant percent of accidents or lane blockages, the Road Ranger service has a positive effect in alleviating congestion and improving mobility. A value of 7.94 indicates a significant return in fuel and delay savings over every dollar invested in the Road Ranger program.

5.6 Benefit-Cost Results District 7

District 7 has both weekend and weekday Road Ranger service. The results of the FSPE model runs are shown in Table 11.

Table 11: District 7 Road Ranger program B/C ratio summary

Zone	Profile	Delay Saving (s)	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
1	WD	359,349	15,045	374,394	134,676	2.78
2	WD	724,900	29,834	754,734	218,849	3.45
3	WD	3,158,979	131,940	3,290,919	179,568	18.33
4	WD	1,945,590	81,826	2,027,416	179,568	11.29
5	WD	2,702,614	102,092	2,804,706	134,676	20.83
6	WD	3,636,311	137,021	3,773,332	179,568	21.01
7	WD	2,995,646	125,119	3,120,765	134,676	23.17
8	WD	1,269,717	42,697	1,312,414	179,568	7.31
9	WD	985,135	35,171	1,020,306	179,568	5.68
10	WD	1,007,036	35,953	1,042,988	179,568	5.81
11	WD	5,028,360	179,520	5,207,880	179,568	29.00
12	WD	897,282	37,567	934,850	179,568	5.21
21	WE	1,028,879	43,077	1,071,956	71,552	14.98
21	WD	10,171	426	10,597	72,950	0.15
22	WE	150,912	6,224	157,136	53,664	2.93
25	WE	984,254	37,181	1,021,434	71,552	14.28
25	WD	27,708	1,047	28,755	72,950	0.39
26	WE	884,827	33,341	918,169	71,552	12.83
27	WE	247,212	10,325	257,537	82,732	3.11

Zone	Profile	Delay Saving (s)	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
27	WD	21,535	906	22,441	72,950	0.31
Overall		28,066,417	1,086,312	29,152,729	2,629,323	**11.09**

District 7 has an overall B/C ratio of 11.09:1. This relatively high value is due to the combination of increased traffic volumes and incident distribution. For District 7, lane blocking accidents are the predominant incident type, followed by breakdowns with lane blockage. These two categories account for 67 percent of all the cases. Accident causing lane blockages have an average duration of 50.13 minutes, in contrast with breakdowns which are being resolved in 33 minutes after arriving on the scene. The combined effect of incident duration and traffic volumes causes an extended, reduced capacity condition that makes the Road Ranger service more valuable to motorists.

5.7 Benefit-Cost Results Florida's Turnpike

Florida's Turnpike has weekend and weekday Road Ranger service. The results of the FSPE model are presented in Table 12. It can be observed that the overall B/C ratio is 3.28:1. This indicates a positive effect of the Road Ranger service on delay and fuel savings to motorists. These results take into consideration the standard open road policy of a 30 minute response time to provide traffic control at an incident scene. Also, it is relevant to mention that the Road Ranger program has a $3.28 return for every dollar invested in the program, even under the increased service standards of the Turnpike (e.g., decrease congestion, and wide shoulders).

Table 12: Turnpike Enterprise Road Ranger program B/C ratio summary

Zone		Profile	Delay	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
Urban	R1	WD	272,841	10,977	283,818	81,132	3.50
	R2	WE	943,695	37,968	981,663	120,463	8.15
	R2	WD	2,308,142	92,864	2,401,006	273,822	8.77
	R3	WE	42,323	1,703	44,026	144,986	0.30
	R3	WD	472,810	19,023	491,832	335,759	1.46
	R4	WD	276,449	11,122	287,571	81,132	3.54
	R5	WE	697,555	28,065	725,620	199,639	3.63
	R5	WD	2,109,968	84,891	2,194,859	420,181	5.22
	R6	WE	623	25	649	32,124	0.02
	R6	WD	60,370	2,429	62,799	141,982	0.44
	R7	WE	333,541	13,419	346,960	108,417	3.20
	R7	WD	856,103	34,444	890,547	243,397	3.66
	Subtotal		8,374,421	336,929	8,711,349	2,183,036	**3.99**
Rural	R8	WE	14,841	597	15,438	32,124	0.48
	R8	WD	77,345	3,112	80,457	141,982	0.57
	R9	WE	2,187	88	2,275	32,124	0.07
	R9	WD	1,599	64	1,664	81,132	0.02
	R10	WE	6,416	258	6,674	32,124	0.21

Zone		Profile	Delay	Fuel Saving ($)	Total Benefits ($)	Cost ($)	B/C Ratio
	R10	WD	4,599	185	4,784	81,132	0.06
	R11	WE	64,114	2,579	66,693	71,300	0.94
	R11	WD	680,568	27,381	707,949	180,078	3.93
	R12	WE	48,968	1,970	50,938	32,124	1.59
	R12	WD	16,362	658	17,020	81,132	0.21
	Subtotal		916,982	36,893	953,875	765,251	**1.25**
Overall			9,291,403	373,822	9,665,224	2,948,287	**3.28**

5.8 Overall Emission Saving

The total emissions savings (gains) for CO, VOC, and NOx are presented in Table 13. As presented in Figure 2 in section 2.1.3, CO and VOC are reduced in most cases with increased speeds. On the other hand, NOx emissions increased at high speeds, therefore the emissions for these pollutants are increased. The same interpretation can be applied to an incident, arguing that a reduction in speed due to an incident may cause a reduction in NOx emissions. If a congested emissions model for freeways is available, the corresponding emissions can be more accurately modeled (see discussion in section 2.1.3). The total emissions savings were estimated at 7,818 Kg for CO and 90,371 Kg for VOC. For NOx, the emissions increased in 59,829 Kg.

Table 13: Road Ranger program total emission changes of three pollutants summary

District	CO (kg)	ROG (kg)	NO_X (kg)
1	486.93	6,044.68	(4,001.80)
2	333.58	4,140.97	(2,741.48)
4	2,833.53	35,174.91	(23,287.10)
5	193.86	2,406.49	(1,593.19)
6	1,331.50	16,529.02	(10,942.82)
7	1,562.69	19,398.94	(12,842.82)
Turnpike	537.75	6,675.57	(4,419.47)
Florida	**7,817.61**	**90,370.59**	**(59,828.68)**

5.9 Overall Benefit-Cost Results

The results for each FDOT district and for the whole state are presented in Table 14. It can be observed that the B/C ratio for the state is 6.68:1, indicating an overall positive effect of the Road Ranger program in alleviating delays caused by accidents, vehicle breakdowns, and debris.

Figure 42 shows a scatterplot of B/C ratios plotted against the average speed (mph) and proportion of lane blockages. The height of the cube represents the B/C ratio. The speed represents a measure of congestion. Segments with higher speeds tend to have lower B/C ratios. The total percentage or probability of lane blockages per zone is taken as a measure of the severity of the disruption due to the incident. Zones with increased probability of lane blockages tend to have higher B/C ratios. This is consistent with the assumptions and the data used to build the FSPE methodology used in this study. In Florida, a significant proportion of the freeways have wide shoulders, facilitating relocation of some of the incidents away from the travel lanes. Delay estimation models, with specific data from Florida, can be developed using data from SunGuide®.

Table 14: Road Ranger program B/C ratio summary

District	Delay Saving ($)	Fuel Saving ($)	Benefits ($)	Cost ($)	B/C Ratio
1	10,370,679	338,493	10,709,172	2,803,000	3.82
2	6,861,641	231,888	7,093,529	941,698	7.53
4	48,503,153	1,969,742	50,472,895	7,005,288	7.20
5	3,493,999	134,760	3,628,759	803,462	4.52
6	22,012,905	925,600	22,938,504	2,888,883	7.94
7	28,066,417	1,086,312	29,152,729	2,629,323	11.09
Turnpike	9,291,403	373,822	9,665,224	2,948,287	3.28
Florida	128,600,175	5,060,615	133,660,790	20,019,939	**6.68**

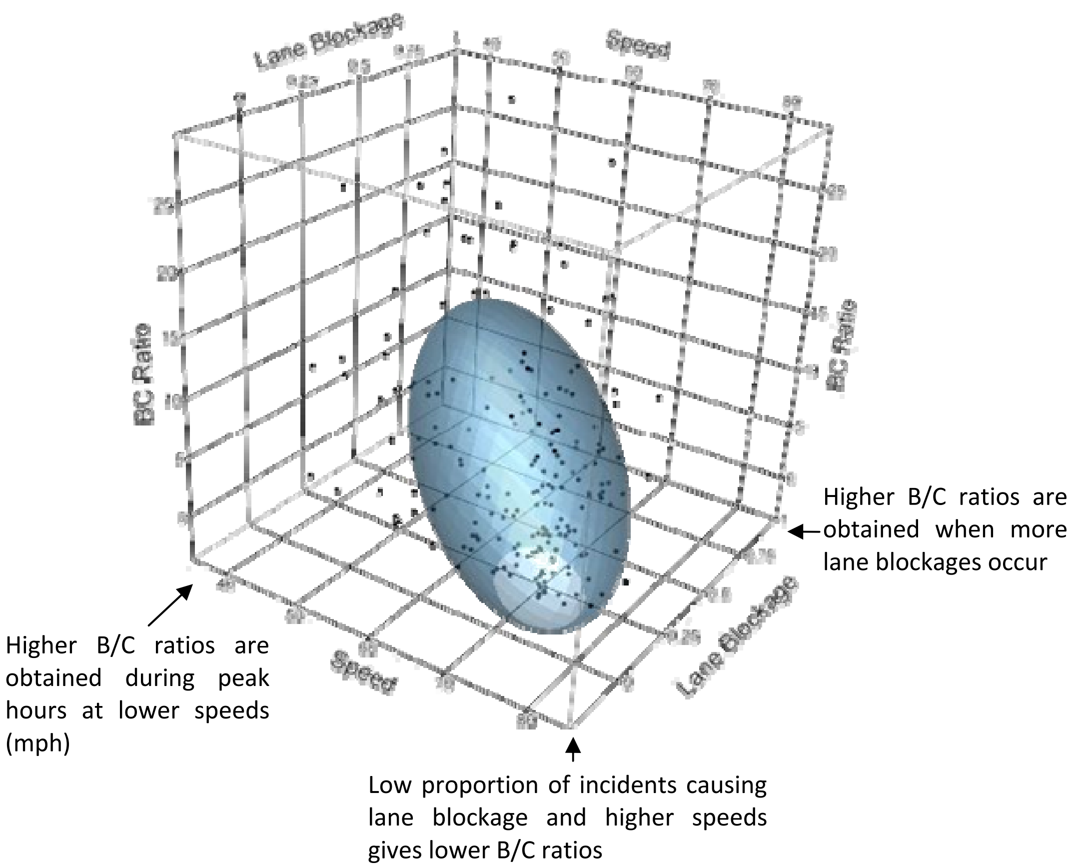

Figure 42: 3-dimensional scatterplot of BC ratios for all districts

6 CONCLUSIONS

In this study, a benefit-cost analysis of the Road Ranger program in the different FDOT districts was performed. The evaluation was carried out using the calibrated FSPE. Several spreadsheets and custom VBA codes in Microsoft Excel were developed to facilitate model building and data handling. A total of 200 models, with each one corresponding to a MS Excel workbook, were developed. Data from the different districts from 2010 was extracted and processed using the Florida SunGuide® system. Compared with the previous B/C ratio analysis [10], more data were collected including more detailed incident data, response time without Road Ranger service, zone information for each district, hourly traffic volume for each zone, average speed, and incident locations.

After applying the updated zone information, incident data, and response time to the recalibrated FSPE model, the overall B/C ratio for the Road Ranger program in 2010 was estimated at 6.68, which indicates that the Road Rangers have a favorable effect in reducing the delay and fuel consumption during freeway incidents. The benefits of the Road Ranger program for each district also well-exceeded the overall cost. The detailed analysis results for each district are summarized as follows:

- District 1
  - The overall B/C ratio for District 1 was 3.82:1, indicating that there is a $3.82 return in fuel and time savings for each dollar invested in the Road Ranger program. The predominant incident type was breakdown on the right shoulder.
  - Breakdowns on the right shoulder, right shoulder debris, and lane blockage debris were the top three categories for lateral distribution of incidents with 70, 9, and 7 percent respectively for weekdays. These three categories account for 76 percent of all the incidents.
  - The top three categories of lateral distribution for incidents during weekends are breakdowns on the right shoulder, debris on the right shoulder, and breakdowns on the left shoulder with 75, 8, and 5 percent respectively. These cases make up 88 percent of incidents.

- District 2
  - The overall B/C ratio for District 2 was 7.53:1, indicating that there is a $7.53 return in fuel and time savings for each dollar invested in the Road Ranger program. The predominant incident type was accident with lane blockages.
  - For District 2, accidents with lane blockage, breakdowns with lane blockage, and breakdowns on the right shoulder were the top three categories for lateral distribution of incidents with 44, 18, and 14 percent respectively. These three categories accounted for 76 percent of all incidents.

- District 4
    - District 4 has an overall B/C ratio of 7.20:1, indicating a positive effect of the Road Ranger program in producing savings in delay and fuel to the motorists. The predominant incident type was right shoulder breakdown.
    - The top three categories of lateral distribution of incidents on weekdays were right shoulder breakdowns, left shoulder breakdowns, and right shoulder accidents with 77, 12, and 3 percent respectively. These categories accounted for 92 percent of the incidents that cause capacity reduction.
    - The top three categories of lateral distribution of incidents on weekends were right shoulder breakdowns, left shoulder breakdowns, and accidents causing lane blockage with 79, 12, and 4 percent respectively. These categories accounted for 94 percent of the incidents causing blockages.

- District 5
    - District 5 has an overall B/C ratio of 4.52, indicating a positive effect of the Road Ranger program in producing savings in delay and fuel to the motorists. The predominant incident type was accident with lane blockages.
    - The top three categories of lateral distribution of incidents on weekdays were accidents with lane blockage, accidents on the right shoulder, and breakdowns causing lane blockages with 44, 21, and 15 percent respectively. These categories accounted for 80 percent of the incidents that cause capacity reduction.
    - The top three categories of lateral distribution of incidents on weekends were accidents with lane blockages, accidents on the right shoulder, and accidents on the left shoulder with 55, 14, and 11 percent respectively. These categories accounted for 80 percent of the incidents causing blockages.

- District 6
    - For the case of District 6, the B/C ratio was calculated at 7.94. The predominant incident type was right shoulder breakdown.
    - Breakdowns on the right shoulder were the top incident/location type in District 6, accounting for 61 percent of all the cases for weekdays. It is followed by breakdowns on the left shoulder with 14 percent and accidents with lane blockages with 8 percent. These cases altogether accounted for 83 percent of all the incidents causing blockage in District 6 occurring on weekdays.
    - The top three occurrences in the lateral distributions of incidents for District 6 for weekends were breakdowns on the right shoulder, breakdowns on the left shoulder, and accidents with lane blockage with 66, 12, and 8 percent respectively. These categories account for 86 percent of the incidents causing lane blockage.

- District 7
    - In District 7 the B/C ratio was calculated at 11.09 indicating a highly positive effect of the Road Ranger program in time and fuel savings. The predominant incident type was accident with lane blockage.
    - The top three categories of lateral distribution of incidents on weekdays were accidents with lane blockage, breakdowns on the left shoulder, and breakdowns causing lane blockages with 50, 19, and 17 percent respectively. These categories accounted for 86 percent of the incidents that cause capacity reduction.
    - The top three categories of lateral distribution of incidents on weekends were accidents with lane blockages, breakdowns on the left shoulder, and breakdowns with lane blockage with 50, 26, and 13 percent respectively. These categories accounted for 89 percent of the incidents causing blockages for occurring on the weekends.

- Florida's Turnpike
    - For the Florida's Turnpike, the B/C ratio was 3.28. For urban areas, this value was 3.99 and for rural areas was 1.25. In rural areas, longer segments and a reduced number of incidents caused a reduction in the B/C ratio. For urban areas, the B/C ratio is significantly influenced by the increased traffic volumes.
    - The top three categories of lateral distribution of incidents on weekdays were breakdowns on the right shoulder, accidents on the right shoulder, and accidents with lane blockages with 31, 23, and 21 percent of the cases respectively. These categories accounted for 75 percent of the incidents causing capacity reductions.
    - The top three categories of lateral distribution for incidents on the Florida's Turnpike for weekends were accidents on the right shoulder, accidents with lane blockage, and breakdowns on the right shoulder with 27, 26, and 22 percent respectively. These cases made up 75 percent of incidents.

- Overall Florida Road Ranger Program
    - The overall B/C ratio for the Road Ranger program was estimated at 6.68, which indicates that the Road Rangers have a favorable effect in reducing the delay and fuel consumption during freeway incidents.
    - The mean time spent was defined as the difference between the departure time and the arrival time of a responder during a particular incident. Overall statistics for Florida showed an average of 45 to 52 minutes for mean time spent on accidents, 18 to 33 minutes for breakdowns, and 11 to 18 minutes for debris.

- Overall Emission Saving
    - The total emissions savings were estimated at 7,818 Kg for CO and 90,371 Kg for VOC. For NOx, the emissions increased in 59,829 Kg. CO and VOC are reduced in most cases with increased speeds. NOx emissions increased at high speeds, therefore the emissions for NO_X are increased.

7 RECOMMENDATIONS

- Continue and expand the Road Ranger program in Florida. In this study, it has been found that even under favorable traffic conditions, the Road Ranger program has a positive impact in alleviating congestion due to traffic incidents.

- Perform annual evaluations or reports on the effectiveness of the Road Ranger program to increase the awareness of the program and facilitate its continuation.

- Current evaluation tools rely on capacity reduction factors calculated in contexts that may not be applicable to all regions in Florida. A joint University-Agency effort to improve the data collection/processing may be necessary to adequately collect, process, and store information to evaluate the Road Ranger program in Florida.

- Create and implement a standardized reporting format for Regional Traffic Management Centers and Road Ranger data across all the FDOT Districts, incorporating automated data collection in the field via tablets or field computers. Also, create standard definitions for incident events for Road Rangers, which can be implemented across all FDOT districts.

- Incorporate an incident delay evaluation procedure in the SunGuide® system. The evaluation procedure can be implemented as a script or based on existing data on the SunGuide® system. The implemented procedure can be run off-line whenever an incident is closed.

- Develop lookup emissions tables specific to Florida for both congested and uncongested freeway scenarios. This will allow a more accurate tracking for different pollutants during incidents, work zones, and special events. It is recommended to have emissions factors based on the MOVES model.

- Develop a model for Road Ranger evaluation with Florida-specific data for freeways capacity reductions, incident types, etc. This model can be made part of SunGuide®.

- Continue with the automation of data collection on Road Ranger assisted incidents and AVL data for all the districts. This will enable further analyses to evaluate benefits of new programs or policies to demonstrate their effectiveness.

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APPENDIX A

Delay Cost Calculation

Table 15: District 1 delay cost

Zone	Value of Time ($/hr)	Percentage of Truck (%)	Average Vehicle Occupancy Rate	Value of Truck Time ($/hr)	Average Occupancy Rate for Truck	Delay Cost ($/hr)
101	$ 16.10	14.26%	1.53	$ 105.67	1.12	$ 37.88
102	$ 16.10	14.26%	1.53	$ 105.67	1.12	$ 37.88
103	$ 16.10	10.75%	1.53	$ 105.67	1.12	$ 34.58
104	$ 16.10	10.75%	1.53	$ 105.67	1.12	$ 34.58
106	$ 16.10	10.59%	1.53	$ 105.67	1.12	$ 34.43
107	$ 16.10	10.59%	1.53	$ 105.67	1.12	$ 34.43
108	$ 16.10	17.02%	1.53	$ 105.67	1.12	$ 40.47
109	$ 16.10	17.02%	1.53	$ 105.67	1.12	$ 40.47
110	$ 16.10	9.68%	1.53	$ 105.67	1.12	$ 33.58
111	$ 16.10	9.68%	1.53	$ 105.67	1.12	$ 33.58
112	$ 16.10	14.26%	1.53	$ 105.67	1.12	$ 37.88
113	$ 16.10	9.18%	1.53	$ 105.67	1.12	$ 33.12

Table 16: District 2 delay cost

Zone	Value of Time ($/hr)	Percentage of Truck (%)	Average Vehicle Occupancy Rate	Value of Truck Time ($/hr)	Average Occupancy Rate for Truck	Delay Cost ($/hr)
201	$ 16.10	19.76%	1.53	$ 105.67	1.12	$ 43.04
202	$ 16.10	7.35%	1.53	$ 105.67	1.12	$ 31.39
203	$ 16.10	12.56%	1.53	$ 105.67	1.12	$ 36.28
204	$ 16.10	14.98%	1.53	$ 105.67	1.12	$ 38.55
205	$ 16.10	1.21%	1.53	$ 105.67	1.12	$ 25.63
206	$ 16.10	1.67%	1.53	$ 105.67	1.12	$ 26.06
207	$ 16.10	8.73%	1.53	$ 105.67	1.12	$ 32.69
208	$ 16.10	6.13%	1.53	$ 105.67	1.12	$ 30.24

Table 17: District 4 delay cost

Zone	Value of Time ($/hr)	Percentage of Truck (%)	Average Vehicle Occupancy Rate	Value of Truck Time ($/hr)	Average Occupancy Rate for Truck	Delay Cost ($/hr)
B1	$ 16.10	5.28%	1.53	$ 105.67	1.12	$ 29.45
B1*	$ 16.10	4.15%	1.53	$ 105.67	1.12	$ 28.39
B2	$ 16.10	5.42%	1.53	$ 105.67	1.12	$ 29.58
B3	$ 16.10	4.10%	1.53	$ 105.67	1.12	$ 28.34
B4	$ 16.10	6.45%	1.53	$ 105.67	1.12	$ 30.55
B5	$ 16.10	9.33%	1.53	$ 105.67	1.12	$ 33.25
B6	$ 16.10	3.62%	1.53	$ 105.67	1.12	$ 27.89
PB1	$ 16.10	9.61%	1.53	$ 105.67	1.12	$ 33.51
PB2	$ 16.10	6.45%	1.53	$ 105.67	1.12	$ 30.55
PB3	$ 16.10	6.64%	1.53	$ 105.67	1.12	$ 30.73
PB4	$ 16.10	6.64%	1.53	$ 105.67	1.12	$ 30.73
PB5	$ 16.10	6.64%	1.53	$ 105.67	1.12	$ 30.73
PBE1	$ 16.10	6.72%	1.53	$ 105.67	1.12	$ 30.80
PBE2	$ 16.10	6.45%	1.53	$ 105.67	1.12	$ 30.55
PBE3	$ 16.10	6.64%	1.53	$ 105.67	1.12	$ 30.73
PBE4	$ 16.10	6.64%	1.53	$ 105.67	1.12	$ 30.73
TC1	$ 16.10	10.07%	1.53	$ 105.67	1.12	$ 33.94
TC2	$ 16.10	13.49%	1.53	$ 105.67	1.12	$ 37.16
TC3	$ 16.10	13.49%	1.53	$ 105.67	1.12	$ 37.16
TC4	$ 16.10	10.78%	1.53	$ 105.67	1.12	$ 34.61
TC5	$ 16.10	9.42%	1.53	$ 105.67	1.12	$ 33.34
TC6	$ 16.10	14.96%	1.53	$ 105.67	1.12	$ 38.54
TC7	$ 16.10	14.96%	1.53	$ 105.67	1.12	$ 38.54
TC8	$ 16.10	14.96%	1.53	$ 105.67	1.12	$ 38.54

Table 18: District 5 delay cost

Zone	Value of Time ($/hr)	Percentage of Truck (%)	Average Vehicle Occupancy Rate	Value of Truck Time ($/hr)	Average Occupancy Rate for Truck	Delay Cost ($/hr)
5/6	$ 16.10	4.84%	1.53	$ 105.67	1.12	$ 29.04
3.4.5	$ 16.10	7.72%	1.53	$ 105.67	1.12	$ 31.74
4/5	$ 16.10	5.89%	1.53	$ 105.67	1.12	$ 30.02
3/4	$ 16.10	8.73%	1.53	$ 105.67	1.12	$ 32.69
2/3	$ 16.10	8.56%	1.53	$ 105.67	1.12	$ 32.53
1/2/3	$ 16.10	9.38%	1.53	$ 105.67	1.12	$ 33.30
1/2	$ 16.10	4.84%	1.53	$ 105.67	1.12	$ 29.04

Table 19: District 6 delay cost

Zone	Value of Time ($/hr)	Percentage of Truck (%)	Average Vehicle Occupancy Rate	Value of Truck Time ($/hr)	Average Occupancy Rate for Truck	Delay Cost ($/hr)
101	$ 16.10	6.37%	1.53	$ 105.67	1.12	$ 30.47
102	$ 16.10	4.99%	1.53	$ 105.67	1.12	$ 29.18
103	$ 16.10	1.96%	1.53	$ 105.67	1.12	$ 26.33
8261	$ 16.10	6.12%	1.53	$ 105.67	1.12	$ 30.24
8262	$ 16.10	8.04%	1.53	$ 105.67	1.12	$ 32.04
8263	$ 16.10	6.12%	1.53	$ 105.67	1.12	$ 30.24
8264	$ 16.10	8.04%	1.53	$ 105.67	1.12	$ 32.04
8266	$ 16.10	6.44%	1.53	$ 105.67	1.12	$ 30.54
951	$ 16.10	3.55%	1.53	$ 105.67	1.12	$ 27.82
952	$ 16.10	2.10%	1.53	$ 105.67	1.12	$ 26.47
953,957	$ 16.10	1.81%	1.53	$ 105.67	1.12	$ 26.19
954	$ 16.10	3.55%	1.53	$ 105.67	1.12	$ 27.82
955	$ 16.10	1.96%	1.53	$ 105.67	1.12	$ 26.33
956	$ 16.10	6.12%	1.53	$ 105.67	1.12	$ 30.24

Table 20: District 7 delay cost

Zone	Value of Time ($/hr)	Percentage of Truck (%)	Average Vehicle Occupancy Rate	Value of Truck Time ($/hr)	Average Occupancy Rate for Truck	Delay Cost ($/hr)
1	$ 16.10	4.68%	1.53	$ 105.67	1.12	$ 28.89
2	$ 16.10	5.22%	1.53	$ 105.67	1.12	$ 29.39
3	$ 16.10	4.76%	1.53	$ 105.67	1.12	$ 28.96
4	$ 16.10	4.54%	1.53	$ 105.67	1.12	$ 28.76
5	$ 16.10	8.02%	1.53	$ 105.67	1.12	$ 32.02
6	$ 16.10	8.10%	1.53	$ 105.67	1.12	$ 32.10
7	$ 16.10	4.76%	1.53	$ 105.67	1.12	$ 28.96
8	$ 16.10	12.23%	1.53	$ 105.67	1.12	$ 35.97
9	$ 16.10	10.00%	1.53	$ 105.67	1.12	$ 33.88
10	$ 16.10	10.00%	1.53	$ 105.67	1.12	$ 33.88
11	$ 16.10	10.00%	1.53	$ 105.67	1.12	$ 33.88
12	$ 16.10	4.68%	1.53	$ 105.67	1.12	$ 28.89
21	$ 16.10	4.68%	1.53	$ 105.67	1.12	$ 28.89
22	$ 16.10	5.15%	1.53	$ 105.67	1.12	$ 29.33
25	$ 16.10	8.02%	1.53	$ 105.67	1.12	$ 32.02
26	$ 16.10	8.10%	1.53	$ 105.67	1.12	$ 32.10
27	$ 16.10	4.76%	1.53	$ 105.67	1.12	$ 28.96
P1	$ 16.10	14.26%	1.53	$ 105.67	1.12	$ 37.88
P2	$ 16.10	15.51%	1.53	$ 105.67	1.12	$ 39.05
P3	$ 16.10	14.26%	1.53	$ 105.67	1.12	$ 37.88
T1	$ 16.10	10.00%	1.53	$ 105.67	1.12	$ 33.88
E1	$ 16.10	10.00%	1.53	$ 105.67	1.12	$ 33.88

Table 21: Turnpike Enterprise delay cost

Zone	Value of Time ($/hr)	Percentage of Truck (%)	Average Vehicle Occupancy Rate	Value of Truck Time ($/hr)	Average Occupancy Rate for Truck	Delay Cost ($/hr)
R1	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R2	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R3	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R4	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R5	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R6	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R7	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R8	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R9	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R10	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R11	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
R12	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06
O1	$ 16.10	5.34%	1.53	$ 105.67	1.12	$ 29.51
O2	$ 16.10	5.16%	1.53	$ 105.67	1.12	$ 29.33
O3	$ 16.10	6.71%	1.53	$ 105.67	1.12	$ 30.79
O4	$ 16.10	9.36%	1.53	$ 105.67	1.12	$ 33.28
O5	$ 16.10	3.44%	1.53	$ 105.67	1.12	$ 27.72
O6	$ 16.10	5.60%	1.53	$ 105.67	1.12	$ 29.75
V1	$ 16.10	5.93%	1.53	$ 105.67	1.12	$ 30.06

APPENDIX B

Beat Service Coverage for Each District

Table 22: Service coverage for District 1

Zone	Length (mi)	Profile	Shift Start	Shift End
101	32.00	WE	6:00	18:00
101	32.00	WD	9:00	21:00
102	32.00	WE	7:00	19:00
102	32.00	WD	9:00	21:00
103	70.32	WE	5:00	21:00
103	70.32	WD	12:00	20:00
104	70.32	WE	6:00	22:00
104	70.32	WD	9:00	21:00
106	27.34	WE	6:00	18:00
106	27.34	WD	9:00	21:00
107	27.34	WE	7:00	19:00
107	27.34	WD	9:00	21:00
108	26.68	WE	6:00	18:00
108	26.68	WD	9:00	21:00
109	26.68	WE	7:00	19:00
109	26.68	WD	9:00	21:00
110	43.00	WE	6:00	18:00
110	43.00	WD	9:00	21:00
111	43.00	WE	7:00	19:00
111	43.00	WD	9:00	21:00
112	17.00	WE	6:00	18:00
112	17.00	WD	9:00	21:00
113	21.00	WE	6:00	18:00
113	21.00	WD	9:00	21:00

Table 23: Service coverage for District 2

Zone	Length (mi)	Profile	Shift Start	Shift End
201	19.74	WD	6:30	18:30
202	18.67	WD	6:30	18:30
203	16.30	WD	6:30	18:30
204	14.50	WD	6:30	18:30
205	16.52	WD	6:30	18:30
206	13.00	WD	6:30	18:30
207	20.03	WD	6:30	18:30
208	16.14	WD	6:30	18:30

Table 24: Service coverage for District 4

Zone	Length (mi)	Profile	Shift Start	Shift End
B1	9.53	WD	6:00	22:00
B1	9.53	WK	6:00	22:00
B1*	5.52	WD	6:00	22:00
B1*	5.52	WK	6:00	22:00
B2	8.31	WD	6:00	22:00
B2	8.31	WK	6:00	22:00
B3	11.80	WD	6:00	22:00
B3	11.80	WK	6:00	22:00
B4	20.41	WD	6:00	22:00
B4	20.41	WK	6:00	22:00
B5	17.32	WD	6:00	22:00
B5	17.32	WK	6:00	22:00
B6	10.51	WD	6:00	22:00
B6	10.51	WK	6:00	22:00
B8	9.53	WD	22:00	6:00
B8	9.53	WK	22:00	6:00
B8*	5.52	WD	22:00	6:00
B8*	5.52	WK	22:00	6:00
B9	8.31	WD	22:00	6:00
B9	8.31	WK	22:00	6:00
B10	11.80	WD	22:00	6:00
B10	11.80	WK	22:00	6:00
B11	17.32	WD	22:00	6:00
B11	17.32	WK	22:00	6:00
B12	10.51	WD	22:00	6:00
B12	10.51	WK	22:00	6:00
PB1	8.38	WD	6:00	22:00
PB1	8.38	WK	6:00	22:00
PBE1	15.45	WD	22:00	6:00
PBE1	15.45	WK	22:00	6:00
PB2	11.90	WK	6:00	22:00
PB2	11.90	WD	6:00	22:00
PBE2	9.75	WK	22:00	6:00
PBE2	9.75	WD	22:00	6:00
PB3	12.42	WK	6:00	22:00
PB3	12.42	WD	6:00	22:00
PBE3	9.62	WK	22:00	6:00
PBE3	9.62	WD	22:00	6:00

Zone	Length (mi)	Profile	Shift Start	Shift End
PB4	8.49	WK	6:00	22:00
PB4	8.49	WD	6:00	22:00
PBE4	15.69	WK	22:00	6:00
PBE4	15.69	WD	22:00	6:00
PB5	9.40	WK	6:00	22:00
PB5	9.40	WD	6:00	22:00
TC1	13.16	WD	6:00	22:00
TC2	6.37	WD	6:00	22:00
TC3	9.42	WD	6:00	22:00
TC4	10.99	WD	6:00	22:00
TC5	11.08	WD	6:00	22:00
TC6	11.97	WD	6:00	22:00
TC7	9.27	WD	6:00	22:00
TC8	9.13	WD	6:00	22:00

Table 25: Service coverage for District 5

Zone	Length (mi)	Profile	Shift Start	Shift End
5/6	23.41	WE	14:30	3:30
5/6	23.41	WD	varies	varies
3.4.5	37.43	WD	varies	varies
4/5	19.41	WE	6:30	15:30
4/5	19.41	WD	varies	varies
3/4	26.24	WE	varies	varies
3/4	26.24	WD	14:30	3:30
2/3	14.51	WE	8:00	17:30
2/3	14.51	WD	varies	varies
1/2/3	40.78	WD	varies	varies
1/2	24.67	WE	0:00	24:00
1/2	24.67	WD	varies	varies

Table 26: Service coverage for District 6

Zone	Length (mi)	Profile	Shift Start	Shift End
101	31.61	WD	5:00	21:00
102	35.68	WD	5:00	21:00
103	19.76	WD	5:00	21:00
104	24.71	WE	0:00	24:00
104	24.71	WD	21:00	5:00
105	71.73	WE	0:00	24:00
105	71.73	WD	21:00	5:00
8261	15.49	WD	5:00	21:00
8262	10.38	WD	5:00	21:00
8263	15.49	WE	0:00	24:00
8263	15.49	WD	21:00	5:00
8264	10.38	WE	0:00	24:00
8264	10.38	WD	21:00	5:00
8266	11.54	WD	5:00	21:00
951	11.74	WD	5:00	21:00
952	19.76	WD	5:00	21:00
953,957	9.66	WD	5:00	21:00
954	11.74	WE	0:00	24:00
954	11.74	WD	21:00	5:00
955	19.76	WE	0:00	24:00
955	19.76	WD	21:00	5:00
956	9.66	WE	0:00	24:00
956	9.66	WD	21:00	5:00

Table 27: Service coverage for District 7

Zone	Length (mi)	Profile	Shift Start	Shift End
1	12.50	WD	6:30	18:30
2	10.50	WD	0:00	24:00
3	6.70	WD	5:30	21:30
4	9.70	WD	5:30	21:30
5	11.10	WD	6:30	18:30
6	14.20	WD	5:30	21:30
7	12.10	WD	6:30	18:30
8	15.50	WD	5:30	21:30
9	17.40	WD	5:30	21:30
10	12.80	WD	5:30	21:30
11	26.60	WD	5:30	21:30
12	13.50	WD	5:30	21:30
21	16.60	WE	5:30	21:30
21	13.10	WD	18:30	6:00
22	10.50	WE	7:30	19:30
25	11.50	WE	5:30	21:30
25	15.40	WD	18:30	6:00
26	14.20	WE	5:30	21:30
27	17.50	WE	0:00	24:00
27	12.90	WD	18:30	6:00
T1	12.80	WD	6:00	10:00
			16:00	20:00
E1	14.00	WD	6:30	18:30

Table 28: Service coverage for Turnpike Enterprise

Zone	Length (mi)	Profile	Shift Start	Shift End
R1	18.44	WD	6:00	10:00
			16:00	20:00
R2	35.11	WE	0:00	24:00
R2	35.11	WD	0:00	24:00
R3	28.48	WE	0:00	24:00
R3	28.48	WD	0:00	24:00
R4	21.64	WD	6:00	10:00
			16:00	20:00
R5	53.03	WE	0:00	24:00
R5	53.03	WD	0:00	24:00
R6	38.37	WE	12:00	20:00
R6	38.37	WD	6:00	20:00
R7	68.79	WE	0:00	24:00
R7	68.79	WD	0:00	24:00
R8	41.35	WE	12:00	20:00
R8	41.35	WD	6:00	20:00
R9	49.44	WE	12:00	20:00
R9	49.44	WD	12:00	20:00
R10	65.87	WE	12:00	20:00
R10	65.87	WD	12:00	20:00
R11	24.17	WE	0:00	24:00
R11	24.17	WD	0:00	24:00
R12	35.66	WE	12:00	20:00
R12	35.66	WD	12:00	20:00
O1	22.54	WE	6:00	20:00
O1	22.54	WD	6:00	20:00
O2	33.20	WE	6:00	20:00
O2	33.20	WD	6:00	20:00
O3	30.84	WE	6:00	20:00
O3	30.84	WD	6:00	20:00
O4	31.86	WE	6:00	20:00
O4	31.86	WD	6:00	20:00
O5	18.85	WE	6:00	20:00
O5	18.85	WD	6:00	20:00
O6	15.89	WE	6:00	20:00
O6	15.89	WD	6:00	20:00
V1	18.35	WD	6:00	10:00
			16:00	20:00

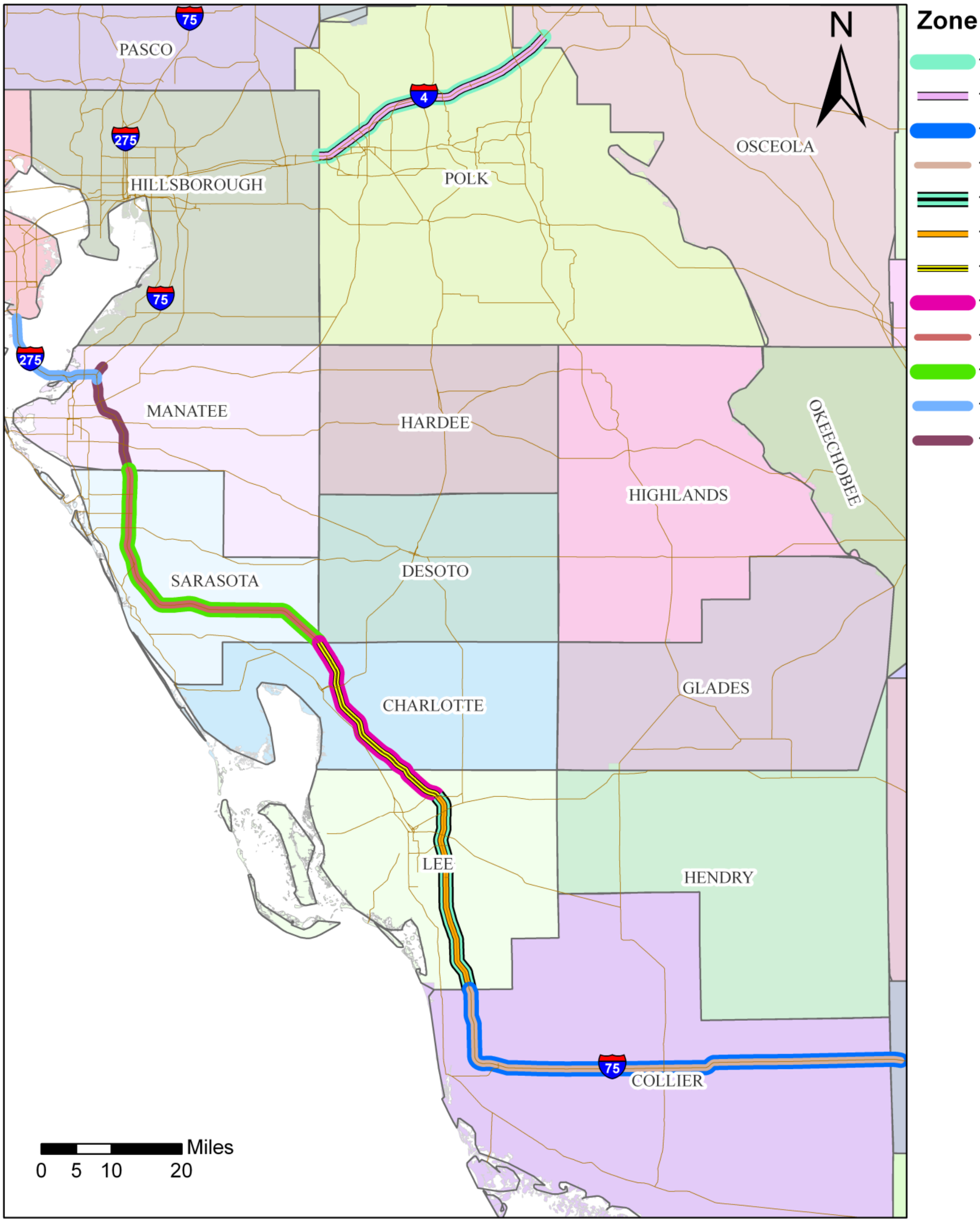
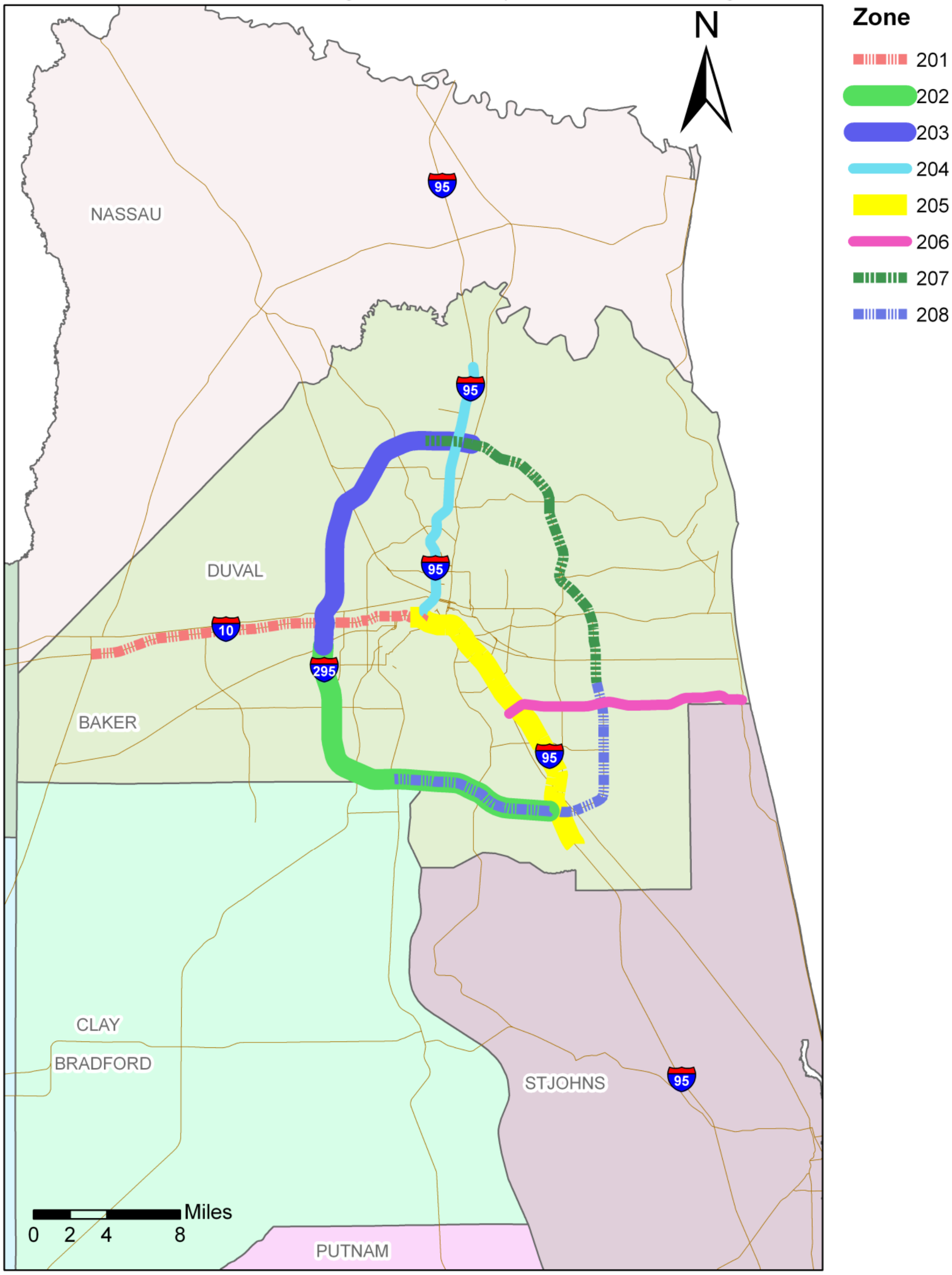


Figure 43: District 1 Road Ranger weekday and weekend coverage



f

Figure 44: District 2 Road Ranger weekday coverage

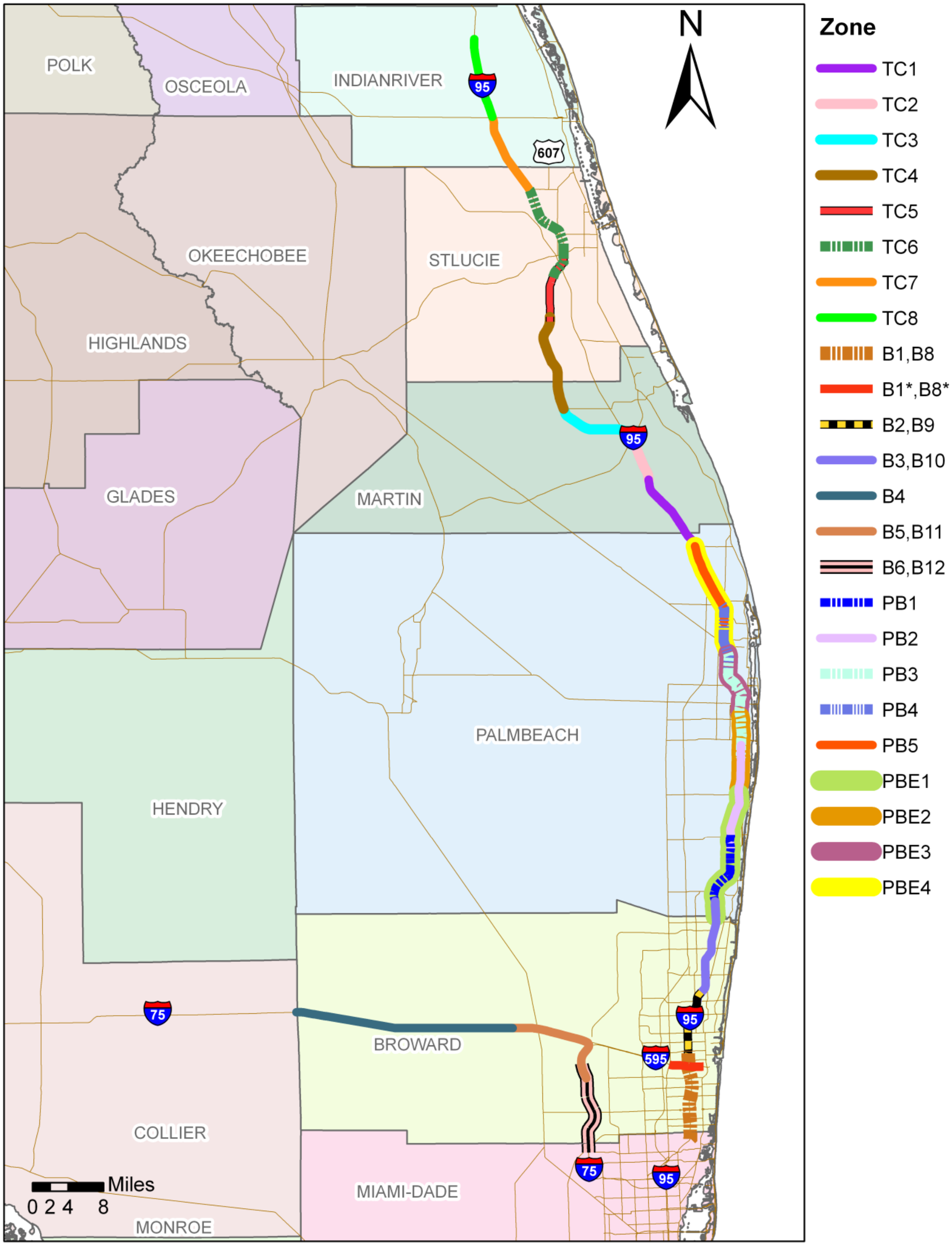


Figure 45: District 4 Road Ranger weekday coverage

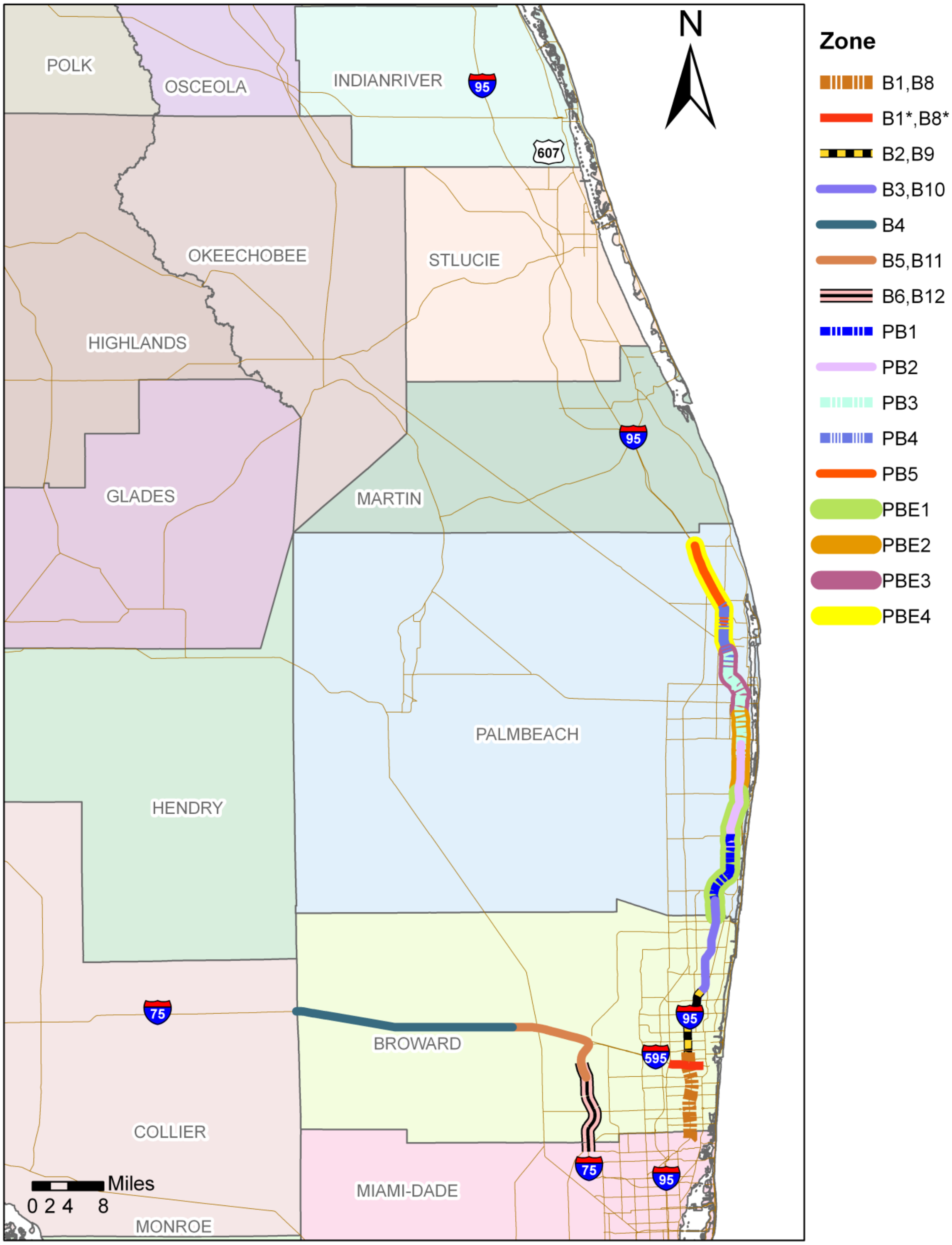


Figure 46: District 4 Road Ranger weekend coverage

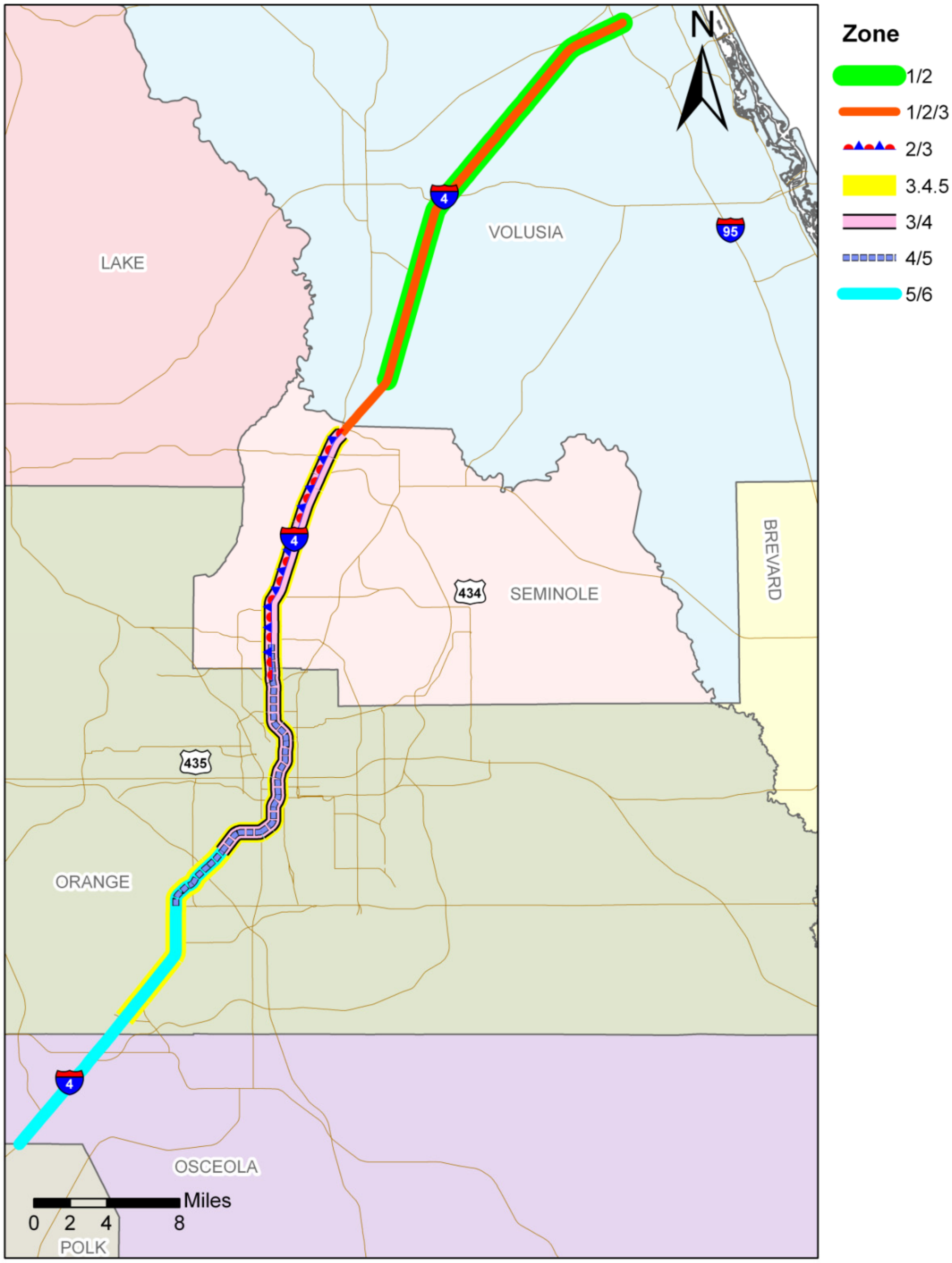


Figure 47: District 5 Road Ranger weekday coverage

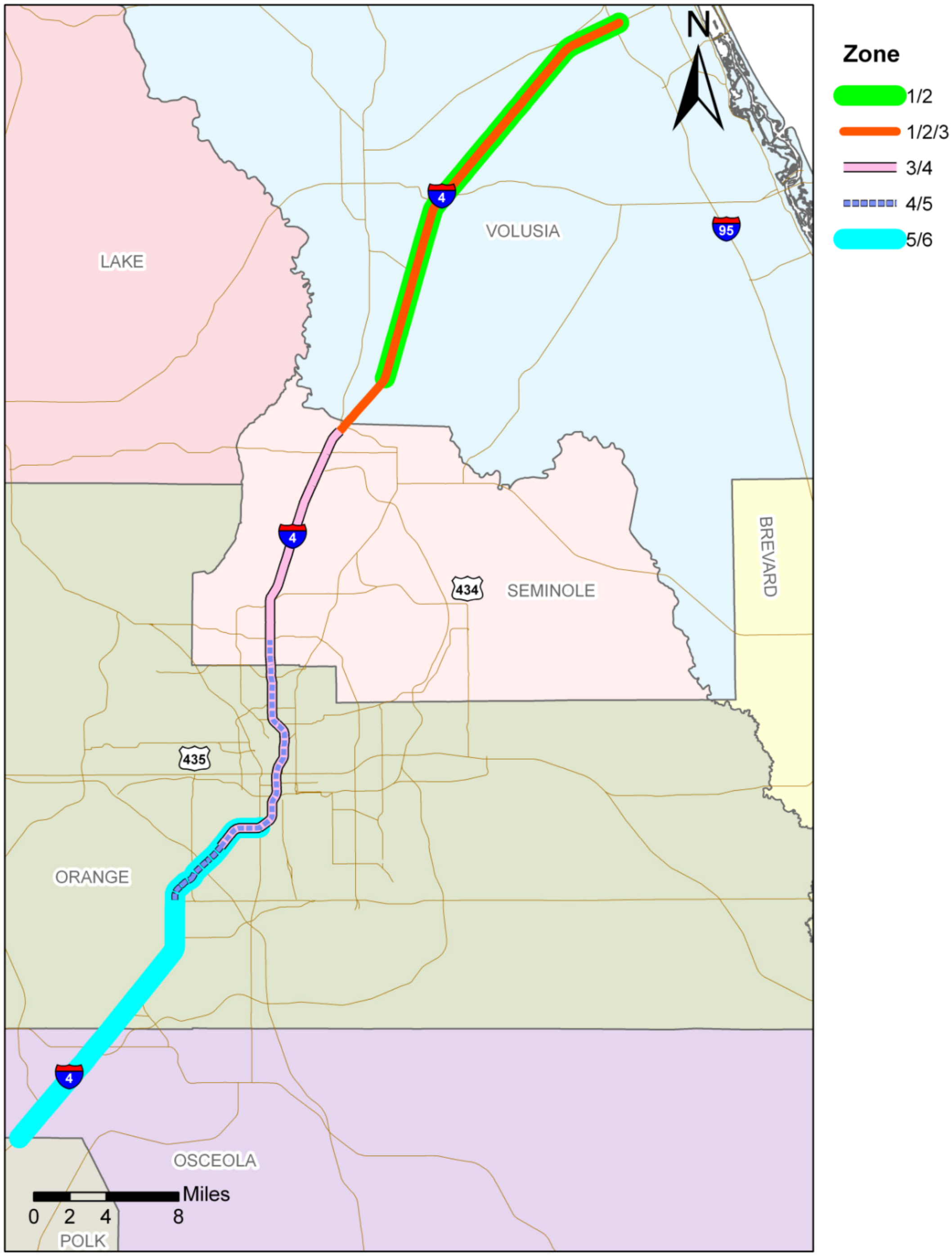


Figure 48: District 5 Road Ranger weekend coverage

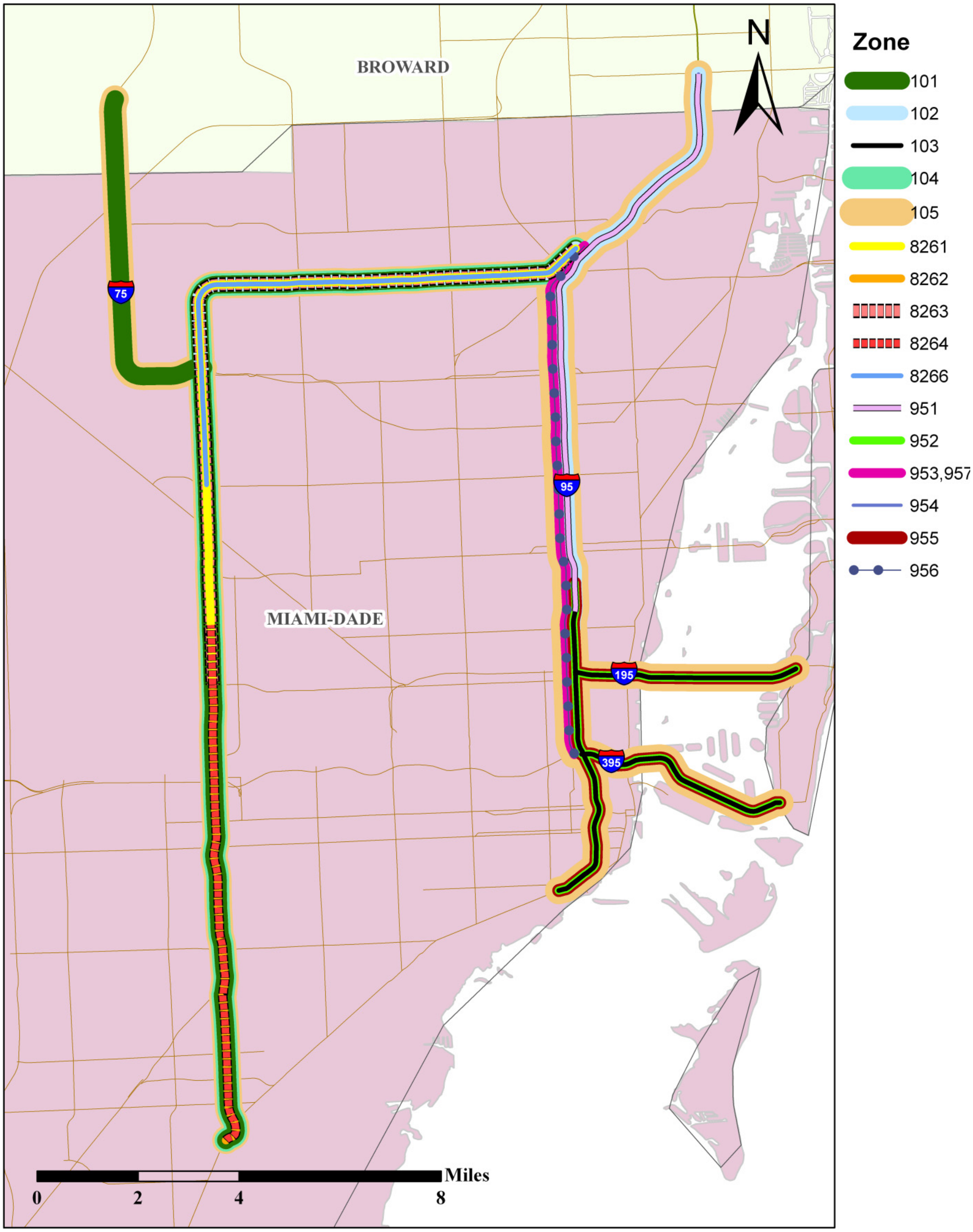


Figure 49: District 6 Road Ranger weekday coverage

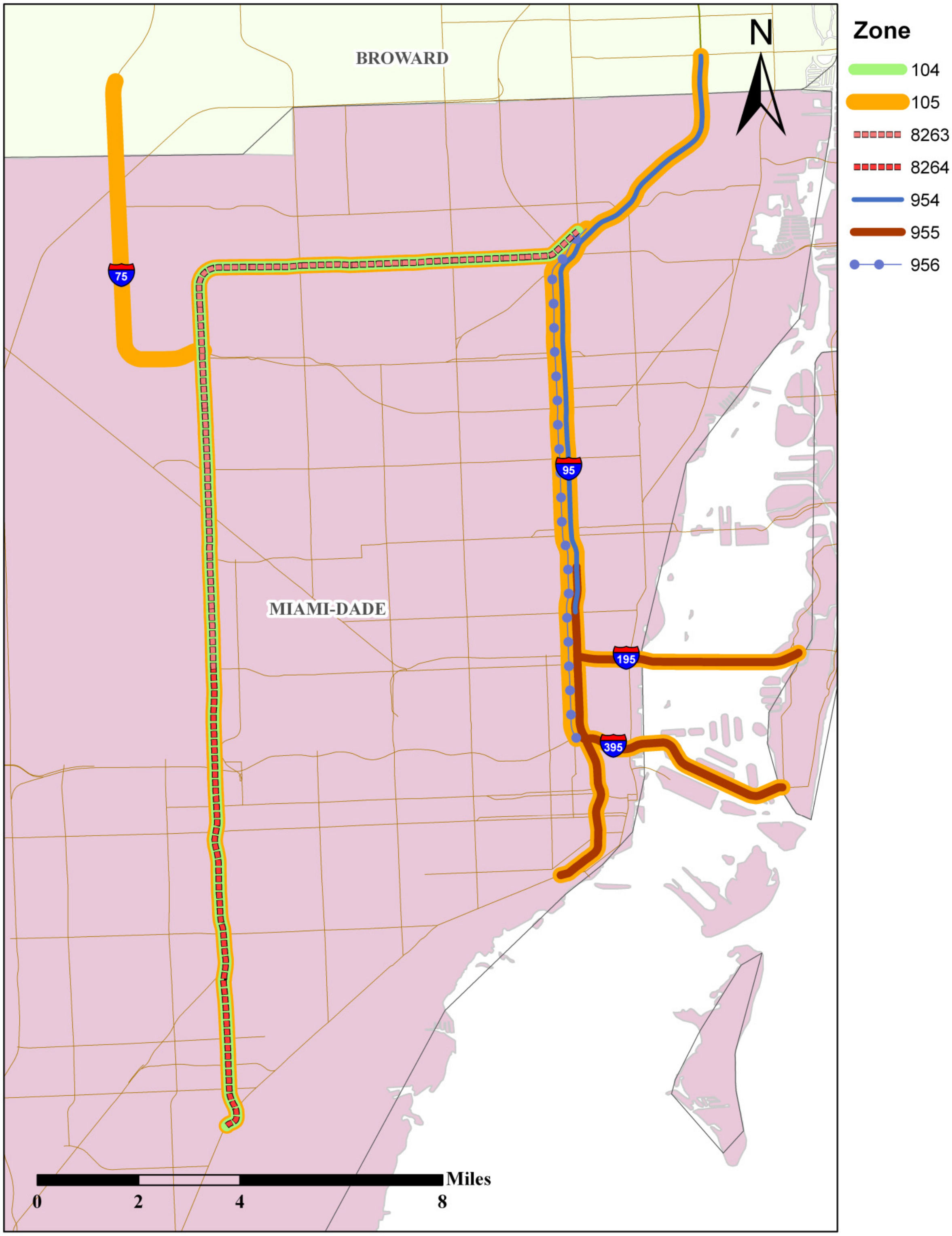


Figure 50: District 6 Road Ranger weekend coverage

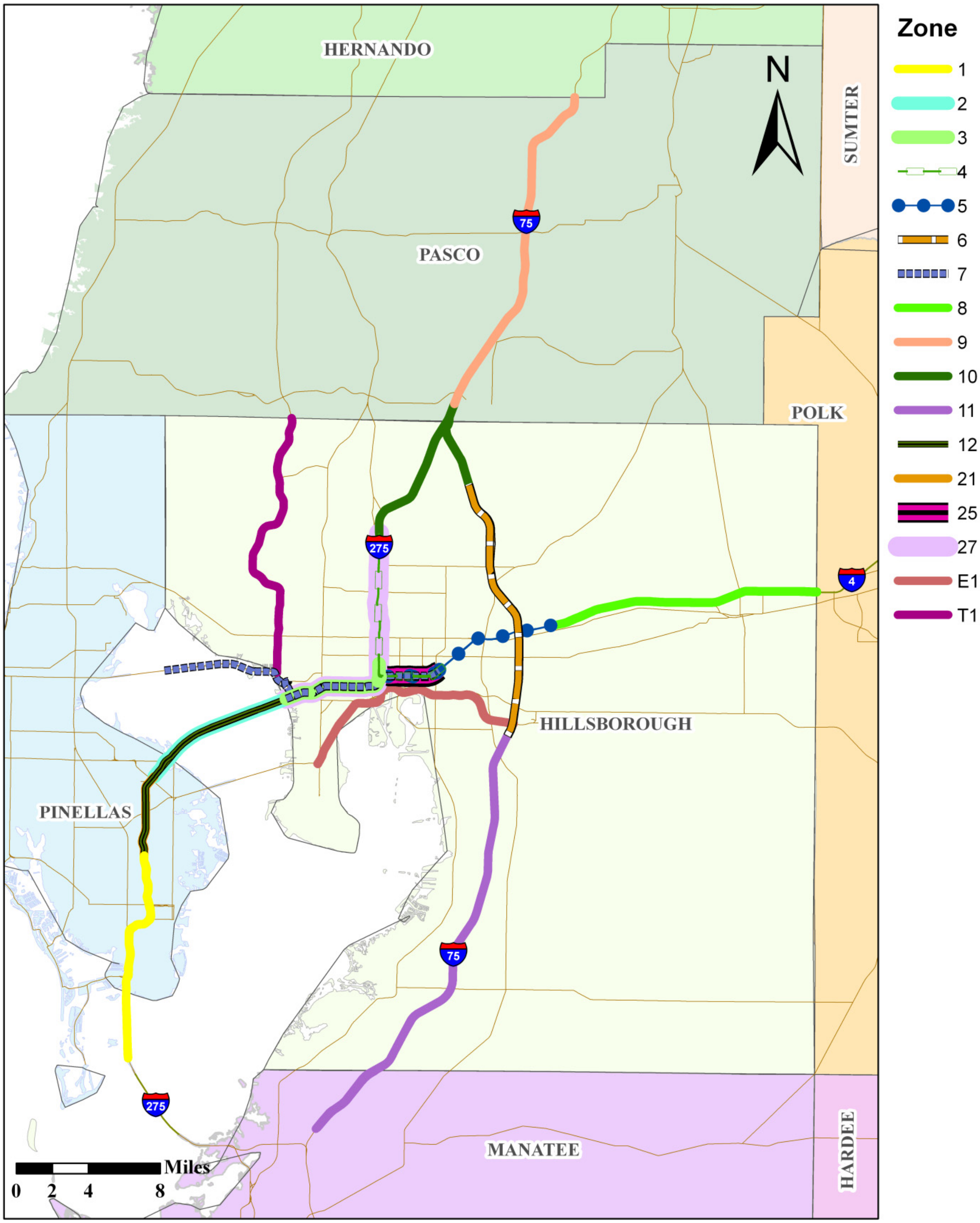


Figure 51: District 7 Road Ranger weekday coverage

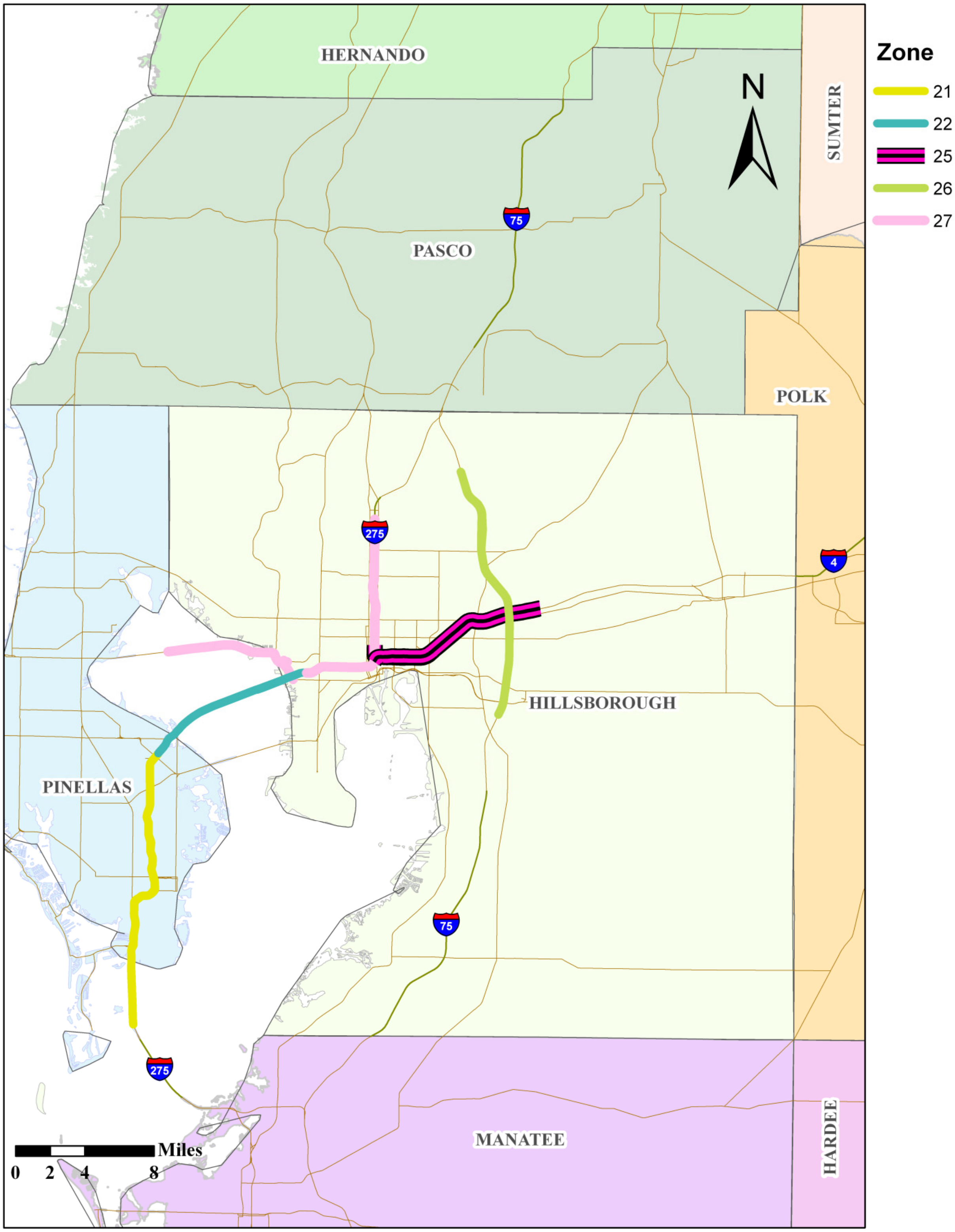


Figure 52: District 7 Road Ranger weekend coverage

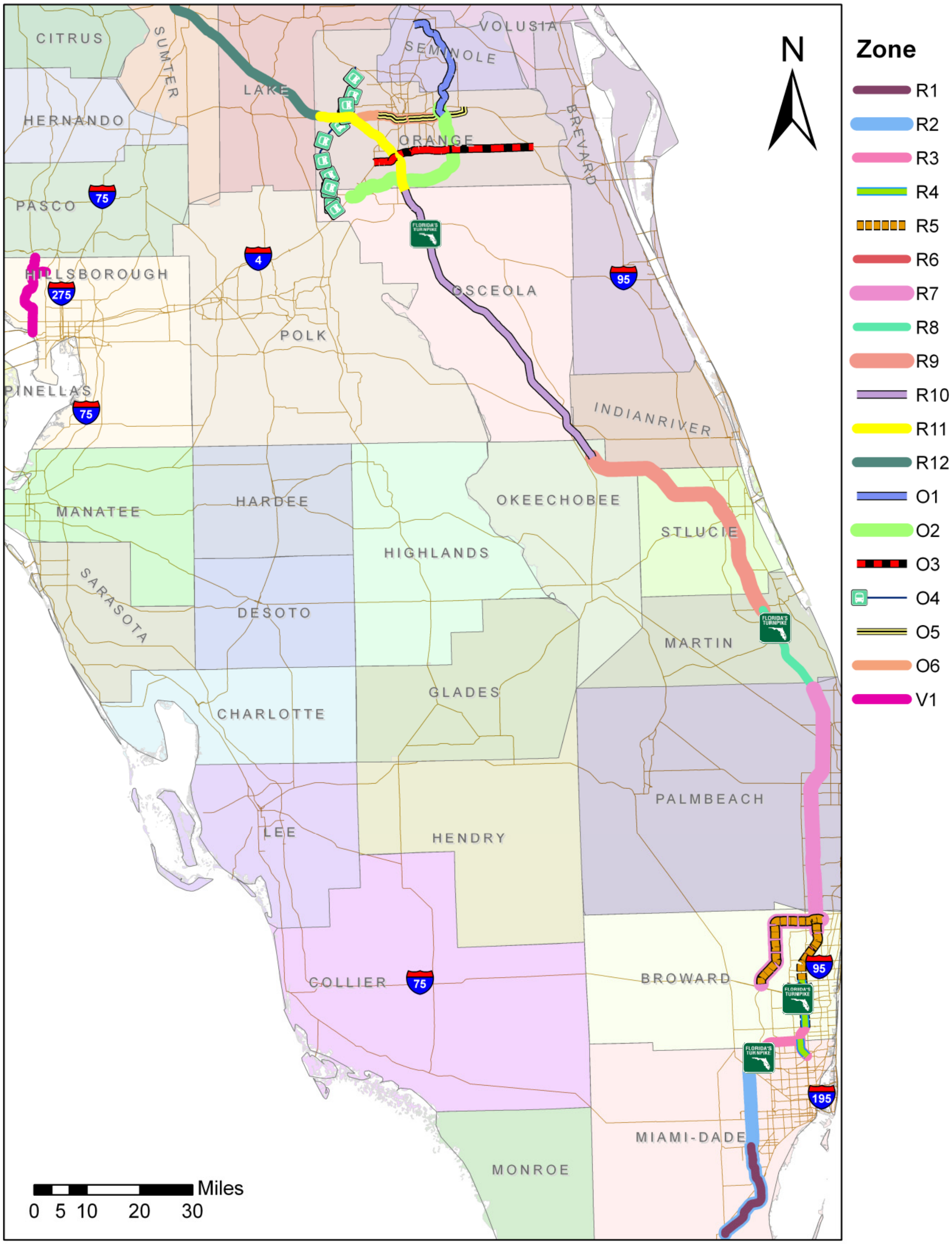


Figure 53: Florida’s Turnpike Enterprise Road Ranger weekday coverage

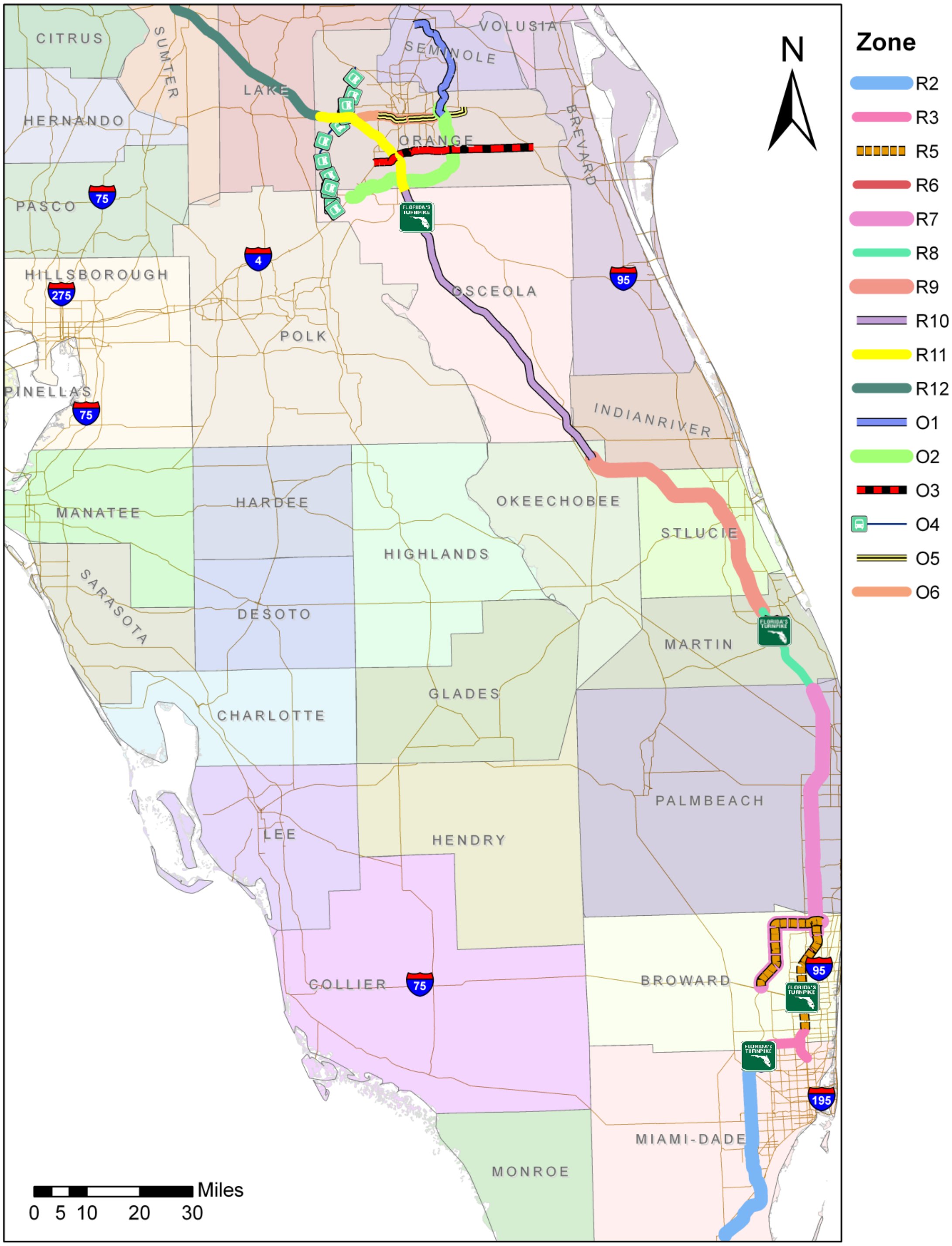


Figure 54: Florida’s Turnpike Enterprise Road Ranger weekend coverage

APPENDIX C

Model Architecture

Several spreadsheets and customized VBA codes in Microsoft Excel were developed to facilitate model building and data handling. A total of 204 models, each one corresponding to a MS Excel workbook, were developed. The information flow on the model architecture is presented in Figure 55.

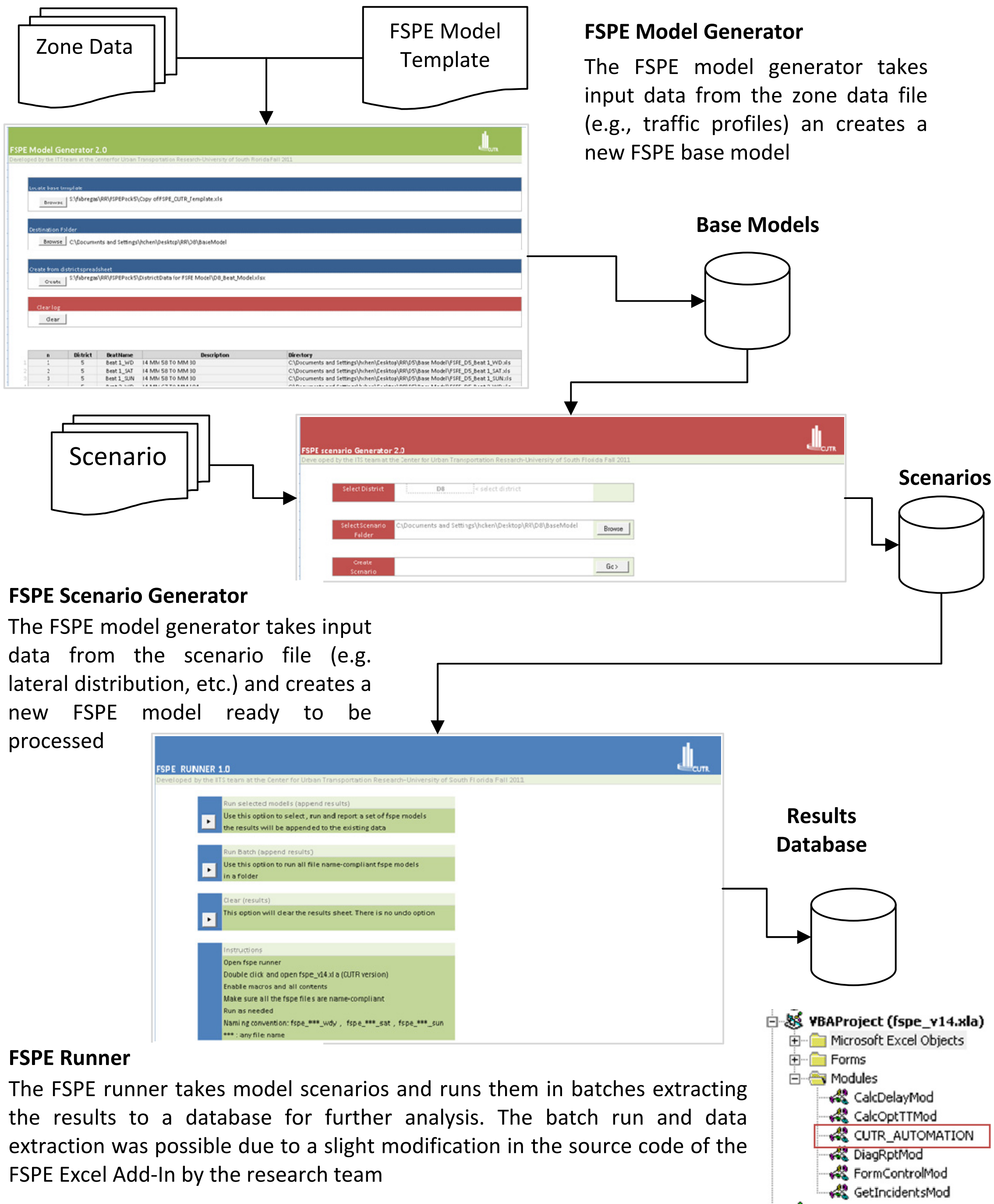


Figure 55: Modeling architecture