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Performance Analysis of Virginia's Safety Service Patrol Programs: A Case Study Approach

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Supplementary Notes

Abstract

Many state departments of transportation (DOTs) operate safety service patrols (SSPs) as part of their incident management programs. The primary objectives of SSPs are to minimize the duration of freeway incidents, restore full capacity of the freeway by removing incidents faster, and help reduce risks to motorists and response personnel. To become and remain competitive for funding, freeway SSPs must be able to quantify and articulate their value, relative to cost.

Although estimates of the benefits of these programs have been quantified in other areas of the United States, the Virginia Department of Transportation (VDOT) does not have a documented methodology for quantifying the benefits of its SSP programs. This study sought to develop such a methodology. The scope of the study involved a state-of-the-practice literature review, the development of the methodology, and an application of the methodology to VDOT's Northern Virginia (NOVA) SSP program as a case study. The case study also included an examination of the NOVA SSP operations and a performance analysis of its incident responses.

To quantify the benefits attributable to SSP programs, a methodology was developed for determining incident durations with and without SSP. This methodology was applied to the NOVA SSP, and the results were used as inputs into the Freeway Service Patrol Evaluation model, developed by the University of California-Berkeley, to estimate delay, fuel consumption, and emissions savings garnered by NOVA SSP deployments. The study found that 75 percent of SSP-recorded incidents are cleared in 15 minutes and approximately 23 percent are cleared in from 15 to 90 minutes. Further, the support of the NOVA SSP reduced the average incident duration by approximately 17 percent. This reduction contributed to an overall NOVA SSP benefit-to-cost (B/C) ratio of 6.2:1. The study recommends that all VDOT SSP programs track performance to measure and monitor trends. The study further recommends that SSPs conduct yearly benefit-cost evaluations using the Freeway Service Patrol Evaluation model and the associated methodology developed in this study for determining incident durations with and without SSP.

FINAL REPORT

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DISCLAIMER

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INTRODUCTION

Highway congestion is an increasing burden on the U.S. economy, productivity, and quality of life. It is a problem nationwide in scope but heavily concentrated in the largest urban areas.[1] Urban freeways, which carry nearly 30 percent of traffic in urban areas, are particularly affected by growing congestion. Los Angeles, New York, San Francisco, Washington, D.C., and Chicago account for about half of the nation's congestion, which is becoming a serious and worsening national problem and one that is receiving increasing attention from transportation engineers, planners, and researchers, as well as other local, state, and national officials.[2] The increase in congestion is the consequence of a host of structural changes in population, employment, and automobile use in the United States including:[1]

- rapid growth of metropolitan areas, especially suburbs
- more people working
- more people driving alone
- more complex commuting patterns
- rapid growth of domestic and social travel.

Traffic congestion can be classified as recurring or nonrecurring. Recurring congestion occurs at the same locations on a daily basis and is caused by lane drops, steep grades, weaving sections, heavy vehicle demand at on/off ramps, etc. Nonrecurring congestion occurs randomly because of incidents such as disabled vehicles, accidents, construction work, potentially hazardous debris, special events, or weather.[3] The Texas Transportation Institute's 2004 Urban Mobility Study[4] reported that road users in 85 large U.S. urban areas incurred $63.2 billion in congestion costs in 2002, and the study attributed 52 to 58 percent of the total delay experienced by motorists to unplanned events or incidents occurring in the roadway.[5]

Incidents include anything that disrupts the normal flow of traffic such as stalled cars, accidents, and objects that have fallen on the roadway. Response may require the dispatch of tow trucks, police, highway patrol personnel, medical help, maintenance crews, HAZMAT teams, or other emergency services to address the incident, clear the road, and restore it to full capacity. Response may also include disseminating incident information via radio, changeable message signs, and other media.[6]

The degree of incident-related congestion depends on the duration of the incident, the number of lanes blocked, and the volume of traffic at the time.[1] Approximately 80 percent of all incidents are due to disabled vehicles, which can reduce freeway capacity by as much as 26 percent.[7] Incidents blocking one or two lanes of a three-lane facility can reduce capacity by as much as 50 and 79 percent, respectively.[8] Further, each minute of lane blockage has been estimated to result in up to 5 minutes of congestion.[9]

In many cases, incident delay also has other short- and long-term consequences, including:[1]

- loss of time and productivity
- increase in fuel consumption or vehicle operating costs
- decrease in air quality
- increase in the cost of delivering goods
- decrease in highway safety
- decrease in a region's economic competitiveness and quality of life.

In response to the growing and adverse impacts of incidents, most large and medium-sized cities have initiated incident management programs. The goal of such programs is to detect and respond to incidents and to restore the freeway to full capacity quickly after the incident occurs.[10] *Freeway incident management* can be defined as the systematic, planned, and coordinated use of human, institutional, mechanical, and technical resources to reduce the duration and impacts of freeway incidents and improve the safety of motorists, crash victims, and incident responders. These resources are also used to enhance the operating efficiency, safety, and mobility of the highway facility by reducing the time to detect and verify an incident occurrence; implementing the appropriate response; and safely clearing the incident while managing the affected traffic flow until capacity is restored.[11] Incident management plays a critical role in the operation of the transportation system and requires cooperation and effective communication among responding agencies, which include fire and rescue, police, towing and recovery, DOTs, and freeway SSPs.

The objectives of freeway SSPs are to reach the scene of an incident quickly, provide assistance to motorists (gas, water, tire changes, jump starts, minor repairs, etc.), set up traffic control, and push or tow vehicles that are blocking the road. They can also confirm that an incident has occurred and advise the Traffic Management Center (TMC) of its nature and the response needed.[6] Studies have shown that freeway SSPs are a cost-effective means for mitigating the effects of minor traffic incidents such as vehicle disablements.[5]

Patrollers usually operate on "beats" (i.e., routes) along a pre-defined stretch of highway, although sometimes they are dispatched on demand. The hours of operation vary with locality and with the specific purpose of the clearance effort; most operate only during peak hours on weekdays only, but a few work around the clock every day of the year.[6] SSPs perform a variety of functions, but always with an overriding emphasis to maximize safety and minimize the operational impact of freeway incidents. They effectively combine incident detection (to verify incident occurrences), response (to identify and initiate appropriate actions), clearance (to clear roadway and restore full capacity), traffic management (to manage the scene), and motorist information (to provide status information). Some of the duties SSP operators are trained to handle include:[12]

- patrolling designated areas seeking disabled vehicles, stranded motorists, debris, spilled loads, accidents, obstructions, and other potential hazards or abnormal occurrences, and then notifying appropriate highway or enforcement personnel
- assisting motorists by pushing or towing disabled vehicles out of the roadway; providing gasoline or water; changing tires; and providing jump starts, minor repairs, etc.
- notifying enforcement authorities of abandoned vehicles and whether the vehicle is impeding traffic
- assisting at accidents by providing first aid, notifying enforcement agencies, removing damaged vehicles from the roadway, providing traffic control at the scene, assisting in extricating injured persons, coordinating communications, providing motorist information, etc.
- assisting in managing traffic in construction and maintenance zones by monitoring traffic controls and providing protection to highway workers
- reporting highway property damage
- providing traffic reports to highway agencies, news agencies, and other traffic sources for use by motorists
- providing information to lost motorists
- providing emergency transportation to stranded motorists
- removing pedestrians from freeways, bridges, and tunnels
- maintaining an established service patrol log, completing an entry for each incident encountered and/or handled.

Performance Evaluations of Safety Service Patrols

In recent years, some state DOTs have instituted performance measure initiatives that reflect program performance, goals, standards, and accomplishments. Performance management is a method to quantify and improve performance, and communicate with citizens and stakeholders.[13] These initiatives are also used to detect problems and correct them through improved management. In the case of transportation operations divisions, the overall goal is to identify measures that do the following:[13]

- help to achieve success and allocate resources for transportation operations
- help to operate and manage the system better
- demonstrate how effective an agency is using its resources
- identify best practices
- use existing data and data that are currently collected
- use data that are observable (i.e., not only modeled)
- inform decision makers both internally and externally
- consider measures that are comparable and can help operations compete for construction/improvement resources and other resource demands within a jurisdiction
- use efficiency measures to demonstrate the value of operations.

Performance Measures

Many SSP programs throughout the nation operate under the umbrella of transportation operations divisions, and some of these programs have developed performance measurement practices that enable the tracking of incident response trends and statistics. Data collected by SSP programs vary, but the majority of programs reviewed collect and conduct performance measure evaluations from the following types of data:

- nature of assists
- services rendered
- types of vehicles assisted
- number of lanes blocked
- response time
- time at incident scene (service time)
- clearance time
- response characteristics (first on scene, dispatched, etc.)
- patrol miles traveled.

A limited number of programs also collect information on response cards that are given to motorists during an assist. The response cards are in the form of a survey that allows an agency to evaluate the public's perception of the program.

The compilation of data among SSP programs varies considerably, but the majority of programs surveyed reported their statistics in the form of weekly, monthly, quarterly, and/or yearly reports. Most reports included the following statistics:

- assists by month
- assists by shift
- assists by route
- assists by type of incident
- assists by detection type

- assists by roadway
- average number of lanes blocked.

A limited number of programs provided more detailed reports and included statistics such as:

- clearance times by response mode
- incidents lasting less than a given unit of time
- incidents lasting between two given units of time
- incidents lasting more than a given unit of time
- blocking incidents vs. non-blocking incidents
- frequency of false alarms.

Benefit Evaluations

In order to quantify the benefit of the service they provide, some SSP programs have conducted comprehensive benefit-cost (B/C) analyses. However, a pervasive problem with B/C studies of incident management programs and SSPs is that several pieces of information required for estimating reductions in traffic delay are often missing. This is particularly true for the period before the implementation of the program and is particularly troublesome since the majority of quantifiable benefits are measured in terms of reductions in motorist delay.[14] To measure reductions in incident durations empirically, comparable data are needed for incidents without operating patrols.[12] Because of the complexities involved with capturing these data, only a limited number of SSP programs throughout the nation have conducted comprehensive benefit evaluations.

Such programs used varying methodologies, and all evaluations were constrained by the availability of data captured by the SSP programs or TMCs. Most B/C ratios range from 1.1:1 to 36:1. This range can be attributed to the different breadth of the studies (i.e., individual route analysis to statewide analysis), differing availability of data used in calculations, and differing response variables. Some programs investigated only motorist delay as the primary factor when computing benefits, and others investigated fuel consumption, emissions, and reductions in secondary incidents. No program was found to have the means and/or data to perform an all-encompassing benefit evaluation that included such items as the reduction in the number of lives lost, medical bills, economic losses (loss of productivity), crash avoidance, increased security to motorists, and environmental impacts of service patrol operations. As a result, B/C studies tend to consider only one or two types of benefits,[15] and therefore, many of the B/C ratios appear conservative in nature.

Some evaluations, such as North Carolina's evaluation of its Incident Management and Assistance Patrols (IMAP) Program, measured the effects of queuing and vehicle delay for incidents and assessed delay using FREEVAL (a model that replicates the freeway facility methodology in Chapter 22 of the 2000 Highway Capacity Manual [HCM]).[10,16] The B/C ratios for the IMAP divisions ranged from 1.1:1 to 10.4:1. However, they were likely conservative since they include only vehicle delay reductions and not fuel and emissions savings. IMAP benefits would likely be higher if fuel and air quality savings were included in the calculations along with secondary incident reductions, consumer appreciation, and benefits to businesses.[10]

Colorado, Michigan, and New York have used queuing models to evaluate the B/C ratio of their programs. In addition to queuing and real time traffic data–based approaches, computer simulation has proven effective in modeling traffic delays attributable to incidents. Some agencies have found annual savings in incident delay, fuel consumption and air pollutant emissions attributable to SSPs by analyzing the number of assists, beat geometries, and traffic volumes[17] and translating savings into benefits using monetary values for delay and fuel consumption using microscopic simulation programs such as CORSIM, VISSIM, and PARAMICS.

Of particular interest to this research effort was the program evaluations performed by the University of Maryland on Maryland's Coordinated Highways Action Response Team (CHART) program.[18] Because Maryland and Virginia share a border, the efficient removal of incidents on highways such as I-95 (and surrounding arterials) is of interest to both states. The CHART program has been evaluated every year since 1996. In all evaluations, the simulation model CORSIM was used to investigate delay savings and resultant fuel consumption and emissions savings. The most recent evaluation reviewed in this study was conducted in 2002, and the results showed that CHART operations saved highway users $467.93 million in 2002. This value included delay savings of 29.98 million-vehicle hours, fuel consumption savings of 5.06 million gallons, and emissions reductions of hydrocarbon (HC) (391.89 tons), carbon monoxide (CO) (4,402 million tons), and nitrogen oxide (NOx) (187.69 million tons) as well as a monetary value placed on the reduction of secondary incidents.[18]

In summary, all reviewed B/C evaluations monetized the travel time savings (reductions in delay) associated with the operation of SSPs. A portion of those evaluations monetized fuel savings and/or emissions reductions, and some agencies quantify avoided crashes (reduction in secondary incidents) and aid to stranded motorists. However, no study reviewed included all of the possible benefit types, and therefore, most B/C analyses are considered conservative.

The Virginia Department of Transportation's Northern Virginia Safety Service Patrol

Prior to 1968, the maintenance personnel of the Virginia Department of Transportation's (VDOT's) Northern Virginia (NOVA) District patrolled segments of the Capital Beltway, I-66, and I-95 on the weekends and were responsible for carcass removal. VDOT did not have a SSP program, but the patrollers were finding that much of their time was spent helping disabled motorists and consequently began taking notes on specific tools that were required to help motorists in need. In 1968, a service patroller was assigned to various freeway segments during holiday weekends, specifically Labor Day, Memorial Day, and the Fourth of July weekends. The patroller would use a superintendent's vehicle with a sign on the back signifying the vehicle's purpose.[19] As the NOVA District became more urbanized, VDOT instituted a full-time service patrol that patrolled 5 days per week on 16-hour-per-day shift assignments. In 1987, the SSP was established as a separate section in the NOVA District Office and began to provide 24/7 service to all coverage areas.

Currently, the NOVA SSP uses 28 patrollers and supervisors and serves 198 centerline miles of the NOVA freeway system. Figure 1 is a map of the route coverage, and Table 1 shows

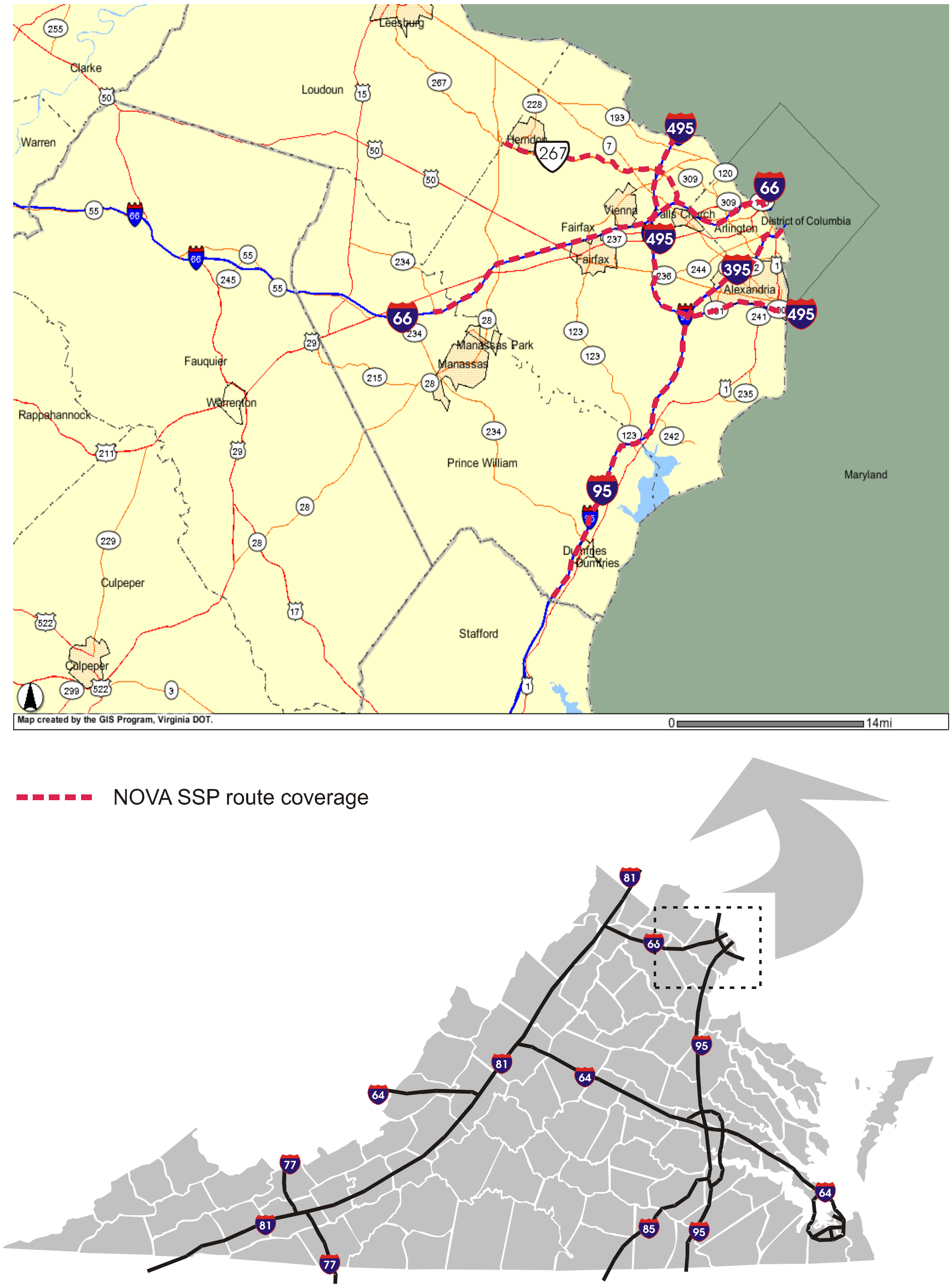

Figure 1. Roadways Covered by NOVA SSP

Table 1. NOVA SSP Route Numbers and Assignment Areas

ROUTE #	ASSIGNMENT AREAS	VDOT #
	DULLES TOLL ROAD (Rte. 267)	
DTR-1	Dulles Toll Road	9913
DTR-2	Dulles Toll Road	9914
	INTERSTATE 395 & INTERSTATE 95	
P-1	(I-395) D.C. Line to Beltway	9915
P-2	(I-95) Beltway to Route 123	9916
P-3	(1-95) Route 123 to Exit 148	9917
	HOV LANE ASSIGNMENTS	
P-4	HOV Lanes (I-395)	9920
P-5	HOV Lanes (I-95 Fairfax County)	9921
P-6	HOV Lanes (I-95 Prince William County)	9922
	INTERSTATE 495 (BELTWAY)	
P-7	American Legion Bridge to Route 236	9930
P-8	Woodrow Wilson Bridge to Route 650	9931
	INTERSTATE 66	
P-9	D.C. Line to Route 243	9940
P-10	Route 243 to Route 234	9941
P-12	HOV and Spur to DTR/I-495	9945
	BRIDGE WRECKER ASSIGNMENTS	
B-1	American Legion Bridge Wrecker	9980
B-2	Woodrow Wilson Bridge Wrecker	9981
B-3	14th Street Bridge Wrecker	9982
	CONGESTION MANAGEMENT	
C-1	Springfield Interchange	9990
C-2	Woodrow Wilson Bridge	9991

a breakdown of the route number, assignment areas, and VDOT patrol numbers. Routes covering the Fourteenth Street Bridge (B-3), the Woodrow Wilson Bridge (C-2 and B-2), the Springfield Interchange (C-1), I-95 (P-2), I-66 (P-10), and the Dulles Toll Road (DTR-1) are considered “priority” corridors and are covered on a consistent basis (7 days a week, 24 hours per day except for the Fourteenth Street Bridge, which is covered only during weekdays). The rest of the routes are covered when staffing levels are sufficient. Routes C-1, C-2, B-3, and the afternoon shift of B2 are federally funded through the Congestion Mitigation and Air Quality (CMAQ) program. Currently, all route lengths are designed so that an off-peak round trip can be made in 20 to 25 minutes.

During peak periods or congested conditions, a round trip can take up to 1 hour, and because of this, the management of the NOVA SSP would like to shorten many of the existing route segments. For example, I-66 is currently broken up into two segments from the D.C. line out to Rt. 234 in Manassas, a distance of about 30 miles. The NOVA SSP would like for this to be three to six routes (of 5 to 10 miles each segment), which would allow for quicker response and detection of incidents. Further, consideration is being given to adding pilot routes on primaries, such as Rt. 28 in Fairfax County, which is becoming a limited access road. Ideally, the pilot routes would be very short segments and have consistent coverage.[20]

Additional information pertaining to the NOVA SSP program, including its fleet characteristics, its relationship to the NOVA Smart Traffic Center (STC), core functions, equipment, patroller training, quick clearance policy, vehicle classification, inter-agency cooperation, and observations from the field, can be found in Appendix A.

VDOT's Incident Management Performance Measures

Recently, VDOT reorganized its divisional structure and reallocated resources to include an elevated focus on operations, of which incident management and SSPs are integral components. In support of this initiative, VDOT's Incident Management Committee held a series of meetings to identify incident management performance measures. The primary purpose of the effort was to develop an incident management measurement tool that can be used by those responsible for incident management programs throughout the state as well as report the performance measures to the public on VDOT's Dashboard (VDOT's publicly accessible, web-based report on program performance).

The Incident Management Committee created an incident definition and developed an incident clearance performance measure that can be used statewide. The incident definition is *an unexpected event that adversely impacts traffic flow,* and the incident clearance performance measure is *X% of all incidents cleared within Y minutes*.[21]

When creating the incident definition, the committee decided to exclude planned events since specific preparations could be made for these events. It was decided that separate evaluation measures should be used to gauge performance on these types of events. It was also decided that only events that affect traffic flow would be considered incidents. For example, a disabled vehicle on the shoulder of a rural interstate should not be considered an incident because it does not adversely impact the light flow of traffic. A disabled vehicle blocking the shoulder during rush hour on an urban interstate should be considered an incident because the roadway is already operating at saturated conditions and any reduction in capacity will adversely impact the already unstable flow of traffic.[21]

When the incident clearance time performance measure was developed, it was decided that the percentage of incidents would be fixed and the number of minutes taken to clear an incident would vary. This measure recognizes that a small percentage of major incidents are far outside the bounds of clearance expectations such as multi-vehicle accidents and hazardous material spills, etc. However, these incidents will not skew the performance measure and impair the ability to meet goals. The NOVA SSP indicated that their incident clearance performance measure is *90 percent of all incidents will be cleared within 90 minutes (with a goal of 85 minutes)*.[21]

Figure 2 shows the incident clearance diagram developed by VDOT's Incident Management Committee. The committee decided that the length of an incident would be measured in minutes from first notification (or detection) of the incident (the time that any responding agency is notified), to the time all travel lanes are open to the public. These two events define the clearance time of an incident. The time the lanes are open to traffic was chosen as the end point since closure of the lanes has the biggest impact on traffic flow. The responding agencies may still be on the scene after the travel lanes are open and traffic flow may be impeded by their presence on the shoulder, but the incident duration for the purpose of this performance measure was considered complete. The committee acknowledged that the ultimate goal for measuring incident duration is to measure the time when traffic returns to conditions similar to those that existed just prior to the incident (i.e., complete recovery of normal traffic flow). However, because technologies for measuring traffic volumes and speeds are installed in only a few areas, it is currently not feasible to collect this information and include it as a statewide performance measure.[21]

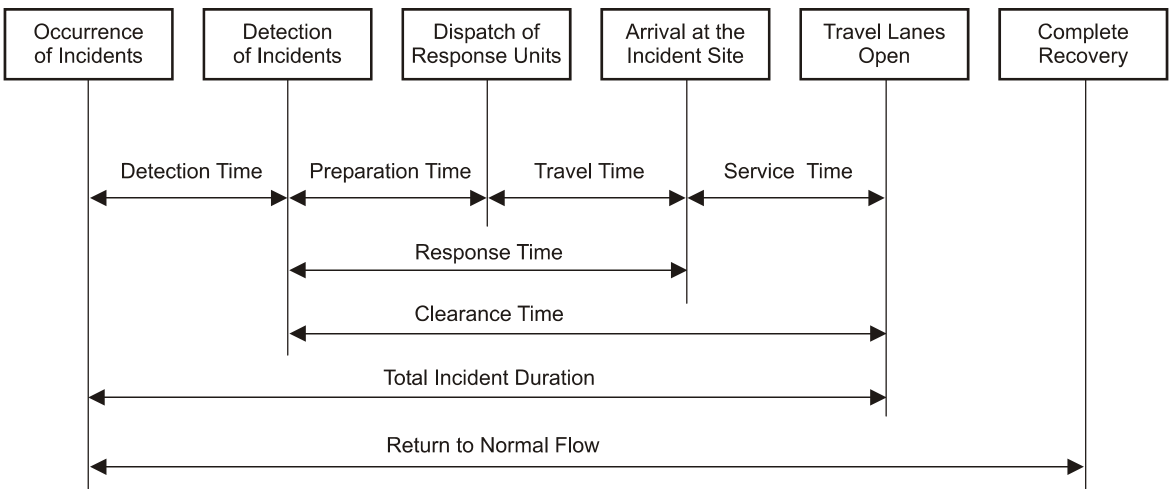

Figure 2. Incident Clearance Time Diagram

PROJECT MOTIVATION

Because of reductions in VDOT's overall FY03 and FY04 budgets, in March 2003, $6 million was removed from the statewide SSP budget. These funding cuts resulted in personnel and fleet losses for Virginia's SSP programs. Of the four programs in Virginia, the two affected most were the Hampton Roads Freeway Incident Response Team (FIRT) and the NOVA SSP. Patrols in the Salem and Staunton district were also affected, but on a more limited basis because of their rural nature and smaller scale operations.

Prior to the 2003 budget cuts, the NOVA SSP budget was $2.9 million. There were 53 full-time employees, 10 contract employees, and a fleet of 55 vehicles. After the cuts, the budget was reduced to $1.4 million, staffing levels were decreased to 32 full-time employees, and the fleet was reduced to 45 vehicles. Hampton Roads' FIRT budget was cut from $2 million to $1 million, staffing levels lowered from 36 full time employees to 16, and the number of available trucks reduced from 36 to 23.

Following the budget cuts, two informal studies of the Hampton Roads FIRT program were conducted. The first study, *Freeway Mobility Report for Hampton Roads, Virginia*,[22] was conducted by the University of Virginia's Center for Transportation Studies in October of 2003. One of the results of the study showed the effect of FIRT budget cuts on incident responses in the region. It was found that the number of reported incidents decreased relative to staff and fleet size and average incident duration in the Hampton Roads area increased. One of the purposes of the second study, *Hampton Roads Freeway Incident Response Team Impact Study*,[23] was to compare Virginia State Police (VSP) and SSP incident response trends before and after cuts. Data analyzed included FIRT and VSP incident responses from 2000 to early 2004. The results of the analyses revealed a rise in the number of disabled vehicle responses by VSP in 2003. Prior to cuts, FIRT responded to more disabled vehicles than VSP by a ratio of 1.5:1. After the cuts, VSP responded to more disabled vehicles than FIRT by a ratio of approximately 2:1. In addition, prior to budget reductions, FIRT personnel provided assistance at 1 in 3 crash scenes responded to by VSP. After the reductions, the number fell to 1 in 5.

No studies of the impact of the NOVA SSP budget reductions were performed immediately after the cuts. However, the Virginia Transportation Research Council (VTRC) was asked to conduct a formal study similar to the B/C studies conducted by Maryland's CHART program. Specifically, the NOVA District asked that a B/C analysis be performed and an evaluation methodology established that could be performed on a monthly, quarterly, or yearly basis to demonstrate the value of its SSPs.

In 2004, VDOT management restored SSP funding for all programs to the levels that were in place in March 2003. This action, however, did not diminish the importance of the research effort. Rather, because formal documentation of SSP programs would provide valuable information as to their benefits, this research was deemed extremely important to the future of such programs. To become and remain competitive for funding, freeway SSPs programs need to be able to quantify and articulate their value, relative to cost.

PURPOSE AND SCOPE

The purpose of this project was to develop methods that VDOT decision-makers could use to evaluate and quantify the effectiveness of the agency's SSP programs. The scope of the project involved a performance analysis of the NOVA SSP program, which entailed distribution analyses of the NOVA SSP incident response statistics, the development of a methodology to quantify the benefits of SSP programs, and an application of the methodology to the NOVA SSP program as a case study.

To quantify the benefits attributable to SSP programs, a methodology was developed to determine incident durations with and without SSP. The methodology was then applied to the NOVA SSP, and the results were used as inputs into the Freeway Service Patrol Evaluation (FSPE) model, developed by the University of California-Berkeley, to estimate delay, fuel consumption, and emissions savings garnered by NOVA SSP deployments for the period of June 1, 2004, through May 31, 2005.

METHODOLOGY

To achieve the study objectives, three tasks were undertaken:

1. Conduct a performance analysis of NOVA SSP incident responses.

2. Develop a benefit evaluation methodology for VDOT SSP programs.

3. Conduct a case study of the NOVA SSP using the methodology developed in Task 2.

Performance Analysis of NOVA SSP Incident Responses

To analyze NOVA SSP incident response statistics, incident data had to be examined from the SSP incident database. Incident data in the database are downloaded after each shift using the NOVA SSP Incident Management software, which is installed on each patroller's laptop. The components of the database are listed in Table 2 and reflect the types of data collected for each incident response. Many of the components were found essential for the performance analysis of the NOVA SSP.

Displaying graphical statistics can help decision-makers gain a better understanding of what is occurring in the field, identify deficiencies in operations, and gauge the performance trends of SSP operations throughout different time periods. Therefore, the performance analysis of incident responses included conducting distribution analyses of SSP incident statistics and displaying the distributions in a graphical format. Incident statistics were obtained for the period June 1, 2004, through May 31, 2005, because the time period provided the most complete set of data (complete year 2005 data could not be evaluated because the year had not been concluded).

Table 2. SSP Database Components

Vehicle ID	Shift Number	Fuel Given
Color	Notify Date	Number of Gallons
Tag # and State	Notify Time	No Service Provided
Vehicle Type	Start Time	Tire Problem
Vehicle Detail	End Time	Tire Changed
Roadway	Lane #	Air Added
Lane	Flares	Lugs Removed
Direction	Push Vehicle	Minor Repair
Service Notes	Debris	Overheated
Wrecker Dispatched	Traffic Control	Water Added
Wrecker Name	Absorbent	Route Number
Weather Cond.	Cell Phone Call	Route Description
Assist Type	Unfounded	Lugs Removed
Detection Source	First on Scene	Jump Start
Date Entered	AddSPPUnits	Abandoned
City Name	First Aid	Location ID
Patroller Name	Motorist Transport	Map ID
Truck Number	Out of Gas	

Based on performance measure practices of DOTs throughout the nation and the initiatives set forth by VDOT's Incident Management Committee, it was decided that distribution analyses would be performed on the following incident statistics with the premise that the results will serve as a basis for evaluations of the NOVA SSP performance measures:

- response rate (SSP response records compared to total number of VSP plus SSP response records) and nature of assists
- incidents by time period
- incidents by roadway
- lane-blocking incidents
- response, service, and clearance times
- incidents detected on patrol vs. dispatched.

Development of Benefit Evaluation Methodology for VDOT SSP Programs

It was postulated that benefit models used in other research studies could be formatted to address the benefits of VDOT's SSP operations. Consideration was given to microscopic simulation programs (VISSIM, CORSIM, PARAMICS), delay-based macroscopic models (HCM, FREEVAL), and deterministic queuing-based models. Most of the microscopic simulation programs and some of the delay-based models required ramp volume data. In many regions of Virginia, there are limitations in the quality and quantity of ramp volume data, thus broad ramp volume assumptions would have to be made if these models were used.

One model, the FSPE model,[24] a deterministic queuing-based model developed at the University of California–Berkeley, employs traffic data commonly available in VDOT, does not require ramp data, and uses commonly applied measures of effectiveness (MOEs) such as reductions in motorist delay, fuel consumption, and emissions. The researchers deemed the FSPE model the most appropriate to deploy for VDOT applications. To use the model, analyses of incident durations with and without SSP needed to be performed because incident duration reductions attributable to SSP operations are used as inputs in the model.

To determine incident durations with and without SSP a two-step methodology was developed that incorporated an analysis of freeway incidents using the VSP computer-aided dispatch (CAD) and SSP databases. To be compatible with FSPE model input requirements, the incidents were sorted by incident type (accident, breakdown, or debris) and their lateral locations on the roadway (left shoulder, right shoulder, or "in-lane"). Using the VSP CAD database, accident clearance times, where VSP was the only responder, were then compared to accident clearance times where VSP and SSP were joint responders to obtain accident incident durations with and without SSP. For breakdowns, clearance times from the SSP database were analyzed and additional time was applied to incidents where the SSP pushed or repaired a vehicle to account for the tow-truck arrival times had the SSP not been present. For debris, clearance times from the SSP database were analyzed and additional time was applied to all incidents to account for the additional debris removal time had the SSP not been present.

Case Study of the Benefits of the NOVA SSP

In this task, the benefit evaluation methodology developed in Task 2 was used to assess the NOVA SSP. It included an application of the methodology to determine incident durations with and without NOVA SSP operations and an application of the FSPE model to the NOVA SSP beats to obtain quantitative values for the MOEs of reductions in delay and associated reductions in fuel consumption and emissions.

RESULTS AND DISCUSSION

Performance Analysis of NOVA SSP Incident Responses

The results of the performance analysis of the NOVA SSP incident responses contain graphical representations of incident response statistics and distributions. Incident statistics and distributions were obtained from the SSP database during the period June 1, 2004, through May 31, 2005; therefore, each distribution represents a “single year” analysis. Future evaluations will enable statistical addendums and a clearer picture of yearly performance trends.

Response Rate and Nature of Assists

The SSP Incident Management database had 22,233 incident records for the study period. The records included accidents, disabled vehicles, debris, special events, and pedestrian entries. As opposed to the incident detail in the NOVA SSP database, the VSP CAD incident database is broken down only by type of accident (injury, property damage, fatality) or type of disabled vehicle (occupied, abandoned, hazard). The VSP CAD database produced 35,556 records for the study period. Of these, 22,823 were disabled vehicle entries and 12,733 were accident entries. Of the 12,733 CAD accident entries, the SSP assisted VSP with 2,672. Of the 22,823 disabled vehicle entries, the SSP assisted with 10,862.

During the study period, VSP and SSP responded to 44,255 incidents in NOVA. Of these, as shown in Figure 3, VSP responded exclusively to 22,022 incidents (49 percent), the SSP responded exclusively to 8,699 incidents (20 percent), and VSP and SSP jointly assisted in 13,534 (31 percent). The VSP response rate was 0.803 (or 80.3 percent), and the SSP response rate was 0.502 (or 50.2 percent).

In conjunction with recording incident type (accident, disabled and debris), location (lateral location on roadway and roadway name), the NOVA SSP records additional incident attributes that can help management identify the nature of assists and the actions taken by patrollers during an assist. Figure 4 shows a distribution of the nature of the SSP assists, and Figure 5 is a distribution of actions taken by the SSP during assists. These distributions do not represent a complete incident summary of the analysis year; however, they do provide an indication that the majority of the assists involved vehicles with tire problems and the dispatching of wreckers accounted for the majority of the actions taken by the SSP followed by tire changes.

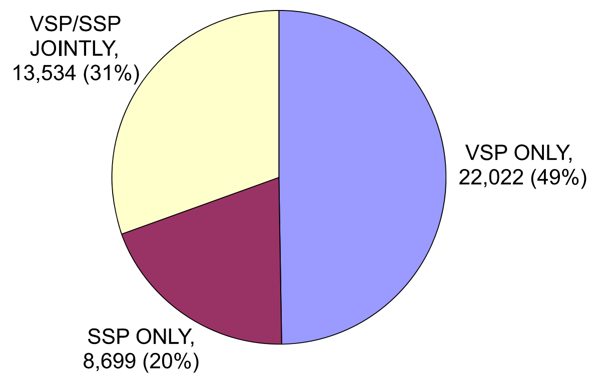

Figure 3. VSP and SSP Incident Assist Totals

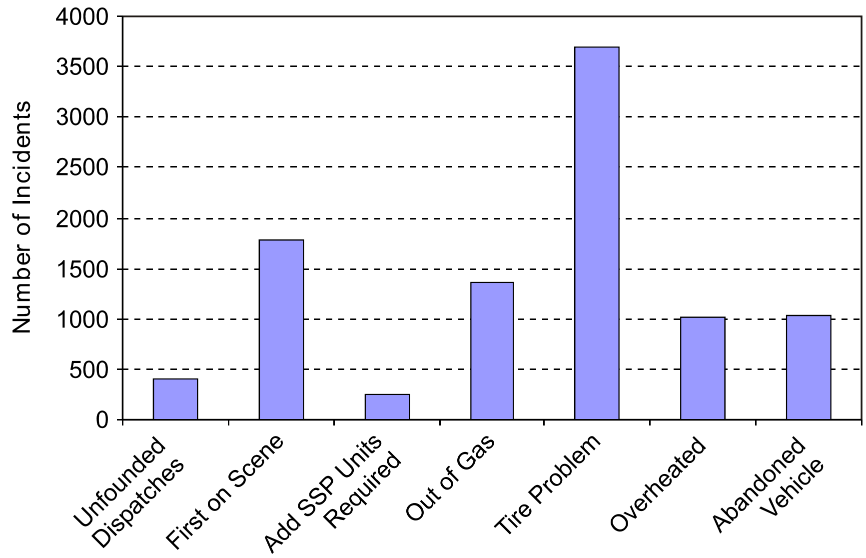

Figure 4. Distribution of Nature of Assists

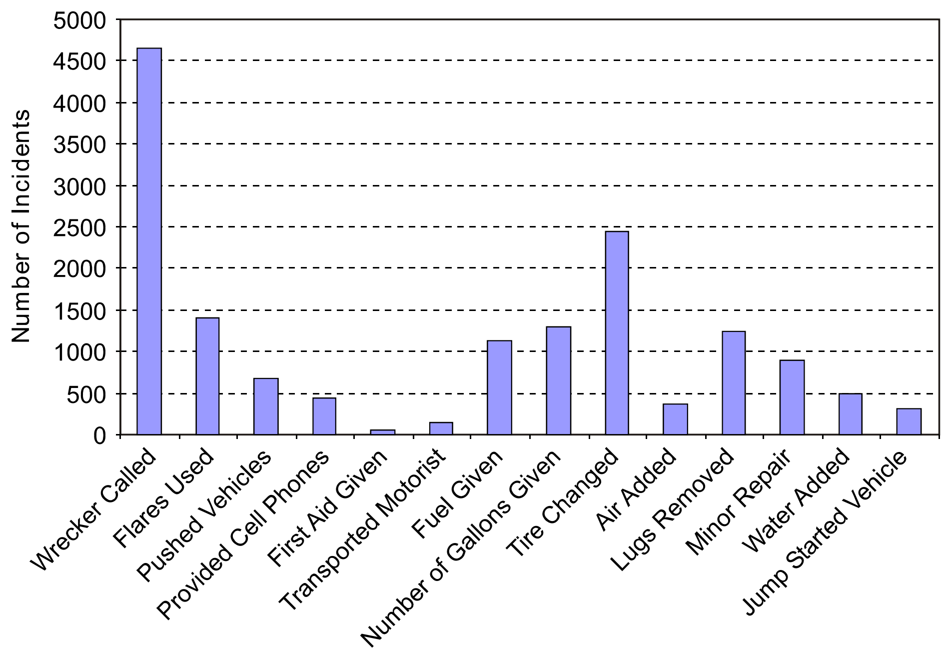

Figure 5. Distribution of Actions Taken During Assists

Incidents by Time Period

Figures 6, 7, and 8 show the breakdown of total incidents per month, average incidents per day of week, and average number of incidents per hour of day, respectively. As can be seen in Figure 6, the greatest number of SSP assists occurred during the summer months, with the highest number in July. Figure 7 shows that the greatest number of assists occurred on Wednesdays. This is due in large part to the shift overlaps that occur on this day. The rest of the days of the week incurred between 2,500 and 3,500 assists throughout the year. There was only a slight drop in assists on the weekends. Figure 8 shows that the highest incident records per hour of day occurred during the A.M and P.M. peak periods. There was a significant drop in incident records between 11 A.M and 12 P.M. that can be attributable to the patroller shift changes during this time period.

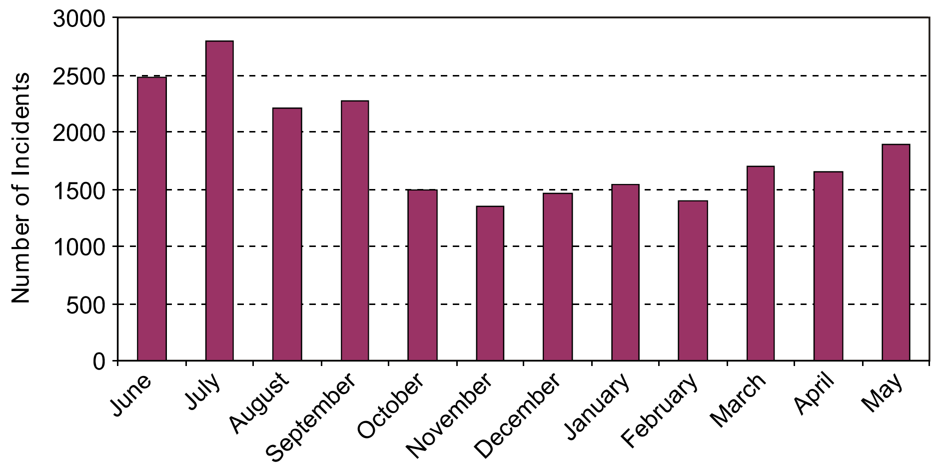

Figure 6. Distribution of Incidents by Month

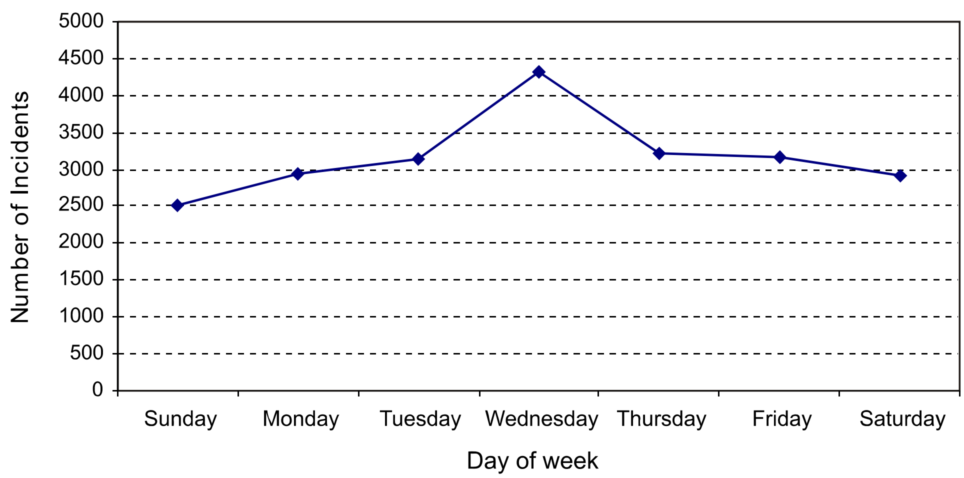

Figure 7. Distribution of Incidents by Day of Week

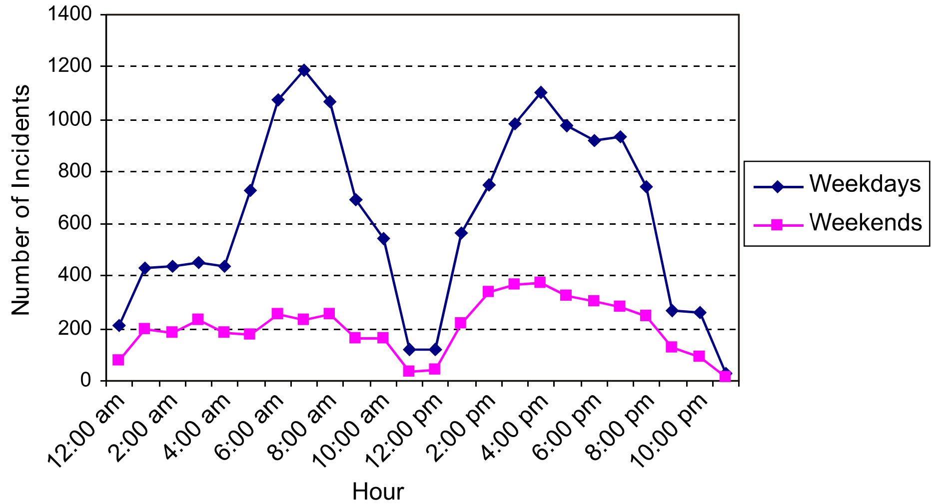

Figure 8. Distribution of Incidents by Hour of Day

Incidents by Roadway

Figure 9 shows the total number of responses to incidents per given roadway. As can be seen, I-95 and I-495 and Rte. 267 incurred the greatest number of responses; however, there is a direct correlation between priority route coverage and number of recorded incidents (i.e., Rte. 267 and sections of I-95 are covered by patrollers on a more frequent basis than the other roadways, and therefore, a higher number of incidents are recorded for these roadways).

The average number of incidents per roadway per week is shown in Figure 10, where the incident responses are broken down by weekday (Monday–Friday), weekend (Saturday–Sunday), and entire week (Sunday–Saturday). Again, I-95 and I-495 incurred the most incident responses per week. A distribution of routes, as shown in Figure 11, verifies this correlation between priority route coverage and increased incident responses. Routes P-2 (I-95 from the Beltway to Route 123), C-1 (Springfield Interchange), and DTR-1 (Dulles Toll Road) are all priority routes.

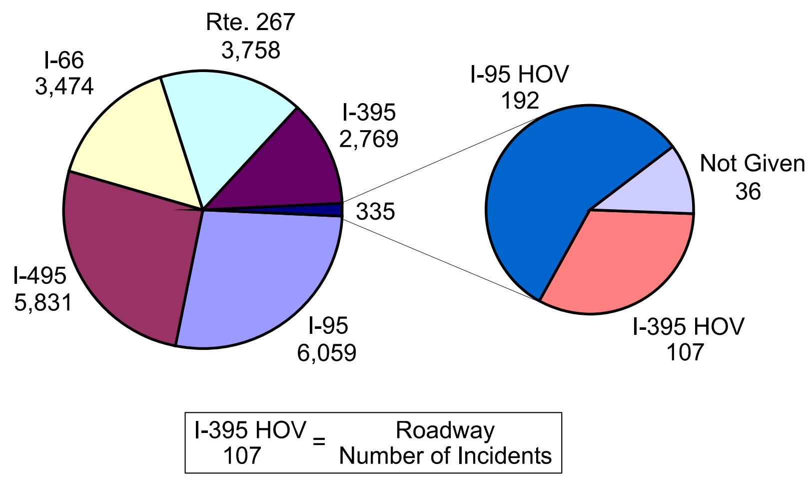

Figure 9. Distribution of Incidents by Roadway

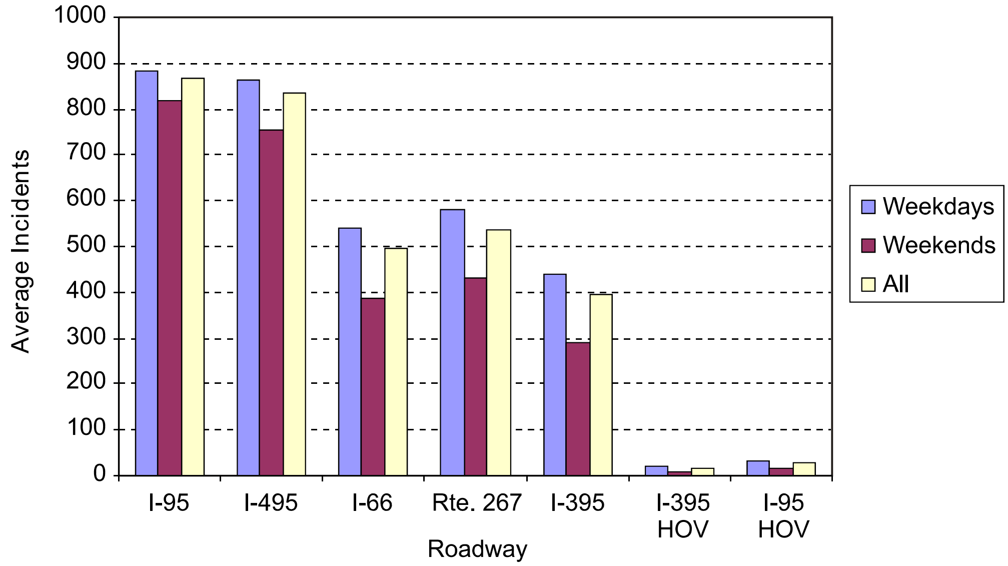

Figure 10. Distribution of Average Incidents by Roadway per Week

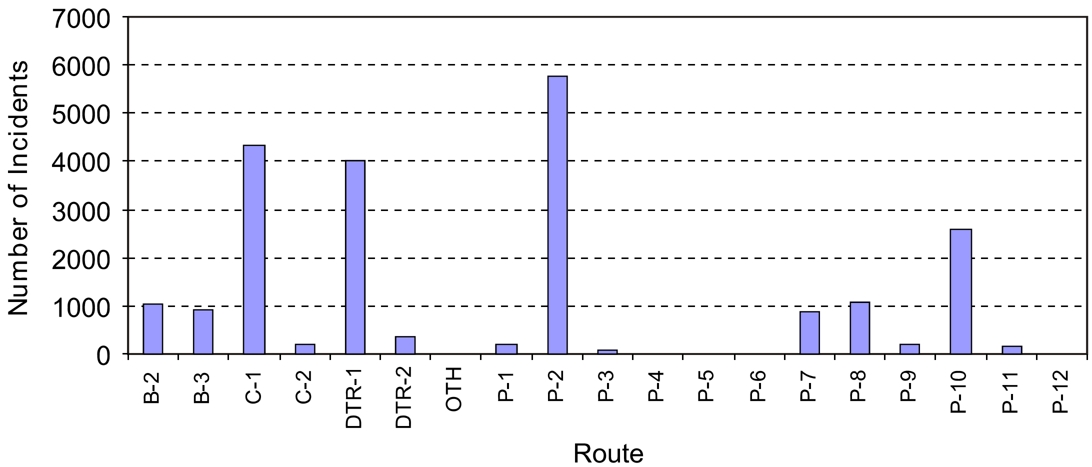

Figure 11. Distribution of Incidents by SSP Route

Lane Blocking Incidents

Figure 12 shows a distribution of lane blocking incidents for all roadways. Incidents on I-495 contributed to the most one- and two-lane blocking incidents, followed by I-95 and then I-395. The trends for I-66 and I-267 were similar. Construction of the Springfield Interchange (which includes sections of I-495, I-95, and I-395) likely contributed to higher numbers of lane blocking incident records.

Figure 13 shows the percentage of lane blocking incidents vs. non–lane blocking incidents for all roadways. I-395 had the highest percentage, followed by I-395 HOV and I-495.

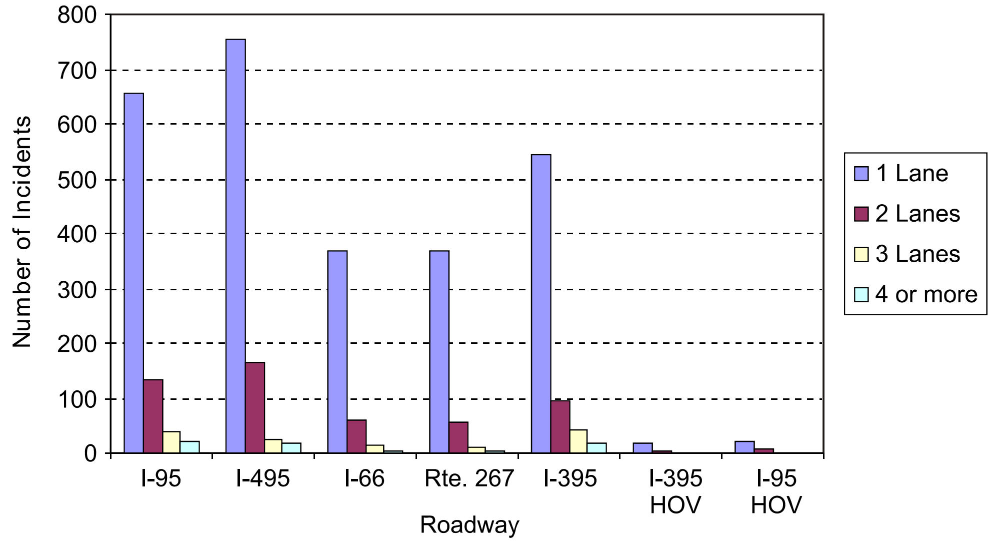

Figure 12. Distribution of Lane Blocking Incidents by Roadway

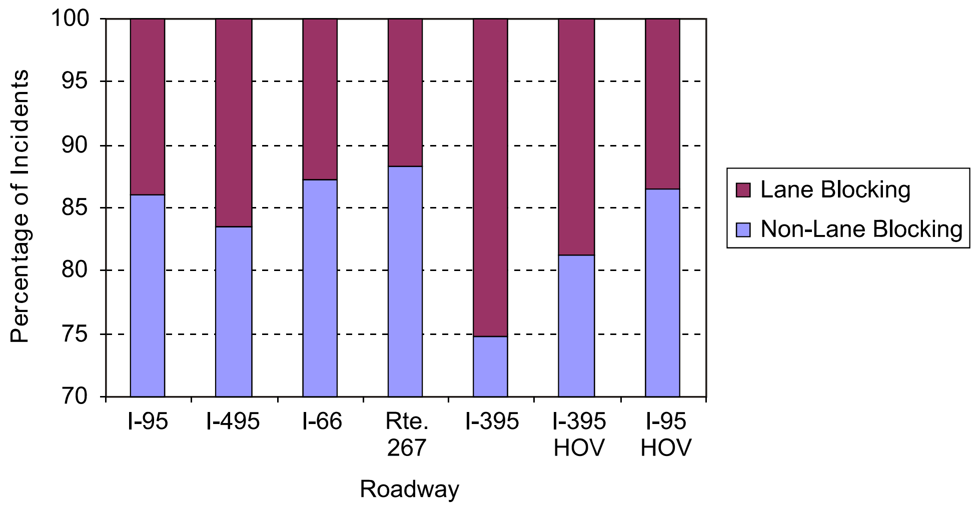

Figure 13. Percent of Lane Blocking/Non–Lane Blocking Incidents by Roadway

Response, Service, and Clearance Times

This section covers critical and "controllable" elements of the SSP programs, specifically, response times, service times, and clearance times. Figure 14 shows the average lane blocking clearance time of all roadways covered by the NOVA SSP. The clearance time of lane blocking incidents equals the response time plus service time at incident sites. The *response time* in this figure consisted of incidents detected on patrol (i.e., the patroller was not dispatched and therefore no response time was recorded) and was calculated by subtracting the arrival time of the patroller to an incident from the time of notification of an incident. The *service time* was calculated by subtracting the notification time of an incident from the end time of an incident. As Figure 14 shows, shoulder incidents (labeled *0* on the x-axis) averaged a clearance time of 11:47 minutes. Incidents that created 1 to 6 lane blockings averaged clearance times of 22:41, 40:50, 62:03, 55:26, 83:17, and 120:28 minutes, respectively. Standard error bars are shown on the graph, and error increases as the number of lane blockages increase, which can be attributed to the infrequency of multilane blockages and subsequent small sample sizes.

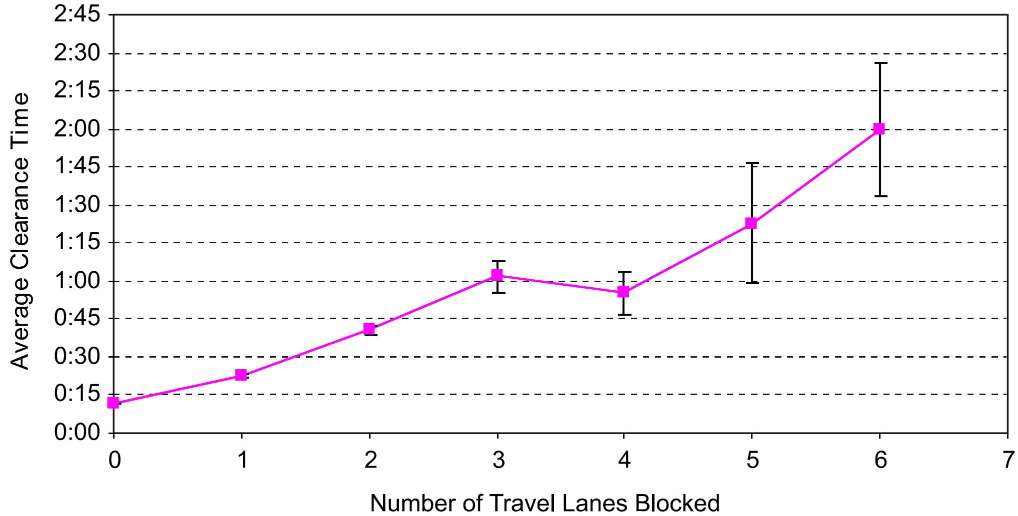

Figure 14. Average Incident Clearance Time vs. Number of Lanes Blocked

Figure 15 shows the breakdown of clearance times by roadway but does not include shoulder incidents. As can be seen, clearance times for one- to four-lane (or more) blockages follow a trend similar to that in Figure 14 where incident clearance times increased with higher numbers of lane blockages. The only anomaly present is on I-95, where the clearance time for four-lane (or more) blocking incidents was less than the clearance time for three-lane blocking incidents.

In an effort to be compatible with the performance measures set by VDOT's Incident Management Committee, clearance time data from the NOVA SSP database were broken down into segments of percent of incidents cleared in less than 15 minutes, 15 to 90 minutes, and greater than 90 minutes. Figure 16 represents these percentages by roadway. When combining all incidents on all roadways, the average percentage of clearance times less than 15 minutes, 15 to 90 minutes, and greater than 90 minutes was 74.9, 23.2, and 1.9 percent, respectively. According to the clearance time data provided in the SSP Incident Management database, 98.1 percent of all incidents were cleared within 90 minutes.

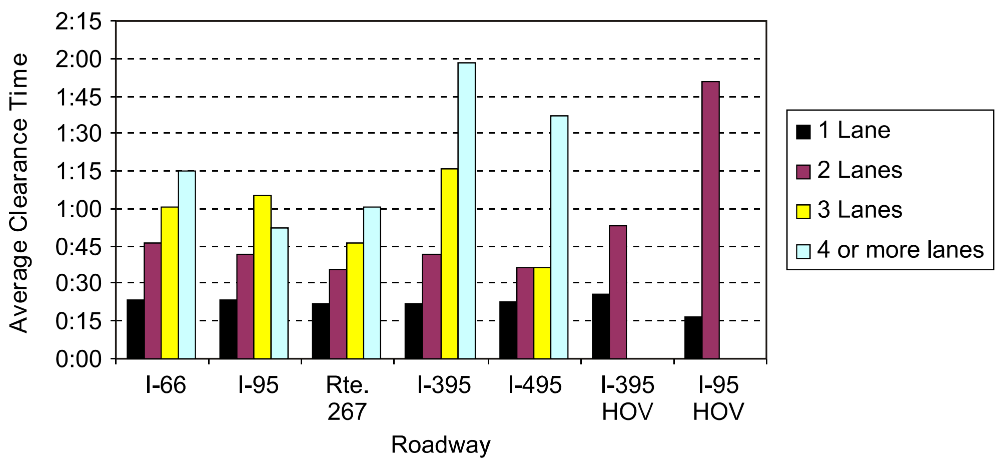

Figure 15. Distribution of Average Lane Blocking Clearance Times by Roadway

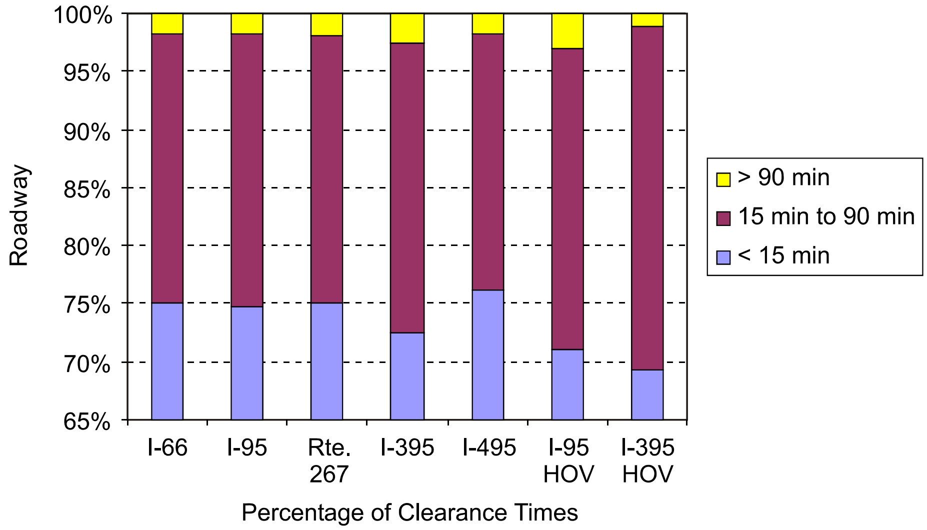

Figure 16. Average Clearance Time Percentages by Roadway

To gain a better understanding of the nature of SSP response, service, and clearance times at incident sites, a distribution of the times was constructed for all roadways and is shown in Figure 17. The *response time* in the figure included all incidents that were dispatched (i.e., does not include incidents detected on patrol). *Service time* included all incidents (both dispatched and incidents detected on patrol). Clearance Time-1 was the average clearance time for all incidents including both dispatched and incidents detected on patrol. Clearance Time-2 excluded all incidents detected on patrol (no response time recorded). Figure 18 reflects the same distribution methodology except the average response, service, and clearance times are segregated by route.

In Figures 17 and 18, Clearance Time-1 revealed a significant decrease in clearance times compared to Clearance Time-2 because there is no response time associated with detecting incidents on patrol. Because of the discrepancy in incident clearance times associated with detecting incidents on patrol vs. responding to incidents upon being dispatched, a distribution of

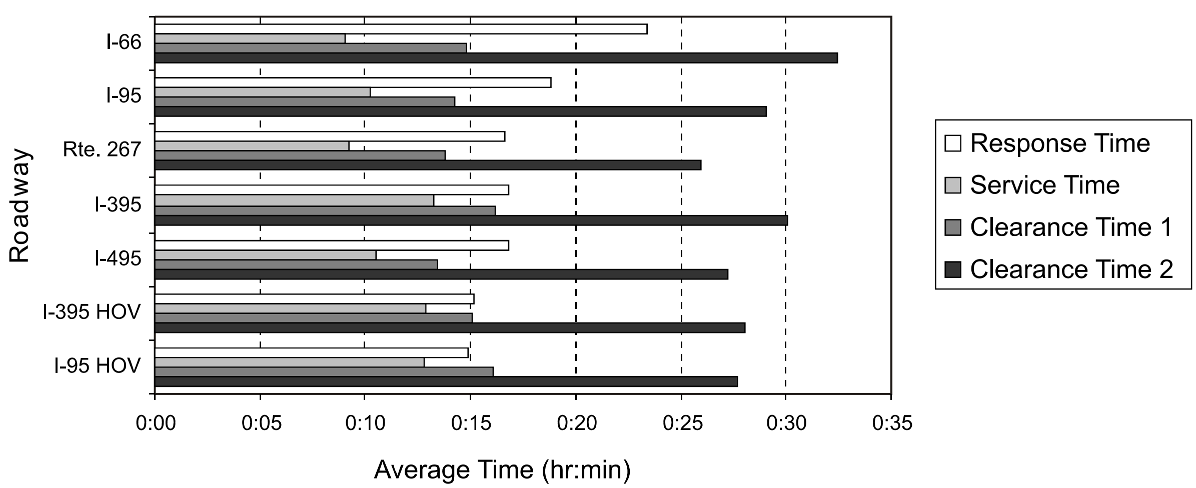

Figure 17. Average Response, Service, and Clearance Times by Roadway

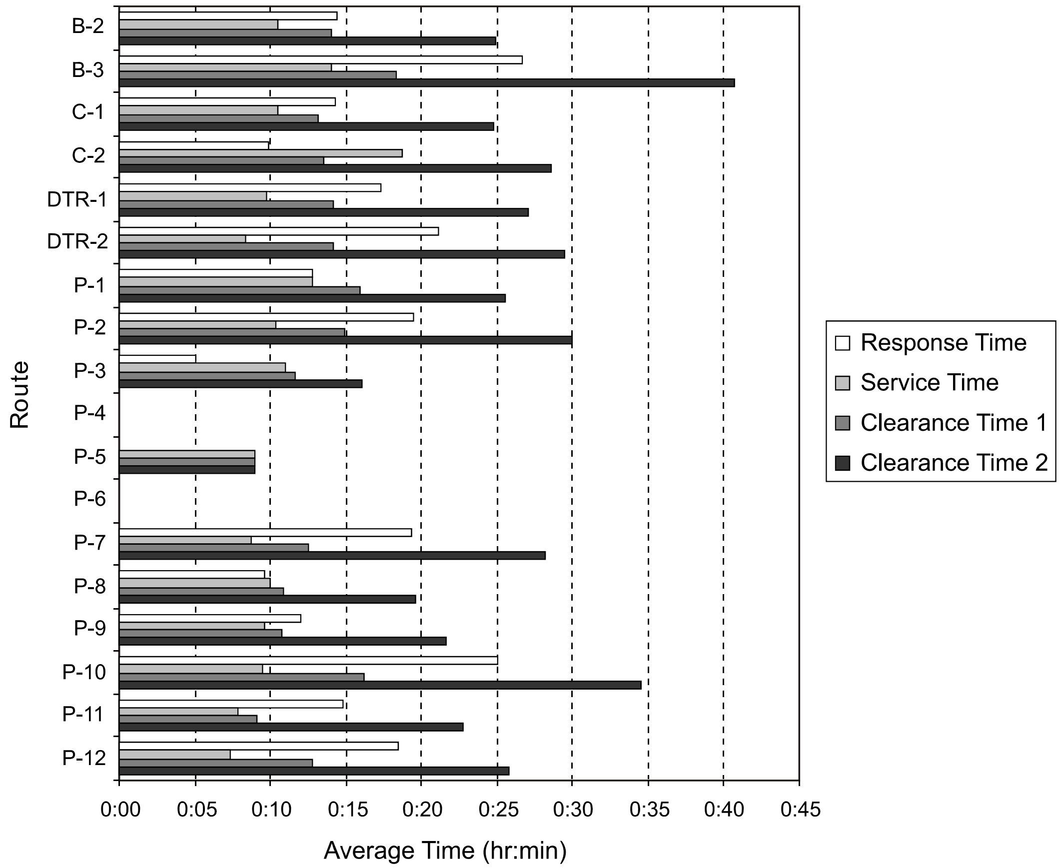

Figure 18. Average Response, Service, and Clearance Times by Route

response, service, and clearance times was constructed for incidents that were dispatched vs. incidents detected on patrol. Figure 19 shows that the average clearance times for incidents dispatched and incidents detected on patrol in the SSP coverage area were 35:17 and 10:55 minutes, respectively.

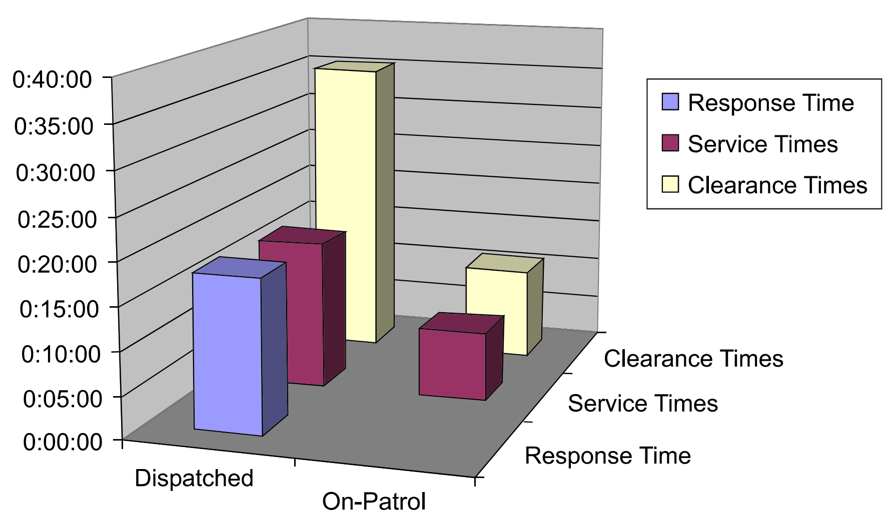

Figure 19. Distribution of Average Dispatched vs. On-Patrol Response, Service, and Clearance Times

Incidents Detected on Patrol vs. Dispatched

In light of the significant difference in clearance times associated with incidents detected on patrol vs. patrollers being dispatched, the authors deemed it important to create distributions showing the type and location of incidents that are detected while patrolling versus those detected by other sources to which patrollers are dispatched. Figure 20 shows a distribution of the percentage of all incidents detected on patrol by roadway. The figure revealed that the majority of recorded incidents (between 55 and 78 percent) were detected on patrol. The percentage of types of all incidents detected on patrol is shown in Figure 21. Of recorded accidents, vehicle fires, medical emergencies, and major incidents (incidents with a greater potential of creating delays on the roadways), 46, 33, 71, and 28 percent, respectively, were detected on patrol.

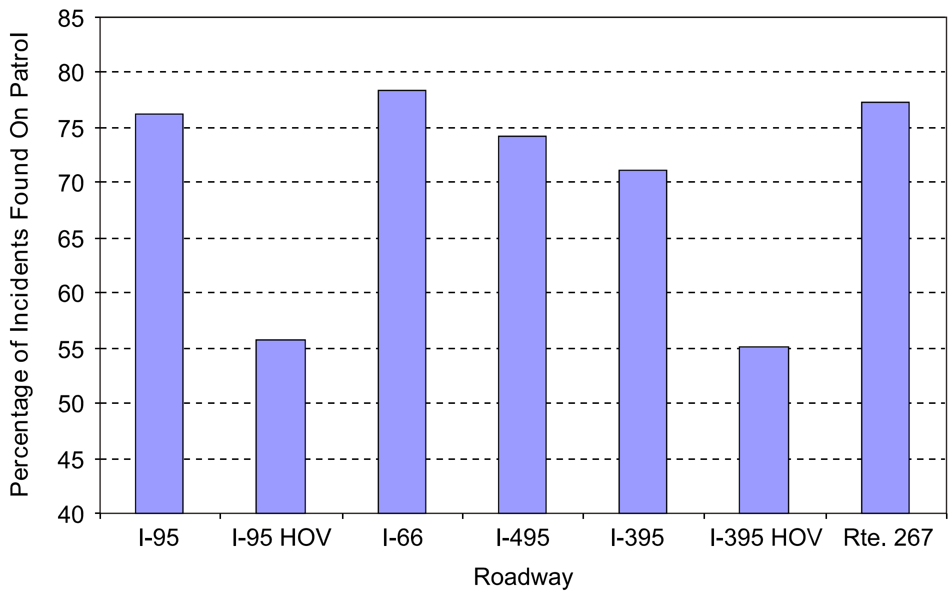

Figure 20. Percentage of Incidents Detected on Patrol by Roadway

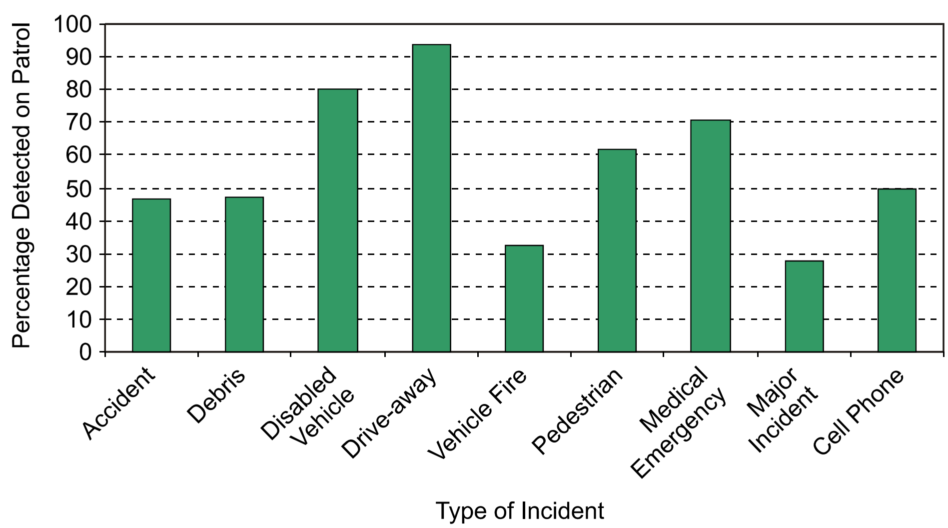

Figure 21. Percentage of Types of Incidents Detected on Patrol

The lane blocking impact that some of the incidents in Figure 21 have on the roadways can be expressed with distributions of lane blocking incidents detected on patrol by roadway and lane blocking incidents that were dispatched to the patrollers. Figure 22 shows a breakdown of lane blocking incidents detected on patrol by roadway, and Figure 23 shows a breakdown of lane blocking incidents that were dispatched to the patrollers. By combining all lane blocking incidents, a percentage of those incidents detected on patrol vs. dispatched can be established and is shown in Figure 24. This figure revealed that between 27 and 51 percent of all lane blocking incidents were found on patrol.

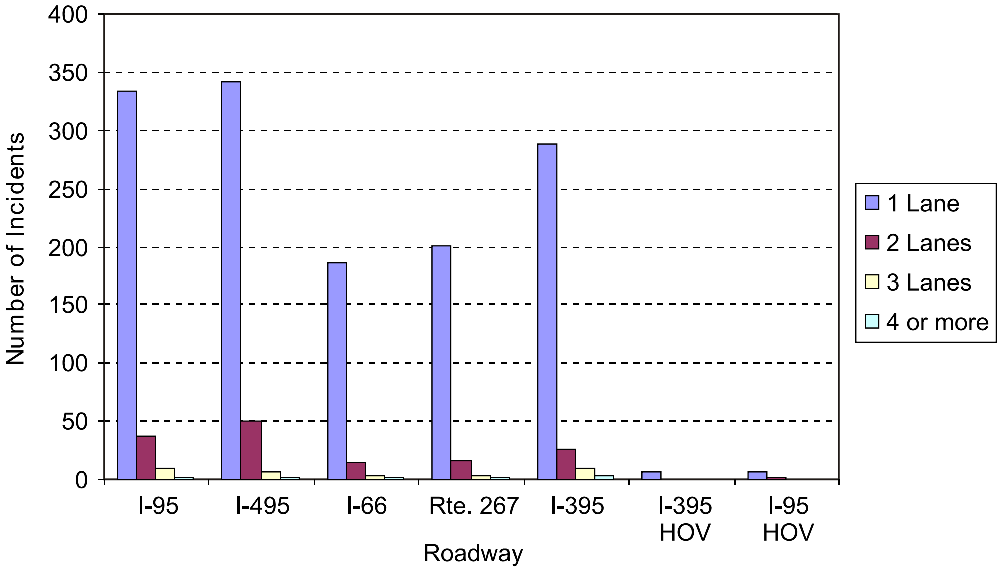

Figure 22. Distribution of Lane Blocking Incidents Detected on Patrol by Roadway

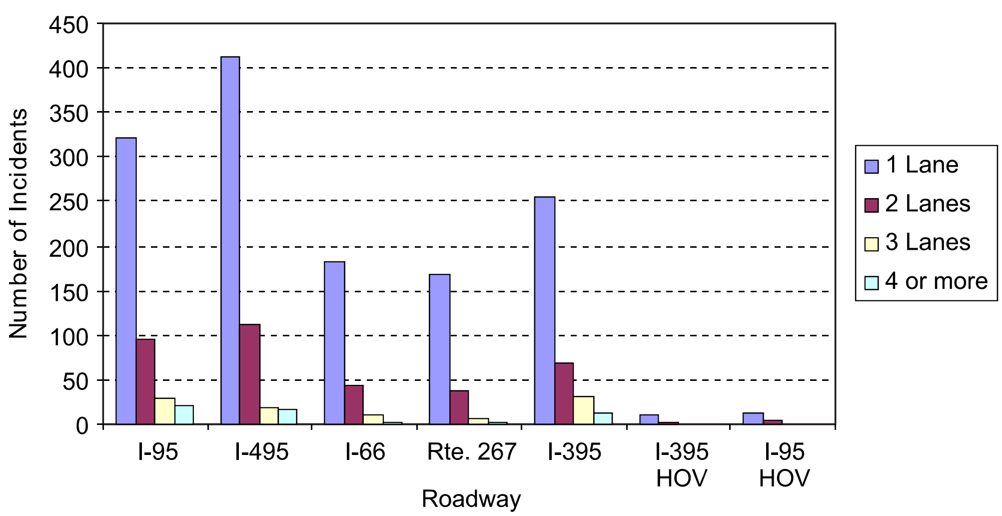

Figure 23. Distribution of Dispatched Lane Blocking Incidents by Roadway

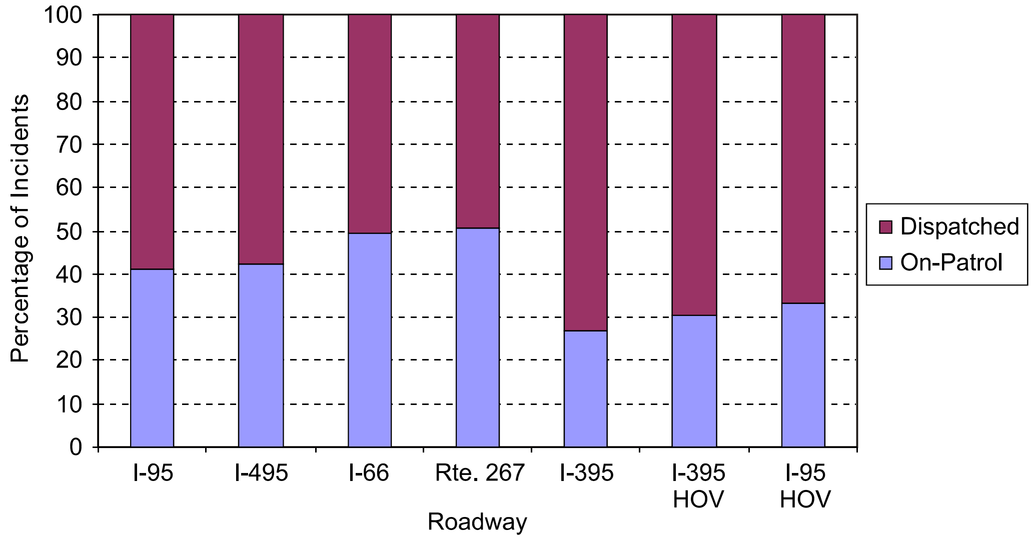

Figure 24. Percentage of Lane Blocking Incidents Found on Patrol vs. Dispatched

Development of a Benefit Evaluation Methodology for VDOT SSP Programs

To evaluate the benefits of VDOT's SSP programs, a methodology was developed that involved (1) determining incident durations with and without SSP, and (2) applying the findings of incident durations with and without SSP to the FSPE model to obtain quantitative values for the MOEs of reductions in delay and associated reductions in fuel consumption and emissions.

Incident Durations With and Without SSP

To determine incident durations with and without SSP, a two-step procedure was developed; the premise was that the incidents analyzed would be used in conjunction with the FSPE model to determine the benefits of SSP operations. In light of the fact that most freeway incidents are categorized into accidents, breakdowns, or debris, the procedure focuses on each of these incident types. Step 1 involves an analysis of SSP database entry clearance times for each incident type. Each incident type must be distributed into lateral locations of left shoulder, right shoulder, and in-lane, and mean clearance times determined for each distribution. A flow diagram for the Step 1 procedure is shown in Figure 25.

Once Step 1 is complete, the procedure moves to Step 2 and involves an analysis of the same incident types as in Step 1. For accidents, the VSP CAD database is used and a determination made as to the type of responder (VSP only or VSP and SSP jointly). For each responder type, each accident entry must be distributed into lateral locations of left shoulder, right shoulder, and in-lane and mean clearance times determined for each distribution. The difference in clearance times without SSP support (i.e., VSP only) must then be applied as a percentage to each accident distribution in Step 1 to determine average clearance time *without* SSP. The value for mean accident clearance times where VSP and SSP were joint responders *is* the average clearance time *with* SSP support.

For breakdowns, the clearance times found in Step 1 are used, and to determine mean clearance times *without* SSP, additional time must be applied to all incidents where the SSP pushed or repaired a vehicle to account for average tow-truck arrival times had SSPs not been present to provide services. For debris, the clearance times found in Step 1 are used, and to determine mean clearance time without SSP, a blanket 5-minute clearance time is applied to all incidents to account for additional removal time had SSPs not been present for the service. The values for breakdown and debris clearance times found in Step 1 *are* the average clearance times *with* SSP support. A flow diagram of the Step 2 procedure is shown in Figure 26.

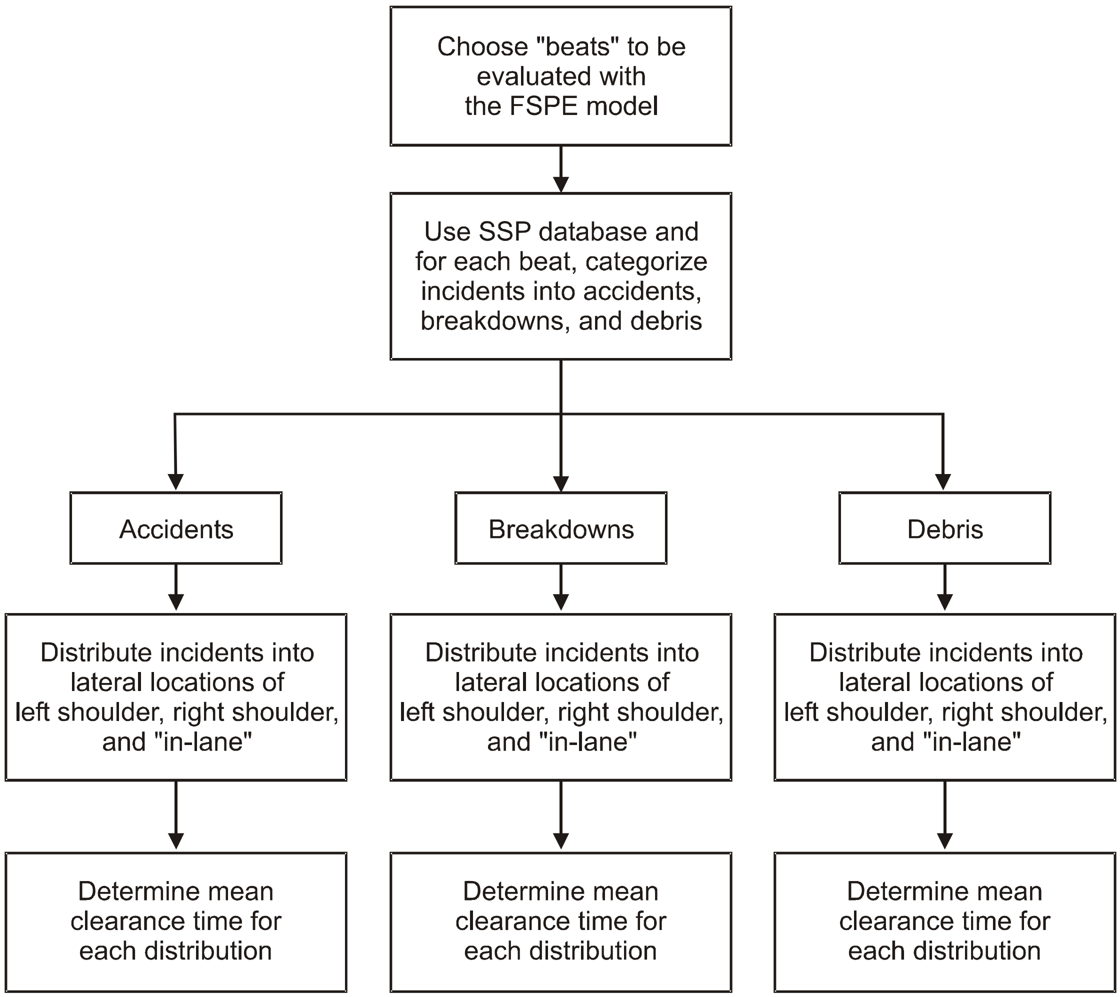

Figure 25. Step 1 Procedure for Determining Incident Durations With and Without SSP

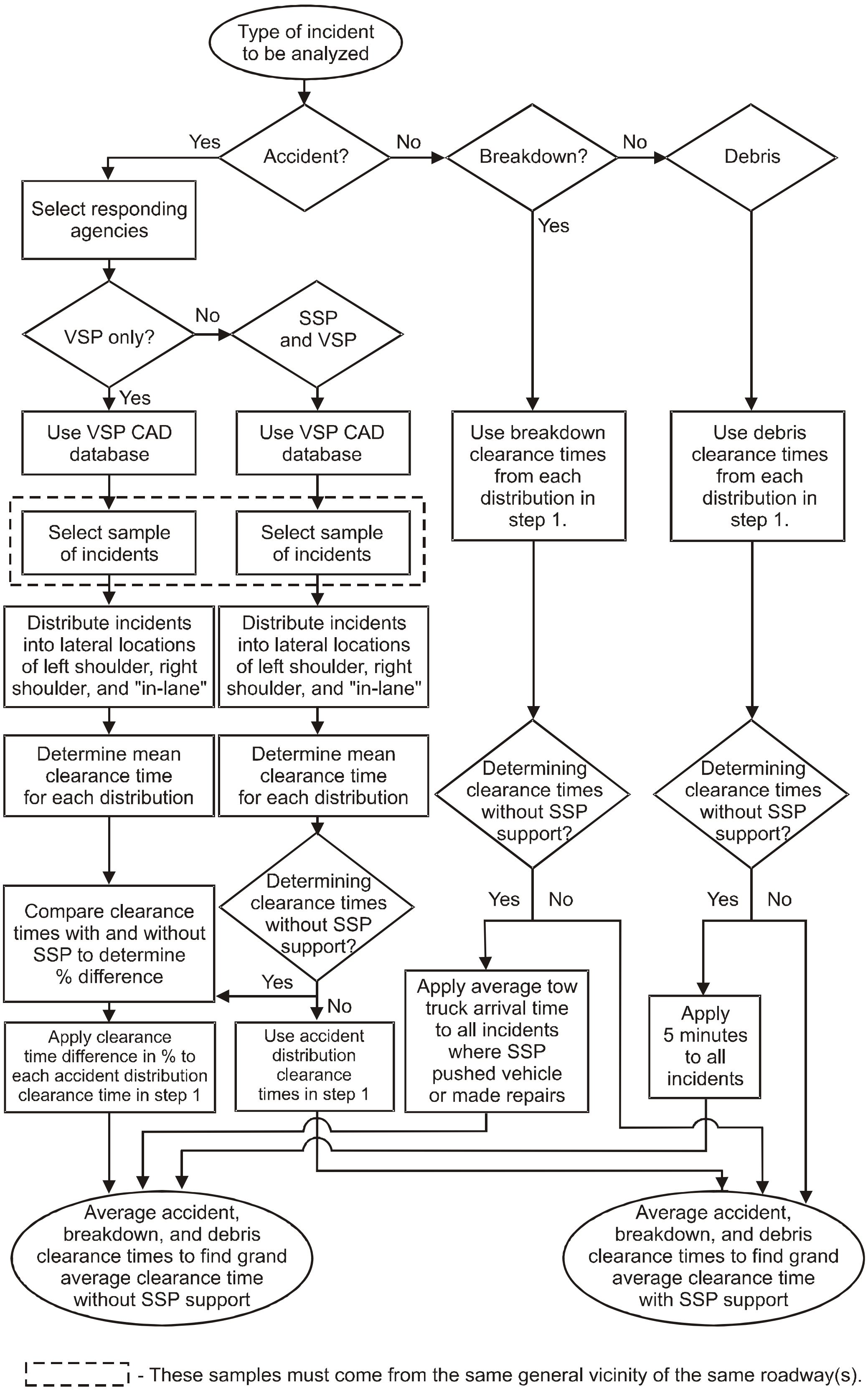

Figure 26. Step 2 Procedure for Determining Incident Durations With and Without SSP

Benefit Evaluation Using the FSPE Model

Model Description

The first FSPE model was developed in 1999 under contract with the California Department of Transportation (Caltrans) and has been used by Caltrans district staff to calculate the B/C ratio of existing service patrol beats since the year 2000. The current FSPE model (version 14.0) is the accumulation of several refinements and updates since the development of the original model. The intent of the model is to assist transportation agencies with the assessment of SSP programs by estimating the B/C ratio of existing patrol beats.[24]

The model's primary MOEs selected for reporting the cost-effectiveness of providing SSPs on freeways are reductions in (1) incident-induced vehicular delays; (2) fuel consumption; and (3) emissions (air pollution). Additional benefits of SSPs are extremely difficult to quantify and thus are not estimated by the FSPE model. The MOEs are developed by calculating hourly directional traffic volumes for each beat by scalar multiplication where directionality factors (D-factors) and time-of-day traffic profiles are multiplied by annual average daily traffic volumes (AADT), thus creating directional hourly traffic volumes from the "without incident" volumes in the FSPE queuing model.[24]

To estimate incident-induced delay and associated delay savings attributable to service patrol operations, the FSPE model employs deterministic queuing models. These models are used to estimate motorist delay associated with queues that form during incident conditions. For freeway applications, deterministic queuing analysis is taken at the macroscopic level where the arrival and service patterns are considered to be continuous and the arrival and service rates (capacity) are high. A cumulative vehicle count vs. time diagram for a typical freeway incident situation is shown in Figure 27. The arrival rate, indicated in the diagram as λ, is specified in vehicles per hour and is considered constant. The normal capacity without an incident is indicated in the diagram as μ, and since it exceeds the arrival rate, no queuing would normally

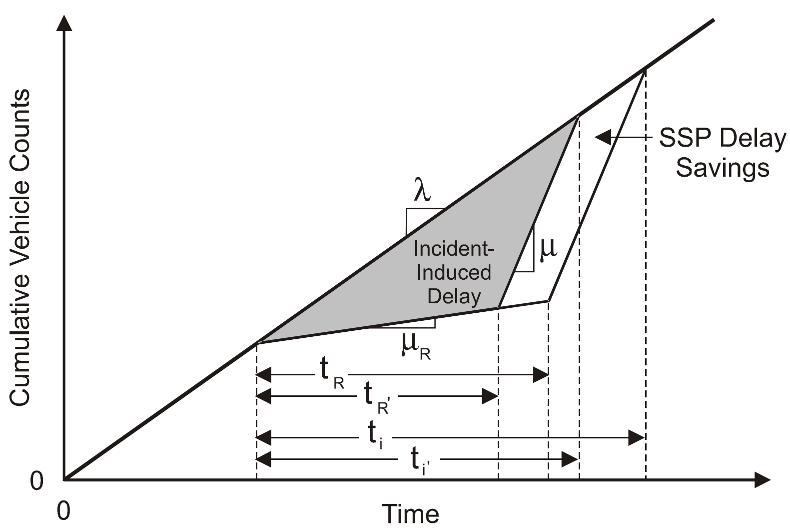

Figure 27. Cumulative Vehicles vs. Time During Incident Conditions with SSP Support

exist. However, when an incident occurs, it reduces the capacity to μ_R, which is below the arrival rate, and this lower capacity is maintained for t_R hours. The deployment of service patrols typically results in shorter response and clearance times provided by SSP operations, which in turn reduces the duration of the incident from t_R to $t_{R'}$ and reduces the time for the facility to return to normal flow from t_i to $t_{i'}$.[25]

where
- λ = vehicle arrival rate (veh/hr)
- μ = the freeway's normal capacity
- μ_R = the freeway's capacity under incident conditions
- t_R = the duration of the incident without SSP service
- $t_{R'}$ = the duration of the incident with SSP service
- t_i = the duration of the incident induced congestion without SSP service (time to normal flow)
- $t_{i'}$ = the duration of the incident induced congestion with SSP service (time to normal flow).

During incident conditions, the FSPE model uses capacity reduction factors in conjunction with the geometric and traffic characteristics of a service patrol beat, the frequency and type of assisted incidents on the beat,[26] and the queuing models to estimate delay. The model proportions the incidents by a two-dimensional time of day and space vehicle miles traveled (VMT) weighting scheme. Time of day is divided into hourly time slices that are weighted by VMT using time-of-day traffic profiles. Over space, each beat is divided into beat-segments, which are weighted by traffic volumes and distance (i.e., VMT) for proportioning incidents into hourly time slices on beat segments. The delay benefits of SSP programs are calculated by subtracting the incident-induced delay with service patrols from the estimated delay without service patrols. The fuel and emission benefits are calculated by cross-referencing fuel and emissions tables that can be generated by air quality models.

Model Workbook and Data Requirements

Prior to the performance of district-wide beat evaluations, the workbook of the FSPE model must be formatted with beat-specific and/or default data. Once this is done, the required data for the analysis of an SSP beat are entered once into a single worksheet (INPUT) and automatically transferred to other worksheets as needed.[24] The FSPE model worksheets include:[27]

- INPUT: Beat input data for the SSP beat to be analyzed. These include *beat service descriptions* (hours of operation, number of trucks, cost of service), *beat design characteristics* (number of links on a beat, length of links, number of lanes, Boolean identifiers for presence of HOV lanes and shoulders), *beat traffic characteristics* (AADT per link, peak directionality factors), and analysis year *beat incident characteristics* (number and mean clearance times of left shoulder, right shoulder, and in-lane accidents, breakdowns, and debris)

- TRAFFIC-PROFILES: Average time-of-day traffic profiles (represented as a percentage of ADT) for weekday, Saturday, and Sunday SSP beat analyses

- DIR-FACTORS: Time-of-day traffic directionality profiles per beat segment (represented as a percentage of hourly traffic volume) for weekday, Saturday, and Sunday SSP beat analyses

- PARAMS: The default model parameters that include *freeway capacity values*, *remaining freeway capacity factors due to incidents* from the HCM 2000,[16] *fuel/emissions rates*, *clearance time reduction data* taken from the methodology to determine incident durations with and without SSP, *travel time costs*, *fuel costs*, and *occupancy rates*.

- FIELDDATA: An optional worksheet that can be used to input segment-specific hourly volumes, capacities, and/or SSP assists, if detailed segment specific data are available.

- RESULTS: Individual time period, daily, and annual savings of the MOEs (delay, fuel, emissions) and the B/C ratio.

A schematic of the FSPE workbook routine, its associated worksheets, and worksheet sections is shown in Figure 28. A template of the FSPE model used for the NOVA case study can be found at http://www.virginiadot.org/vtrc/main/online_reports/pdf/append/06-r33.htm. The original model developed for Caltrans was reformatted for VDOT applications.

Model Limitations

- No data inputs are required for freeway interchanges, e.g., on/off ramp descriptors (number of ramp lanes, diamond vs. cloverleaf configuration), ramp density (or average number of ramp interchanges per freeway mile), etc. The only freeway geometry descriptors required are the number of HOV and mixed-use lanes and Boolean identifiers for presence (or absence) of left and right shoulders. In addition, no inputs regarding lane widths or horizontal and vertical alignments are required.[24] These limitations can result in less accurate queuing modeling and capacity reduction estimates.

- Many traffic flow characteristics that affect accident rates are not required as inputs, e.g., percent of trucks/buses, and no descriptors are required for weaving/merging areas. Further, the aggregate nature of service patrol beat evaluation data may have obscured some relations between assist rates and the beat descriptors. For example, daily variations in traffic volumes and daily variations in SSP-assist rates are not available as descriptors; only total number of annual assists and AADT are required as inputs.[24] These limitations can result in less accurate capacity reduction estimates and delay estimations.

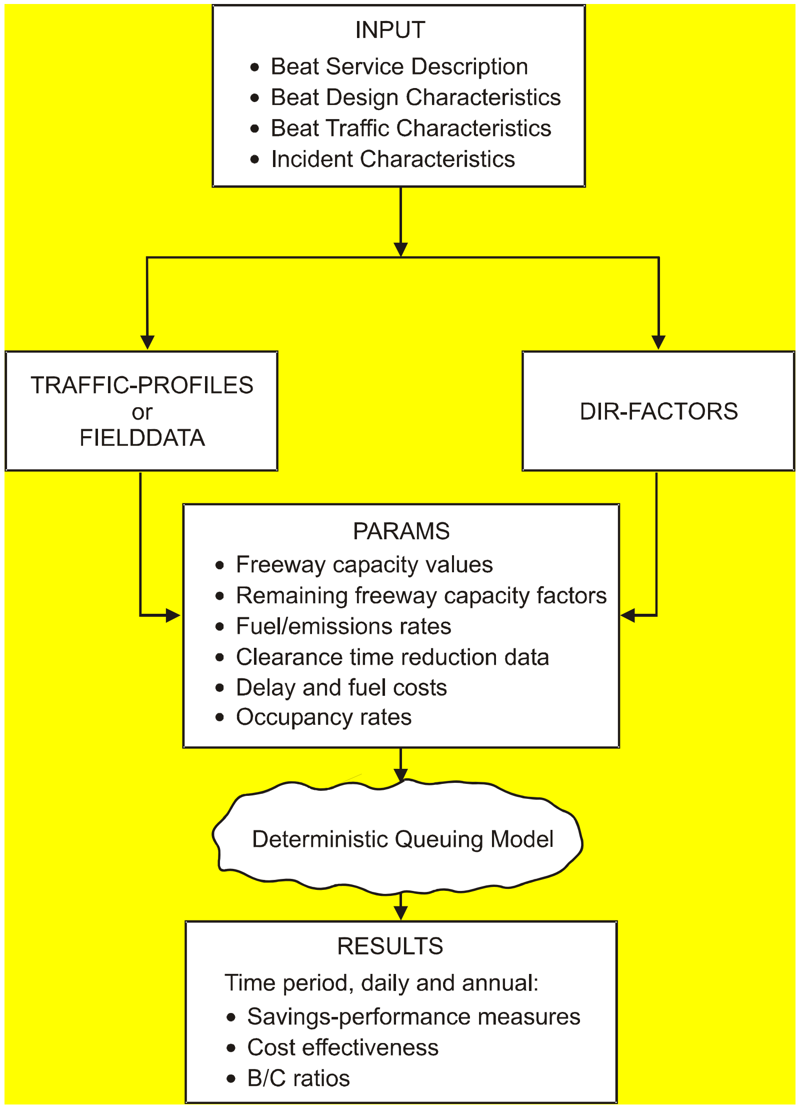

Figure 28. Schematic of FSPE Workbook Routines

- The fuel consumption and air pollution emission estimates are based on average vehicle speeds and do not explicitly consider time spent in each driving mode (cruise, acceleration, and idling). Thus, actual fuel consumption and emissions would be higher than estimated especially for congested freeway segments with significant portions of the time spent under stop-and-go traffic conditions.[24]

- Because the model is designed as a beat evaluator, incident responses that occur outside the boundaries of a regularly patrolled beat cannot be modeled. Quite often, SSPs assist with incidents outside the boundaries of a defined beat, however, the total number of occurrences throughout the year can be considered minimal compared to incidents occurring within beat limits.

Case Study of the Benefits of the NOVA SSP

This section of the report describes how the benefit evaluation methodology developed for VDOT SSP programs was used to assess the benefits of the NOVA SSP. It includes a discussion of (1) how the procedure for determining incident durations with and without SSP was applied to the NOVA SSP, and (2) the application of the FSPE model to NOVA SSP beats.

Determining Incident Durations With and Without SSP

To examine incident duration with and without NOVA SSP operations using the methodology shown in Figures 25 and 26, VSP CAD and NOVA SSP database entries had to be analyzed and compared. Most incidents fall into one of three categories: accident, breakdown, or debris; thus, it was decided that each of these incident types would be investigated in both VSP and SSP databases to determine incident durations with and without SSP. An analysis of VSP CAD database entries found that incidents are entered as *type of accident* (injury, property damage, fatality) or *type of disab*led (occupied, abandoned, hazard) but does not include entries involving debris. Further, it was found that the CAD database does not indicate the number of lanes blocked for accidents and provided limited information for disablements (or breakdowns).

Accident Clearance Times With and Without SSP

The data analyzed were obtained from the VSP CAD, which included accident data entries on I-66 (Route 29 at Centreville to the Beltway), I-395 (D.C. line to the Beltway), and I-495 (Woodrow Wilson Bridge to Rte. 650) for the period June 1, 2004, through September 30, 2004. The sections of I-66, I-395, and I-495 were chosen because they are not considered "priority" corridors by the NOVA SSP and, therefore, by choosing these sections, the likelihood of finding incidents that were handled by VSP without SSP assistance was increased.

Because the clearance times associated with number of lanes blocked vary considerably, the methodology employed to compare accident clearance times with and without the NOVA SSP involved an analyses of lane blockages To do this, a comprehensive incident "matching" exercise had to be conducted using accident reports the VSP files with the Department of Motor Vehicles. The accident reports are accessible through VDOT's CRASH Report Database, and each shows a crash diagram that gives an indication as to the number of lanes blocked.

Specific CRASH reports were found by searching the appropriate NOVA District sections for I-66, I-395, and I-495. The reports were then matched with the records from the CAD incident data by using date, time of day, mile marker, and location fields. Upon finding a match, the incident details and diagram from the report were analyzed and led to an estimation of the number of lanes blocked. The lane blockage estimation involved determining the location of the vehicle or vehicles on the roadway, estimating damage to the vehicle or vehicles, and determining whether the vehicles had to be towed and if any injuries were sustained by the occupants. The clearance time per number of lanes blocked for each incident without SSP assistance was calculated by subtracting the "notification time" of the incident from the "clear time" of the incident. These were then compared with the clearance times of lane blocking accidents with SSP (each entry into the CAD database indicates whether SSPs were present at the incident site). Lane blocking determination for incidents with SSP were found by matching the same incidents from the CAD database with the SSP database.

There are "notification" and "clear" time discrepancies between the VSP CAD and SSP databases for same incidents. The philosophy of the NOVA SSP is that an incident is ended or "cleared" once travel lanes are open. VSP may not "clear" an incident immediately after the travel lanes are open, however, and thus the clearance times for accidents in the CAD database and SSP database can differ. For the purposes of uniformity, the VSP CAD database was used to analyze accident clearance times with and without SSP.

A sample size of 504 incidents was analyzed: 398 were VSP only responses that were matched with VDOT's CRASH database to estimate number of lanes blocked, and 106 were VSP and SSP joint responses that were matched with the SSP database to find number of lanes blocked. Table 3 shows the results of the analyses for shoulder and in-lane clearance times with and without SSP. At a 95 percent confidence interval, the lower and upper clearance time bounds for shoulder incidents overlap; likewise, boundary overlaps occur for the in-lane case. These boundary overlaps indicate a degree of variance within clearance times, which may be attributed to deficiencies in sample sizes.

Table 3. Mean Accident Clearance Times With and Without SSP

		Mean	Std	95% Confidence Interval	
		(min)	Error	Lower Bound	Upper Bound
Shoulder	With SSP	45.02	2.70	39.72	50.33
	Without SSP	56.27	4.95	46.55	65.98
In-Lane	With SSP	65.04	3.79	54.45	75.63
	Without SSP	74.55	5.39	67.10	82.00

Breakdown and Debris Clearance Times With and Without SSP

A sample of breakdown incidents was taken from the SSP database and consisted of incidents from all routes analyzed by the FSPE model. To determine the average breakdown clearance time without SSP support, 30 minutes of additional clearance time was added to those incidents where SSP either pushed or repaired the vehicles. An assumption was made that all incidents where the NOVA SSP pushed or repaired vehicles would have been towed by a wrecker, and the NOVA SSP estimates an average wrecker response time of 30 minutes.

For debris incidents, the SSP database sample consisted of incidents from all routes analyzed by the FSPE model. To determine average debris removal clearance times without SSP support, 5 minutes of additional clearance time was added to all incidents. This 5-minute assumption was made because NOVA SSP personnel estimate it would take this much longer to remove debris if SSPs were not present.

Incident Duration Reductions With SSP Support

It was important to determine the mean clearance time difference for all incidents with and without SSP for each route included in the FSPE benefit evaluation. Therefore, to be compatible with FSPE model inputs, the percentage difference of mean accident clearance times with and without SSP were applied to all routes covered in the FSPE model. Similarly, shoulder and in-lane breakdown and debris clearance time differences with and without SSP were applied to all routes covered in the FSPE model.

The aggregate results for accident, breakdown, and debris clearance times with and without SSP for all routes included in the benefit evaluation are shown in Table 4. The analyses found that the average percent reduction in clearance times with SSP support for debris, shoulder breakdowns, in-lane breakdowns, shoulder accidents, and in-lane accidents is 25.0, 15.0, 33.3, 20.6, and 12.9 percent, respectively. For all incidents (inclusive), the average clearance time reduction with SSP is 17.3 percent.

The critical factors for obtaining clearance time reductions with SSP shown in Table 4 were the applications of (1) a fixed percentage difference for accidents with and without SSP, (2) an additional 30-minute clearance time for all incidents where SSP pushed or repaired broken down vehicles (to account for tow-truck arrival times had SSPs not been present), and (3) an additional 5-minute clearance time for all debris incidents had SSPs not been present to remove the debris. Of these three applications, tow-truck arrival time has the greatest potential to cause variations in clearance time reductions. Because of this, a sensitivity analysis was performed to understand how a 10, 20, 30, 40, and 50 minute tow-truck arrival time would affect the percent reduction in clearance time. Figure 29 shows there is a linear relationship between tow-truck arrival times and percent reduction in clearance time with SSP. This can be expressed by the following equation:

$$y = 3.4013x + 6.841$$

where y = reduction in clearance time with SSP (%), and x = tow-truck arrival time (min).

Table 4. Incident Clearance Time Reduction with SSP Support per Incident Type

INCIDENT CLEARANCE TIME REDUCTION WITH SSP SUPPORT						
	Debris	Breakdowns		Accidents		TOTAL
	Total	Shoulder	In-Lane	Shoulder	In-Lane	(All Incidents)
Number	681	10545	614	558	725	13123
Clearance Time w/SSP (min)	14.91	12.12	23.05	29.43	44.81	15.31
Clearance Time w/o SSP (min)	19.89	14.26	34.56	37.06	51.43	18.52
% Reduction	**25.0%**	**15.0%**	**33.3%**	**20.6%**	**12.9%**	**17.3%**

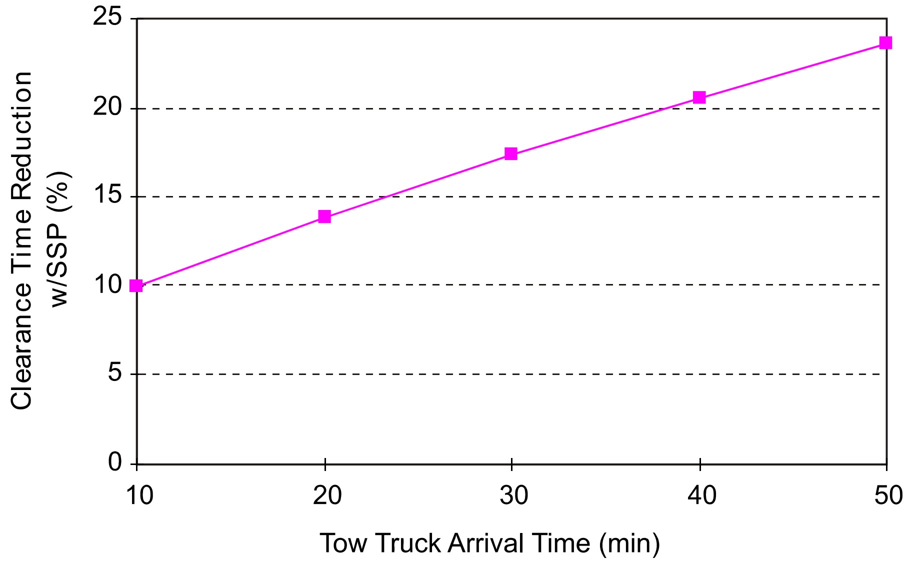

Figure 29. Effect of Tow-Truck Arrival Times on Clearance Time Reduction

Determining NOVA SSP Benefits Using the FSPE Model

The FSPE model was applied to NOVA SSP beats as a case study to obtain quantitative values for the MOEs of reductions in delay and associated reductions in fuel consumption and emissions. Particular benefits that were not quantified or that are difficult to quantify include:

- *Benefits to VSP.* SSP service results in fewer minor incidents (such as breakdowns) attended by VSP, thereby allowing VSP to attend to major incidents and law enforcement activities.

- *Benefits to the STC.* SSP service provides faster recovery of the freeway to normal conditions when freeway incidents occur and improves incident detection capabilities. The roving SSP trucks are able to locate incidents and report them promptly to the STC and VSP.

- *Improved safety.* SSP vehicles provide motorists with a sense of security on the freeway, and the faster clearance of incidents may contribute to reducing secondary accidents. The determination of safety improvements, however, requires data on accident rates and traffic volumes on the SSP beats over long time periods. A secondary incident is defined as an incident that resulted directly from the primary incident. However, there is no established definition of how to measure secondary incidents; e.g., during peak traffic periods, it is very difficult to determine whether an incident resulted from the congestion related to a primary incident or from recurrent congestion and associated bottlenecks.

- *Public perception.* The NOVA SSP receives numerous comments from assisted motorists throughout the year in the form of letters, emails, and phone calls. These comments are compiled in a yearly "What the Customer Had to Say" report. These yearly reports are typically quite large, which is an indication that the traveling public appreciates the services of the NOVA SSP. Motorists view the services as a public benefit, yet one that cannot be quantified.

Formatting Model Workbook for NOVA SSP Evaluation

To apply it to the NOVA SSP, the FSPE model had to be formatted to NOVA-specific conditions. This involved determining roadway geometrics, traffic data, and incident data for each route patrolled by the SSP. Because the model is designed as a beat evaluator, routes that had a limited number of incident reports (i.e., routes covered on a limited basis) would not be evaluated. Prior to the 2003 budget cuts, much of the NOVA freeway system was covered by the NOVA SSP. However, because of the cuts and resulting loss of staff, route coverage had to be scaled back.

Currently, Routes DTR-1, C-1, C-2, P-2, P-10, B-2, and B-3 are covered daily and on a consistent basis. Of these routes, DTR-1 is funded by the Dulles Toll Road facility and C-1, C-2, and B-3 are federally funded through the CMAQ program. The intent of the evaluation was to model the benefits of the SSP compared to VDOT expenditures and therefore, because these routes are not funded by VDOT, they were not considered in the evaluation. The A.M. shift of Route B-2 is funded by VDOT, and the P.M. shift is funded through the CMAQ program. Therefore, the P.M. shift of Route B-2 was not evaluated. All incidents occurring on the reversible HOV routes (P-4, P-5, P-6 and P-12) are recorded by the NOVA SSP in conjunction with their corresponding mainline routes and therefore were not evaluated. Currently, Routes P-1, P-3, and P-9 are not patrolled on a consistent basis and, therefore, were not evaluated, but each route's design, traffic, and incident characteristics were made available to the model for when staffing levels allow for their coverage. Routes P-7 and P-8 were evaluated, although coverage on these routes was inconsistent (i.e., not covered daily) because of staffing limitations.

Upon determining which routes would be evaluated, the FSPE model and its associated worksheets were formatted to address each. An example of an application of the FSPE model to Route DTR can be found in Appendix B.

Workbook Formatting Assumptions

- The FSPE model was formatted such that each route contains a set of unique traffic profiles and D-factors for weekdays, Saturdays, and Sundays. These traffic profiles and D-factors were derived from dual CCS detectors located within one segment of each route. Thus, the model assumes that every other segment within a route exhibits the same traffic profiles and D-factors of the segment that contained the CCS detectors.

- The fuel/emissions rates table was constructed with the assumption of a vehicle fleet composed of only light-duty gasoline vehicle (LDGV) classifications. Therefore, the FSPE model uses LDGV fuel rates when calculating fuel consumption benefits and, thus, tends to underestimate "real world" fuel consumption rates.

- The average SSP truck speed, as entered into the PARAMS worksheet, is assumed to be 55 mph.

- A 30-minute clearance time reduction with SSP support is assumed for all incidents where SSP trucks pushed a vehicle out of the travel lanes or provided repairs to a vehicle that allowed the vehicle to resume travel. It also accounts for the additional tow-truck arrival times had SSP not been present.

- A 5-minute clearance time reduction with SSP support is assumed for all debris related incidents.

- The model assumes a proportional distribution of incidents by applying a two-dimensional time-of-day and space VMT weighting scheme.

Beat Evaluation Results

Once each FSPE workbook was formatted, the model was run for weekday, Saturday, and Sunday evaluations for each route. The RESULTS worksheet presents daily and annual delay savings (veh-hrs), fuel consumption savings (gal), and reactive organic gases (ROG) (kg), CO (kg), and NOx (kg) emissions savings for weekday, Saturday, and Sunday model runs. The RESULTS worksheet also provides B/C ratios for daily and annual operations where the benefits are represented as delay and fuel dollar savings and the costs are the cost of the SSP service.

Table 5 shows the annual delay and fuel consumption savings estimates for weekday, Saturday, and Sunday operations on all routes included in the evaluation (P-2, P-7, P-8, P-10, and B-2). The combined total annual delay savings for the routes were 225,322 veh-hrs and the total annual fuel consumption savings were 339,883 gal. Route P-2 exhibited the most beneficial delay and fuel consumption savings, followed by P-10, B-2, P-7, and P-8.

Table 5. Annual Delay and Fuel Consumption Savings Estimates

	Annual Delay Savings (veh-hrs)				Annual Fuel Consumption Savings (gal)			
Route	Weekday	Saturday	Sunday	TOTAL	Weekday	Saturday	Sunday	TOTAL
P-2	139,674	12,421	24,527	176,622	210,688	18,736	36,997	266,421
P-7	10,749	136	229	11,114	16,214	205	346	16,765
P-8	1,385	39	11	1,435	2,089	59	17	2,165
P-10	16,854	1,864	3,889	22,607	25,424	2,811	5,866	34,101
B-2	13,544	-	-	13,544	20,431	-	-	20,431
TOTAL	182,206	14,460	28,656	225,322	274,846	21,811	43,226	339,883

Annual ROG, CO, and NOx emissions savings per route are shown in Tables 6, 7, and 8, respectively. The total ROG, CO, and NOx emissions savings for all routes were found to be 28,368 kg, 1,498 kg, and 6,318 kg, respectively. As was the case in annual delay and fuel consumption savings, Route P-2 exhibited the most beneficial savings followed by P-10, B-2, P-7, and P-8.

The estimated SSP benefits and costs for each route are presented in Table 9, and the resulting B/C ratios are presented in Table 10. The total annual delay and fuel benefits for all routes were found to be $5,027,838, and the total annual SSP operating costs were found to be $805,897, thus representing an overall B/C ratio for NOVA SSP operations of 6.2:1. As can be seen from the table, all weekday benefits exceeded costs except service in Route P-8 (0.5:1).

Table 6. Annual ROG Emissions Savings Estimates

	Annual ROG Emissions Savings (kg/yr)			
Route	Weekday	Saturday	Sunday	TOTAL
P-2	17,585	1,564	3,088	22,237
P-7	1,353	17	29	1,399
P-8	174	5	1	180
P-10	2,122	235	490	2,847
B-2	1,705	-	-	1,705
TOTAL	22,939	1,821	3,608	28,368

Table 7. Annual CO Emissions Savings Estimates

	Annual CO Emissions Savings (kg/yr)			
Route	Weekday	Saturday	Sunday	TOTAL
P-2	929	83	163	1,175
P-7	71	1	2	74
P-8	9	-	-	9
P-10	112	12	26	150
B-2	90	-	-	90
TOTAL	1,211	96	191	1,498

Table 8. Annual NOx Emissions Savings Estimates

	Annual NOx Emissions Savings (kg/yr)			
Route	Weekday	Saturday	Sunday	TOTAL
P-2	3,917	348	688	4,953
P-7	301	4	6	311
P-8	39	1	-	40
P-10	473	52	109	634
B-2	380	-	-	380
TOTAL	5,110	405	803	6,318

Table 9. Estimated SSP Benefits and Costs

Route	Total Annual Benefits (Delay and Fuel)				Total Annual Costs			
	Weekday	Saturday	Sunday	TOTAL	Weekday	Saturday	Sunday	TOTAL
P-2	$3,116,681	$ 277,157	$ 547,294	$3,941,132	$ 201,396	$ 40,279	$ 40,279	$ 281,954
P-7	$ 239,845	$ 3,032	$ 5,117	$ 247,994	$ 42,603	$ 7,746	$ 6,971	$ 57,320
P-8	$ 30,905	$ 870	$ 256	$ 32,031	$ 64,292	$ 9,295	$ 5,422	$ 79,009
P-10	$ 376,088	$ 41,586	$ 86,778	$ 504,452	$ 201,396	$ 40,279	$ 40,279	$ 281,954
B-2	$ 302,229	$ -	$ -	$ 302,229	$ 105,660	$ -	$ -	$ 105,660
TOTAL	$4,065,748	$ 322,645	$ 639,445	$5,027,838	$ 615,347	$ 97,599	$ 92,951	$ 805,897

Table 10. Estimated SSP B/C Ratios

Route	B/C RATIO			
	Weekday	Saturday	Sunday	TOTAL
P-2	15.5	6.9	13.6	14.0
P-7	5.6	0.4	0.7	4.3
P-8	0.5	0.1	0.0	0.4
P-10	1.9	1.0	2.2	1.8
B-2	2.9	0.0	0.0	2.9
TOTAL	6.6	3.3	6.9	6.2

Costs also exceeded benefits for Saturday and Sunday service on Routes P-7 (0.4:1, 0.7:1) and P-8 (0.1:1, 0.0:1). It should be noted that Routes P-7 and P-8 are not patrolled on a consistent basis (i.e., the number of weekdays that were evaluated for each route was 55 and 83; the number of Saturdays was 10 and 12; and the number of Sundays was 9 and 7, respectively).

A sensitivity analysis was performed to understand how a 10-, 20-, 30-, 40-, and 50-minute tow-truck arrival time (given no SSP presence for breakdown repairs and pushes) would affect the total benefits shown in Table 9. As can be seen in Figure 30, annual delay and fuel benefits increase with increased tow-truck arrival times and can be best expressed as a linear relationship (adjusted R^2 = 0.94) with the following equation:

$$y = 367465x + 4 \times 10^6$$

where y = Total annual delay and fuel benefits ($), and x = tow-truck arrival times (min).

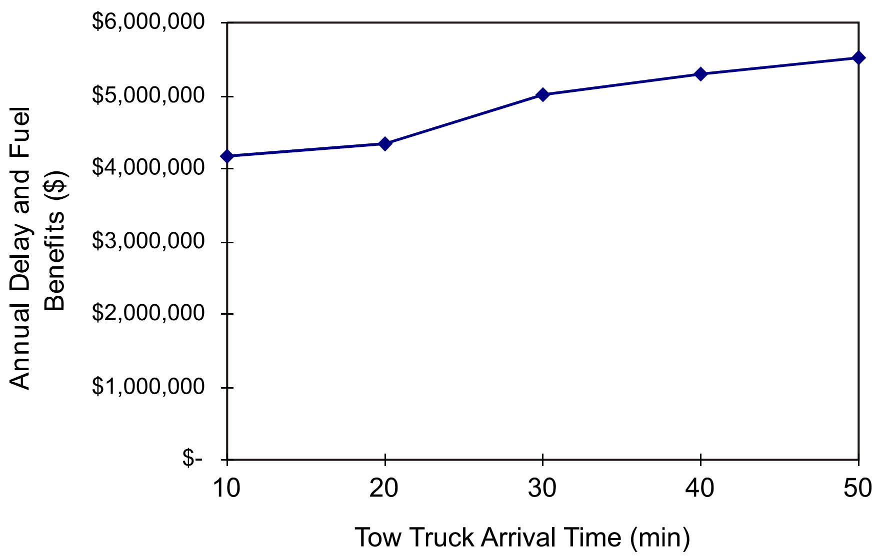

Figure 30. Effect of Tow-Truck Arrival Times on Annual Delay and Fuel Benefits

FINDINGS AND CONCLUSIONS

Some of the conclusions and findings of this study are specifically applicable to the NOVA SSP, and others are applicable to SSP programs in other regions of the Commonwealth.

Specific to the NOVA SSP Program

- *The incident data captured by the NOVA SSP are sufficient to enable management to conduct a variety of performance measure analyses, including analyses of lane blocking statistics and associated response, service, and clearance times.*

- *Incident records dropped between 11 A.M. and 12 P.M. in the region.* This can be attributable to patroller shift changes. Based on the hourly incident trends during the study year, it is plausible that 300 to 400 incidents are missed during this period.

- *Because NOVA SSP staffing levels are not equal to those that existed prior to the 2003 budget cuts, route coverage has been lessened.* Routes P-1, P-3, P-7, P-8, and P-9 were once covered on a consistent basis, but because of staff reductions, coverage is now inconsistent. Assuming there is a linear relationship between the occurrence of incidents and AADT, and that incidents increase as AADT increases, approximately 12,500 incidents may be missed because of the lack of coverage on these routes. Routes P-7 and P-8, which have the highest and third highest average route AADTs, respectively, in the region, would account for approximately 3,200 and 2,500 of these missed incidents.

- *Based on the application of the methodology for determining incident durations with and without SSP, the operation of service patrols in NOVA reduces average incident durations by*

17.3 percent. A critical factor in determining incident durations with and without SSP is tow-truck arrival times had SSPs not been present to push or repair disabled vehicles (for the NOVA case, a 30-minute average tow-truck arrival time was used). Based on a sensitivity analysis of 10-, 20-, 30-, 40-, and 50-minute tow-truck arrival times, incident duration reductions attributable to an SSP presence will range from 9.9 to 23.6 percent and annual delay and fuel benefits will range from $4.1 million to $5.2 million.

- *The benefits attributable to SSP coverage on the Dulles Toll Road exceeded the costs for weekday periods; however, the costs of Saturday and Sunday service far exceeded the benefits.* Since this route is not funded by VDOT, it was not factored into the overall B/C ratio for NOVA SSP operations.

- *If all routes evaluated and service days are combined (excluding the Dulles Toll Road route), the benefits of operating service patrols in NOVA outweigh the operational costs by a factor of 6.2:1.* However, the operational costs of operating service patrols in NOVA outweigh the benefits for weekday operations on Route P-8; for Saturday operations on Routes P-7 and P-8; and for Sunday operations on Routes P-7 and P-8. Because these routes are covered inconsistently, incident records were limited. If one assumes that a linear relationship exists between the occurrence of incidents and AADT, it may be plausible to assume that the benefits associated with covering these routes would outweigh the costs if coverage was consistent.

- *Quantifying all the benefits of service patrols is difficult.* One benefit that could not be evaluated in this study was delay savings resulting from reductions in secondary incidents (incidents resulting from primary incidents). Ascertaining whether an incident resulted directly from a primary incident is difficult, especially in urban areas where recurring congestion is common. In addition, although emission quantities were obtained, a dollar amount was not applied to the emissions savings estimates because of the complexities in attributing costs to pollution. Therefore, the findings of overall benefits associated with NOVA SSP operations appear to be conservative.

VDOT's SSP Programs in General

- *Lane blocking incidents (incidents that occur in the travel lanes) are common to all regions in the state.* These incidents obstruct traffic flow and can create substantial delays for motorists. By capturing relevant lane blocking data, SSP programs have the ability to evaluate the nature, type, and severity of incidents on the roadways, thereby helping them to allocate resources to handle such incidents more effectively and efficiently.

- *Roadway incidents are random, and their number and type cannot be "controlled" by an SSP.* However, SSPs can influence response, service, and clearance times, which helps to decrease incident-related congestion and the potential for secondary incidents.

- *Incidents detected "on patrol" incur no response times, unlike those for which a patroller must be dispatched.* Therefore, capturing data from incidents detected on patrol vs. those where patrollers are dispatched can provide data about incident clearance time reductions associated with roaming SSPs.

- *The methodology developed in this study to determine incident durations with and without an SSP presence can be used in all regions of the state.* However, the amount of effort involved in applying the methodology is dependent on the level of integration of SSP and VSP CAD databases in those regions.

- *The FSPE model is a macroscopic freeway service patrol beat evaluation tool that uses commonly collected traffic data and is a practical means for evaluating delay, emissions, and fuel savings benefits resulting from SSP operations.* However, the model does not reflect microscopic beat details, such as ramp volumes and geometries, percent of trucks and buses, and descriptors for weaving and merging areas that would allow for more accurate estimates of the benefits of SSP operations.

RECOMMENDATIONS

Specific to the NOVA SSP Program

1. *The NOVA SSP should consider staggering shift hours for all routes so that coverage is more consistent during the 11 A.M. and 12 P.M. shift change periods*. This will ensure that SSP incident assistance is maximized during shift changes.

2. *The NOVA SSP should give priority beat coverage on I-495 (Routes P-7 and P-8) on a more consistent basis when staffing levels become sufficient*. This action will minimize the possibility of missed incidents on these routes.

3. *The VSP CAD and NOVA SSP databases should be integrated and VSP response, service, and clearance times should be captured by both the NOVA SSP and the STC*. In addition, the NOVA SSP and STC should capture the number and lateral location of lanes blocked for all incidents where the NOVA SSP was not present. This will enable the NOVA SSP to streamline its benefit evaluations or reduce the time it takes to conduct them.

VDOT's SSP Programs in General

4. *All VDOT SSP programs should evaluate performance on a monthly (or at a minimum, quarterly) and a yearly basis to allow for a more systematic approach to measuring and monitoring performance trends*. This will enable decision-makers to have a better understanding of what is occurring in the field and identify deficiencies in operations throughout different time periods. Pertinent data such as roadway incident statistics; lane blocking statistics; on-patrol detection vs. dispatched statistics; and associated response, service, and clearance times should be captured and archived to enable such evaluations.

5. *Annual benefit evaluations should be conducted by each of VDOT's SSP programs*. This will enable the programs to communicate their value relative to cost. These evaluations should use (1) the methodology contained in this report for determining incident durations with and without SSP, and (2) the FSPE model or other models that employ commonly collected traffic data.

SUGGESTIONS FOR FUTURE RESEARCH

- *In order to obtain more "real world" assessments of SSP beat operations, VDOT's Operations Division should consider a study to enhance the ability of the FSPE model to capture more microscopic traffic and design characteristics of a beat.* This would entail restructuring beat traffic and design characteristics tables to account for ramp volumes and geometries, percent of trucks and buses, and descriptors for weaving and merging areas.

- *To help develop more effective SSP resource allocation strategies, VDOT's Operations Division should consider assessing the practicality of utilizing the FSPE model's counterpart, the Freeway Service Patrol Predictor (FSPP) model.* The FSPP model can be used to predict the B/C ratios of new or proposed SSP beats where no SSP service is provided. FSPP does this by first predicting the number of SSP-assists based on the perspective beat's design and traffic characteristics and the assumed FSP service and then calculating the B/C ratio using the same methodology as in the FSPE model. The FSPP model can also be used to forecast the impacts of operational changes on existing beats such as additional service hours and weekend service.[24]

- *To account better for additional benefits that SSPs provide, VDOT's Operations Division should consider initiating a study that determines the role SSPs have on reducing secondary incidents and the additive delay these types of incidents generate.* The first step would be to create a secondary incident definition. Currently, there is no established definition for *secondary incidents* because of the difficulty in (1) identifying when these incidents occurred, and (2) confidently associating them with primary upstream incidents. Once a definition is created, the second step would be to develop a methodology for capturing them and measuring the additive delay associated with such incidents. In rural areas, this may not be a difficult methodology to produce, but in urban areas, where recurrent congestion is omnipresent, it can be difficult distinguishing delay caused by secondary incidents from recurrent congestion.

BENEFITS AND COSTS ASSESSMENT

Specific to the NOVA SSP

- *Staggering shift hours to enable SSP coverage during the 11 A.M. to 12 P.M. period will result in higher annual assist totals for all routes, thus resulting in greater delay, fuel, and emissions savings. No additional costs would be associated with this recommendation.*

- *Placing priority on beat coverage on I-495 (Routes P-7 and P-8) on a 24/7 basis when staffing levels become sufficient could result in additional costs of approximately $560,000 per year.* Assuming a relationship exists between incident occurrence and AADT, these routes have incident totals similar to those of Route P-2. If Routes P-7 and P-8 exhibit annual incident characteristics similar to those of Route P-2 (left shoulder, right shoulder, and in-lane accidents, breakdowns, and debris), delay and fuel savings could result in additional benefits in excess of $8 million per year. In addition, NOx, CO, and ROG emissions could be reduced by approximately 10,000, 2,400, and 45,000 kg per year, respectively.

VDOT's SSP Programs in General

- *There is an inherent labor cost associated with tracking SSP performance on a monthly or quarterly and yearly basis.* However, these costs can be minimized with effective database management practices. By implementing the recommendation of tracking performance on a regular basis, VDOT SSP programs will realize more effective allocation of resources to manage incidents on roadways better.

- *Performing yearly SSP benefit evaluations using the methodology set forth in this report will require additional labor costs.* However, these costs can be minimized by integrating the VSP CAD and SSP databases and managing them in such a way that would enable the capturing of relevant and pertinent benefit evaluation data. After initializing SSP program beat data into the FSPE model and assuming beat design characteristics remain constant, only yearly beat incident and traffic characteristics adjustments would be required, thus entailing minimal labor efforts.

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APPENDIX A

ADDITIONAL ATTRIBUTES OF THE NOVA SSP PROGRAM

The following provides additional information pertaining to the NOVA SSP program, including its fleet characteristics, relationship to the NOVA Smart Traffic Center (STC), core functions, equipment, patroller training, quick clearance policy, vehicle classification, inter-agency cooperation, and observations from the field.

Fleet Characteristics

The NOVA SSP operates a fleet of vehicles with different capabilities and functions. The fleet has 35 patrol vehicles that are Chevrolet 2500 Series Heavy Duty, 6.6 Turbo pickup trucks (shown in Figure A-1) equipped with push bumpers and a tow package with the ability to pull semi-trucks out of the roadway. The fleet also has of 2 flatbeds, 2 small self-loading wreckers, 2 large wreckers, and 4 incident command vehicles used for unified command operations. The incident command vehicles consist of 4 Suburban, a Dodge Van (used for airborne video), a Ford Van (used for communications), and a traffic control unit that can carry up to 250 traffic cones.

Figure A-1. NOVA SSP Vehicle

Relationship to NOVA STC

The NOVA STC's mission statement is: "To monitor the traffic flow on the interstate Highways in the Northern Virginia District and provide an immediate response to any highway incident in order to minimize traffic congestion and delays." To perform its mission, the STC uses a computerized freeway surveillance and control system that monitors regular traffic flow along I-395, I-66, I-95, and the Woodrow Wilson Bridge. The total length of the system is 70 miles.

Calls for assistance from VSP come into the control room, and operators notify the appropriate patroller via VDOT radio. Once on the scene, the patrollers notify the control room of the location of the stop, the type of vehicle requiring assistance, and once assistance is provided, the type of assistance. The type of assistance is recorded as one of five categories: disabled, abandoned, accident, debris, or other. The control room operator logs these data into a database for future analysis and reporting. In addition, in the event of a major incident, traffic management activities are coordinated from the control room, with information and instructions provided to patrollers at the scene via a dedicated VDOT radio.[1] Figure A-2 shows an information flow diagram for a traffic-related incident. The diagram is categorized by the sources of incident detection, verification, response, closure of event, and reporting and the actions taken by the sources.

A longstanding issue between the NOVA SSP program and the STC is the lack of integration between the two operations. Currently, both operate out of different facilities and the organizational structure of each is independent. Although both operations are in communication,

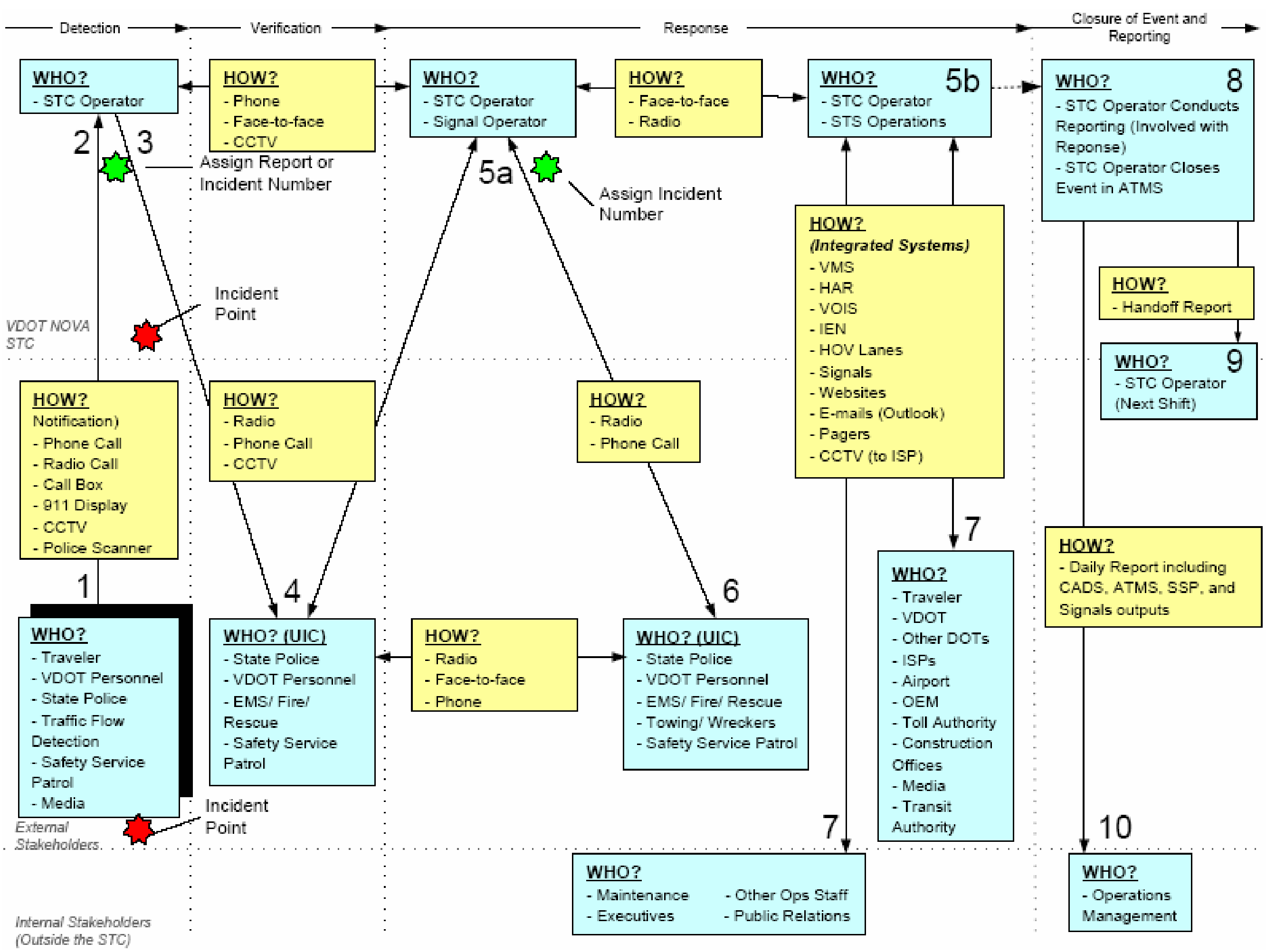

Figure A-2. NOVA STC Information Flow Diagram for Roadway Traffic-Related Incident

it is acknowledged that there is room for improvement in terms of coordination and data integration. Within the past year, the NOVA District was involved in a reorganization of staff and is in the process of reorganizing the structure of the traffic operations system of which the STC and SSP are an integral part. Some of the improvements in STC and SSP coordination include using phones with built-in digital cameras, allowing the SSP units to report state property damage from the field for repairs, and for the SSP personnel to send incident images the STC does not have the ability to see from its vantage point. In addition, the NOVA SSP is currently investigating the possibility of installing automatic vehicle location (AVL) technology in all vehicles that will allow STC operators and SSP field supervisors to monitor all field resources.

Within the past few months, a new incident management system has taken the place of the old SSP Incident Management software that was referenced for this project. This new system, developed by the University of Maryland for VDOT, allows STC controllers to monitor incident database entries from the field in real time. This innovative integrated communication link is considered essential for improved incident response activities.[2] To realize the goal of complete integration of SSP, STC, and VSP resources and operations, a new Public Safety Transportation Operations Center (PSTOC) is being built that will jointly house SSP, STC, and VSP personnel.

Core Functions

The NOVA SSP provides service on a 24-hour basis 365 days a year on the NOVA interstate system, the Dulles Toll Road, and the Woodrow Wilson Bridge. The SSP is VDOT's primary response team for unplanned incidents and events, congestion management during major interstate construction projects such as the Springfield Interchange, and for planned events including providing traffic control for the Marine Corps Marathon, the Fourth of July fireworks, the Army 10-miler and various other events held in the region.[1]

Its self-established mission is "to patrol the interstate system in the Northern Virginia District to ensure the safe and efficient transportation of motorists, goods, and services in order to meet the economic, environmental and public demands placed on the Commonwealth of Virginia's transportation network.[1] The following constitute the core functions the NOVA SSP program provides. It is the responsibility of a safety service patroller to:[3]

- stop and assist every stopped vehicle on the interstate system
- provide jump starts to any disabled vehicle requiring it
- remove debris from the travel lanes and shoulders safely
- provide gasoline to any motorist needing it
- notify VSP of any abandoned vehicle that is creating a hazard
- initiate maintenance action reports when needed
- provide personal assists including first aid, CPR, and transports
- change or assist in the changing of a tire on a motorist's vehicle requiring such a service
- perform minor mechanical repairs such as tightening battery terminals, duct taping leaking hoses, reconnecting spark plugs, wires, etc.

Patrollers should perform such tasks if and only if they are trained and have the equipment assigned to the patrol vehicle to complete such repairs and should complete only tasks that can be done on site within a 10-minute time frame. Anything beyond 10 minutes, the patroller should assess the situation, and if it is determined that an assist would exceed 10 minutes, the patroller should notify the VSP dispatch for assist by a wrecker service. The 10-minute guideline is applicable only to minor mechanical repairs, tire changing, etc. Another guideline is that minor mechanical repairs should be completed while a patroller is standing and the patroller should not need to crawl under a vehicle.[3]

When responding to incidents, priority should be placed in the following order: (1) incidents on the travel portion of the highway, (2) incidents on the shoulder area, and (3) incidents in rest areas. However, these priorities may vary due to the nature of the incident, i.e., HAZMAT spills and personal injury. When conditions warrant, patrollers are encouraged to stay with occupied disabled vehicles when possible. However, if it becomes necessary to leave a motorist on the shoulder, a flare pattern is to be set behind the disabled vehicle.[3]

Equipment

SSP patrol vehicles are equipped with various traffic control devices such as arrow boards, strobe lights, traffic cones, and flares. The vehicles also carry a variety of tools and items such as tire jacks, air tanks, water, gas, and jumper cables to assist disabled motorists. Soon after funding was restored to Virginia's SSP programs, money was made available before staffing level increases were approved. The NOVA SSP took advantage of the extra money to install better lighting on the trucks and acquire leaf blowers, go-jacks (to help push disabled vehicles), and chainsaws for each vehicle. The following is a list of the equipment carried on each patrol vehicle:

2 fire extinguishers (10 lb and 25 lb)	1 air tank
1 first aid kit	1 floor jack
1 jumper cable	1 standard lug wrench
2 gallons of gas	1 metric lug wrench
1 longneck funnel	1 shovel
5 1-gallon bottles of water	1 broom
2 boxes of safety flares	1 scoop
1 electric impact wrench	1 leaf blower
Impact sockets	1 chainsaw
Sand	Go-jacks
6 cones with weights and night sleeves	Stay-dry

In the future, NOVA SSP management would like to add larger bodied trucks to the fleet (similar to what Maryland's CHART program uses to respond to incident scenes) for use by shift supervisors. These larger vehicles, shown in Figure A-3, have the ability to carry more equipment and supplies, such as brooms, absorbent long-term road closure signs, scene lighting, and fuel tanks for storing fuel pumped off tractor trailers.

Figure A-3. Maryland's CHART Emergency Response Vehicle

VDOT also maintains strategically located staging areas at firehouses, police stations, truck scales, and area headquarters where 14 portable message signs and 6 cone trailers are kept. These staging areas enable quick access to the equipment when there is a need.
Patroller communication equipment includes VDOT (STC) and VSP two-way radios, CB radios, and cellular phones. SSP incident management vehicle communication equipment includes satellite phones, airborne video downlink from aircraft, cellular fax machine, and portable 800-megahertz fire/rescue/police two-way radios, enabling coordination with other responding agencies during major incidents. The cellular phones are Nextel phones with built-in cameras and GPS. The camera phones are new, and the images captured are sometimes sent to the STC, VSP, and towing companies. VSP finds this technology useful because they sometimes do not have the time or capability to take pictures of an incident, and towing companies find this technology useful because can get a "feel" of the severity of the incident prior to arriving on the scene.[2]

Each patrol vehicle is also equipped with a laptop that enables the patroller to enter incident information in the field and considerably reduces the amount of time a patroller spends at an incident scene. Prior to laptops being in the vehicle, a patroller would have to fill out paperwork that, in some incident cases, could take a lot of time. The laptops allow patrollers to view CCTV images from anywhere in the field, thus enabling regional surveillance of traffic conditions, and SSP supervisors have the VSP CAD system installed on their laptops, which enables them to view critical VSP information relating to incidents. After each shift, incident data are downloaded from the patroller's laptop into an SSP incident database.

Another item carried by patrollers is a Motorist Travel Package. The NOVA SSP Patrollers Manual states that upon stopping to assist a motorist the patroller should upon approaching the vehicle hand the operator a Motorist Travel Package and each patroller is to ensure that his or her name is on each packet handed out. This packet serves as a great customer service tool, and many motorists have commented in letters on their appreciation for receiving the packet (secondary to their appreciation for the assist).

Included in the packet is a "MOVE IT – IT'S THE LAW" card that states if you have a non-injury crash, it is not necessary to wait for law enforcement before moving the vehicles involved. If the vehicles can be driven, they should be moved to a safe location and then the parties involved should exchange necessary information or contact law enforcement. The packet also includes such items as:

- Virginia map
- work zone driving instructions
- Springfield Interchange Informational Map
- VDOT's Smart Travel Program Guide
- Riders Guide to Commuter Rail Service
- VDOT Road Construction Guide
- I-95 lane closings/bottlenecks and upcoming events (from Maine to Florida)
- Virginia Map Games and Puzzles.

The NOVA SSP also gives their mail address and email address on the packet for those who would like to send comments about the assistance provided; they do receive a tremendous amount of positive feedback from motorists who were assisted.

Patroller Training

Perspective NOVA SSP patrollers must complete a standard Commonwealth of Virginia application that is screened by VDOT Human Resources and SSP management. Graduation from high school or equivalent experience and a Class B commercial drivers license (CDL) or Class A CDL (for senior patrollers and supervisors) is required for employment. Once employed, the newly hired patroller is placed on VDOT's standard 1-year probationary period. During the probationary period, the patroller must undergo extensive training that usually takes approximately 2 weeks to complete. The first week of training is spent with a patrol supervisor where the trainee is exposed to all aspects of the SSP vehicle and equipment. The second week is spent on the road with patrollers. Within 6 months of the hiring date, the new employee must attend courses and/or be trained on the following items:

- policies and procedures (safety, reporting, incident management, wreckers, HAZMAT)
- monthly statistical reports
- traffic management system (STC)
- VMS boards
- push bumper training
- radio communications
- special operations (major incidents)
- CPR first aid

- work zone safety
- flagging/directing traffic
- hazardous materials
- working with other agencies
- responding to calls
- assisting citizens
- blood-bourne pathogens
- fire extinguisher training
- torts and liability
- patrol routes
- emergency vehicle operations.

Quick Clearance Policy

The establishment of a quick clearance practice can expand the capabilities and optimize the efficiency of incident management initiatives while enhancing the safety of responders, victims, and passing motorists. A quick clearance practice effectively supports an ongoing incident management program; however, unlike specific incident mitigation strategies, the policies and procedures constituting a quick clearance practice address the congestion and safety impacts of various traffic incident severity levels beginning from the time of incident occurrence.[4] Quick clearance practices have the potential to yield numerous direct benefits to road users and the surrounding community, such as decreases in the following:[4]

- non-recurrent congestion delay
- secondary incidents
- vehicle fuel consumption
- vehicle emissions
- response time to traffic incidents and other emergencies
- motorist stress levels
- aggressive driving behavior
- impact on the movement of freight in the region
- impact on the regional economy
- impact on local tourism
- impact on future potential land uses.

Quick clearance procedures share the core objective of a quick clearance practice and aim to reduce incident clearance and restoration time. Service patrol vehicles that are equipped with push bumpers and have the authority to push vehicles out of the roadway can significantly enhance clearance operations. Virginia has an established "MOVE IT" program, but many motorists are unaware of this Virginia law. In Maryland, CHART operators adhere to a quick incident clearance policy instead of merely a "MOVE IT" program because Maryland legislation legally allows their operators to push a vehicle or spilled cargo out of the roadway without approval by law enforcement and without being held liable for damages to the property. In Virginia, only VSP and local law enforcement officials have jurisdiction over moving a vehicle, cargo, or personal property. VDOT does not have the authority to push a vehicle out of the way or order the owner to move the vehicle unless it is under the direction of law enforcement. VDOT management is currently examining the development of a quick clearance policy that can be embraced by VDOT, VSP, local police, and fire/rescue.[2]

Vehicle Classification

Recently, there has been dialogue between NOVA SSP management and VDOT management regarding the classification of SSP patrol vehicles. VDOT's SSP vehicles are not classified as emergency vehicles, and therefore the drivers do not have the same authority as drivers of other emergency responding vehicles (police, fire, and rescue vehicles) such as preempting signals, using shoulders to bypass traffic en-route to an incident, and using red strobe lights with sirens. Some states, such as Maryland, New Mexico, Florida, and South Carolina in addition to Washington, D.C., have passed legislation that assigns service patrol vehicles an emergency vehicle classification.[2]

In order for Virginia's SSP vehicles to be designated emergency vehicles and attain the associated statutory privileges, the definition of *emergency vehicles* in the *Code of Virginia* would need to be amended either to include the vehicles specifically or to add broader language such as the language used in the *Code of Maryland* or the D.C. statutes. This broader language could either define emergency vehicles as state provided vehicles serving an emergency purpose or could delegate the responsibility of designating emergency vehicles to a specific person within the executive branch of the government.[5] Currently, NOVA SSP patrollers are classified as emergency workers and patrollers take an Emergency Vehicle Operators Course (EVOC), but their vehicles remain unclassified as emergency vehicles.

Inter-Agency Cooperation

Complex organizational relationships can thwart the development and operation of incident management programs, but an effective organizational structure can overcome many hurdles. In many cases, the most significant obstacle to efficient incident response and recovery is the need to communicate information about the incident to the appropriate organizations, rapidly make informed decisions about the needs of the incident and appropriate response techniques, and maintain smooth communication between organizations throughout the process.[6] Inter-agency coordination and cooperation facilitates efficiency in incident management operations and is accomplished by improving working relationships among incident management agencies responsible for transportation, law enforcement, fire and rescue, and environmental monitoring and safety from several jurisdictions (city, county, and state).[7]

The Northern Virginia Incident Management Team uses an operating manual entitled *Northern Virginia Incident Management Team Operating Manual Plan for the Management of Incidents on Northern Virginia Highways.*[8] It is used by many agencies for planning and managing incidents on NOVA highways. The manual provides guidelines for personnel responsible for managing various incident response aspects in NOVA and documents the traffic management services provided by VDOT and other area agencies. The manual also defines agency roles and responsibilities when highway incidents occur; provides guidelines for the declaration of a major incident, alternative routes and maps, agreements and state codes, resources on the incident command system, HAZMAT guides, and important telephone numbers. The agencies that are members of the NOVA Incident Management Team include:[8]

- Virginia Department of Transportation (NOVA STC and SSP)
- Virginia State Police (Division 7)
- Alexandria Emergency Operations Center (EOC)/Police
- Arlington County EOC/Police
- Fairfax City EOC/Police
- Fairfax County Police
- Fairfax County Public Safety Communications Center (PSCC)
- Falls Church City EOC/Police
- Loudoun County Sheriff
- Prince William County Police
- Maryland State Police, Forestville
- Maryland State Police, Rockville
- Washington, D.C., Police
- Washington, D.C., Mayor's Command Center.

VDOT also partners with the State of Maryland and Washington, D.C, in the Capital Wireless Integrated Network (CapWIN) program to develop an interoperable first responder data communication and information sharing network. CapWIN is a unique and challenging program that has created the first multi-state and multi-discipline interoperable public safety and transportation wireless data system in the United States.[9]

The CapWIN Program serves as a good example of innovative interagency cooperation and is expanding in agency usage throughout Virginia. NOVA SSP units are currently using CapWIN to communicate directly with many agencies including VSP, Maryland State Police, Maryland CHART, Delaware DOT, and many other emergency responder agencies.[2]

Field Observations

In May of 2005, a field trip was made to the NOVA SSP office for the purposes of gathering operations information and to accompany patrollers on "ride-alongs." Three days were spent in the field with patrollers, and 2 days were spent interviewing office staff and management. The ride-alongs provided the opportunity to witness, first hand, the incident management functions and operations of the NOVA SSP.

On May 16, 2005, much of the day was spent at a fatal accident scene that took place on the Route 1 entrance ramp off Furnace Road. The NOVA SSP typically does not work arterials, but VSP requested help with traffic control in the area because a portion of Furnace Road would be shut down for an extended period of time. Three SSPs assisted with setting up traffic control including putting up VMS signs that notified motorists of the road closure and the detour route.

SSP personnel also contacted VDOT's Traffic Engineering to notify them of the incident and recommended increasing the green time of the signals on the detour route. The responders at the scene included:

- Fairfax Fire and Rescue (attending to injured/HAZMAT)
- Fairfax City Police (traffic control)
- Prince William County Police (traffic control)
- VSP (lead agency - involved in pursuit of vehicle)
- VDOT (traffic control)
- Redman's towing (towing of vehicle involved in the crash)
- Waggy's towing (towing of truck involved in the crash)
- funeral home (recovery of the body)

The crash investigation was the longest task because each piece of debris in the roadway had to be surveyed for investigation purposes, as shown in Figure A-4. Once the investigation was complete, the debris was removed from the roadway and one lane of traffic was opened. Approximately 3 hours after the incident, both lanes were opened to traffic. There is currently a

Figure A-4. Crash Scene Investigation

project underway at the Virginia Transportation Research Council that is examining the potential of Virginia using photogrammetry when investigating crash scenes. This investigation technique involves taking pictures of the scene and reenacting the crash using computer software. Virginia currently does not conduct investigations using photogrammetry, but it is acknowledged that the time and money saved (in terms of reductions in motorists delay) in using this technique may far outweigh the costs.

Ride-alongs with patrollers were taken on Tuesday, May 17, from 12:30 P.M. to 7:30 P.M., and on Thursday, May 19, from 12:30 P.M. to 6:30 P.M. Both days covered routes on sections of I-95. There were 33 incidents logged for those 2 days, of which 9 were dispatch calls from VSP, 6 were dispatch calls from the STC, and 18 were found on patrol (i.e., not dispatched). The nature of the incidents consisted of 6 gone on arrivals (patroller dispatched to an incident, but no incident found), 17 shoulder incidents, 2 lane blocking debris incidents, 6 vehicular lane blocking incidents, and 1 referral to another SSP patroller. There were three logged incidents of particular note that are shown in Figures A-5 through A-8.

Figure A-5 shows a lane blocking incident to which the SSP patroller was dispatched by the STC. The vehicle ran out of fuel and was partially blocking a travel lane, and the motorist was standing beside the vehicle. The SSP patroller subsequently pulled behind the vehicle, which created a safety buffer zone, and filled the vehicle with 2 gallons of gas. This allowed the motorist to drive away and clear the travel lane. The quick response of the patroller and the fast recovery of the travel lane considerably reduced the potential for this lane blocking incident to turn into a major incident because there were no shoulders at this particular location on the roadway.

Figure A-5. Disabled Motorist Blocking Travel Lane

Figure A-6 shows a patroller giving VSP protection at an on-ramp where a stolen vehicle had been pulled over. The two suspects were arrested at the scene, but it took approximately 1 hour to clear the ramp because of the time it took for the arrest procedure and the removal of the vehicle by a towing company. Typical NOVA SSP protocol is to urge VSP to move an incident to a shoulder (if one exists) as quickly as possible for the recovery of the travel lanes. In this instance, the patroller requested that VSP move their vehicles closer to the shoulder to allow more acceleration distance for vehicles entering the highway. VSP acted on this request, thus showing the excellent cooperation between the NOVA SSP and VSP.

Figure A-7 shows an incident where an overheated vehicle on the shoulder was engulfed in flames and had to be extinguished by the fire department. The NOVA SSP created a safety buffer zone for the emergency responders by providing traffic control. Three travel lanes were closed during this incident, thus creating a major vehicle backup, as shown in Figure A-8. The SSP's main priority at incident scenes is providing for the safety and well-being of emergency responders and the traveling public. A secondary, but important, priority is the quick and efficient opening of travel lanes, thereby reducing traveler delay. Often there are incidents, similar to the incident shown in Figure A-7, where the number of lanes closed by emergency responders can be reduced, thereby providing more highway capacity for approaching vehicles. Typically, the quick re-opening of travel lanes is not a priority for emergency responders. This is an example of the philosophical conflicts that can occur between highway agencies and other responding agencies when handling incidents.

Figure A-6. NOVA SSP Providing VSP with Safety Buffer During Arrest

Figure A-7. Fire Department Personnel Attending to Vehicle Fire on Shoulder

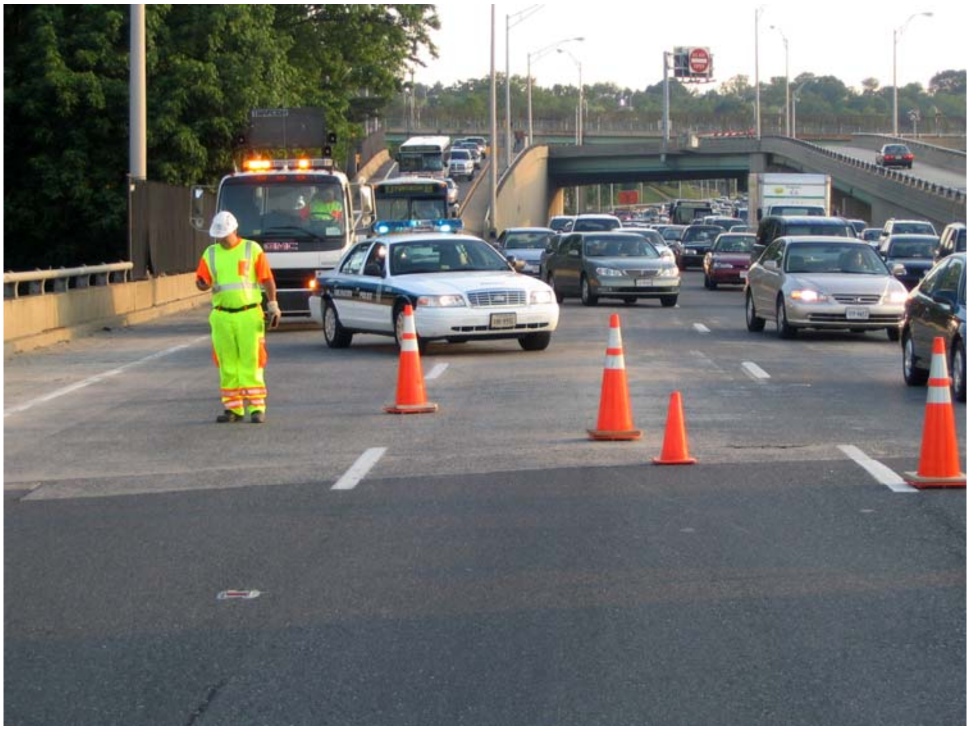

Figure A-8. Lane Closures and Resulting Congestion from Vehicle Fire

While in the field with the patrollers, the research team observed a large number of abandoned vehicles on the shoulders. Typically, an abandoned vehicle is towed if it is not removed from the shoulder within 24 hours of being tagged. NOVA SSP management would like to investigate the prospect of having patrollers tag abandoned vehicles. Tags are bright stickers that are placed on vehicles and identify the time and date the vehicle was checked on. Currently, only VSP and MAP (Motorist Assistance Patrol) units engage in tagging vehicles. With tagging authority, SSPs can assist in keeping the clutter of abandoned vehicles off the interstates.[14] NOVA SSP management thinks this would be relatively easy to implement and could serve as a useful data source since the existing VSP CAD system supports capturing data involving the tagging of vehicles. However, it is recognized that this practice would require buy-in from VSP and a higher level of dedication from them to remove the vehicles at the 24-hour mark.

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APPENDIX B

FSPE MODEL EXAMPLE APPLICATION

The following is a discussion of an example application of the FSPE model, its associated worksheets, and data requirements. Route DTR (the Dulles Toll Road) was used for the example.

INPUT Worksheet

Beat/Service Description

Table B-1 shows an example of the *Beat/Service Description* table. The last line in the table shows the cost of SSP service. This cost is determined by summing the hourly rate of the patrol vehicles, the average salary of a patroller (including benefits), and the administrative overhead (represented as 10 percent of a patroller's salary). Table B-2 shows the cost rates for each route covered in the evaluation and the shift hours and number of SSP trucks, all of which are inputs in the *Beat/Service Description* table.

Table B-1. Weekday Beat Service Description for Route DTR

A. Beat/Service Description			
Route Number	1		
Analyst	Lance Dougald		
Date	April 23, 2006		
VDOT Number	9913		
Route Description	Dulles Toll Road		
Hours of Operation/# SSP Trucks	**Start-Time (hr:min)**	**End-Time (hr:min)**	**# SSP Trucks**
AM Shift	2:00	12:00	1
Midday Shift			
PM Shift	12:00	22:00	1
Number of Service Days/Yr	260		
Cost of SSP Service ($/truck-hr)	$ 38.73		

Table B-2. Route Shift Hours and Cost Figures

Route	Number of Vehicles Per Shift (AM)	Number of Vehicles Per Shift (PM)	Shift Hours (AM)	Shift Hours (PM)	Truck Hourly Rate ($/hr)	Patroller Salary (PS) ($/hr)	Overhead (10% of PS) ($/hr)
DTR-1	1	1	00:00-10:00	12:00-22:00	9.82	26.28	2.63
P-2	1	1	00:00-10:00	12:00-22:00	9.82	26.28	2.63
P-7	1	1	00:00-10:00	12:00-22:00	9.82	26.28	2.63
P-8	1	1	00:00-10:00	12:00-22:00	9.82	26.28	2.63
P-10	1	1	00:00-10:00	12:00-22:00	9.82	26.28	2.63
B-2	1	1*	04:00-12:00	12:00-20:00*	17.91	27.19	2.71

*Shift funded by CMAQ Program.

Beat Design Characteristics

This section describes the segments and the associated roadway geometrics pertaining to the route being evaluated. A segment is typically defined as a one-way freeway section between on- and off-ramps, locations where there is a change in freeway capacity (lane drops, weaving sections, steep grades, etc.), or locations with significant changes in traffic volumes. Segment data were obtained from VDOT's Traffic Engineering database for each route, and the parameters (in terms of segments) are shown in Table B-3. An example of the input table for the Beat Design Characteristics section is shown in Table B-4. *Beat Design Characteristics* tables for all other routes can be found at http://www.virginiadot.org/vtrc/main/online_reports/pdf/append/06-r33.htm.

Table B-3. Segment Coverage per Route

SEGMENT COVERAGE PER ROUTE			
Route	Segment Begin	Segment End	Total # of Segments
DTR	SR 28 Sully Rd	I-66	11
P-1	I-95; I-495	District of Columbia	13
P-2	SR 123 Gordon Blvd	I-395, I-495 Capital Beltway	8
P-3	Stafford County Line	SR 123 Gordon Blvd	6
P-7	SR 236 Little River Turnpike	Maryland State Line, Potomac River	9
P-8	29-650 Gallows Rd	District of Columbia Line, Potomac River	9
P-9	SR 243 Nutley St	DC Line, Potomac River; Roosevelt Bridge	14
P-10	SR 234	SR 243 Nutley St	8

Table B-4. Beat Design Characteristics for Route DTR

B. Beat Design Characteristics											
Beat Length (miles)	16.32										
#Segments	11										
DIRECTION-1	EB										
Segment#	1	2	3	4	5	6	7	8	9	10	11
Length (mi)	1.24	1.11	1.40	0.37	0.95	2.89	3.44	0.87	1.21	0.41	2.43
# Mixed-Flow Lanes	3	3	3	3	3	3	3	4	4	3	2
HOV Lane	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
Rt Shdr	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
DIRECTION-2	WB										
Segment#	1	2	3	4	5	6	7	8	9	10	11
Length (mi)	1.24	1.11	1.40	0.37	0.95	2.89	3.44	0.87	1.21	0.41	2.43
# Mixed-Flow Lanes	3	3	3	3	3	3	3	4	4	3	2
HOV Lane	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
Rt Shdr	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

Beat Traffic Characteristics

Eastbound and Westbound AADTs for Route DTR are shown in Figure B-1. These AADTs needed be combined and input into the *Beat Traffic Characteristics* section shown in Table B-5 for "weekday" evaluations. Tables B-6 and B-7 were constructed for Saturday and Sunday evaluations, respectively. The *Beat Traffic Characteristics* tables for all other routes can be found at http://www.virginiadot.org/vtrc/main/online_reports/pdf/append/06-r33.htm. (The

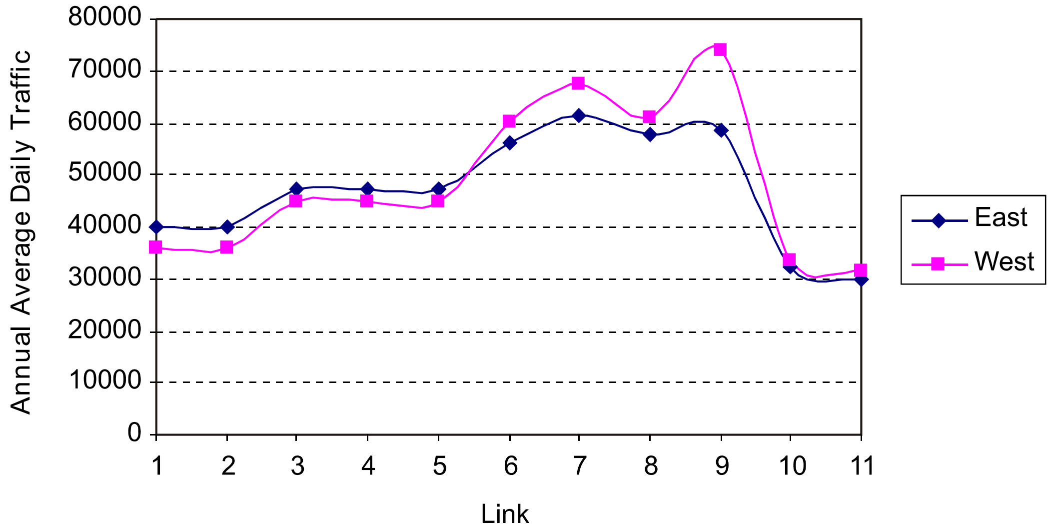

Figure B-1. AADTs per Segment for Route DTR

Table B-5. Weekday Beat Traffic Characteristics for Route DTR

C. Beat Traffic Characteristics											
Segment #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
AADT	75,868	75,868	92,056	92,056	92,056	116,312	129,026	118,593	132,568	65,660	61,203
AM PEAK Dir.	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB
D factor (%)	61.65	61.65	61.65	61.65	61.65	61.65	61.65	61.65	61.65	61.65	61.65
MD PEAK Dir.	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB
D factor (%)	51.94	51.94	51.94	51.94	51.94	51.94	51.94	51.94	51.94	51.94	51.94
PM PEAK Dir.	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB
D factor (%)	58.08	58.08	58.08	58.08	58.08	58.08	58.08	58.08	58.08	58.08	58.08
Off-PEAK Dir.	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB
D factor (%)	61.88	61.88	61.88	61.88	61.88	61.88	61.88	61.88	61.88	61.88	61.88

Table B-6. Saturday Beat Traffic Characteristics for Route DTR

C. Beat Traffic Characteristics											
Segment #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
AADT	52,459	52,459	63,652	63,652	63,652	80,424	89,215	82,001	91,664	45,401	42,319
AM PEAK Dir.	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB
D factor (%)	60.87	60.87	60.87	60.87	60.87	60.87	60.87	60.87	60.87	60.87	60.87
MD PEAK Dir.	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB
D factor (%)	52.44	52.44	52.44	52.44	52.44	52.44	52.44	52.44	52.44	52.44	52.44
PM PEAK Dir.	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB
D factor (%)	51.75	51.75	51.75	51.75	51.75	51.75	51.75	51.75	51.75	51.75	51.75
Off-PEAK Dir.	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB
D factor (%)	56.09	56.09	56.09	56.09	56.09	56.09	56.09	56.09	56.09	56.09	56.09

Table B-7. Sunday Beat Traffic Characteristics for Route DTR

C. Beat Traffic Characteristics											
Segment #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
AADT	44,637	44,637	54,161	54,161	54,161	68,432	75,912	69,774	77,996	38,631	36,009
AM PEAK Dir.	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB	EB
D factor (%)	59.88	59.88	59.88	59.88	59.88	59.88	59.88	59.88	59.88	59.88	59.88
MD PEAK Dir.	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB
D factor (%)	51.92	51.92	51.92	51.92	51.92	51.92	51.92	51.92	51.92	51.92	51.92
PM PEAK Dir.	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB
D factor (%)	55.95	55.95	55.95	55.95	55.95	55.95	55.95	55.95	55.95	55.95	55.95
Off-PEAK Dir.	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB	WB
D factor (%)	61.18	61.18	61.18	61.18	61.18	61.18	61.18	61.18	61.18	61.18	61.18

methodology for determining the D-factors shown in the *Beat Traffic Characteristics* tables is discussed in the FIELDDATA, TRAFFIC-PROFILES, and DIR-FACTORS Worksheets section.)

Because weekend traffic volume data were not available on segments without CCS detectors, AADTs had to be estimated for each route using an AADT factor. Saturday and Sunday AADT factors for each route are shown in Table B-8, and the corresponding Saturday and Sunday segment AADTs were found by multiplying the AADT factor (first term in the following equations) by segment AADT:

$$\frac{Average\_Saturday\_CCS\_ADT}{CCS\_AADT} \times Segment\_AADT ,$$

$$\frac{Average\_Sunday\_CCS\_ADT}{CCS\_AADT} \times Segment\_AADT$$

Table B-8. Saturday and Sunday AADT Factors per Route

AADT FACTOR								
Route	DTR	P-1	P-2	P-3	P-7	P-8	P-9	P-10
Saturday	0.69145	0.981988	0.857788	0.865898	0.876297	0.873446	0.904155	0.925914
Sunday	0.588347	0.809661	0.863484	0.871648	0.829086	0.729143	0.845659	0.86466

Incident Characteristics

This section describes the incident characteristics for each route for the analysis year. Incidents are distributed proportionally during model runs throughout a route based on a weighted VMT time of day and space scheme. The percentage of incidents and average clearance time for each incident type need to be obtained from the SSP database. Table B-9 shows an example of the *Incident Characteristics* table. Data for only one period (weekdays, Saturdays, or Sundays) are entered in the INPUT worksheet (for example purposes, all periods were combined into Table B-9). The *Incident Characteristics* tables for routes used in the benefit evaluation can be found at http://www.virginiadot.org/vtrc/main/online_reports/pdf/append/06-r33.htm.

Table B-9. Incident Characteristics for Route DTR

D. Incident Characteristics		Weekdays		Saturdays		Sundays	
Total SSP Assists (Inc/yr)		2746		483		456	
Incident Type/Location		# Incidents or (%)	Clearance Time (min)	# Incidents or (%)	Clearance Time (min)	# Incidents or (%)	Clearance Time (min)
Accident	Right Shoulder	2.8%	24.32	2.3%	24.63	1.8%	27.12
	Lt Shldr (Median)	1.1%	34.62	0.4%	56.00	1.1%	73.00
	In Lane	5.2%	44.23	5.4%	41.88	4.2%	50.78
Breakdown	Right Shoulder	73.9%	12.50	76.6%	12.45	78.1%	12.83
	Lt Shldr (Median)	7.5%	15.58	5.8%	15.25	3.5%	14.50
	In Lane	5.2%	23.02	4.6%	17.58	5.3%	33.95
Debris	Right Shoulder	0.5%	41.71	1.0%	32.60	0.9%	26.00
	Lt Shldr (Median)	0.2%	6.40	0.0%	-	0.7%	120.00
	In Lane	3.7%	5.58	3.7%	16.12	4.6%	12.62

FIELDDATA, TRAFFIC-PROFILES, and DIR-FACTORS Worksheets

The FSPE model can either use empirical hourly traffic volumes directly (input by the user on the FIELDDATA worksheet) or can estimate hourly traffic volumes from AADT via a set of hourly traffic profiles and default time dependent directionality factors obtained from continuous count station (CCS) detectors within or near the beat being analyzed. The TRAFFIC-PROFILES and DIR-FACTORS worksheets are used by the Visual Basic for Applications (VBA) macros that create the deterministic queuing diagrams, which in turn are used to estimate the vehicular delays attributed to the modeled incidents and delay savings attributed to providing SSP service on the modeled beat.[1] For each NOVA SSP beat evaluation, historical hourly traffic counts were obtained from CCS detectors using VDOT's Traffic Engineering traffic volume database. From these, route average hourly traffic flow profiles were created as shown in Figure B-2 for an average weekday, Saturday, and Sunday.

In addition to deriving empirical route specific flow profiles, a directionality factor function was created using paired sets of CCS detectors (a paired set of detectors would consist of a northbound or eastbound detector and a southbound or westbound detector at the same location of the freeway).[1] The INPUT worksheet requires only A.M., P.M., midday, and off-peak D-factor inputs as opposed to empirical hourly D-factors inputs, but the algorithms contained within the model create fairly accurate hourly D-factors. Figure B-3 shows empirically obtained hourly D-factors for an average weekday. Figure B-4 shows the models replication of hourly D-factors, and Figure B-5 shows a graphical example of the D-factors role in directional splitting of the average weekday traffic profiles. Average Saturday and Sunday D-factors are shown in Figures B-6 and B-7, respectively. All other route traffic profiles and D-factors can be found at http://www.virginiadot.org/vtrc/main/online_reports/pdf/append/06-r33.htm.

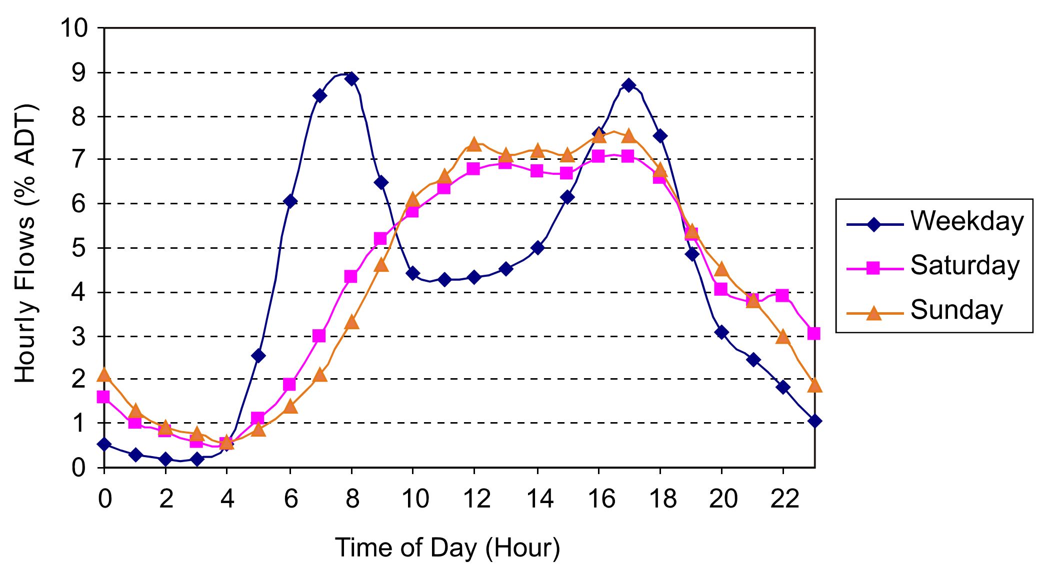

Figure B-2. Average Traffic Profiles for Route DTR

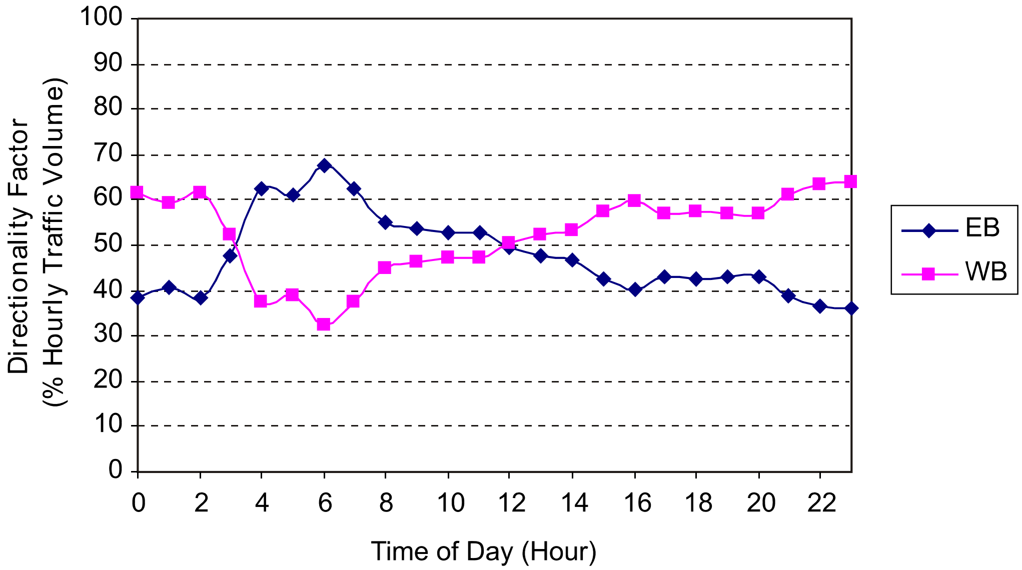

Figure B-3. Average Weekday Directionality Factors for Route DTR

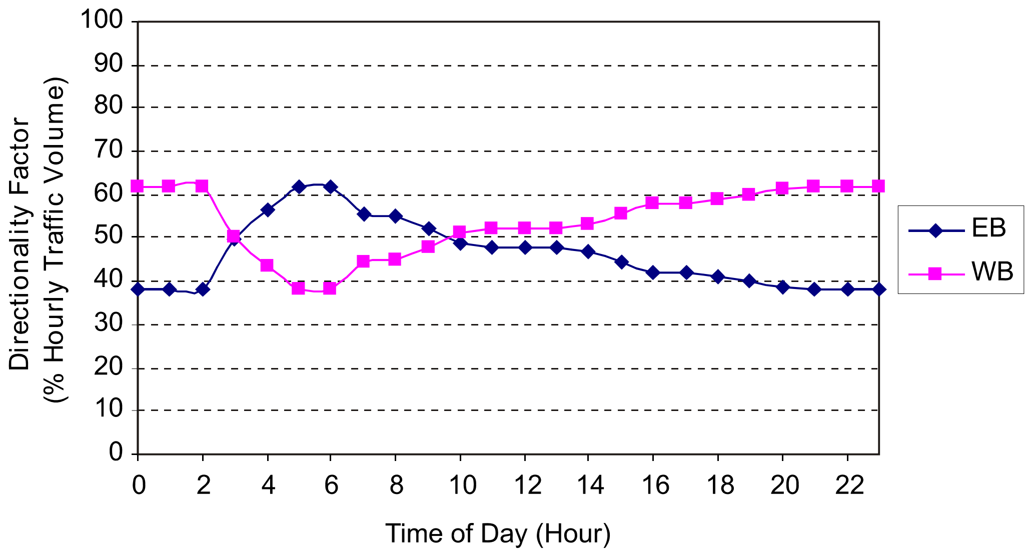

Figure B-4. FSPE Model Replication of Directionality Factors for Route DTR

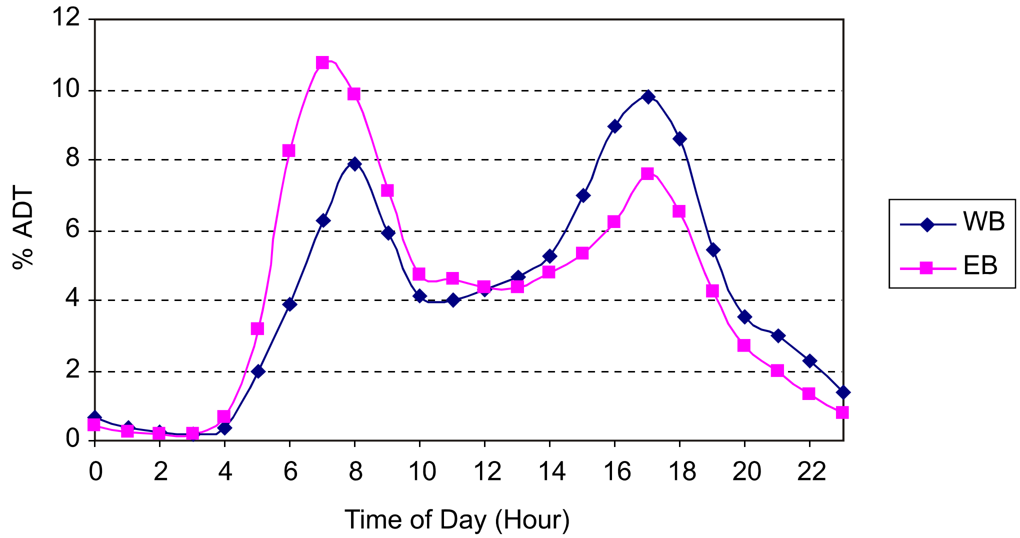

Figure B-5. Average Weekday Traffic Profiles for Route DTR

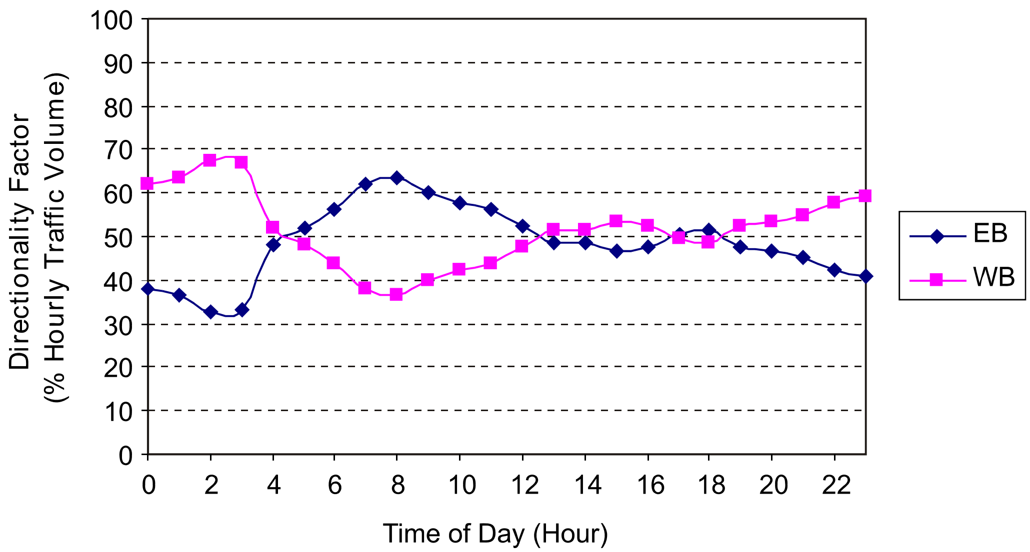

Figure B-6. Average Saturday Directionality Factors for Route DTR

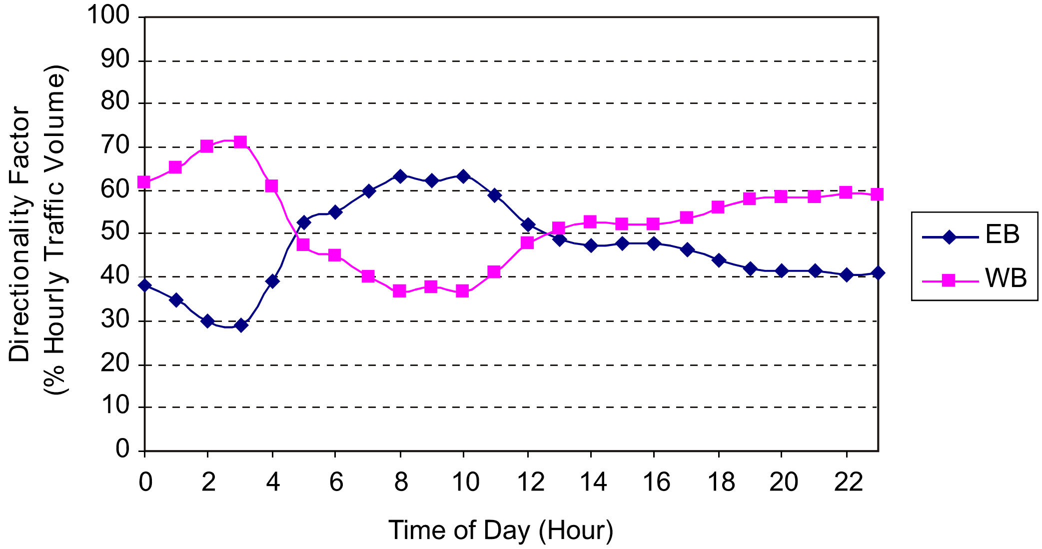

Figure B-7. Average Sunday Directionality Factors for Route DTR

PARAMS Worksheet

The FSPE model gives the user the option to use either the default values from the PARAMS worksheet or the FIELDDATA worksheet when running an evaluation. The PARAMS worksheet contains the default model parameters, and the FIELDDATA worksheet is used if locally obtained, empirical segment data are available. The bulleted items are found in the PARAMS worksheet:

- freeway capacity values*
- remaining freeway capacity factors (HCM table)
- fuel/emissions rates table
- clearance time reduction data
- delay and fuel costs
- traffic-profiles table (extracted from TRAFFIC-PROFILES worksheet)*
- occupancy rates.

The items labeled with an asterisk are bypassed when running the FSPE model if the user opts to run the model in FIELDDATA mode (the FIELDDATA worksheet allows the user to enter segment-specific freeway capacity values, hourly traffic volumes, and spatial distributions of incidents).

Freeway Capacity Values

The FSPE model allows the user to select from two capacity options: (1) Capacity = Default or FIELDDATA Capacity, or (2) Capacity = Max(Capacity, Thru-flows). The second option automatically increases the assumed roadway capacity for route segments where traffic volumes exceed the default capacity.[1] When performing all NOVA SSP beat evaluations, values of 2,100 vphpl for mixed-use lanes and 1,800 vphpl for HOV lanes were used. These values were obtained from the NOVA District Planning Office and are considered the "ideal" capacities for much of the freeways in NOVA.

Remaining Freeway Capacity Factors

The model's default parameter estimates for "remaining capacity during incidents" are based on Exhibit 22-6, Proportion of Freeway Segment Capacity Available Under Incident Conditions, on page 22-11 of the HCM 2000[1,2] and is shown in Table B-10. The capacity reduction factors are not applied to incidents blocking two or more lanes; however, all SSP assisted incidents that block two or more lanes are accounted for in the INCIDENT CHARACTERISTICS table of the INPUT worksheet.

Table B-10. Percentages of Remaining Freeway Capacity Due to Incidents

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

Fuel/Emissions Rates Table

The emission and fuel rates section of the PARAMS worksheet includes emission values for reactive organic gases (ROG), carbon monoxide (CO), and nitrogen oxides (NOx) and can be obtained from regional-specific air quality models, such as MOBILE6. The FSPE model provides a dollar value for excess fuel, based on gasoline costs; however it does not estimate a dollar value for excess emissions because of the complexities in assigning a dollar value to pollution. The amount of excess fuel consumption and the amount of excess ROG, CO, and NOx air pollutant emissions from motor vehicles are calculated in the FSPE model as follows:[1]

$$\mathbf{F}_{\boldsymbol{i}} = \mathbf{D} \times \boldsymbol{e_i}$$

F_i = Fuel or Emissions

$i = 1$, fuel consumption in gallons
$i = 2$, HC emissions in kg
$i = 3$, CO emissions in kg
$i = 4$, NOx emissions in kg

D = incident-induced delays

e_i = fuel or emissions factor

The emission and fuel rates used for the NOVA SSP evaluation are shown in Table B-11. The emission values for ROG, CO, and NOx were produced by the Metropolitan Washington Council of Governments using MOBILE6 and are specific to Fairfax County; they did not have data available for incremental fuel rates; therefore, the rates shown were taken from the FSPE defaults for California. It should be noted that the fuel rates shown are for LDGV and do not consider any other vehicle classification. Therefore, the model will tend to underestimate fuel consumption. As shown in Table B-12, LDGVs represented 41 percent of the vehicle miles traveled (VMT) in Fairfax County in 2005. Also shown in the table are the other classifications that make up the bulk of the vehicle mix in Fairfax County.

Table B-11. 2005 Fairfax Emissions and Fuel Rates at Incremental Speeds

2005 Fairfax County Emissions/Fuel Rates				
SPEED (mph)	ROG (gr/mi)	CO (gr/mi)	NOx (gr/mi)	FUEL (mi/gal)
5	1.563	11.415	2.258	1.750
10	0.716	6.819	1.668	9.996
15	0.489	5.524	1.361	12.778
20	0.394	5.229	1.307	15.708
25	0.343	5.131	1.272	18.581
30	0.307	5.106	1.254	21.159
35	0.278	5.262	1.248	23.203
40	0.26	5.7	1.274	24.510
45	0.244	6.153	1.322	24.950
50	0.231	6.62	1.392	24.487
55	0.221	7.1	1.49	23.184
60	0.215	7.629	1.626	21.184
65	0.211	8.178	1.815	18.685

Table B-12. Fairfax County Vehicle Types and Associated VMT

CAL_YEAR	VTYPE	GM_MILE	GM_DAY	STARTS	ENDS	MILES	MPG	VMT
2005	LDGV	5.7092	171.92	7.28	5.3799	30.1125	24.04	0.4108
2005	LDGTI	3.9664	153.255	8.06	5.7548	38.638	18.64	0.0822
2005	LDGT2	4.0565	156.733	8.06	5.7548	38.638	18.64	0.2733
2005	LDGT3	4.356	182.828	8.06	5.7548	41.9716	14.29	0.0947
2005	LDGT4	4.5159	189.538	8.06	5.7548	41.9716	14.29	0.0436
2005	HDGV2b	6.0287	240.381	6.88	4.9123	39.8727	10.06	0.0185
2005	HDDV8b	1.6817	356.458	6.65	4.7481	211.9578	6.25	0.0283

Fuel and emission rates vary with the speed, and the model incorporates varying speeds depending on whether the freeway facility is operating under free-flow or congested conditions. Figure B-8 is a graphical representation of Table B-11 and shows the degree to which fuel and emission rates vary with speed.

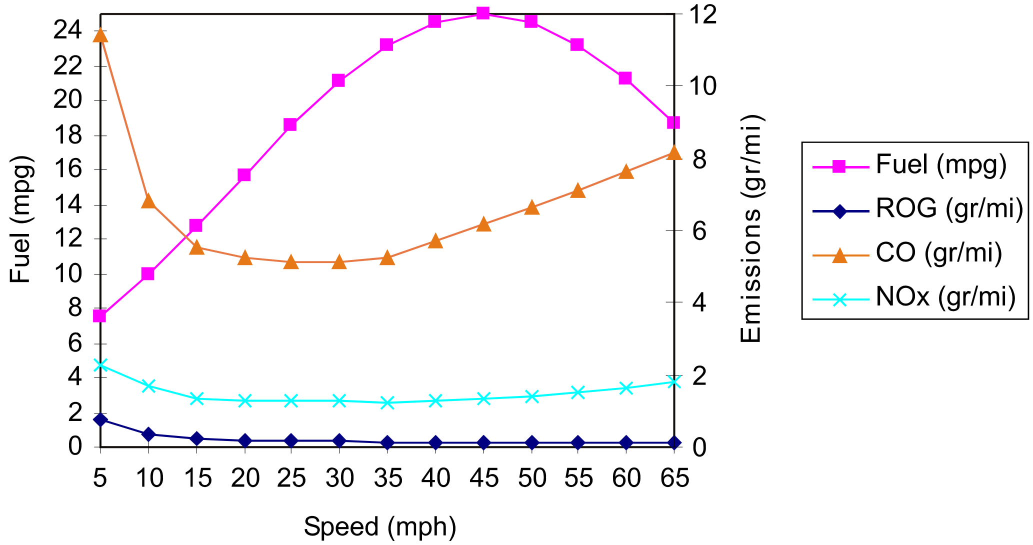

Figure B-8. Fuel and Emissions Rates vs. Speed

Clearance Time Reduction Data

This section consists of inputs for Beat Length, Average SSP Truck Speed, Mean Clearance Time Without SSP, and Clearance Time Reduction With SSP. Beat Length is automatically extracted from the INPUT worksheet, and the other inputs must be hard coded. Average delay reductions from SSP operations use the inputs for Mean Clearance Time Without SSP and Clearance Time Reduction With SSP and were obtained from the methodology for determining incident durations with and without SSP. The average clearance time differences for accidents, breakdowns, and debris were applied as a percentage to the incident types shown in the DTR example of Table B-13. This table is not used by the FSPE model; however, the mean clearance times with and without SSP, shown in the last row of the table, are used as the inputs in the model.

Table B-13. DTR Weekday Mean Clearance Time With and Without SSP per Incident Type

Total SSP Assists (Inc/yr)		2,746	Mean Clearance Time	
Incident Type/Location		# Incidents or (%)	With SSP (min)	Without SSP (min)
Accident	Right Shoulder	2.8%	24.32	30.40
	Lt Shldr (Median)	1.1%	34.62	43.27
	In-Lane	5.2%	44.23	50.70
Debris	Right Shoulder	0.5%	41.71	46.71
	Lt Shldr (Median)	0.2%	6.40	11.40
	In-Lane	3.7%	15.58	20.58
Breakdown	Right Shoulder	73.9%	12.15	14.47
	Lt Shldr (Median)	7.5%	15.58	18.21
	In-Lane	5.2%	23.02	37.39
		AVERAGE (min)	**15.49**	**18.96**

Delay and Fuel Costs

A single unit value for delay costs (or travel time value) must be included in the worksheet and should take into account the appropriate mix of trucks and passenger vehicles for the area under study. Travel time value in $/hr can be expressed as:

$$\left(\frac{\$}{vehicle\_hour} \times occupancy\_rate \times \%vehicles\right) + \left(\frac{\$}{truck\_hour} \times \%trucks\right)$$

According to TTI's Urban Mobility Report 2005, travel time value for each occupant in a vehicle is $13.45/hr and for trucks is $71.05/hr.[3] Assuming an average vehicle occupancy of 1.22,[4] and the percentage of trucks in total traffic as 4.6 percent, the travel time value used for the analysis was $18.92/hr (travel time value in $/hr = {$13.45/hr ×1.22 × 0.954}+ {$71.05/hr × 0.046} = $18.92/hr). Fuel costs were entered as $2.25/gal.

Occupancy Rates

To split mixed-use lane and HOV lane volumes, the occupancy rates table requires an average percentage for 1 person/vehicle, 2 persons/vehicle, and 3 persons/vehicle occupancies and an average percentage of HOV usage (i.e., the average percentage of HOVs that will use designated HOV lanes). For each NOVA SSP beat evaluation, occupancy rates for 1 person/vehicle, 2 persons/vehicle, and 3 persons/vehicle were entered as 82, 14, and 4 percent, respectively. The percentage of HOV use was entered as 95 percent.

RESULTS Worksheet

Once all data are entered into the appropriate worksheets, the model runs all calculations and presents the results in the RESULTS worksheet from which individual time period, daily, and annual savings of the MOEs (delay, fuel, emissions) and the B/C ratio are found. The RESULTS worksheet for the weekday DTR example application is shown in Table B-14.

Table B-14. FSPE Weekday Summary Evaluation Results Worksheets for Route DTR

FSP Beat Evaluation & Prediction Routines (version 14.0)						
Summary Evaluation Results Worksheet						
Input Data				**SSP Operational Parameters**		
Route Number		1		Delay Cost ($/veh-hr)	$ 18.92	
Analyst		Lance Dougald		Fuel Cost ($/gal)	$ 2.25	
Date		May 1, 2006				
VDOT Number		9913		Mean Clearance Time w/o SSP (min)	19.0	
Route Description		Dulles Toll Road				
Beat Length (miles)		16.32		SSP Clearance Time (min)		
				AM Peak	15.5	
	Start	End	# SSP	Midday		
Hours of Operation/ # SSP trucks	Time	Time	Trucks	PM Peak	15.5	
AM Shift	2:00	12:00	1			
Midday Shift				SSP Clearance Time Reduction (min)		
PM Shift	12:00	22:00	1	AM Peak	3.5	
				Midday		
Number of Service Days/Yr	260			PM Peak	3.5	
Cost of SSP Service ($/truck-hr)	$ 38.73					
Total SSP Assists (Incidents/yr)	2,746			Traffic Profile	Weekday	
Time Period				**Daily/Annual**		
Savings-Performance Measures	**AM Peak**	**Midday**	**PM Peak**	**Savings-Performance Measures**	**Daily**	**Annual**
Delay (veh-hrs)	23.0		25.9	Delay (veh-hrs)	48.97	12,733
Fuel Consumption (gal)	34.8		39.1	Fuel Consumption (gal)	73.87	19,207
Emissions				Emissions		
ROG (kg/day)	2.90		3.26	ROG (kg/day, kg/yr)	6.17	1,603
CO (kg/day)	0.15		0.17	CO (kg/day, kg/yr)	0.33	85
NOx (kg/day)	0.65		0.73	NOx (kg/day, kg/yr)	1.37	357
Cost Effectiveness				**Cost Effectiveness**		
Delay Benefits ($/day)	$ 436		$ 491	Delay Benefits ($/day, $/yr)	$ 927	240,916
Fuel Benefits ($/day)	$ 78		$ 88	Fuel Benefits ($/day, $/yr)	$ 166	43,217
Total Benefits ($/day)	$ 514		$ 579	Total Benefits ($/day, $/yr)	$ 1,093	$ 284,133
Cost of the SSP Service	$ 387		$ 387	Cost of the SSP Service	$ 775	$ 201,396
B/C Ratio(s)	**1.33**		**1.49**	**B/C Ratio**	**1.41**	
Capacity: Default Capacity (or FIELDDATA)						

The outcome of the DTR FSPE analysis is shown in Table B-15. As can be seen, the B/C ratio for weekday SSP service on Route DTR is 1.4:1; for Saturday and Sunday SSP service, the costs far exceed the benefits; and the overall B/C ratio (weekday, Saturday, and Sunday evaluations combined) is 1.0:1 Because route DTR is not funded by VDOT, the benefits and costs associated with this route are not factored into the overall NOVA SSP benefit results.

Table B-15. Route DTR FSPE Results

ROUTE DTR RESULTS				
Savings	Weekday	Saturday	Sunday	TOTAL
Delay (veh-hrs/yr)	12,733	4	2	12,739
Fuel Consumption (gal/yr)	19,207	6	3	19,216
ROG (kg/yr)	1,603	1	-	1,604
CO (kg/yr)	85	-	-	85
NOx (kg/yr)	357	-	-	357
Benefits				
Delay Benefits ($/yr)	240,916	78	38	241,032
Fuel Benefits ($/yr)	43,217	14	7	43,238
Cost of SSP Service ($/yr)	201,396	40,279	40,279	281,954
Benefits to Cost				
B/C Ratio	1.4	0.0	0.0	1.0

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