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A Return on Investment Study of the Hampton Roads Safety Service Patrol Program

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LANCE E. DOUGALD
Associate Research Scientist

Virginia Transportation Research Council, 530 Edgemont Road,
Charlottesville, VA 22903-2454, www.vtrc.net, (434) 293-1900

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Author:
Lance E. Dougald

Performing Organization Name and Address:
Virginia Transportation Research Council
530 Edgemont Road
Charlottesville, VA 22903

Sponsoring Agencies' Name and Address:
Virginia Department of Transportation
1401 E. Broad Street
Richmond, VA 23219

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Abstract

Safety Service Patrol (SSP) programs are widely used to help mitigate the effects of nonrecurring congestion on our nation's highways and have become an increasingly vital element of incident management programs. SSPs are typically deployed in areas that have high traffic volumes (e.g., urban freeways). They are charged with clearing obstructions such as debris and disabled vehicles from roadways and assisting state police with traffic control at crash scenes. In recent years and in conjunction with performance measurement activities, some state departments of transportation have initiated benefit evaluations of their SSP programs.

In support of the Virginia Department of Transportation's return on investment initiatives, staff from VDOT's Operations Planning Division requested that a benefit-cost study be conducted with regard to the Hampton Roads SSP. To perform the study, an analysis of route geometrics, traffic characteristics, and incident data was conducted in the Hampton Roads area for the period from July 1, 2005, through June 30, 2006. These data were then used as inputs into an SSP evaluation model to obtain the benefits of the program.

The research found that the total annual benefits of the Hampton Roads SSP (in terms of delay and fuel consumption) were approximately $11.1 million. The costs associated with patrolling the routes in the region were approximately $2.4 million: thus the savings generated by this program are nearly 5 times the expenditures it takes to run it. To understand better the program's return on investment, the study recommends that the Hampton Roads SSP conduct an annual review of its benefits versus costs. In addition, because the Hampton Roads region experiences heavy tourist/vacation traffic during the summer months (especially during the weekends), similar reviews should also be conducted on a seasonal basis to assess the fluctuations in costs and benefits that occur during different times of the year. Performing such evaluations will require additional labor costs, but these costs can be minimized by integrating the Virginia State Police computer-aided-dispatch and SSP databases and managing them in such a way that would enable the capturing of relevant and pertinent benefit evaluation data.

FINAL REPORT

A RETURN ON INVESTMENT STUDY OF THE HAMPTON ROADS SAFETY SERVICE PATROL PROGRAM

Lance E. Dougald
Associate Research Scientist

Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

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ABSTRACT

Safety Service Patrol (SSP) programs are widely used to help mitigate the effects of nonrecurring congestion on our nation's highways and have become an increasingly vital element of incident management programs. SSPs are typically deployed in areas that have high traffic volumes (e.g., urban freeways). They are charged with clearing obstructions such as debris and disabled vehicles from roadways and assisting state police with traffic control at crash scenes. In recent years and in conjunction with performance measurement activities, some state departments of transportation have initiated benefit evaluations of their SSP programs.

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INTRODUCTION

Safety Service Patrol (SSP) programs are widely used to help mitigate the effects of nonrecurring congestion on our nation's highways and have become an increasingly vital element of incident management programs. SSPs are typically deployed in areas that have high traffic volumes (e.g., urban freeways). They are charged with clearing obstructions such as debris and disabled vehicles from roadways and assisting state police with traffic control at crash scenes.

In recent years, some state departments of transportation have initiated studies that attempt to quantify the benefits associated with their SSP programs. Benefits are typically quantified by measuring reductions in motorist delay, fuel consumption, emissions, and secondary accidents. The underlying means used to obtain such benefits are determining incident durations with and without SSP operations. Obtaining incident duration data prior to SSP program implementation has often proven difficult because of the lack of available data. Therefore, many studies either make an assumption of incident duration reductions with SSP or attempt to analyze incident duration reductions using current SSP and state police computer-aided-dispatch (CAD) data.

Using incident duration data (either analytical or assumed) in conjunction with modeling techniques that calculate motorist delay allows the benefits of a program to be quantified. A recent study by the Virginia Transportation Research Council (VTRC)[1] that evaluated the benefits of the Northern Virginia (NOVA) SSP estimated a 17 percent reduction in overall incident durations with SSP operations. These reductions were found via a comprehensive analysis of both Virginia State Police (VSP) CAD and SSP data. By applying the incident duration reduction percentages to the Freeway Service Patrol Evaluation (FSPE) model (a macroscopic route-based deterministic queuing model developed at the University of California-Berkeley),[2] the benefits of the NOVA SSP, measured in terms of savings in motorists delay and associated fuel consumption and emissions, were obtained.

The NOVA SSP evaluation[1] showed that the benefits outweighed the costs associated with SSP operations by a ratio of 6.2:1. As a result of this study and in support of the Virginia Department of Transportation's (VDOT) return on investment (ROI) initiatives, staff from VDOT's Operations Planning Division requested that a similar study be conducted with regard to the Hampton Roads SSP.

PURPOSE AND SCOPE

The purpose of this study was to use the FSPE model to quantify the benefits associated with reductions in motorist delay, fuel consumption, and emissions that are attributable to the Hampton Roads SSP. The scope of the study involved an analysis of traffic and incident data for the Hampton Roads area for the period from July 1, 2005, through June 30, 2006 (1 year). The scope of the project was limited to the following:

- *Analyzing incidents that occur within route boundaries*. Because the FSPE model is a route evaluator, incidents occurring outside the boundaries of a defined SSP route were not included in the evaluation. In addition, because the FSPE model is a macroscopic program, the evaluation did not account for disaggregate-level operational detail (e.g., day-to-day or seasonal variations in SSP activities).

- *Quantifying only the benefits associated with motorist delay*. The study did not attempt to predict the potential reduction in secondary incidents or reductions in environmental or medical costs associated with SSP operations. Further, although the study quantifies emissions reductions, it did not attempt to place a dollar value on these reductions.

METHODOLOGY

To achieve the study objectives, the following tasks were undertaken:

1. Examine operational aspects of the Hampton Roads SSP.

2. Query SSP-assisted incidents in VDOT's Archived Data Management System (ADMS) and allocate incidents to routes.

3. Determine incident duration reductions with SSP.

4. Configure the FSPE model for each route.

5. Run the FSPE model to determine the benefits of the Hampton Roads SSP.

Examine Operational Aspects of the Hampton Roads SSP

The first task involved examining the operational aspects of the Hampton Roads SSP. To achieve this, interviews were conducted with SSP management and fleet management from both VDOT[3] and the Hampton Roads SSP contractor: URS Corporation.[4] The purpose of the interviews was to gain insight into the following:

- *Route configurations*. The intent of this inquiry was to identify which roadways are traversed by the SSP including the "begin" and "end" nodes and the constituent segment links of each route.

- *Staffing, shift hours, and personnel costs*. To be compatible with the FSPE model requirements and to help identify costs associated with the program, an examination of the number of patrollers per shift per route, patroller shift hours per route (hours/day and days/week), and VDOT personnel expenditures was conducted.

- *Fleet costs and route assignments*. The intent of this inquiry was to determine the hourly vehicle costs for VDOT (for both VDOT-owned vehicles and URS-leased vehicles) and to identify the number of patrol vehicles that operate on a given route.

Query SSP-Assisted Incidents in ADMS and Allocate to Routes

Upon the completion of Task 1, the next step was to gather SSP incident-assist information for the Hampton Roads region from the ADMS database. This task involved distributing all incidents (accidents, breakdowns, and debris) to the respective locations on the roadways on which they occurred. The ADMS database indicates the longitudinal location (freeway segment and direction) for each incident occurrence, which enables the allocation of incidents to individual patrol routes.

Determine Incident Duration Reductions with SSP

To perform this task, data from the VSP CAD were analyzed and compared to data from the ADMS. Specifically, incident data *without* SSP support were analyzed from the VSP CAD data for accidents and breakdowns within each SSP route boundary. The incident durations were then compared to SSP-assisted incident durations from the ADMS database for the same incident types (accidents and breakdowns) within each route boundary. Once determined, clearance time reductions with SSP were applied to the FSPE model.

Configure FSPE Model for Each Route

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. During incident conditions, the FSPE model uses capacity reduction factors in conjunction with the geometric and traffic characteristics of an SSP route, the frequency and type of assisted incidents on the route,[5] and the queuing models to estimate delay.

The FSPE model consists of six spreadsheet-based workbooks that must be configured for each SSP beat (the term *beat* refers to an SSP "route"). The workbooks include INPUT,

PARAMS, FIELDDATA, TRAFFIC PROFILES, DIR FACTORS, and RESULTS. The following describes each workbook:[1,6]

- 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). Data for this workbook were obtained through interviewing personnel from the Hampton Roads SSP and the Hampton Roads District Equipment Section[5] and querying VDOT's GIS Integrator, traffic management system (TMS), statewide planning system (SPS), and ADMS databases.

- TRAFFIC-PROFILES: Average time-of-day traffic profiles (represented as a percentage of ADT) for weekday, Saturday, and Sunday SSP beat analyses. Data for this workbook were obtained from VDOT's TMS database.

- DIR-FACTORS: Time-of-day traffic directionality profiles per beat segment (represented as a percentage of hourly traffic volume).

- PARAMS: The default model parameters that include *freeway capacity values*, *remaining freeway capacity factors due to incidents* from the HCM 2000,[7] *fuel/emissions rates*, *clearance time reduction data*, *travel time costs*, *fuel costs*, and *occupancy rates*. Emission rates were obtained from the Hampton Roads Planning District Commission (HRPDC). Clearance time reduction data were obtained from an analysis of the VSP CAD and ADMS databases. Travel time costs and fuel costs were obtained from the Texas Transportation Institute (TTI).[8] Occupancy rates (persons/vehicle) were obtained from the Federal Highway Administration's (FHWA) 2001 National Household Travel Survey.[9]

- 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 in delay, fuel, and emissions (benefits) and individual time period, daily, and annual costs for SSP service.

Run FSPE Model to Determine Benefits of Hampton Roads SSP

Once all workbooks were configured, the FSPE model was run for each route. Because average weekday, Saturday, and Sunday traffic characteristics are distinctly different, separate evaluations were run for each period. For each route and period, the measures of effectiveness

(MOEs) of savings in delay, fuel consumption, and emissions were obtained from the RESULTS workbook of the model. In addition, the RESULTS workbook displayed an approximate dollar value of the benefits and the annual cost of SSP service.

RESULTS AND DISCUSSION

Operational Aspects of the Hampton Roads SSP

The Hampton Roads SSP is located at the Hampton Roads Smart Traffic Center (STC) in Virginia Beach, Virginia. SSP patrollers provide traffic control and roadside assistance for motorists traveling on approximately 80 interstate miles throughout Hampton Roads 24 hours a day, 7 days a week. Services provided by the SSP are free of charge and include the following:[10]

- jump starting vehicles
- providing gasoline
- providing water
- changing tires
- removing debris from the roadway
- providing cellular telephone services to disabled motorists
- calling for a tow truck
- providing directions and a state map
- Providing CPR and limited first aid until emergency services arrive.

The Hampton Roads SSP patrols 10 routes. Table 1 shows the routes, roadways, and "begin" and "end" nodes of each route. Of the 10 routes, 8 are patrolled on a continuous, 24-hours-per-day, 7-days-per-week basis. The other 2 routes (HI and 2I) are dispatch only routes (e.g., the routes are not physically patrolled). Of the 10 routes, 8 are staffed in a three-shift configuration: A.M. shift (0400-1200), P.M. shift (1200-2000), and night shift (2000-0400). Routes MMMBT (Monitor-Merrimack Memorial Bridge Tunnel) and HRBT (Hampton Roads Bridge Tunnel) are not staffed during the night shift because of shortages in staffing levels. Shift hours are typically staggered by ±30 minutes to ensure consistent coverage.

During the evaluation year, the routes shown in Table 1 were current. However, at the time of this writing, changes had been made to the route configurations. Specifically, there are now 11 routes and all are operating on a continuous 24/7 basis. Route ColB (Coliseum B) was replaced by Route Lee Hall, which begins at J. Clyde Morris Boulevard and ends at the Lee Hall/Yorktown exit (Exit 247), and a route was added, Route Bowers Hill, which patrols the Portsmouth side of I-264 toward Route HI (Highrise). The evaluation described here is based on the previous route structure and corresponding incident data.

Staffing is supplied by URS and consists of 1 SSP manager, 4 forepersons, and 41 patrollers. The average burdened rate (i.e., base salary plus overhead and benefits) that VDOT pays URS for a manager, foreperson, and patroller is $51.49, $28.37, and $20.63 per hour, respectively. In addition to labor costs, the Hampton Roads SSP maintains and owns 48 SSP

Table 1. Hampton Roads SSP Patrolled Routes

Route Name	Roadway(s)	Begin	End
Reversible Roadway (RR)	I-64 and I-564 (reversible lanes)	Indian River Rd.	Naval Base Gate 3 on I-564
Naval Base (NB)	I-64 and I-564	Indian River Rd.	Naval Base Gate 3 on I-564
2 Inner (2I)	I-264	Lynnhaven Pkwy. via inside lanes	Campostella Rd.
2 Outer (2O)	I-264	Lynnhaven Pkwy. via outside lanes	Military Hwy.
Hampton Roads Bridge Tunnel (HRBT)	I-64	4th View St.	Armistead Ave.
Coliseum A (ColA)	I-64 and I-664	J. Clyde Morris Blvd.	Mallory St. on I-64 and Terminal Ave. on I-664
Coliseum B (ColB)	I-64 and I-664	J. Clyde Morris Blvd.	Mallory St. on I-64 and Terminal Ave. on I-664
Highrise (HI)	I-64	Route 17	Indian River Rd.
Downtown Tunnel (DT)	I-264 and I-464	Military Hwy. via Berkeley Br.	I-464 /I-64 Interchange
Monitor-Merrimack Memorial Bridge Tunnel (MMMBT)	I-664	Aberdeen Rd. through MMMBT	Dock Landing Rd.

pick-up trucks, and the rental rate that the Hampton Roads District Equipment Section charges the SSP is $10.08 per truck-hour. In a typical week, an SSP truck is used an average of approximately 40 hours, and during routine operations, 1 truck is assigned for each route.

During the evaluation year, staffing, fleet levels, and salary structure were current. At the time of this writing, staffing, fleet levels, and salary structure had been modified. Staffing currently consists of 1 SSP manager, 6 forepersons, and 51 patrollers and VDOT compensates URS $2,986,589 per year for labor. In addition to labor costs, URS charges VDOT $0.22 per mile for 16 URS-owned SSP pick-up trucks, which includes expenses such as fuel, routine maintenance, insurance, and lease payments. On average, VDOT pays URS approximately $900,000 per year in fleet costs.

Incidents in ADMS and Allocation to Routes

All SSP-assisted incidents are reported in real-time by SSP patrollers to the STC, where incident details are entered into STC Central Software, which sends the data to the ADMS. To find incident detail relevant to the purpose of this study, ADMS queries included the following:

- TMS_CALL_NUMBER
- ROADNAME
- DIRECTION
- LANE
- LOCATION_CODE
- INC_BEGIN (incident begin date and time)
- INC_TYPE (incident type)
- DURATION.

For the period from July 1, 2005, through July 30, 2006, the query yielded 40,789 entries. These entries were then filtered to reflect "actual" incidents (accidents, breakdowns, and debris) and sorted by location to allocate incidents into respective SSP routes. Because routes RR (Reversible Roadway) and NB (Naval Base), 2O (2 Outer) and 2I (2 Inner), and ColA (Coliseum A) and ColB constitute similar roadway segments, respectively, and incident detail in ADMS is not SSP route discriminatory (i.e., "SSP route" is not a field in the ADMS), these routes were combined (i.e., RR/NB, 2O/2I, and ColA/ColB) to show the total number of incidents occurring within roadway "start" and "end" nodes. Table 2 shows the total number of incidents that occurred within each route during the evaluation year.

Some routes overlapped; thus, the total number of incidents occurring within the boundaries of a route had to be distributed based on a weighted ratio of the length of the overlaps and the total length of the route. For example, Route HRBT overlaps Routes ColA and ColB (ColA and ColB are identical routes) between Armistead Avenue and Mallory Street. Therefore, incidents occurring on I-64 between Armistead Avenue and Mallory Street had to be distributed to Routes HRBT and ColA/ColB. This was accomplished for Route HRBT using the following equation (similar calculations were performed for other route overlaps):

$$I_{HRBT} = I_{Section} \cdot \left[\frac{\frac{1}{L_{HRBT}}}{\frac{1}{L_{HRBT}} + \frac{1}{L_{ColA}} + \frac{1}{L_{ColB}}} \right]$$

where:

I_{HRBT} = number of incidents distributed to Route HRBT
$I_{Section}$ = total number of incidents occurring between Armistead Avenue and Mallory Street
L_{HRBT} = length of Route HRBT
L_{ColA} = length of Route ColA
L_{ColB} = length of Route ColB.

Table 2. Number of Incidents per Route

Route	Number of Incidents
Naval Base/ Reversible Roadway (NB/RR)	9.135
Hampton Roads Bridge Tunnel (HRBT)	1.556
Coliseum A/Coliseum B (ColA/B)	2.899
Highrise (HI)	3.616
Downtown Tunnel (DT)	4.277
Monitor-Merrimack Memorial Bridge Tunnel (MMMBT)	1.207
2 Outer/2 Inner (2O/2I)	11.187

Incident Duration Reductions with SSP

To determine incident duration reductions with SSP, SSP-assisted accident and breakdown incident durations were examined in the ADMS database and compared to accident and breakdown incident durations *without* SSP obtained from the VSP CAD database. Table 3 shows the total number of accident, breakdown, and debris incidents and clearance times per

Table 3. SSP and VSP-Assisted Incidents and Mean Clearance Times for Each Route

` Route	SSP (ADMS Database) Number of Incidents	Mean Clearance Time (min)	VSP (CAD Database) Number of Incidents	Mean Clearance Time (min)
Naval Base/Reversible Roadway (NB/RR)				
Accidents	870	30.52	3175	61.12
Breakdowns	7722	9.46	1929	34.35
Debris	543	5.47		
Hampton Roads Bridge Tunnel (HRBT)				
Accidents	150	20.72	2037	65.83
Breakdowns	1345	9.37	1557	34.75
Debris	61	5.95		
Coliseum A/Coliseum B (ColA/B)				
Accidents	179	27.50	952	68.68
Breakdowns	2551	9.02	866	34.62
Debris	169	5.88		
Highrise (HI)				
Accidents	203	24.55	2701	67.47
Breakdowns	3198	8.82	2077	32.40
Debris	215	6.13		
Downtown Tunnel (DT)				
Accidents	263	26.18	891	68.45
Breakdowns	3725	8.22	733	33.09
Debris	289	5.71		
Monitor-Merrimack Memorial Bridge Tunnel (MMMBT)				
Accidents	53	22.75	609	86.18
Breakdowns	1068	7.80	797	34.15
Debris	86	3.63		
2 Outer/2 Inner (2O/2I)				
Accidents	793	29.32	2020	69.20
Breakdowns	9791	8.93	1586	33.22
Debris	603	4.70		

Note: Because the VSP CAD has no information on incidents involving debris, cells pertaining to debris are empty.

route for SSP-assisted incidents and the total number of accidents and breakdowns and clearance times per route for VSP only–assisted (no SSP presence) incidents. Because the VSP CAD has no information on incidents involving debris, cells pertaining to debris are empty.

Comparisons were made for incidents occurring on each of the SSP-covered routes, and the mean clearance times for VSP-assisted accidents and breakdowns were applied to the number of SSP-assisted accidents and breakdowns to determine average clearance time reductions with SSP. To perform these comparisons, an assumption was made that all incident "begin" times in both the VSP CAD and the ADMS databases reflected actual incident notification times and that all incident "end" times reflected the time the incident was cleared from the roadway. Table 4 shows an example of how the clearance time comparisons were accomplished for incidents that occurred on Route DT (Downtown Tunnel). Because the VSP CAD does not include debris-related incidents, a blanket 5-min reduction with SSP was applied to all debris incidents. This 5-min reduction is an assumed value and was based on findings from the NOVA SSP evaluation.[1]

Table 4. Mean Clearance Time with SSP and Without SSP for Route DT (Downtown Tunnel)

Incident Type	Number of Incidents	Mean Clearance Time (min)	
		With SSP (ADMS)	Without SSP (VSP CAD)
Accidents	263	26.18	68.45
Breakdowns	3,725	8.22	33.09
Debris	289	5.71	10.71
Total	4,277	9.15	33.75

As can be seen from Table 4, the average reduction in clearance time with SSP for Route DT was 24.6 min (33.75–9.15 min). Similar analyses were conducted for each evaluation period (average weekday, Saturday, and Sunday evaluations) for each route. Upon aggregating all evaluation periods, incident types, and routes, the mean clearance times for incidents with SSP support and without (VSP only) were 10.17 and 49.01 min, respectively.

FSPE Model Configuration for Each Route

To perform route-based evaluations, route incident, traffic, and geometric data were compiled for the analysis year. For Routes NB and RR, 2O and 2I, and ColA and ColB, aggregating incidents to a particular SSP "route" was not possible because incident data are captured and reported in terms of the roadway segment and direction. Each of these route combinations traverses approximately the same roadway segments (e.g., Route ColA and ColB traverse the identical roadway segments). Therefore, to use the FSPE model efficiently for these six routes, NB and RR were combined as one route (NB/RR) as were 2O and 2I (2O/2I) and ColA and ColB (ColA/B). Because the Hampton Roads SSP uses a 1 truck to 1 route per shift ratio, the FSPE model was configured based on a 2 truck to 1 route per shift ratio for each of these route combinations (NB/RR, 2O/2I, and ColA/B).

Route NB/RR created additional modeling difficulties because Route RR is a barrier-separated two-lane high-occupancy vehicle (HOV) facility. From 1 A.M. to 11 A.M., the facility is open to westbound traffic (HOV-2 restrictions from 6 A.M. to 8 A.M.); from 1 P.M. to 11 P.M. (HOV-2 restrictions from 4 P.M. to 6 P.M.), the facility is open to eastbound traffic. The facility is closed to all traffic from 11 to 1 both A.M. and P.M. When the facility is open to westbound traffic, the RR patroller travels westbound on the reversible lanes and eastbound on Route NB. When the facility is open to eastbound traffic, the patroller travels eastbound on the reversible lanes and westbound on Route NB. During the time period that the facility is closed, the RR patroller is involved in support operations on Route NB. For modeling purposes, segments where the reversible roadway facility exists on Route NB/RR were configured as an eight-lane facility (three mixed-use lanes and one HOV lane per direction).

Upon combining the necessary routes and collecting the required input data (route incident, traffic, and geometric data), the FSPE model was configured for each route. Of the six FSPE workbooks used by the FSPE model, three were used for data entry: INPUT, PARAMS, and TRAFFIC-PROFILES. Separate models were created for each route shown in Table 2. Further, for each route, separate models were created for weekday, Saturday, and Sunday evaluations, respectively. For example purposes, configuration of the three workbooks is shown using a weekday evaluation of Route DT.

INPUT Workbook

The INPUT workbook consists of four tables: Beat/Service Description, Beat Design Characteristics, Beat Traffic Characteristics, and Incident Characteristics.

Beat/Service Description

Data entered into Beat/Service Description includes the route name, shift hours, number of trucks/shift, number of service days/year, and cost of SSP service in $/truck-hour. Route DT is covered 24 hours per day, with three shifts that use one truck per shift. For a "weekday" evaluation, the number of service days was entered as 260. The cost of SSP service in $/hour was input as $32.05. This value was obtained by adding average truck costs in $/hour to average labor costs in $/hour. The hourly truck rental rate is $10.08, and the average labor cost is $21.97. The average labor cost was found by:

$$\text{Labor costs (\$/hr)} = \frac{(\$51.49 \times 1) + (\$28.37 \times 4) + (\$20.63 \times 41)}{46} = \$21.97\,/\,\text{hr}$$

Beat Design Characteristics

Each Hampton Roads SSP route was broken down into segments (sections between interchanges and/or city boundaries). In the Beat Design Characteristics Table, shown in Table 5, data entered for each segment include the length of the segment; number of mixed-flow lanes; and Boolean identifiers for presence of HOV lanes, right shoulders, and left shoulders. No shoulder presence (Boolean identifier = N) was input on segments where paved shoulder widths were less than 5 ft.

Table 5. Beat Design Characteristics for Route DT (Downtown Tunnel)

DIRECTION-1 (EB)									
Segment No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Length (mi)	0.98	1.06	1.89	1.17	0.87	0.78	0.84	0.87	3.09
No. Mixed-Flow Lanes	3	3	3	2	2	3	3	3	3
HOV Lane	N	N	N	N	N	N	N	Y	Y
Right Shoulder	Y	Y	Y	Y	N	N	Y	Y	Y
Left Shoulder (Median)	Y	Y	Y	N	N	N	N	Y	N
DIRECTION-2 (WB)									
Segment No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Length (mi)	0.98	1.06	1.89	1.17	0.87	0.78	0.84	0.87	3.09
No. Mixed-Flow Lanes	3	3	3	2	2	3	3	3	3
HOV Lane	N	N	N	N	N	N	N	Y	Y
Right Shoulder	Y	Y	Y	Y	N	N	Y	Y	Y
Left Shoulder (Median)	Y	Y	Y	N	N	N	N	Y	N

Note: Beat length is 11.55 miles with 9 segments.

Beat Traffic Characteristics

For each segment in the Beat Traffic Characteristics Table, shown in Table 6, bi-directional AADTs were input as well as A.M., mid-day, P.M., and off-peak traffic directions and associated directional factors for each peak direction. D-factors are used to split average hourly traffic volumes into directional volumes and are represented as a percentage of hourly traffic volume.

Table 6. Beat Traffic Characteristics for Route DT (Downtown Tunnel)

Segment No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
AADT	47,430	40,385	44,661	42,791	51,765	126,198	116,843	112,469	128,212
A.M. Peak Dir.	WB	WB	WB	WB	WB	WB	WB	WB	WB
D factor (%)	50.73	50.73	50.73	50.73	50.73	50.73	50.73	50.73	50.73
MD Peak Dir.	EB	EB	EB	EB	EB	EB	EB	EB	EB
D factor (%)	52.62	52.62	52.62	52.62	52.62	52.62	52.62	52.62	52.62
P.M. Peak Dir.	EB	EB	EB	EB	EB	EB	EB	EB	EB
D factor (%)	51.52	51.52	51.52	51.52	51.52	51.52	51.52	51.52	51.52
Off-Peak Dir.	EB	EB	EB	EB	EB	EB	EB	EB	EB
D factor (%)	51.18	51.18	51.18	51.18	51.18	51.18	51.18	51.18	51.18

AADT = annual average daily traffic; MD = mid-day; Dir. = direction; WB = westbound; EB = eastbound.

Incident Characteristics

The last table in the INPUT workbook is the Incident Characteristics Table, shown in Table 7. For each route, total SSP assists per year were input as well as the percentages of the total and mean clearance times for right shoulder, left shoulder, and in-lane accidents; breakdowns; and debris. The FSPE model proportions incidents occurring on a route via 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 route is divided into segments, which are weighted by traffic volumes and distance (e.g., VMT) for proportioning incidents into hourly time slices on route segments.

Table 7. Incident Characteristics Table for Route DT (Downtown Tunnel)

Incident Type/Location		**% of Incidents**	**Mean Clearance Time**
Accident	Right Shoulder	3.2	20.94
	Left Shoulder (Median)	0.9	26.96
	In-Lane	2.8	20.94
Breakdown	Right Shoulder	80.2	8.24
	Left Shoulder (Median)	3.9	11.33
	In-Lane	2.0	20.48
Debris	Right Shoulder	4.3	5.40
	Left Shoulder (Median)	0.4	3.54
	In-Lane	2.2	4.83

Note: There were 3,245 total SSP assists from July 1, 2005, through June 30, 2006.

PARAMS Workbook

The PARAMS workbook consists of data entry tables, which include *Freeway Capacity Values*, *Remaining Freeway Capacity Factors*, *Fuel/Emissions Rates*, *Clearance Time Reduction Data*, *Travel Time and Fuel Costs*, and *Occupancy Rates*.

Freeway Capacity Factors

When performing all Hampton Roads SSP evaluations, the researcher used values of 2,100 vehicles per hour per lane (vphpl) for mixed-use lanes and 1,800 vphpl for HOV lanes. These values are considered the "ideal" capacities for much of the freeways in Virginia.[1]

Remaining Freeway Capacity Factors

The model's default parameter estimates for "remaining capacity during incidents" are based on the Highway Capacity Manual 2000, Exhibit 22-6, Proportion of Freeway Segment Capacity Available Under Incident Conditions,[7] and are shown in Table 8. The capacity reduction factors are not applied to incidents blocking two or more lanes, but incidents that block two or more lanes are accounted for in the *Incident Characteristics* Table of the INPUT worksheet.

Table 8. Percentages of Remaining Freeway Capacity Due to Incidents

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

Fuel/Emissions Rates Table

Emission rates for incremental speeds were obtained from the HRPDC and are shown in Table 9. Fuel rates were not available, and therefore the fuel rates applied in the NOVA evaluation[1] were used. Further, the fuel rates are for light-duty gas vehicles (LDGV) and do not reflect any other vehicle classifications. Therefore, the model will tend to underestimate fuel consumption.

Clearance Time Reduction Data

Data obtained from Task 3 were used for this table. Data entry includes *Mean Clearance Time Without SSP* in minutes and *Clearance Time Reduction* in minutes. For Route DT, "weekday" input values were 33.75 and 24.43 min, respectively. Separate values were obtained for each route in accordance with Task 3 methods or each evaluation type (weekday, Saturday, and Sunday evaluations).

Table 9. 2006 Hampton Roads Emission and Fuel Rates at Incremental Speeds

Speed (mph)	ROG (gr/mi)	CO (gr/mi)	NOx (gr/mi)	Fuel (mi/gal)
5	2.792	33.657	2.203	7.510
10	1.499	24.008	1.699	9.996
15	1.179	21.123	1.431	12.778
20	1.046	20.349	1.369	15.708
25	0.973	19.965	1.340	18.581
30	0.924	19.711	1.324	21.159
35	0.880	19.741	1.317	23.203
40	0.852	20.285	1.338	24.510
45	0.828	20.857	1.380	24.950
50	0.806	21.459	1.445	24.487
55	0.787	22.102	1.543	23.184
60	0.772	22.791	1.690	21.184
65	0.770	22.889	1.712	18.685
Factor	39.773	1.773	26.576	1.508

ROG = reactive organic gases; CO = carbon monoxide; NOx = nitrogen oxides.

Travel Time and Fuel Costs

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

$$\left(\frac{\$}{\text{vehicle hour}} \times \text{occupancy rate} \times \%\ \text{vehicles}\right) + \left(\frac{\$}{\text{truck hour}} \times \%\ \text{trucks}\right)$$

According to staff at TTI,[8] the latest travel time values for each occupant in a vehicle in Virginia is $15.04/hr and the travel time value for commercial vehicles is $73.32/hr. Travel time costs were configured for each route based on the truck percentages of each route. For Route DT, assuming an average vehicle occupancy of 1.22[9] and the percentage of trucks in total traffic as 4.6 percent, the travel time value used for the analysis was $21.10/hr (travel time value in $/hr = [$15.04/hr ×1.22 × 0.95] + [$73.32/hr × 0.05] = $21.10/hr). Fuel costs were obtained from the American Automobile Association's website for retail gasoline prices,[11] where the average value for the evaluation period was approximately $2.45/gal.

Occupancy Rates

To split mixed-use and HOV-lane traffic volumes, the occupancy rates table requires an average percentage for 1 person/vehicle, 2 persons/vehicle, and 3 persons/vehicle occupancies; occupancy rate; and an average percentage of HOV usage (i.e., the average percentage of HOVs that will use designated HOV lanes). For each Hampton Roads 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 occupancy rate was entered as 1.22 persons/vehicle, and the percentage of HOV use was entered as 95 percent.

TRAFFIC-PROFILES Workbook

The TRAFFIC-PROFILES workbook is used by the FSPE model to allocate average daily traffic volumes along a route. Average hourly traffic-profiles (represented as percentage of ADT) obtained from count station data in the Traffic Management System (TMS) database throughout the evaluation year were created for each route and time period (average weekday, Saturday, and Sunday). For routes with multiple count stations, the hourly flows were averaged to obtain a route-wide average flow profile. An example of Route DT's average traffic flow profile is shown in Figure 1.

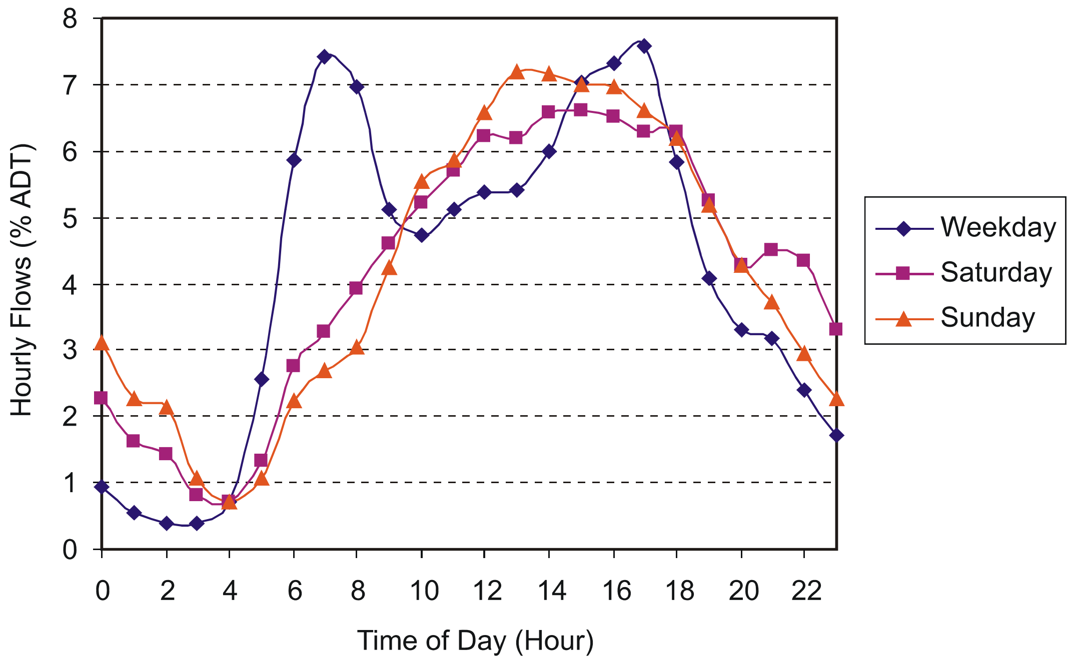

Figure 1. Route DT (Downtown Tunnel) Average Hourly Traffic Profiles

FSPE Model Limitations

Due to the macroscopic nature of the FSPE model, there are several geometric and traffic modeling limitations. These limitations include the following:[1,2]

- *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. 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. These limitations can result in less accurate capacity reduction estimates and delay estimations.

- *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.

Benefits of Hampton Roads SSP According to FSPE Model

Once each SSP route was configured, the FSPE model was run to determine the benefits associated with the Hampton Roads SSP. Separate evaluations were performed for average weekday, Saturday, and Sunday analyses. The output of the model runs is shown in the RESULTS worksheet, which provides daily and annual delay savings (veh-hr), fuel consumption savings (gal), and emissions savings (kg/day, kg/year). Further, the model estimates the cost-effectiveness of the SSP operations by providing values for delay benefits ($/day, $/year) and fuel benefits ($/day, $/year). By comparing the daily and annual cost of the SSP service with the total benefits quantified by the model (delay and fuel), an ROI can be calculated.

Table 10 shows the annual delay savings, fuel consumption savings, and emissions savings for each SSP route for all evaluation periods (e.g., weekday, Saturday, and Sunday evaluations are combined for each route shown). The total delay savings and fuel savings attributable to the Hampton Roads SSP operations are 455,856 veh-hr and 687,624 gal, respectively. The total emissions savings for reactive organic gases (ROG), carbon monoxide (CO), and nitrogen oxides (NOx) are 118,131 kg, 805 kg, and 12, 115 kg, respectively. The routes with the greatest delay savings, fuel consumption savings, and emissions savings are NB/RR and 2O/2I.

Table 10. Estimates of Annual Delay Savings, Fuel Consumption Savings, and Emissions Savings

Route	Annual Delay Savings (veh-hr)	Annual Fuel Consumption Savings (gal)	Annual Emissions Savings (kg)		
			ROG	CO	NOx
Naval Base/Reversible Roadway (NB/RR)	138,843	209,434	5,521	246	3,690
Hampton Roads Bridge Tunnel (HRBT)	59,620	89,932	2,372	105	1,585
Coliseum A/Coliseum B (ColA/B)	20,149	30,393	802	35	536
Highrise (HI)	21,683	32,707	863	38	576
Downtown Tunnel (DT)	21,434	32,331	852	38	569
Monitor-Merrimack Memorial Bridge Tunnel (MMMBT)	10,669	16,094	424	18	284
2 Outer/2 Inner (2O/2I)	183,458	276,733	7,297	325	4,875
Total	**455,856**	**687,624**	**18,131**	**805**	**12,115**

ROG = reactive organic gases; CO = carbon monoxide; NOx = nitrogen oxides.

Table 11 shows the annual delay and fuel benefits, annual costs, and benefit/cost (B/C) ratios for each route for all evaluations (weekday, Saturday, and Sunday evaluations). All routes except ColA/B had an associated ROI that was positive. The routes with the greatest benefits were 2O/2I, HRBT, and RR/NB, with benefits that exceeded costs by factors of 10.17, 7.74, and 6.46, respectively. Overall, the Hampton Roads SSP produced benefits that exceeded costs by a factor of 4.71 to 1.

As noted, Tables 10 and 11 represent the combined results of separate weekday, Saturday, and Sunday evaluation periods. Individual time period B/C ratios for each route are shown in Table 12. Included in the table are the average incidents per day and volume/capacity (V/C) ratios. The FSPE model creates hourly V/C ratios per segment per direction based on average traffic profiles, directionality factors, and AADT. The V/C values shown in the table represent an average of the highest 3-hr V/C ratios per segment per direction.

Table 11. Annual Benefits and Costs Estimates and Benefit/Cost Ratios

Route	Total Annual Delay and Fuel Benefits ($)	Total Annual Costs ($)	B/C Ratio
Naval Base/Reversible Roadway (NB/RR)	3,314,873	513,312	6.46
Hampton Roads Bridge Tunnel (HRBT)	1,445,382	186,660	7.74
Coliseum A/Coliseum B (ColA/B)	503,544	513,312	0.98
Highrise (HI)	528,759	256,656	2.06
Downtown Tunnel (DT)	531,466	256,656	2.07
Monitor-Merrimack Memorial Bridge Tunnel (MMMBT)	276,296	186,660	1.48
2 Outer/2 Inner (2O/2I)	4,475,573	439,982	10.17
Total	**11,075,893**	**2,353,238**	**4.71**

Table 12. Average Route Incidents/Day, V/C Ratios, and Benefit/Cost Ratios

Route	Average Incidents/Day	V/C Ratio	B/C Ratio
Naval Base/Reversible Roadway (NB/RR) (wk)	27	0.58	8.04
NB/RR (Sa)	22	0.42	2.93
NB/RR (Su)	20	0.40	2.09
Hampton Roads Bridge Tunnel (HRBT) (wk)	4	0.66	8.02
HRBT (Sa)	5	0.58	9.94
HRBT (Su)	4	0.56	4.18
Coliseum A/Coliseum B (ColA/B) (wk)	9	0.50	1.08
ColA/B (Sa)	7	0.46	1.03
ColA/B (Su)	6	0.43	0.44
Highrise (HI) (wk)	11	0.56	2.72
HI (Sa)	9	0.41	0.70
HI (Su)	7	0.36	0.11
Downtown Tunnel (DT) (wk)	12	0.47	2.90
DT (Sa)	11	0.31	0.00
DT (Su)	9	0.26	0.00
Monitor-Merrimack Memorial Bridge Tunnel (MMMBT) (wk)	4	0.54	2.00
MMMBT (Sa)	3	0.32	0.26
MMMBT (Su)	2	0.28	0.10
2 Outer/2 Inner (2O/2I) (wk)	33	0.70	12.21
2O/2I (Sa)	28	0.35	0.00
2O/2I (Su)	25	0.31	0.00

V/C = volume/capacity ratio; B/C = benefit/cost ratio; wk = weekday; Sa = Saturday; Su = Sunday.
Note: V/C values represent an average of the highest 3-hr V/C ratios per segment per direction.

For weekday evaluations, all routes were associated with a B/C ratio greater than 1. For Saturday and Sunday evaluations for Routes HI, DT, MMMBT, and 2O/2I and the Sunday evaluation for Route ColA/B, the associated B/C ratios were less than 1. In determining the benefits of a particular route, many factors were considered; the primary factors were route incident characteristics (number, type, and lateral location); geometry (route length and number of lanes); and traffic characteristics (AADT, hourly flow profiles, and directionality factors). Based on these factors, an assumption can be made that there is a relationship between incident-induced delay and the V/C ratio. Therefore, to understand better why particular routes were associated a low B/C ratio, an analysis was conducted that examined the relationship between the average route V/C ratio and the B/C ratio for each evaluation period.

Figure 2 is a plot of the average route V/C ratio vs. B/C ratio for each route and evaluation period, respectively. As indicated in the figure, a V/C value of 0.42 corresponds to the point where the trend line of the plot intersects a B/C value of 1, thus indicating that an average route V/C ratio of less than 0.42 will likely have an associated B/C ratio of less than 1. This relationship may help explain why the Saturday and Sunday evaluations for Route 2O/2I showed no benefits even though the average number of daily incidents was high. The one data point that shows a B/C ratio less than 1 and a V/C ratio greater than 0.42 is the Sunday evaluation for ColA/B. One explanation of this anomaly is that the average number of daily incidents was low compared to that of routes with a similar V/C ratio.

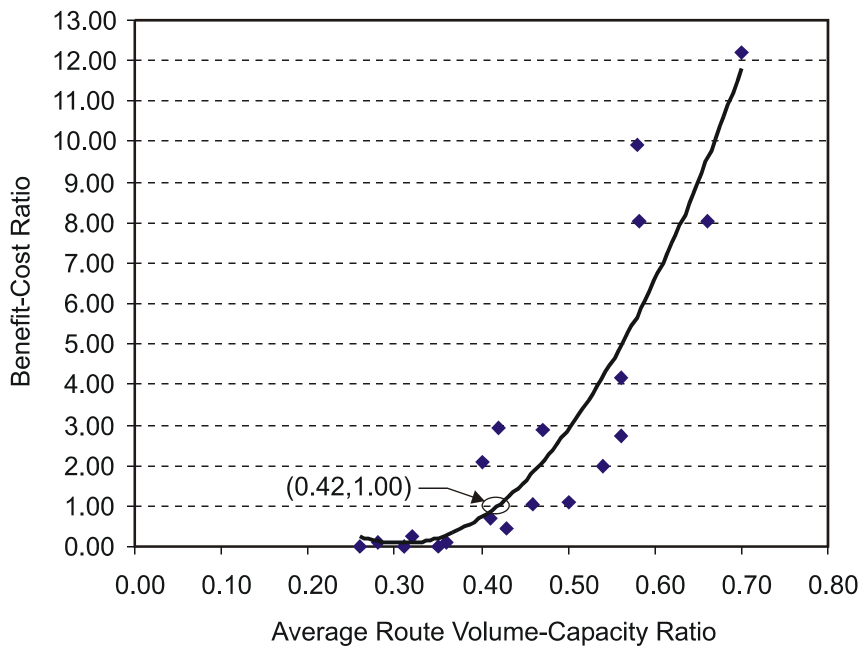

Figure 2. Benefit/Cost Ratios vs. Average Route Volume/Capacity Ratios

STUDY LIMITATIONS

There are many benefits that can be attributable to SSP operations that are difficult to quantify and thus were not evaluated in this study. Some of these benefits include the following:

- *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.[1]

- *Benefits to other emergency responders.* SSP support at incident scenes directly benefits other emergency responders such as fire department personnel, emergency medical technicians (EMTs), and wrecker services.[3] By roaming defined routes, SSPs are frequently the first to arrive at an incident site and, therefore, can begin clearance procedures such as pushing a lane-blocking vehicle to the shoulder, removing debris, setting up traffic control, providing a safety buffer (securing the scene), and initiating first aid to injured motorists. These activities directly support the incident management objectives of other emergency responders and help expedite the removal of freeway incidents. Although the benefits to other emergency responders can be indirectly quantified by clearance time reductions, the direct benefits are difficult to quantify.

- *Benefits to the STC.* SSP service provides faster recovery of the freeway to normal conditions when freeway incidents occur and improves incident detection capabilities.[1] The roving SSP trucks are able to locate incidents and report them promptly to the STC.

- *Improved safety*. SSP vehicles provide motorists with a sense of security on the freeway,[1] and the more rapid clearance of incidents may contribute to reducing secondary accidents (a *secondary incident* is defined as an incident that resulted directly from the primary incident). The determination of safety improvements, however, requires data on accident rates and traffic volumes on the SSP beats over long time periods. There is no established protocol for measuring secondary incidents. 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 Hampton Roads SSP receives numerous comments from assisted motorists throughout the year expressing gratitude for their services. Motorists view the services as a public benefit, yet one that cannot be quantified.[3]

CONCLUSIONS

- *The Hampton Roads SSP generates a positive return on VDOT's investment*. The estimated dollar benefit of the Hampton Roads SSP (measured in terms of savings in delay and fuel consumption) was approximately $11.08 million from July 1, 2005, through June 30, 2006. VDOT's investment, in terms of supplying patrollers and patrol vehicles to the routes, was approximately $2.35 million for the same period. Thus, the savings generated by the program are nearly 5 times the expenditure it takes to run it. (In other words, the B/C ratio of the program is nearly 5:1.) Over an average week (weekdays and weekends included), all

Hampton Roads SSP routes except for Routes ColA and B are associated with a B/C ratio greater than 1. That is, for every dollar spent on the program, more than 1 dollar is saved.

- *Incidents occurring at locations with low V/C ratios will have less of an impact on motorists (in terms of delay); this appears to be the case for the routes that have an associated low B/C ratio.* Of the 21 evaluations performed, 9 revealed a B/C ratio of less than 1; all were Saturday and Sunday evaluations. A contributing factor to the low B/C ratio is low route-wide V/C ratios. High V/C ratios indicate that traffic volumes are near (or above) the facility's capacity and thus even minor incidents occurring at locations with high V/C ratios (such as shoulder disablements) have a greater chance of creating delay to motorists.

- *During the summer months when there is a large number of vacationers traveling on I-264, the V/C ratios will likely increase and thus the B/C ratios will likely increase.* Because this study evaluated the benefits of the Hampton Roads SSP during a 1-year period, seasonal variations in traffic volumes and incidents were attenuated. For example, Route 2O/2I had a high number of Saturday and Sunday incidents during the evaluation year yet was associated with low B/C ratios, primarily because of low V/C ratios.

- *By integrating databases and establishing consistent protocols for incident "start" and "end" times, a comprehensive incident duration reduction analysis can be performed in the Hampton Roads region that would reflect more accurate incident duration reductions.* Based on clearance time data obtained from the VSP CAD and the ADMS databases for all accident, breakdown, and debris incidents within the boundaries of SSP-covered routes, the average clearance times for VSP assists (with no SSP support) and SSP assists were 49.01 and 10.17 min, respectively. These clearance time values indicate an incident duration reduction of approximately 79 percent with SSP support. This percentage, however, can be misleading because VSP personnel typically respond to more major incidents that require more time to clear. Further, because of limitations in VSP CAD details (e.g., absence of information on the number of lanes blocked), irregularities present in both databases with incident "start" and "end" times, and the fact that the databases are not integrated, a comprehensive incident duration reduction analysis that compares clearance times for like incidents could not be performed. The NOVA SSP study[1] found a 17 percent incident duration reduction with SSP support. This finding was obtained via a time-consuming incident matching and comprehensive statistical analysis of clearance times with and without SSP for similar incident severity types. Such an analysis was not performed for the Hampton Roads SSP because of the inconsistencies in data entry protocols and the absence of VSP CAD incident detail. If such an analysis could be performed, incident duration reduction values might be closer to those of the NOVA SSP study.[1]

RECOMMENDATIONS

1. *To understand better the program's return on investment, the Hampton Roads SSP should conduct an annual review of its benefits versus costs using the FSPE model or other models that use available traffic and incident data.* In addition, because the Hampton Roads region

experiences heavy tourist/vacation traffic during the summer months (especially during the weekends), similar evaluations should also be conducted on a seasonal basis to assess and understand better the fluctuations in benefits and costs that occur during different times of the year.

2. *To enable a higher degree of accuracy with respect to determining incident durations with and without the SSP, the Hampton Roads STC should ensure that incident durations entered into ADMS are consistent with VSP protocol for incident "entry" and "clear" times.* In particular, incident "clear" or "end" times should be the time that the roadway is clear. This is applicable to shoulder and in-lane blockages.

COSTS AND BENEFITS ASSESSMENT

Performing annual or seasonal SSP benefit evaluations will enable the Hampton Roads SSP to gain insight into the effect their operations have on the delay that the traveling public encounters when incidents occur on the roadways. Further, such evaluations will allow VDOT managers to provide feedback on the dollar amount saved by motorists from offering such services. Performing these evaluations using the FSPE model or other similar models 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. If SSP program beat data are entered into the FSPE model and beat design characteristics remain constant, only annual route incident and traffic characteristics adjustments would be required, thus entailing minimal labor efforts.

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