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16. Abstract

On July 1, 2003, legislation went into effect that established a highway safety corridor (HSC) program for Virginia. The intent of the HSC program is to address safety concerns through a combination of law enforcement, education, and engineering countermeasures. Fines for violations in the highway safety corridors are doubled, subject to a $200 minimum for criminal infractions and a $500 maximum for traffic offenses. The *Code of Virginia* required the Commonwealth Transportation Commissioner, in conjunction with the Commissioner of the Department of Motor Vehicles and the Superintendent of the Virginia State Police, to develop criteria for designating and evaluating highway safety corridors. The legislation required that this process include a review of "crash data, accident reports, type and volume of vehicular traffic, and engineering and traffic studies."

This report documents the results of a study to develop a method to designate HSCs on Virginia's interstate and primary systems. The impacts of the HSC program on interstate crashes and speeds are also presented. The framework for the interstate program described was adopted and applied by the Virginia Department of Transportation, resulting in the installation of three HSCs around the state. The results of an evaluation of the data for 2004 indicate that the program did not produce a benefit in terms of safety or speed reduction, although the results were based on only 1 year of data. Preliminary crash data for 2005 indicate that a positive safety benefit may have occurred at the I-81 and I-95 Richmond HSCs. A rigorous analysis of the 2005 data could not be performed since comparison site data were not yet available, but the preliminary data seem promising.

The HSC program currently does not have any dedicated resources with which countermeasures may be implemented; this may limit the potential effectiveness of the program. Additional effects might be observed if dedicated resources were available to allow a more systematic approach to enforcement, education, and engineering within the designated HSCs. Further analysis of the HSCs using at least two more years of data should be performed to gain a more accurate picture of whether the HSCs have had a positive safety benefit.

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FINAL REPORT

DEVELOPMENT AND EVALUATION OF VIRGINIA'S HIGHWAY SAFETY CORRIDOR PROGRAM

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INTRODUCTION

On July 1, 2003, legislation went into effect establishing a highway safety corridor (HSC) program for Virginia. The goal of the HSC program is to identify locations on interstates and primary roads with demonstrated safety problems and to address those concerns through a combination of law enforcement, education, and safety enhancements. The legislation required the Commonwealth Transportation Commissioner, in cooperation with the Commissioner of the Department of Motor Vehicles (DMV) and the Superintendent of the Virginia State Police (VSP), to develop criteria for designating and evaluating HSCs. Further, the process had to include a review of crash data, traffic volume information, vehicle classification data, and engineering and traffic studies. Fines for violations in the highway safety corridors were doubled, subject to a $500 maximum for traffic infractions and a $200 minimum for criminal infractions. The fines collected in HSCs are deposited into the Literary Fund and are not used to support any part of the HSC program. The relevant sections of the *Code of Virginia* are provided in Appendix A.

The Virginia Department of Transportation (VDOT) asked the Virginia Transportation Research Council (VTRC) to develop methods for identifying candidate HSCs. VTRC was also asked to perform an effectiveness evaluation of designated HSCs. VDOT's Traffic Engineering Division (TED) was responsible for implementing the HSCs and administering the HSC program. This report summarizes the procedures developed by VTRC to screen and select HSCs and provides some initial results on the effectiveness of the established HSCs.

PURPOSE AND SCOPE

The purpose of this project was to develop and evaluate an HSC program for Virginia. The objectives of the project were:

1. Develop a method for screening and selecting locations for HSC designation on the interstate system

2. Evaluate whether the HSC program produced a positive safety benefit on the interstate system

3. Develop a potential methodology for extending the HSC program to the primary system.

The scope of the project was limited to roads covered by the HSC legislation, namely the interstate and primary systems. Crash and traffic data were analyzed for the years 2000 through 2004 for the interstate system and 2002 through 2004 for the primary system. VTRC was responsible for developing the HSC identification process and evaluating deployed HSCs. TED was responsible for implementing the HSCs in cooperation with the VDOT districts, VSP, and DMV. VTRC performed a support role for TED in these functions.

METHODOLOGY

This research project was different from many others in that implementation occurred in parallel with the research activities. As processes were developed, they were approved and implemented if found to be acceptable. Given the concurrent paths of the research implementation and the research itself, it was often difficult to differentiate the two activities clearly. For the sake of clarity, the methods documented here include both the activities that occurred during the research and a summary of the implementation activities.

This project was initially subject to significant time constraints. Virginia's HSC legislation went into effect on July 1, 2003, and there was a political mandate to have at least one HSC installed by the beginning of January 2004. The VTRC research project was initiated in late August, which meant that a process for identifying and selecting HSCs had to be developed and approved within approximately 4 months. In Virginia, there are approximately 8 times as many miles of primary roads as miles of interstates. Interstates also tend to be more homogeneous than primary roads in terms of crash characteristics, geometry, and traffic characteristics. Thus, VTRC and TED made the decision to create a stratified structure for the development and implementation of the HSC program whereby interstates were examined first, followed by primaries. Initial tasks in the methodology were focused on developing the methodology for the interstate HSC program, with later tasks focused on evaluating the HSC program and developing a methodology for the primary system. The time constraint served to move the methodology to a relatively straightforward, easily executable procedure.

Specifically, five tasks were conducted to achieve the study objectives:

1. Review the literature to gather information on initiatives in other states that were similar to Virginia's HSC program.

2. Develop a method for screening and selecting locations for HSCs on the interstate system.

3. Select and implement the interstate HSCs.

4. Determine the effectiveness of the interstate HSCs in improving safety.

5. Develop a potential methodology for extending the HSC program to the primary system.

A brief overview of the methods is provided here. More in-depth descriptions are provided in the "Results" section to allow the reader to follow the process more easily.

Review of the Literature

The VTRC Library, the University of Virginia Library, the Transportation Research Information Service database, legal databases, and the Internet were used to identify applicable states. The literature review was conducted to answer four primary questions:

1. Have other states designated safety corridors?
2. Have other states used increased fines as a deterrent in these corridors?
3. How were these programs operated by other states?
4. Is there any evidence that increased fines, in isolation, can improve safety?

Development of Method for Screening and Selecting Locations for Interstate HSCs

The first step in developing selection criteria for the interstate system was to examine the crash characteristics of the various interstates throughout the state. The crashes were examined within the context of the HSC legislation, which required that the program include consideration of "crash data, accident reports, type and volume of vehicle traffic, and engineering and traffic studies." During this step, a variety of screening measures and thresholds was examined. An iterative process was used to identify appropriate measures and thresholds. VTRC would develop a range of possibilities and present them to TED staff. Then, VTRC and TED staff would discuss the results to try to set measures and thresholds so that a reasonable number of sites would be selected as candidates. The objective of this process was to generate a list of candidates that simultaneously pinpointed areas with safety concerns while ensuring that the number of candidate HSCs produced was small enough for a detailed review to be conducted to select a preferred corridor for implementation.

Once a candidate methodology for identifying candidates was developed, it was presented to the HSC oversight committee, which consisted of the Commonwealth Transportation Commissioner, the DMV Commissioner, and the VSP Superintendent. The committee was responsible for approval of the methodology. Following initial approval, the methodology was presented at three public hearings held in Salem, Northern Virginia, and Hampton Roads. After public comment on the methodology, the Commonwealth Transportation Commissioner issued his final approval of the selection methodology.

Selection and Implementation of Interstate HSC Locations

Application of the screening process produced a list of candidate interstate segments that met the HSC eligibility criteria. The next step in the process was to perform a detailed analysis of the candidate segments. The goal of the analysis was to identify which sites would be the most likely to benefit from the HSC program and to identify any issues related to enforcement or signing of the HSC.

In this step, VTRC provided a summary of the crash types, contributing factors, and year-by-year crash trends. TED took this summary and produced further analyses of the crash characteristics of the corridors. TED staff then met with the appropriate VDOT district staff to talk about the crash analysis and the feasibility of implementing a particular HSC. Division and area VSP offices were also contacted by TED to determine the feasibility of enforcement for a particular corridor.

Following these meetings, TED and VTRC staff worked together to identify the single "preferred" HSC that appeared to have the most promise. With the concurrence of VDOT management, a public hearing near the proposed corridor was held as required by the legislation. The findings from the criteria assessment and the public comments were forwarded to the Commissioner for approval. Following approval, a designation date was set, signs were installed on the HSC, and increased enforcement and educational campaigns were implemented. Draft sign designs were developed and forwarded to the Federal Highway Administration (FHWA) for approval prior to installation. Local judicial braches were notified of the designation starting date for the increased fine structure. TED also worked with the appropriate VDOT district to perform a road safety assessment (RSA) that attempted to diagnose specific safety problems within the HSC that might be easily correctable through low-cost engineering countermeasures. Safety measures were also monitored within the designated HSCs and reported annually, as required by the *Code of Virginia.*

Determination of Effectiveness of Interstate HSCs in Improving Safety

The effectiveness evaluation had two components: a crash evaluation and a speed evaluation.

Crash Evaluation

Crash data from 2000 through 2004 were examined during this analysis. The 2005 crash data will not be completely coded until the summer of 2006, so only preliminary data were available. As a result, only sites that were installed by early 2004 were subjected to a statistical analysis. The 2005 crash data reported by VSP are presented to provide some indication of the recent effectiveness of the HSCs, but these data could not be rigorously analyzed.

The crash data from the sites were analyzed using two methods: (1) a non-statistical comparison of the rate and frequency at the site with and without the HSC with those of other similar locations, and (2) the empirical Bayes (EB) approach. The EB approach uses the available crash data to develop crash estimation models that predict how many crashes would have occurred at the HSC sites had no HSC been installed. Since the 2005 statewide crash and volume data had not been finalized as of the date of this report, this method could be applied only at sites where an HSC was implemented in 2004. The data from the sites with no HSC installed allow the model to predict the number of crashes that would have occurred at the HSC site while simultaneously controlling for a variety of other factors. The crash estimation model used takes the form:

$$Crashes = \alpha_y \left(Factor_1\right)^b \left(Factor_2\right)^c \ldots \left(Factor_n\right)^n$$

where α_y is the parameter accounting for the specific year being predicted, and *Factor* is the variable being used to predict crash frequency.

A comparison of the predicted number of crashes and the actual number of crashes provides insight into the effectiveness of the HSC in reducing crashes. If the actual number of crashes in the HSC was lower than the predicted value, the HSC had a positive impact on safety.

Speed Evaluation

Speed is often used as a surrogate measure for safety, and it was hypothesized that the HSC designation might improve compliance with the posted speed limit. Given the high speeds and volumes on the interstate HSCs, these data were collected using the inductive loops at the pre-existing VDOT permanent count stations within the corridor rather than by placing temporary traffic counters. Speed data were collected before and after installation of the HSC on Tuesdays, Wednesdays, and Thursdays to minimize daily bias. Mean speeds, compliance with the posted speed limit, and percentage of vehicles traveling more than 15 mph over the posted speed limit were compared using a generalized linear model with and without the HSC present. The model allowed the role of speed limit and site location to be controlled for within the analysis.

Development of Potential Methodology for Extending the HSC Program to the Primary System

The final step was to develop a method for identifying candidate locations for HSCs on primary roads. Primary roads have a number of fundamental differences from interstates, including:

- presence of mainline traffic control devices, such as traffic signals and stop signs
- frequent access points and crossing conflict points
- greater variability in network geometry and cross section
- greater variation in traffic volumes and the vehicle type mix (fleet).

Because of these differences, a different process for identifying potential primary HSCs was required. Crash and traffic data from Virginia primaries were analyzed to determine analysis techniques, measures, and eligibility thresholds.

RESULTS AND DISCUSSION

Literature Review

Based on the literature review, state programs similar to Virginia's HSC program could be broadly separated into three classifications:

1. programs with HSCs and increased fines
2. programs with increased fines in work zones
3. programs with HSCs without increased fines.

Virginia's HSC program falls into the first classification. The information from the other two categories could offer insight into the possible effectiveness of the HSC program as well as potential ways to improve the effectiveness of the program. This section summarizes the findings from the literature review for each of type of program.

Programs with HSCs and Increased Fines

Pennsylvania, New Jersey, New Mexico, California, and Oregon have laws that allow increased fines in designated safety corridors. At this time, only New Mexico, California, and Oregon have evaluated the effects of their law on corridor safety. Pennsylvania, California, and Oregon did not initially have increased fines in the corridors, but they added them later.

Pennsylvania

The Pennsylvania DOT (PennDOT) established the first HSC program in 1988 in response to a mandate from the Governor to improve safety on a specific high-risk corridor.[1] Although the program did designate HSCs, fines were not initially increased in them. The concept behind this program was to provide a corridor-wide, multidisciplinary solution to observed safety problems rather than only making spot improvements. A task force composed of elected officials, PennDOT representatives, and enforcement agencies was created to determine ways to improve safety on the HSC. Ultimately, a series of engineering and enforcement initiatives was recommended. The number of crashes reported on the HSC decreased by 40 percent following the improvements created by the program.[2]

Pennsylvania House Bill 2410 became effective in December 2002. This law allowed fines to be doubled in designated HSCs. Double-fine legislation for work zones was modified so that it was applicable to other corridors designated by PennDOT. The legislation allows PennDOT to specify HSCs based on a traffic and engineering investigation. There is no information on its effect on safety at this time.

New Jersey

In February 2004, New Jersey designated 130 miles of HSCs within the state.[3] The HSCs designated were located only on primary roads, and fines were doubled within designated HSCs. The HSCs were designated by the New Jersey DOT based on crash rates, fatalities, traffic volume, and other highway traffic safety criteria. As of the date of this report, no data on the effectiveness of the New Jersey program were available.

New Mexico

New Mexico also initiated an HSC program where fines were doubled for speeding infractions.[4] The program identified corridors where there were high crash or fatality rates. New Mexico also used a multidisciplinary task force to identify engineering, enforcement, and education (3-E) countermeasures to apply to the sites. Initial results from a deployment on U.S. 82 showed a 17.1 percent decrease in the number of crashes and a 19.2 percent decrease in the number of injury crashes.

California

California started a HSC program in 1992.[5] This program did not initially allow fines to be increased. The lead agency in this program was the California Highway Patrol (CHP), not the California Department of Transportation (Caltrans). The initial pilot test of the HSC program occurred on a 21-mile section of the Pacific Coast Highway north of Los Angeles County. A multidisciplinary task force composed of federal, state, local, and private sector groups was assembled in order to address the safety problem. The task force implemented a number of enforcement, education, and engineering improvements, which was due in part to their ability to secure more than $1.8 million in funding. Data from CHP showed that the number of injury crashes on the Pacific Coast Highway declined by about 25 percent following the implementation of the countermeasures.[2]

In 1995, Senate Bill 414 was signed into law in California. This law allowed fines to be doubled for specified types of moving violations and alcohol-related traffic offenses in designated HSCs.[6] Six pilot locations were specified by the legislature for the evaluation of the HSC concept, and the law did not provide funding for additional enforcement at these locations.

Caltrans evaluated the effectiveness of the double-fine zones in reducing crashes. Caltrans confined their analysis to locations that did not undergo major traffic control or geometric changes during the study period. They also discarded locations that were subjected to unrelated targeted enforcement programs. As a result, only three of the six sites could be analyzed to determine the exclusive impact of the double-fine law. The remaining three sites were not examined.

For the three sites examined, Caltrans compared 3 years of crash data before the implementation of the double-fine zone and 1 year of crash data following the installation of the zone. Caltrans also solicited information on citations from CHP. The Caltrans analysis of the effect of the double fines found the following:

- There was no clear trend in the number of citations written in the double-fine zones. In some cases, the number increased, and in other cases the number declined.

- Following installation of the double-fine zone, the overall crash rate on the HSCs declined by 11 to 37 percent. The rates for crashes involving fatalities or injuries declined by 13 to 47 percent.

Caltrans concluded that although the double-fine zones appeared to improve safety, more data were needed to make a definitive assessment of the program's effectiveness. The number of crashes at a given site is often highly variable from year to year. For example, a corridor might have annual crashes of 80, 60, and 100 for 3 consecutive years. If a countermeasure were to be implemented such that 80 crashes occurred in the corridor during the fourth year, it is possible that the reduction from 100 to 80 had nothing to do with the countermeasure but was simply part of the random variation in crashes. Because of the random nature of crashes, it is common practice for engineers to examine at least 3 years of crash data to ensure that random variation was not responsible for any trends observed. Since only 1 year of crash data were examined, Caltrans was concerned that the reductions might be due to random variation. Since the initial evaluation was completed, the number of HSCs in California has increased to 11. All were designated by the California legislature, and no standard criteria were used to identify sites.

Oregon

Prior to 2002, the Oregon DOT (ODOT) attempted to improve safety on major highways and arterial routes in the state through enforcement, education, and engineering improvements without increasing fines.[7] Under the program, designated corridors are signed as either "Safety Corridors" or "Truck Safety Corridors" depending on the volume of commercial traffic. In December 2001, Oregon's law doubling fines for traffic violations in safety corridors became effective. Although no data on this law's effect are available, there is a substantial amount of information available on Oregon's safety corridor program prior to the law's implementation. This section summarizes the data that are available from the period before the safety corridor double fine law became effective.

ODOT administers the program, and has developed a well-defined process for determining when locations meet the criteria to be designated an HSC. It has also developed guidelines for removing the designation. To begin this process, an outside individual or organization must ask ODOT's Traffic Management Section to initiate a study. ODOT has defined three criteria for establishing an HSC:[8]

1. The 3-year average of the fatal/injury crashes rate is at or above 110 percent of the 3-year statewide average for similar roadway types.

2. State or local law enforcement officials will commit to making the HSC a "patrol priority." The ODOT guidelines require that a minimum of 50 extra hours of regular enforcement per month be provided. The top five problem corridors in the state are funded for overtime patrols, educational efforts, and minor engineering improvements.

3. The evaluation team agrees that the corridor length is manageable from an enforcement and education point of view. Corridor lengths in Oregon currently range from 4 to 30 miles.

Members of ODOT evaluate the nominated HSCs based on these criteria. Once an HSC has been defined, ODOT forms a task force of local stakeholders to develop the actual HSC plan. The task forces are multidisciplinary teams composed of local safety, school, media, and community groups. These teams are used to develop a unified initiative that will address enforcement, education, highway improvements, and emergency medical initiatives.

The HSCs are reviewed yearly to determine if they are still needed. ODOT's Traffic Management Section recommends that an HSC be decommissioned if its 3-year crash rate average of fatal/injury crashes falls below 110 percent of the statewide average for similar roadways. If the local stakeholders agree, the HSC is removed. If the local stakeholders disagree, the HSC can be maintained provided that the local groups maintain their contributions to the HSC safety plan.

The program currently covers 150 miles of the Oregon Highway System, but these 150 miles carry 12 percent of all truck-involved crashes in the state.[9] Data on the effectiveness of the program are somewhat limited. ODOT notes that crashes have decreased in 7 of 12 HSCs, and fatalities based on 1 year of after data have declined in 10 of 12 HSCs. Reports from ODOT do not distinguish whether the HSCs funded for improvements have larger safety improvements than those that were not funded.

Programs with Increased Fines in Work Zones

The legislation used to increase work zone fines is similar to what Virginia uses for HSCs. In both situations, fines are used as a deterrent to violating motor vehicle laws. The effectiveness of increasing work zone fines may provide insight into the possible impact of a HSC program.

As of December 2002, every state except Hawaii had a mechanism to increase fines for moving violations in work zones. The vast majority of these laws were passed in the mid- to late 1990s. Despite the large number of states using these laws, relatively little has been published on how these increased fines have affected safety.

National Trends

A 1997 Texas Transportation Institute (TTI) study attempted to assess the impact of increased fine legislation on the number of fatal crashes in long-term freeway work zones in the United States.[10] Data from the Fatality Analysis Reporting System (FARS), a national database of all fatal crashes, were analyzed to determine if trends in fatal crashes in work zones were significantly different between states with and without increased fines in work zones. At the time, only 14 states had at least 1 year of crash data following the implementation of the increased fine legislation. The data from these states were compared to data from the remaining

36 states that had not enacted legislation. The researchers found no significant difference between the trends in the number of fatal work zone crashes.

Data from Individual States

Fatal work zone crashes represent a very small and unstable data set, particularly when only a few years of data are available for analysis. Therefore TTI attempted to examine all available crashes in work zones. TTI found only five states where this type of information was readily available. TTI analyzed the crash data from these states in an attempt to assess the impact of increased work zone fines on all types of crashes (property damage only, injury, and fatal crashes).[10]

In 1991, Maryland increased fines for speeding in work zones. After implementation of the law, the number of crashes in work zones increased.[10] Maryland had difficulty determining the effectiveness of the law, however, because they did not have a good measure of the number of work zones or the volume of traffic in the before and after periods. It is possible that more work zones were in place in the years after 1991. This increased exposure could account for the increase in work zone crashes. Thus, the impact of the legislation was inconclusive.

In 1994, Minnesota implemented a double-fine law in work zones for moving violations.[10] The crash data did not show any change after the law. Again, it is difficult to assess the true effectiveness of the law since exposure information was not available.

Pennsylvania doubled the fine for moving violations in work zones in 1989.[10] After implementation of the law, the number of work zone crashes did not change significantly. Beginning in 1994, Pennsylvania began placing the state police on the approaches to all work zones. This reduced the number of work zone crashes and has proved to be more effective at improving safety than simply increasing fines.

In 1997, Texas doubled the minimum and maximum fine that could be levied for all moving violations in a work zone. The presiding judge was free to set the actual fine within this range. A TTI evaluation attempted to determine the effectiveness of this law on improving safety and reducing speeds in work zones.[11] The researchers examined speeds at 10 work zones before and after the increased fines were implemented. Data were collected prior to the implementation of the law and then at least 4 months after the law had gone into effect in order to allow drivers to become accustomed to the signs. The researchers found that speeds often did not change significantly after the law was implemented. The following trends were in evidence at the Texas sites:

- Only 4 of the 10 sites had statistically significant reductions in mean speeds. Changes in mean speed at each site ranged from a 4-mph decrease to a 6-mph increase.

- The percentage of vehicles exceeding the posted speed limit declined by less than 2.5 percent.

- Citation frequency did not change significantly after the law was put into effect. However, a higher proportion of drivers did elect to take defensive driving rather than pay the fine after the law became effective.

In 1994, Washington doubled the fine for speeding in a work zone.[10] This was one component of a widespread work zone safety program that included improved worker protection, operating procedures, training, and incident reporting. Following the implementation of these measures, the number of crashes in work zones declined. However, it was not possible to determine the contribution of the increased fine structure to this decline since a number of other efforts were occurring simultaneously.

Programs with HSCs without Increased Fines

Several states have used HSCs or targeted enforcement to address safety concerns in specific areas. These programs do not increase fines and have their origins in the Corridor Safety Improvement Program approach put forth by FHWA in the early 1990s.[12] In a previous VTRC report, Jernigan performed a detailed assessment of this type of program; interested readers should consult that report for more information.[2] The report also summarizes the California and Pennsylvania programs prior to implementation of the increased fine legislation. Some of the experiences with these programs are briefly summarized here.

Washington

In Washington State, an initial pilot program established in 1993 examined four HSCs.[13] The HSCs were selected by the Washington Traffic Safety Commission based on their crash history. A steering committee consisting of representatives of traffic safety associations and government agencies was selected to help develop an action plan for each HSC. The committee identified specific corridor safety problems and then implemented appropriate countermeasures. Crash data from the 3 years following the implementation of the program showed a 9 to 30 percent reduction in crashes when compared to the 3 years prior to the implementation of the HSC program.

North Carolina

North Carolina has used targeted enforcement in an effort to improve commercial vehicle safety in 1998. The North Carolina DMV increased commercial vehicle enforcement activity in 21 counties the North Carolina DOT (NCDOT) identified as having the most truck-related crashes.[14] This resulted in the following:

- a 129 percent increase in the number of roadside inspections, resulting in a 20 percent increase in the number of vehicles placed out of service and an 89 percent increase in the number of drivers placed out of service in the targeted counties

- a 50 to 300 percent increase in the number of citations given to commercial vehicles for serious moving violations (reckless driving, erratic lane changes, etc.)

- increased public outreach and education.

From FY 1998 to FY 1999, fatal crashes involving trucks decreased by 17.7 percent in the targeted counties. Fatal crashes involving trucks increased by 7.6 percent in the counties not targeted for enforcement. Although the number of fatal crashes was reduced in the targeted counties, the total number of crashes was not. During the after period, there was a 4.6 percent reduction in the total number of crashes in the targeted counties and a 5.2 percent reduction in the non-targeted counties. The study did not account for changes in exposure (such as traffic volume), so it is difficult to determine the true impact of the program.

Summary

Table 1 summarizes the impact of the three types of programs in other states. Changes in crash rates often cannot be attributed solely to the impact of a specific program. Most studies did not control for factors such as traffic volumes; underlying trends in crashes; changes in the amount of congestion at a site; and, in the case of the programs involving increased fines in work zones, changes in the number of sites. These factors can significantly affect safety and may have influenced the results. As a result, it is possible that the safety impacts reported in these studies were due to factors other than whether fines were increased at a site.

Table 1. Summary of Experiences in Other States

Type of Program	State	Key Elements	Impact on Safety
Safety Corridor with Increased Fines	California	Corridors specified by legislature, no funding for additional safety countermeasures	Crash rates reduced by 11% to 37%; injury crash rate reduced 13% to 47%
	Oregon	Safety corridor program administered by ODOT	Double-fine law is new; safety corridors without increased fines produced decrease in fatalities or crashes in most cases
	Pennsylvania	Corridors specified by PennDOT	New law, no data available
	New Jersey	Program administered by NJDOT	No data available
	New Mexico	Selection based on fatal and crash rates	17% reduction in crashes; 19% reduction in injury crashes
Safety Corridor or Targeted Enforcement with No Increased Fines	North Carolina	Increased commercial vehicle inspection in counties with high truck crash rate	Reduction in fatal crashes; no change in overall crash rate
	Washington	Education, enforcement, and engineering countermeasures used to enhance safety	Crash reductions of 9% to 30% per corridor
No Safety Corridor But Increased Fines in Work Zones	Maryland	Increased speeding fines	Crashes increased
	Minnesota		No effect
	Pennsylvania	Police presence required at work zones	Reduction in crashes
	Texas	Minimum and maximum fines doubled	Significant speed reductions in 40% of sites

Method for Screening and Selecting Locations for Interstate HSCs

The process of developing a procedure for identifying potential HSC candidate locations consisted of four major steps:

1. determination of the safety measures to be used to select HSCs
2. development of analytical method to identify candidate HSCs
3. development of thresholds for HSC selection
4. approval of methodology.

The first three steps consisted of an iterative process whereby VTRC and TED personnel discussed and revised measures and thresholds based on a quantitative examination of the crash data. The final result of the identification process was a listing of candidate locations that had a high number and rate of crashes as compared to locations on other interstates.

As mentioned previously, the *Code of Virginia* required that the methodology used to select HSCs be presented at a series of public hearings. As a result, it had to be easily understandable by a broad cross section of the population. This meant that rigorous, statistically intensive methods were not considered appropriate. The time constraints for selecting and deploying the first interstate HSC also required that the procedures developed be based on straightforward methods.

Determination of Safety Measures Used to Select HSCs

The *Code of Virginia* requires that the HSC selection methodology "include a review of crash data, accident reports, type and volume of vehicle traffic, and engineering and traffic studies." Although this language provides some guidance as to what should be used, there is still considerable room for interpretation of what measures should be examined.

In an effort to gain further insight, TED and public affairs staff participated in a series of safety roundtables conducted by DMV around the state. Community leaders and members of the safety community participated. Some of the safety data available for the interstate system were presented, and feedback was solicited from the participants. The feedback showed that the participants were particularly concerned about the severity of crashes and the number and rate of truck crashes.

VTRC and TED used this information to develop a list of candidate safety measures that would be examined in determining whether an HSC should be designated. These included:

- *Crash frequency weighted by severity.* One method for accounting for this parameter is the equivalent property damage only (EPDO) technique. The method weights crashes so that injury and fatal crashes "count" as multiples of property damage only (PDO) crashes. In reviewing states that have used this method, VDOT elected to pursue a modified version of the weights originally developed in Pennsylvania whereby an injury crash was treated as 8 PDOs and a fatal crash was treated as 20 PDOs.

- *Crash rate.* Although the crash frequency is important, it is biased toward high-volume roadways. Generally, high volume roads will have more crashes than lower volume facilities simply because there is more exposure on those roads. Another important concern is the rate at which crashes occur. As a result, the crash rate, expressed in terms of crashes per 100 million vehicle miles of travel (VMT), was also examined. By including consideration of VMT, this measure also addresses the requirement in the *Code of Virginia* to examine the volume of traffic.

- *Truck-involved crash rate.* Given the concern about the rate of truck crashes, it was also decided to look at the truck-involved crash rate. "Truck-involved" simply means that at least one vehicle involved in the crash was a truck, not that the truck caused the crash. Only crashes with the "vehicle 1" or "vehicle 2" coded as large trucks (6 or more tires) were examined to determine if one of the primary vehicles involved was a truck. This measure also helped address the requirement in the *Code of Virginia* to examine the type of traffic.

The most recent 3 years of crash data were used to develop these criteria values. At the time the process was initially developed, the years 2000 through 2002 were the most recent 3 years of data available to VDOT. A 3-year analysis period is commonly used in highway safety analysis to minimize the influence of random variation in crashes.

Development of Analytical Method to Identify Candidate HSCs

The next major step in the HSC identification methodology development process was to determine how the interstate system would be analyzed to develop the safety measures developed. First, the characteristics of the crash and volume data were examined, and the distribution of crashes statewide was reviewed. The purpose of this was to try to define homogeneous regions so that valid comparisons could be made between different highways. This review revealed that the state could generally be broken into three regions consisting of three VDOT districts each, based on the crash frequency and crash rates identified on the interstate system. Each region had traffic, crash, and topographic characteristics that provided differentiation from the other regions. The regions identified were:

1. *Region 1 (West):* Bristol, Salem, and Staunton
2. *Region 2 (Southeast):* Hampton Roads, Lynchburg, Richmond
3. *Region 3 (Northeast):* Culpeper, Fredericksburg, Northern Virginia.

Figure 1 shows the three regions along with some summary information on their crash characteristics. Table 2 shows that Region 1 has the lowest average EPDO density and crash rate. The region is predominately rural with mountainous terrain and has relatively little congested urban flow. Region 3 consists of the districts surrounding Washington, D.C., and includes many of the chronically congested interstates. Crash density was highest for this region. Region 2 consists of a mixture of rural and urban interstates, with the crash characteristics generally intermediate between the other two regions.

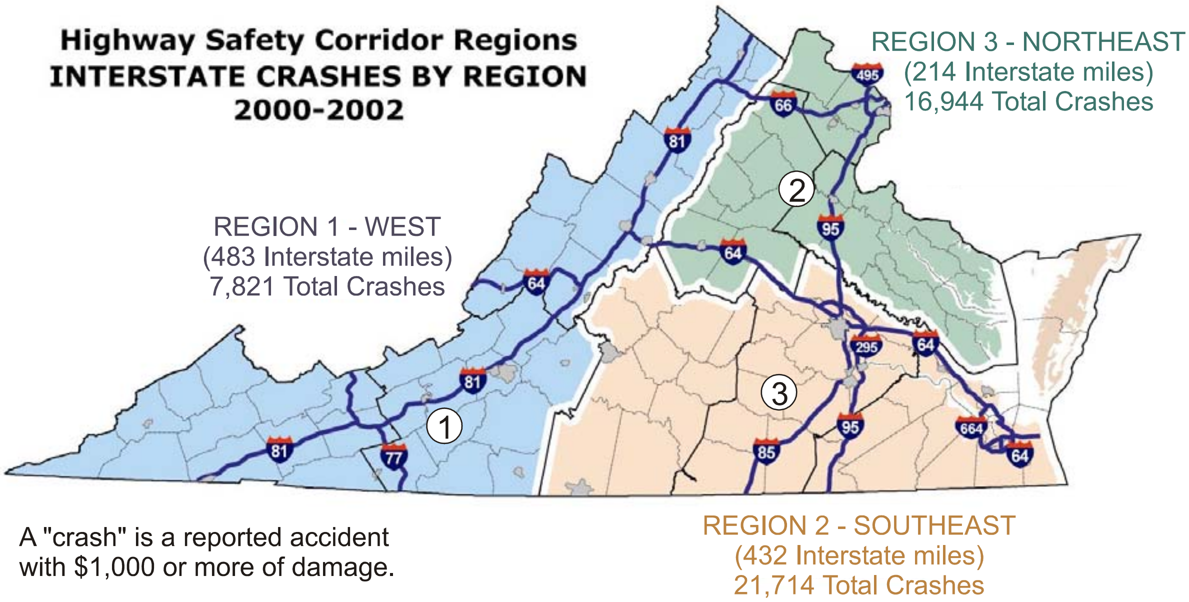

Figure 1. HSC Regions with Crash Data, 2000-2002

Table 2. Summary of Crash Characteristics for HSC Regions, 2000-2002

Region	Total Crashes	Average Crashes/Mile/Year	Total EPDOs	Average EPDOs/Mile/Year	Average Crashes per 100 Million VMT
1	7,821	5.4	29,552	20.4	44.2
2	21,714	16.8	75,875	58.5	81.0
3	16,944	26.4	60,902	94.9	81.0
State	46,479	13.7	166,329	49.1	71.1

EPDO = equivalent property damage only.

The regional approach has several advantages over a statewide approach, including:

- *It guarantees that HSCs are distributed throughout the state.* If the crash data were examined on a statewide basis, it is likely that interstate HSCs would be clustered in the congested urban areas.

- *It allows for easier comparison of the crash history of a road to those of similar facilities.* Each region has different traffic, geometric, and topographic characteristics that could influence crashes. For example, the regional approach ensures that the crash history on a rural section of I-77 in southwestern Virginia is not compared to the crash history of I-95 in Northern Virginia. As a result, sections of road are identified if they have a poor safety performance relative to similar facilities.

- *The Commissioner wanted to keep the number of HSCs to a manageable level.* If each region contained only one or two signed HSCs, the overall number designated at one time would be minimized.

The next issue to be resolved was the specific method used to develop the safety measures selected for evaluation. In the VDOT database, the crash and VMT data are referenced to the route milepost of each interstate. It was possible to parse these data into 1-mile segments and analyze the entire interstate roadway system systematically using uniform 1-mile segments.

There was also a desire to set a minimum length for an HSC. A minimum length was developed to simultaneously make it easier for VSP to develop an enforcement plan and also to help reduce the perception that the HSC program was creating spot "speed traps." VSP noted that 5 miles was the minimum length that they felt was practically enforceable given the time a vehicle would be in the corridor on higher speed facilities. To define a minimum length, the crash data were summarized using a "moving window" technique. Figure 2 helps illustrate this concept using a 5-mile window along I-81. First, the crash data are summarized from the Virginia-Tennessee line to milepost 5. The window is then moved 1 mile, and the data are re-summarized from milepost 1 to milepost 6. This process is repeated until the EPDO frequency, crash rate, and truck-involved crash rate are summarized for every road.

Several window sizes were tested to determine the size that appeared to balance a desire to be sensitive to localized problems while ensuring that the HSCs were long enough to be efficiently signed and enforced. Window sizes of 5, 10, and 15 miles were tested by examining the EPDO density, crash rate, and truck-involved crash rate. Examples using a 5-mile analysis window of the figures summarizing this analysis are provided in Figures 3 through 5. Mileposts start on the southern or western side of the state for each road, depending on its orientation of travel. Figures 3 and 4 compare the EPDO density and crash rate on three major interstates, and

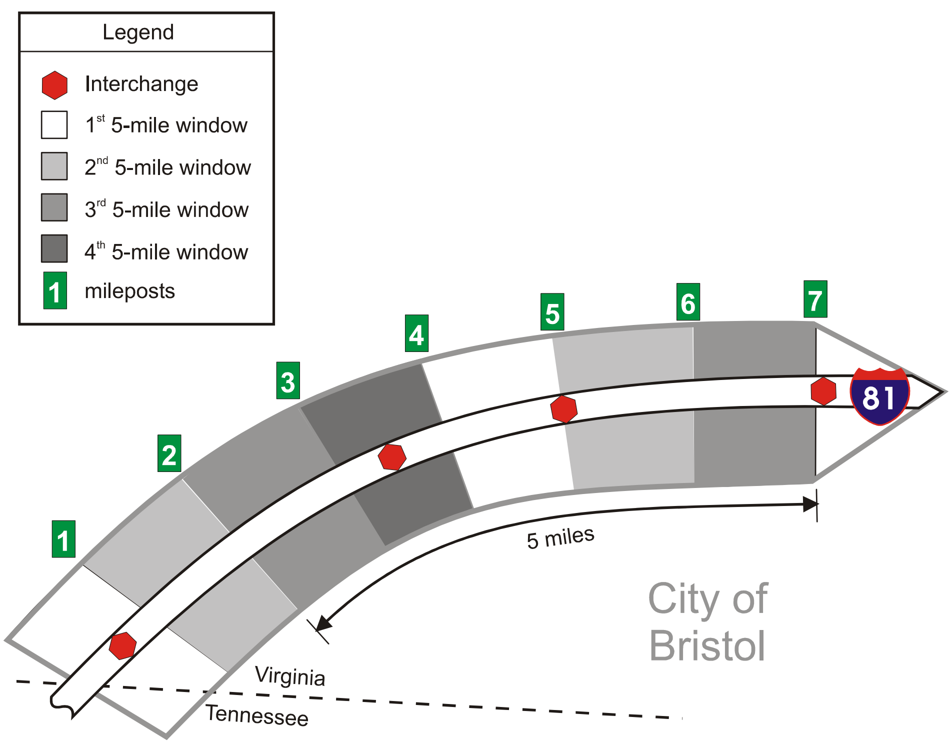

Figure 2. Example of Moving Window Analysis of Crash Data

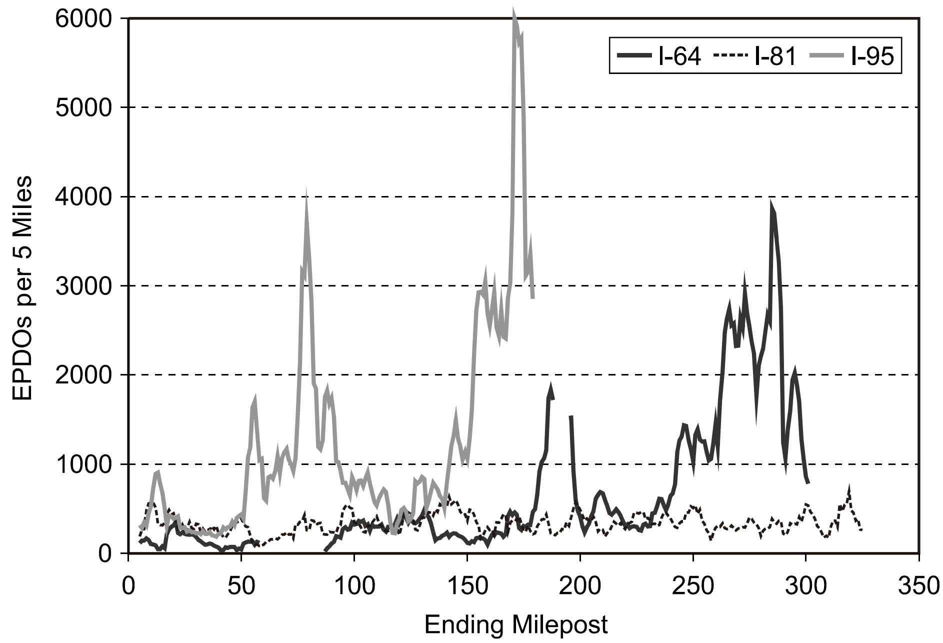

Figure 3. Comparison of EPDOs on Major Interstates, 5-Mile Window, 2000-2002

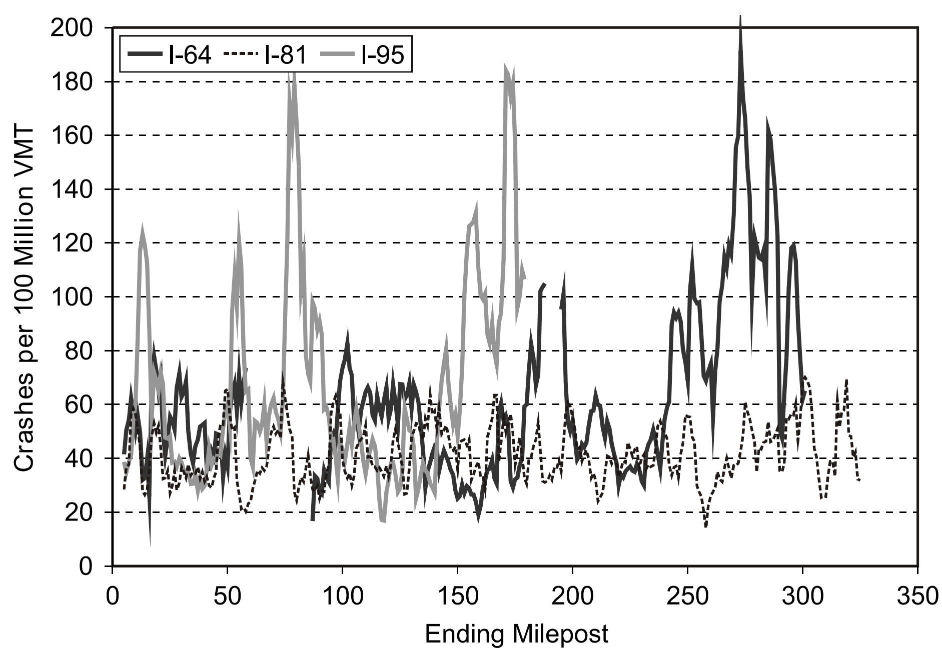

Figure 4. Comparison of Crash Rates on Major Interstates, 5-Mile Window, 2000-2002

Figure 5 compares the truck crash rate to the overall crash rate on I-81. When the longer windows were tested, it was discovered that the sections of highway identified were generally longer and did not identify localized problems. This was particularly problematic on interstates where there was greater variation in the crash statistics, such as I-81. In that case, potential HSCs seemed to be identified only in urbanized areas, rather than at more localized problems in rural areas. After consultation with the HSC oversight committee, a 5-mile analysis window was selected, thereby setting the minimum HSC length at 5 miles.

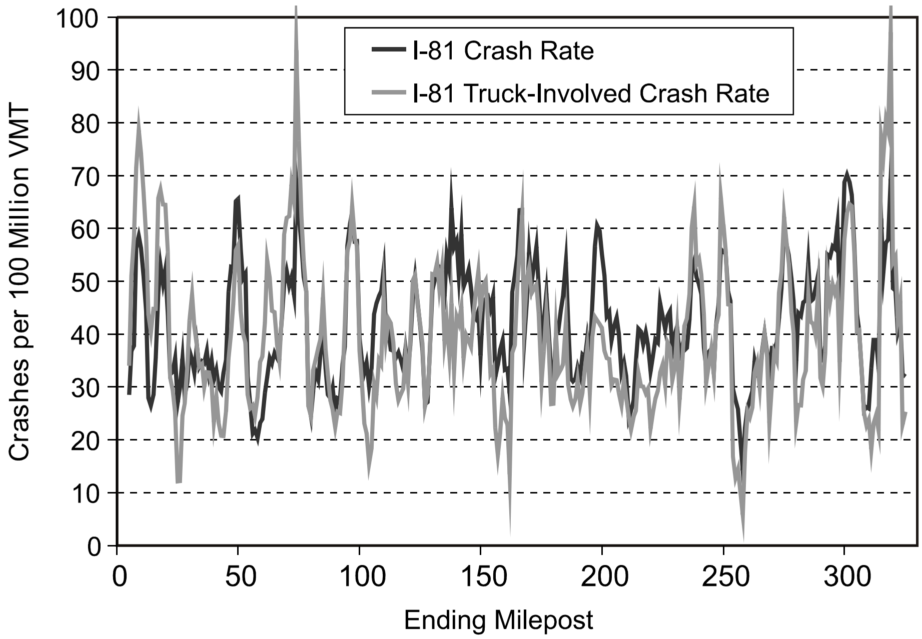

Figure 5. Overall versus Truck-involved Crash Rate, I-81, 2000-2002

Development of Thresholds for HSC Selection

The next major task was to define threshold levels for crash rate, EPDO density, and truck-involved crash rate that would justify inclusion of an interstate segment in the HSC program. These thresholds had to narrow the number of candidate segments to a relatively small number while simultaneously ensuring that only road segments with a demonstrated safety problem were identified.

To define these values initially, the standard deviation of the crash rates and EPDO frequencies were examined among the windows in each region. Thresholds were set to a value that roughly corresponded to 1 standard deviation above the mean value for each measure for a region. For example, the standard deviation of the crash rate among the 5-mile windows in Region 1 was 10.8 crashes per 100 million VMT. There was a concern, however, that using standard deviations may be difficult to convey within the confines of public hearings. As a result, the thresholds were expressed as the percentage above the regional average that a candidate segment would need to exceed regional average values. Thus, 1 standard deviation above the average crash rate was translated into a crash rate threshold of 125 percent of the regional average crash rate. As a result of this process, the following thresholds were defined:

- The crash rate must exceed 125 percent of the regional average.

- The EPDO frequency must exceed 150 percent of the regional average on a per-mile basis.

- The truck-involved crash rate must exceed the overall regional crash rate.

The crash rate and EPDO frequency roughly correspond to 1 standard deviation over the regional average. The truck-involved crash rate had significant variability in each region, primarily due to the large fluctuations in truck VMT that were present on different roads. So that the truck crash rate threshold did not control the designation of candidate segment lengths, the truck-involved crash rate simply needed to be overrepresented versus all crashes. The threshold values used to select candidates for each region based on these criteria are shown in Table 3.

Table 3. Interstate Screening Criteria Based on 2000-2002 Data

Screening Factor	Criteria	Region		
		1	2	3
EPDO Density (EPDOs/Mile/Year)	> 150% of Regional Average EPDO Density	30.6	87.8	142.4
Crash Rate (Crashes per 100 Million VMT)	> 125% of Regional Average Crash Rate	55.3	101.3	101.3
Truck-Involved Crash Rate (Crashes per 100 Million VMT)	> Regional Crash Rate	44.2	81.0	81.0

EPDO = equivalent property damage only; VMT = vehicle miles traveled.

Approval of Methodology

Next, the analysis method, safety measures, and thresholds were presented for approval. First, the policy board reviewed and approved the methodology. The methodology was then presented at three public hearings in the Salem, Hampton Roads, and Northern Virginia districts. There were no adverse public comments on the methodology, so the proposed methods and criteria were adopted and implementation moved forward. Figure 6 is a flowchart showing the final analysis methodology adopted for the identification of candidate interstate HSCs.

Selection and Implementation of Interstate HSC Locations

Selection

The approved methodology was applied to all three regions, resulting in the identification of eight candidates in Region 1, six candidates in Region 2, and five candidates in Region 3. The candidate HSCs identified from the screening process were as follows:

- Region 1

    1. I-77 from milepost (MP) 0 to 17
    2. I-81 from MP 3 to 10
    3. I-81 from MP 90 to 99
    4. I-81 from MP 127 to 142
    5. I-81 from MP 244 to 251
    6. I-81 from MP 295 to 302
    7. I-81 from MP 310 to 319
    8. I-581 from MP 0 to 6.

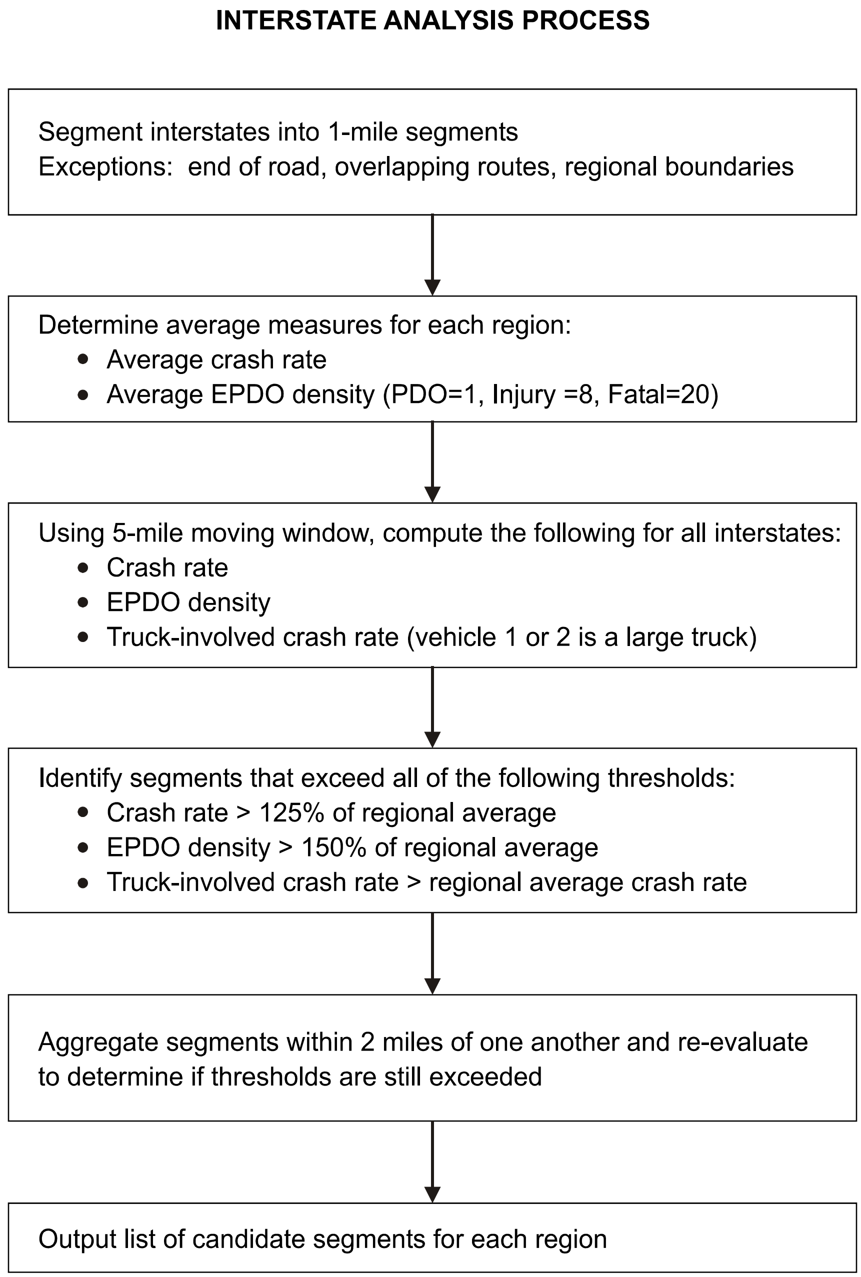

Figure 6. Analytical Process Used to Identify Candidate HSCs

- Region 2

  1. I-64 from MP 181 to 188
  2. I-64 from MP 246 to 252
  3. I-64 from MP 260 to 297
  4. I-95 from MP 50 to 56
  5. I-95 from MP 70 to 83
  6. I-264 from MP 1 to 19.

- Region 3

    1. I-66 from MP 58 to 69
    2. I-95 from MP 149 to 160
    3. I-95 from MP 165 to 179
    4. I-395 from MP 0 to 10
    5. I-495 from MP 0 to 5.

Figure 7 is a flowchart of how the HSC implementation process was conducted following identification of the candidate HSCs.

After candidate HSCs were identified, VTRC produced a detailed crash summary of each candidate. An example of some of the analyses for one candidate is provided in Appendix B. A preliminary ranking of HSCs for each region was then generated based on the crash rate and EPDO density at each site. These crash measures were normalized by dividing the value for a site by the maximum crash rate or EPDO density for a region. This produced a normalized score for each measure for each candidate between 0 and 100. The two measures were then added and the combined score was used to produce an initial ranking to establish priority for implementation. The final rankings using 2000-2002 data are shown in Appendix C.

Using the crash data on the types of crashes and causal factors, TED staff then consulted with the applicable VDOT district and VSP offices to determine if there were any issues related to implementing the HSCs. VSP was asked if each candidate HSC could be safely and effectively enforced. The VDOT district was asked to assess whether enough right of way existed at the candidate site to accommodate the HSC signing and if the additional signing created any "cluttering" issues for reasonable visibility and recognition. TED and the district also examined the crash summaries to determine whether any low-cost safety improvements could be implemented to address the safety concerns, as well as to determine whether increased enforcement was likely to address the underlying causes of the observed safety problem.

The review by VSP and the districts eliminated a number of candidates based on implementation concerns. In most cases, a number of candidates that were initially highly ranked based on crash rate and EPDO density could not be feasibly implemented. In other cases, the HSC limits were slightly altered to support signing or enforcement activities. These candidates were then advanced to public hearings and followed by final approval by the Commonwealth Transportation Commissioner. Based on this process, three segments were identified and approved for installation:

1. Region 1: I-81 from milepost 127 to 142 (Roanoke area)
2. Region 2: I-95 from milepost 70 to 83 (Richmond area)
3. Region 3: I-95 from milepost 149 to 160 (Prince William County).

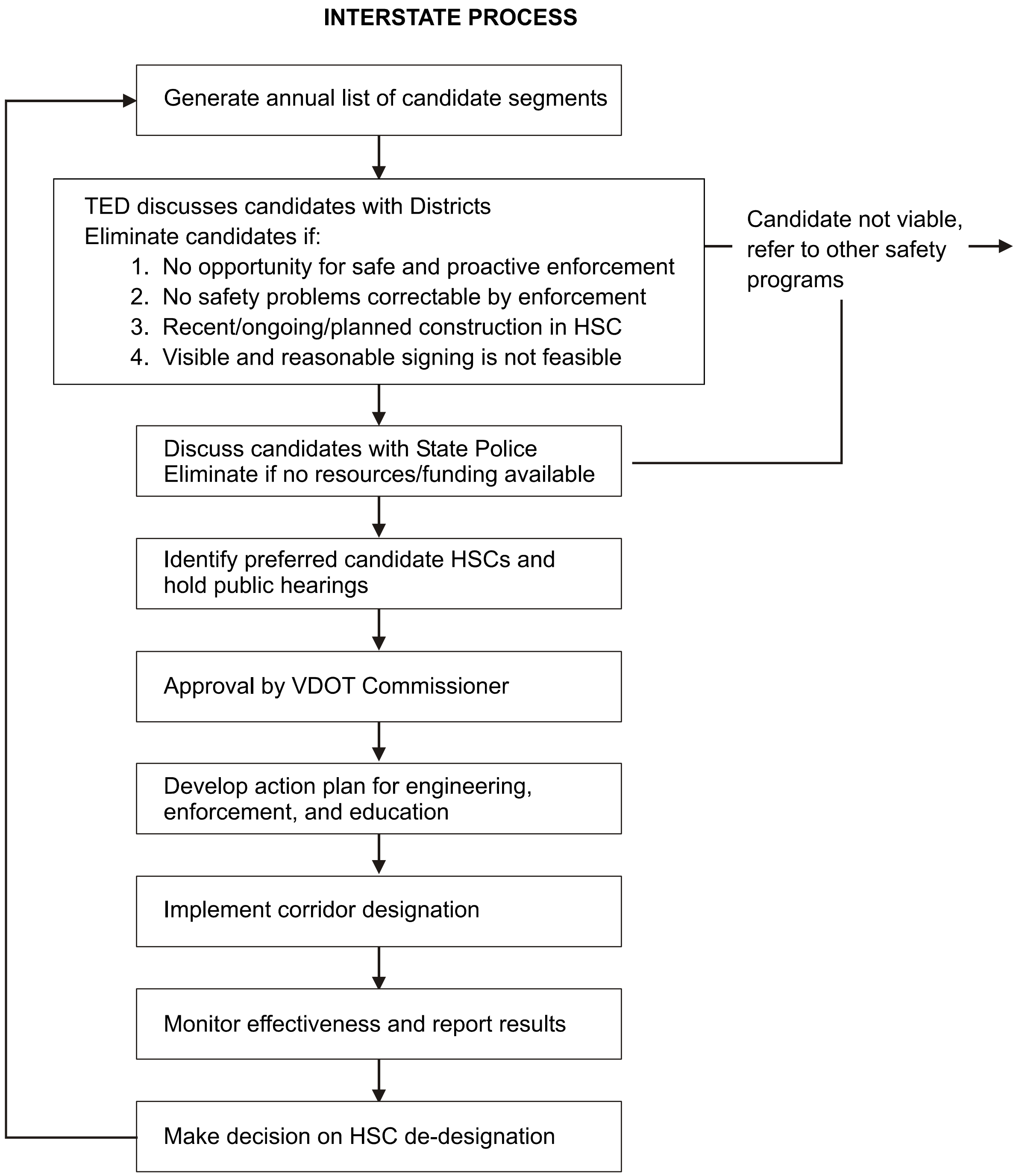

Figure 7. Implementation Process for Interstate HSCs

Implementation

An action plan for enforcement and education was then developed for each HSC. Engineering safety reviews were conducted to determine if maintenance and construction projects could be prioritized for the corridor segments. Letters were sent to notify the local court justices about the new law and the start dates. The HSCs were installed on the following dates:

- Region 1: January 13, 2004
- Region 2: January 6, 2005
- Region 3: March 18, 2005.

Signs alerting drivers to the HSCs were installed, and VSP increased enforcement on these sections. An example of the signs posted is provided in Figure 8. The signs were posted at the start of the HSC or after each interchange or entrance ramp in cases where mainline locations were not feasible. A sign notifying drivers of the end of the HSC was also posted.

Educational initiatives implemented in the HSCs involved a public information campaign. Initially, focus groups were surveyed in each region to determine the critical safety issues, concerns, and messages in the local area. Reaction to the HSC program was generally positive and reflected a needed partnership between groups involved with enforcement, engineering, and education (the 3 Es) to ensure program effectiveness. Speeding and aggressive driving were identified by the focus groups as primary concerns. Informational materials were then tailored for each regional market. Posters and direct mail flyers, billboards and bus placards, and radio public service announcements were also produced to help inform drivers of the HSC. Further, joint press events with the partnering agencies and supportive politicians were staged prior to the first day of the HSC enforcement. VSP also increased enforcement within the HSCs, subject to officer availability. Except for regular pavement resurfacing and new pavement markings, no substantial engineering safety improvements have been completed in the designated HSCs due to limited funding.

Figure 8. Signs Posted in HSCs

Effectiveness of Interstate HSCs in Improving Safety

Two major measures of effectiveness were examined to determine whether the HSCs were effective: vehicle speeds and crashes. Vehicle speeds were examined for the I-95 Richmond and I-81 sites. Crashes were examined using the EB method only for the I-81 site since it was the only site with a full year of post-implementation data available. Summary crash information is presented for the I-95 Richmond site.

Speed Data Analysis

Speed data were examined for the I-81 HSC and the I-95 HSC in Richmond. An examination of speed data was outside the scope of the original project proposal but was undertaken since some speed data were already being collected in the HSCs by VDOT. The data from these sites were collected from the existing VDOT permanent count stations and newly installed stations located within the HSC. The mean speed, compliance with the posted speed limit, and percentage of vehicles traveling more than 15 mph over the speed limit were examined for these stations.

Speed data were also originally going to be examined for the I-95 HSC in Prince William County. Unfortunately, there were no permanent count stations in the designated HSC, so the Archived Data Management System (ADMS) was used to collect the speeds. Examination of the ADMS data revealed that the speed data were of very poor quality, principally due to problems with the detectors. On average, only about 20 to 40 percent of speeds were found to be valid, and the time of day when speeds were valid fluctuated significantly from day to day. In particular, it appears that the quality of the speed data available became significantly worse approximately 5 weeks after the implementation of the HSC. As a result, the speeds for the I-95 HSC in Prince William were not examined since data quality could not be ensured.

I-81 HSC Speed Analysis

Figures 9 and 10 show the average speeds for the stations near the I-81 HSC for the northbound (NB) and southbound (SB) directions, respectively. No count stations were initially located in the HSC, but additional sites were later installed in the NB and SB direction within the limits of the HSC after it was installed. The HSC was installed before these stations could be brought online for monitoring, so the only speed data available prior to HSC installation were at stations located approximately 3 to 4 miles north of the northern limit of the HSC. Given the lack of adequate data before the HSC installation within the zone, it was impossible to conduct any statistical analysis of the I-81 speed data. Figures 9 and 10 show that mean speeds were generally stable within the HSC, fluctuating by no more than 1 mph.

The extent of compliance with the speed limits, as well as the proportion of extremely high-speed vehicles, was also examined. Figures 11 and 12 show the percentage of vehicles traveling at or below the posted speed limit in the NB and SB directions. Strict compliance with the posted speed limit was often poor within the HSC, sometimes falling below 10 percent of all vehicles. Compliance was generally better in the 65 mph zones than in the 60 mph zones, although less than half of all drivers generally complied with the posted speed limit, even in

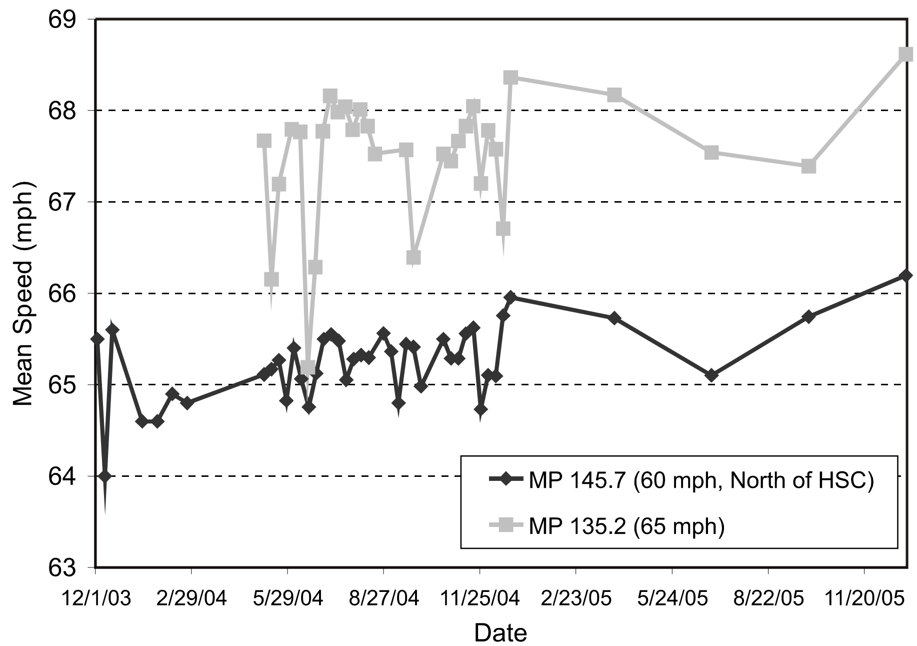

Figure 9. I-81 HSC Mean Speeds, Northbound

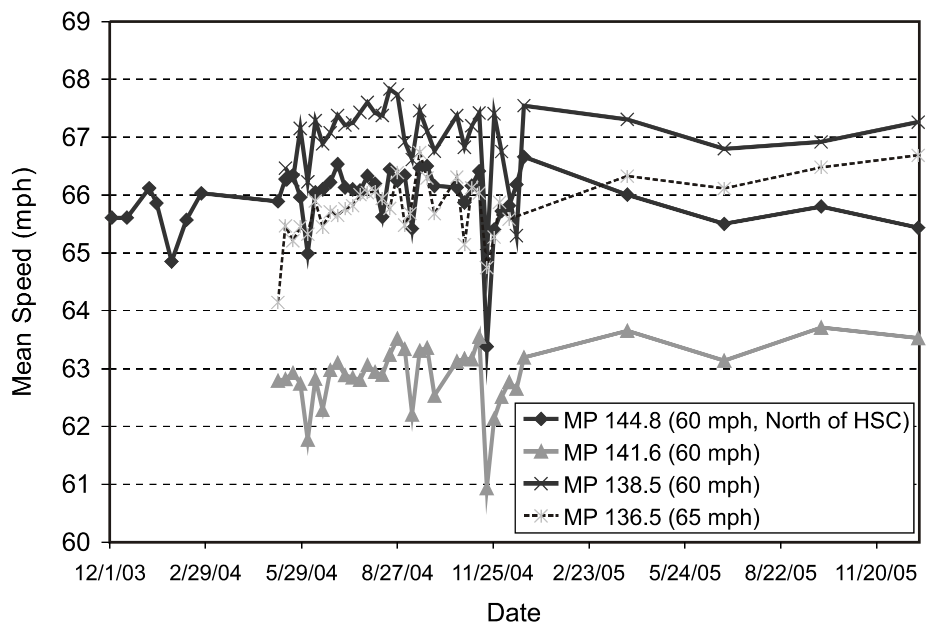

Figure 10. I-81 HSC Mean Speeds, Southbound

those zones. Figures 13 and 14 show the percentage of vehicles traveling 15 mph or more over the posted speed limit. The proportion of vehicles traveling at high speeds was usually small, often less than 4 percent of traffic, with the exception of the data collected at milepost 138.5 in the SB direction. Further, the portion of excessive speeders generally decreased slightly within the HSC compared to the site north of the HSC.

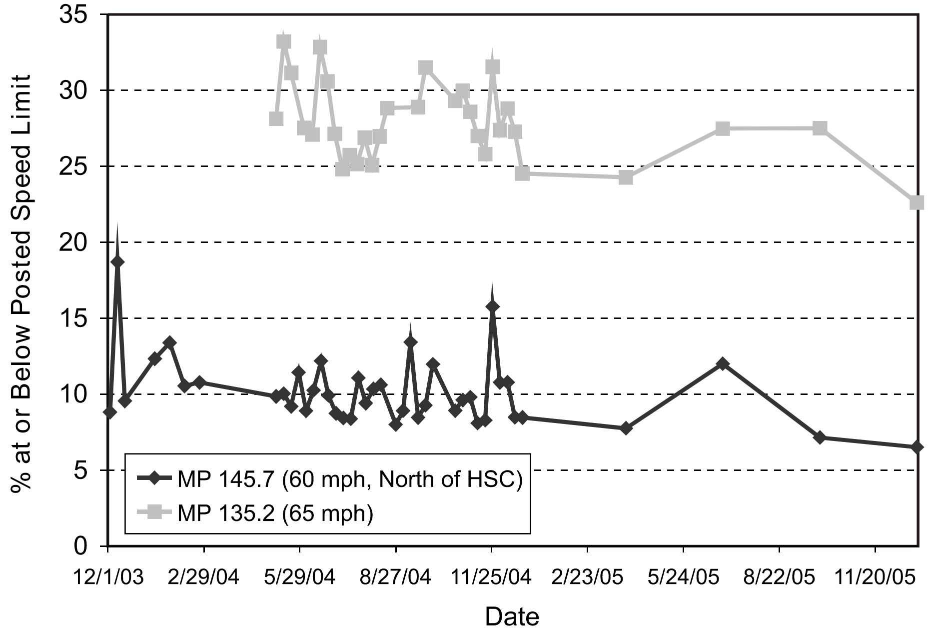

Figure 11. I-81 HSC Speed Limit Compliance, Northbound

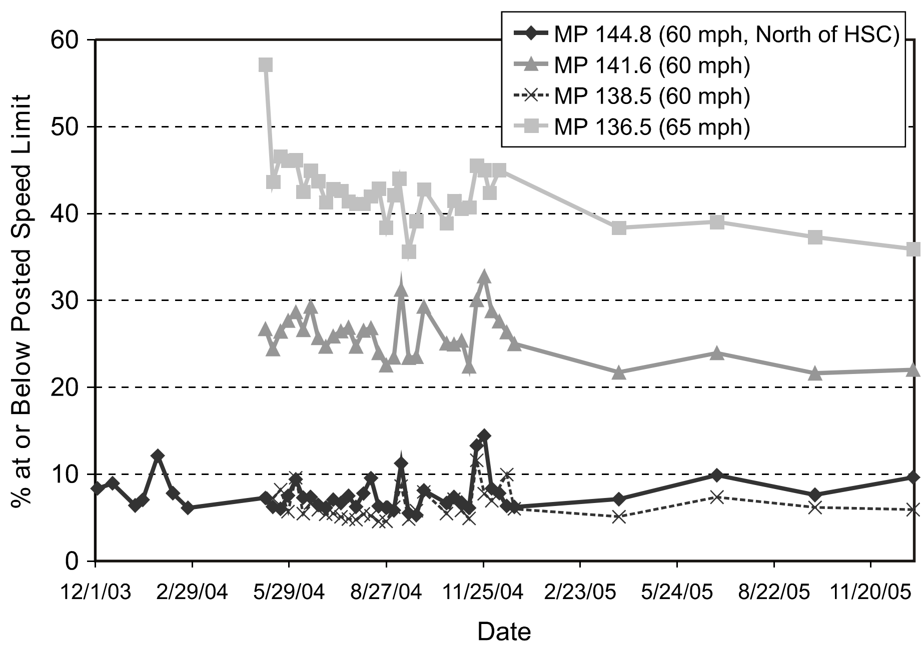

Figure 12. I-81 HSC Speed Limit Compliance, Southbound

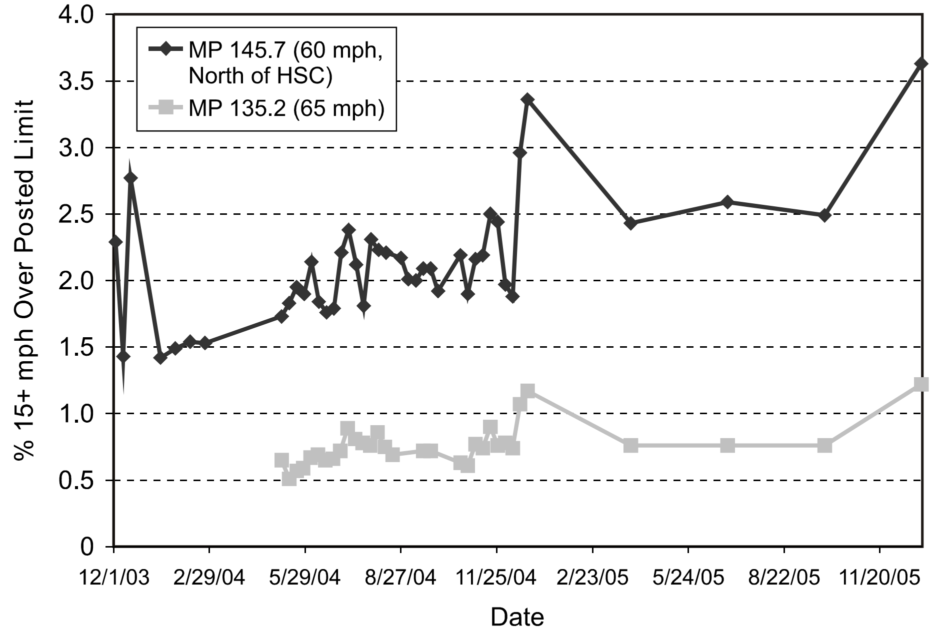

Figure 13. I-81 HSC % > 15 mph Over Speed Limit, Northbound

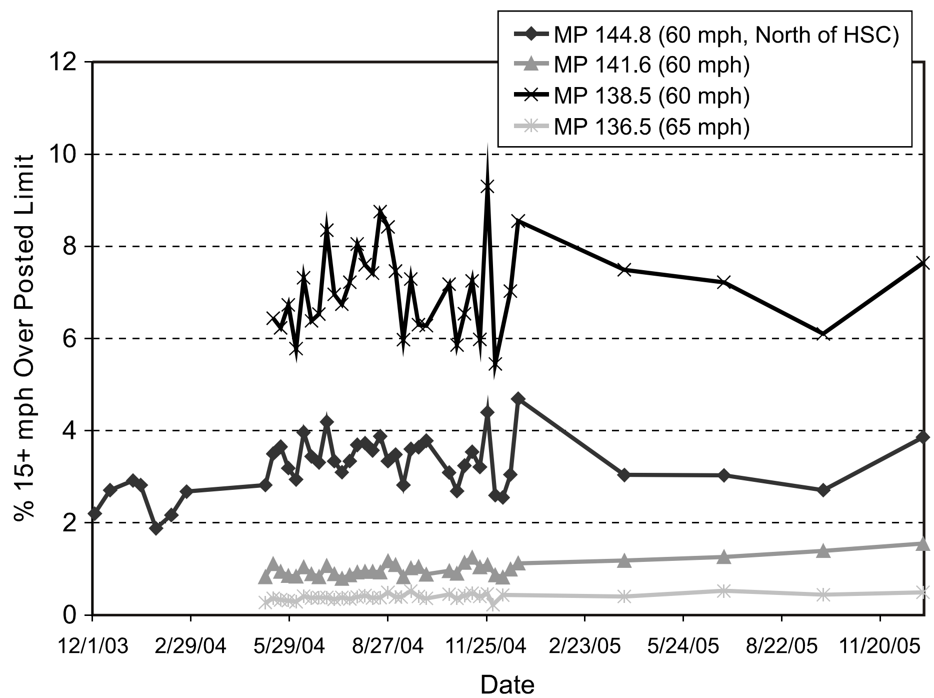

Figure 14. I-81 HSC % > 15 mph Over Speed Limit, Southbound

I-95 Richmond Speed Data Analysis

In contrast to the I-81 HSC, speed data were available for the I-95 Richmond HSC before it was installed. This allowed for a more rigorous statistical analysis of the speed data. Univariate analysis of variance (ANOVA) using a general linear model was used to examine mean speed, compliance with the posted speed limit, and percentage of vehicles traveling more than 15 mph over the posted speed limit. The model used accounted for differences in speed limit, site location, presence/absence of HSC designation, and traffic at the site. Only sites for which there were data before and after implementation of the HSC were examined. Site conditions also had to remain the same before and after implementation of the HSC. As a result, only three stations could be used for this analysis: mileposts 71.48 NB, 77.03 NB, and 71.77 SB. The general linear model was used to control for factors that varied across stations, such as posted speed limit.

Figures 15 and 16 show the mean speeds in the NB and SB directions on I-95. The speed limit at milepost 82.55 NB changed during the time period monitored from 55 to 60 mph. After installation of the HSC, the average speed across the three sites where speed limits did not change during the period increased by about 0.3 mph, but this was not statistically significant at $\alpha = 0.05$. Changes in speeds at the individual stations were also not statistically significant at $\alpha = 0.05$.

Figures 17 and 18 show the compliance with the posted speed limit at the I-95 Richmond HSC. Once again, there was a large variation in compliance among the different stations, ranging from around 5 to around 40 percent. Compliance levels appeared to be primarily influenced by the level of congestion near the site, with the highest compliance levels near downtown Richmond. Compliance also increased sharply at the site where the speed limit was increased by 5 mph. The ANOVA again showed no statistically significant increase in compliance with the posted speed limits across all three sites that remained unchanged at $\alpha = 0.05$. Further, no statistically significant changes in compliance were found for any of the individual locations.

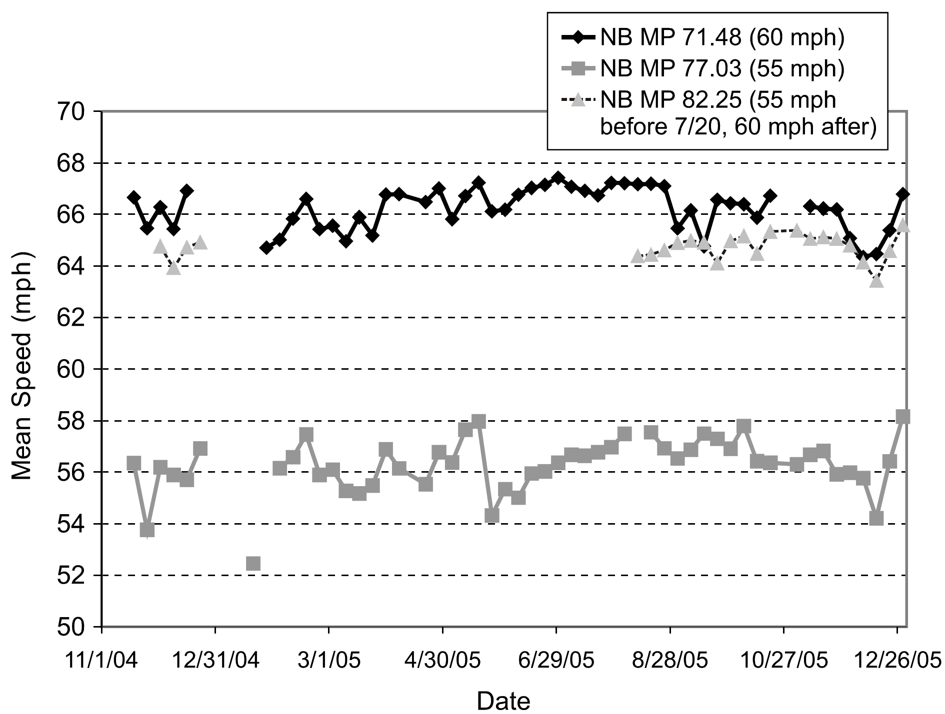

Figure 15. I-95 Richmond HSC Mean Speeds, Northbound

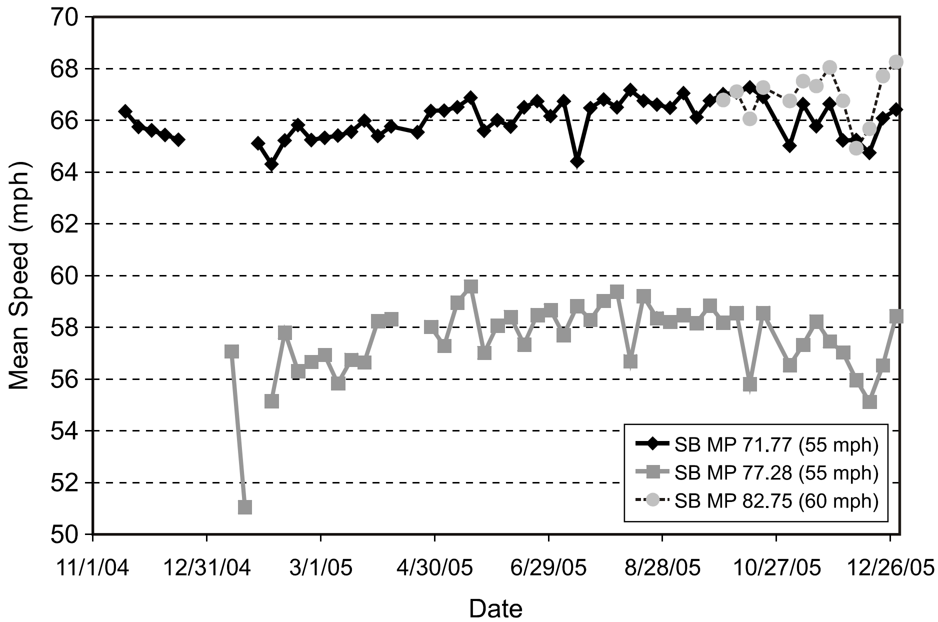

Figure 16. I-95 Richmond HSC Mean Speeds, Southbound

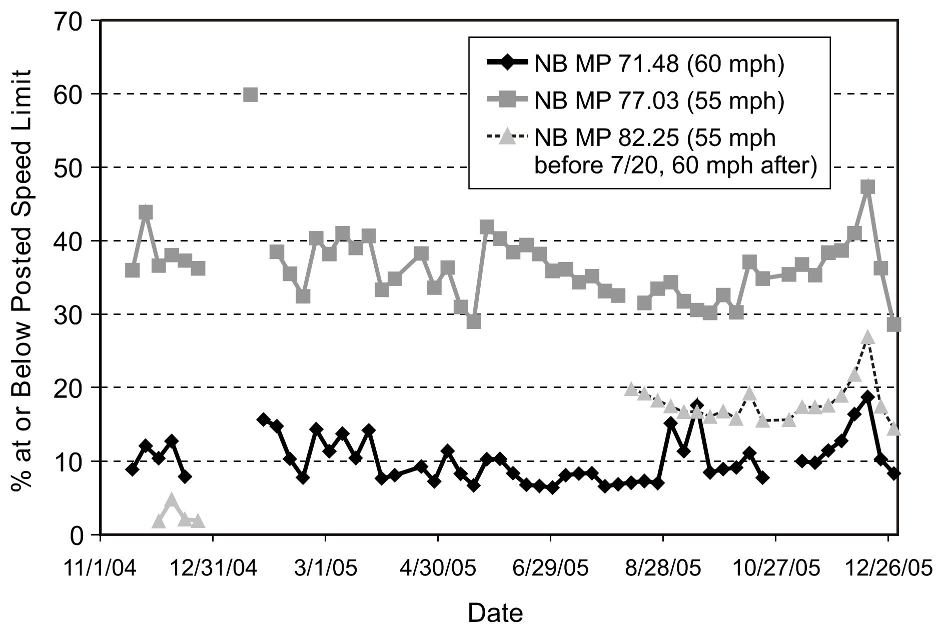

Figure 17. I-95 Richmond HSC Compliance with Posted Speed Limit, Northbound

Figures 19 and 20 show the percentage of drivers that exceeded the posted speed limit by more than 15 mph. In this case, it appears that the initial HSC designation did have a short-term impact on the number of extremely high-speed vehicles. The stations at mileposts 71.48 NB, 77.03 NB, and 71.77 SB all show an initial reduction in the percentage of high-speed vehicles following HSC designation. These reductions range from 1 to 2 percent up to 5 percent. It appears that percentages rebounded to their pre-installation levels within 1 to 2 months, however. The proportion of vehicles traveling more than 15 mph over the posted speed limit did not

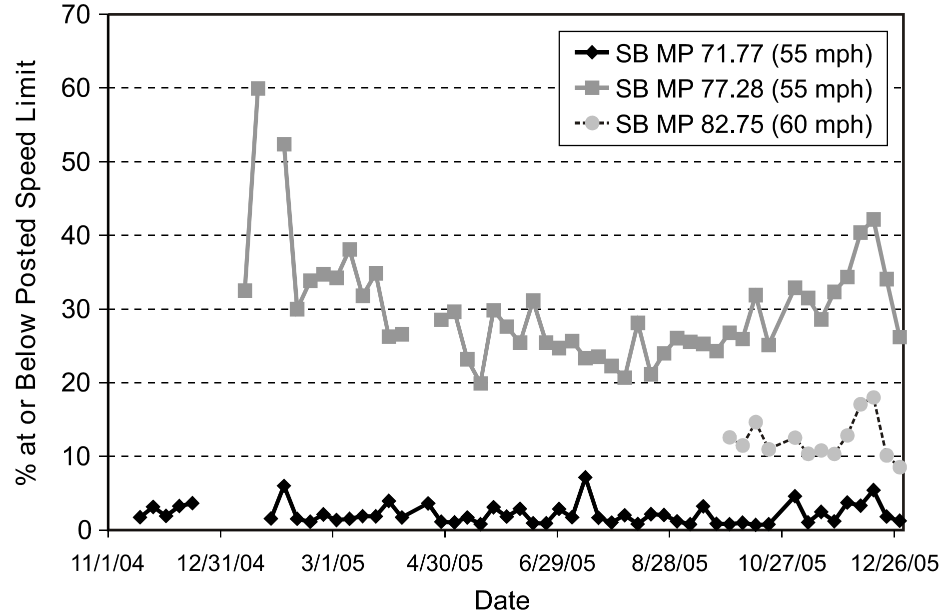

Figure 18. I-95 Richmond HSC Compliance with Posted Speed Limit, Southbound

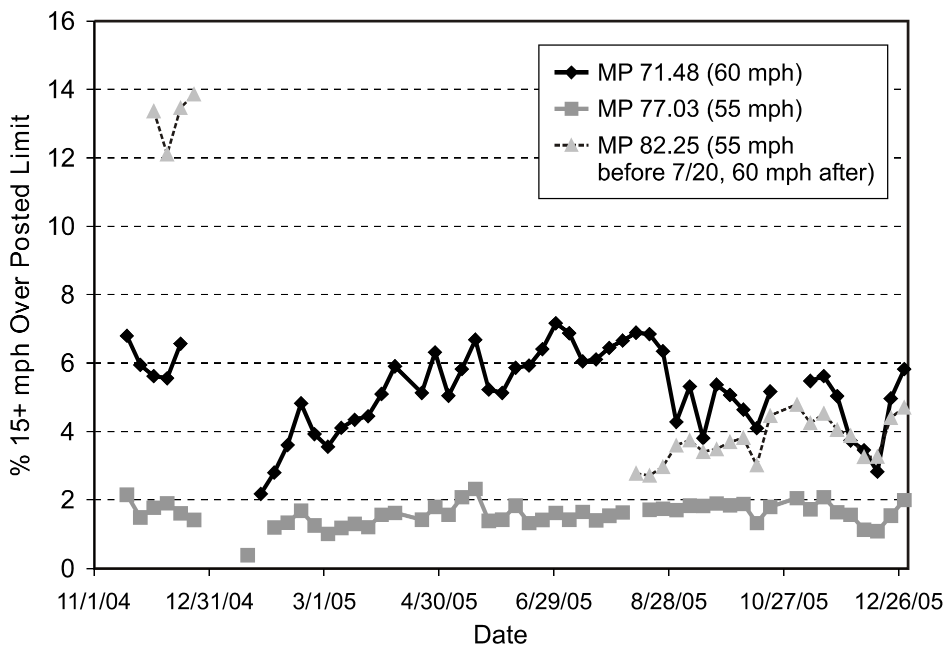

Figure 19. I-95 Richmond HSC % > 15 mph, Northbound

change by a statistically significant amount when all sites were examined collectively or individually. As a result, it appears that the apparent initial reduction was not enough over the analysis period to produce a statistically significant difference before and after the HSC was installed. However, the south end of the HSC, and particularly the southbound lanes, had higher proportions of excessive speeding.

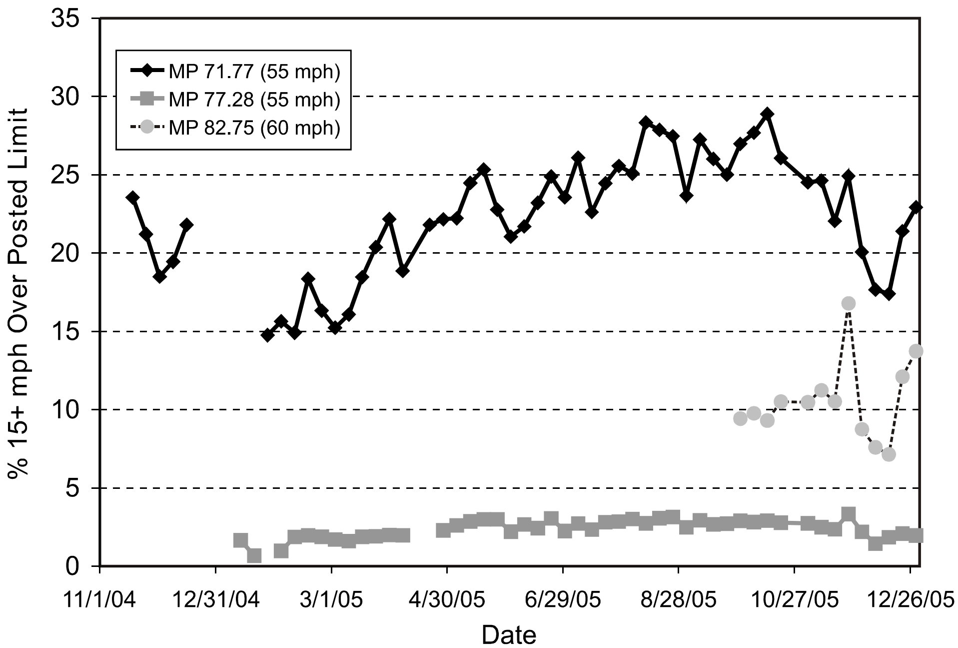

Figure 20. I-95 Richmond HSC % > 15 mph, Southbound

Crash Data Analysis

Only the I-81 HSC had been installed for more than 1 year at the time of this study, so it was the only site for which sufficient crash and volume data existed to allow a detailed statistical crash analysis. Preliminary crash data from 2005 were provided by VSP for the I-81 and I-95 Richmond HSCs, but a detailed analysis of that data could not be performed since 2005 VMTs had not been finalized. In addition, there is a 6- to 8-month lag between when a crash occurs and when it is entered into VDOT's Highway Traffic Records Information System (HTRIS). This lag time makes it impossible to perform any statistical analyses that involve contrasts to comparison sites using the 2005 data. The 2005 crash frequency numbers for the two HSC sites are presented here, however, to show some of the trends that developed at these sites.

I-95 Richmond HSC Data

Figure 21 shows the crash density for the I-95 Richmond HSC between 2000 and 2005. Before the HSC was installed at the site, crashes were increasing by an average of 8 percent per year. Following the installation of the HSC, crashes declined by approximately 13 percent. Given that 2005 crash and VMT data were not yet available, it is impossible to perform any rigorous statistical analysis of these data, but these results appear to be promising.

I-81 HSC Data and Comparison

The crash rates and crash density for the I-81 HSC were also examined. Since the I-81 HSC was installed in early 2004, crash and VMT data were available to allow comparisons of the crash experience at the I-81 HSC with those of other similar locations for the 2004 time frame. The crash statistics for the I-81 HSC were compared with those of four sites along I-81

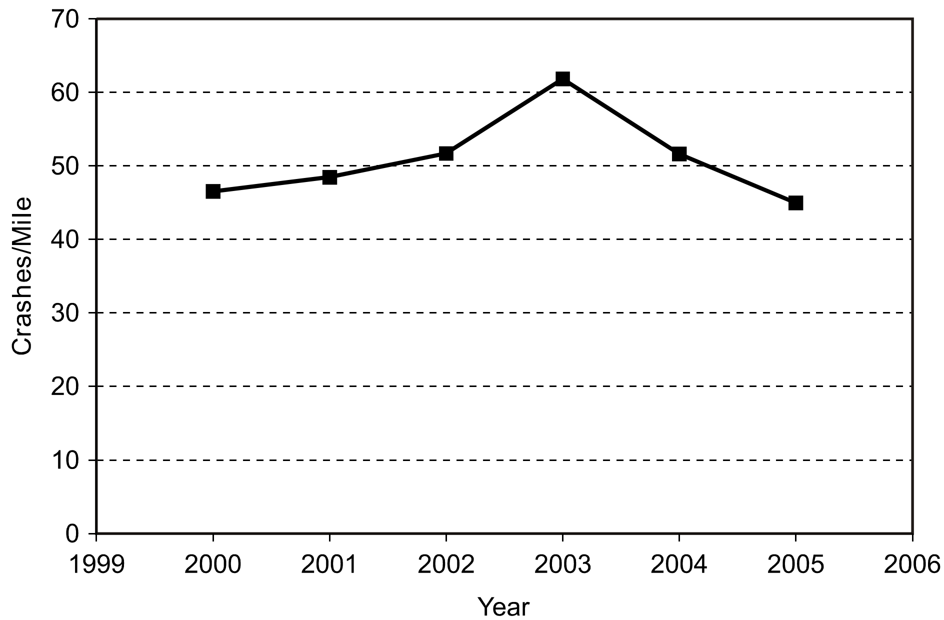

Figure 21. Crash Density at I-95 Richmond HSC, 2000-2005

and one site on I-64. All sites ran through urbanized areas and had volumes within 10,000 vehicles per day of those in the HSC. The comparison sites were as follows:

- I-81 from milepost 0 to 9 (Bristol)
- I-81 from milepost 219 to 226 (Staunton)
- I-81 from milepost 242 to 249 (Harrisonburg)
- I-81 from milepost 309 to 319 (Winchester)
- I-64 from milepost 118 to 124 (Charlottesville).

Crash data for all of these sites were pulled from HTRIS. TED has performed manual counts of the crashes within the I-81 HSC based on the police crash reports submitted and found that their hand counts were about 5 percent higher than the numbers reported in HTRIS. For the sake of consistency in the analysis, only the HTRIS-reported values were used.

Figure 22 compares the crash densities for the I-81 HSC for 2000 through 2005. The crash density is compared to that at the comparison sites for 2000 through 2004. As noted earlier, the 2005 crash and VMT data had not been finalized, the 2005 I-81 crash density is shown without any comparison sites. An interesting trend at both the HSC and comparison sites is that the average number of crashes per mile increased annually until 2004, and then leveled off. This may indicate broad systematic influences of weather or changes in the vehicle fleet. The rate of increase in crash density did appear to be larger for the HSC than for the comparison sites, and the HSC had a higher crash density overall than for the comparison sites. There was a 25 percent drop in the crash density at the I-81 site in 2005. It is difficult to determine the significance of this drop since no data from the comparison sites were available at the time this report was prepared. This may be a positive indicator that the HSC is having a positive effect at the site, but the significance of this reduction cannot be determined until comparison site data

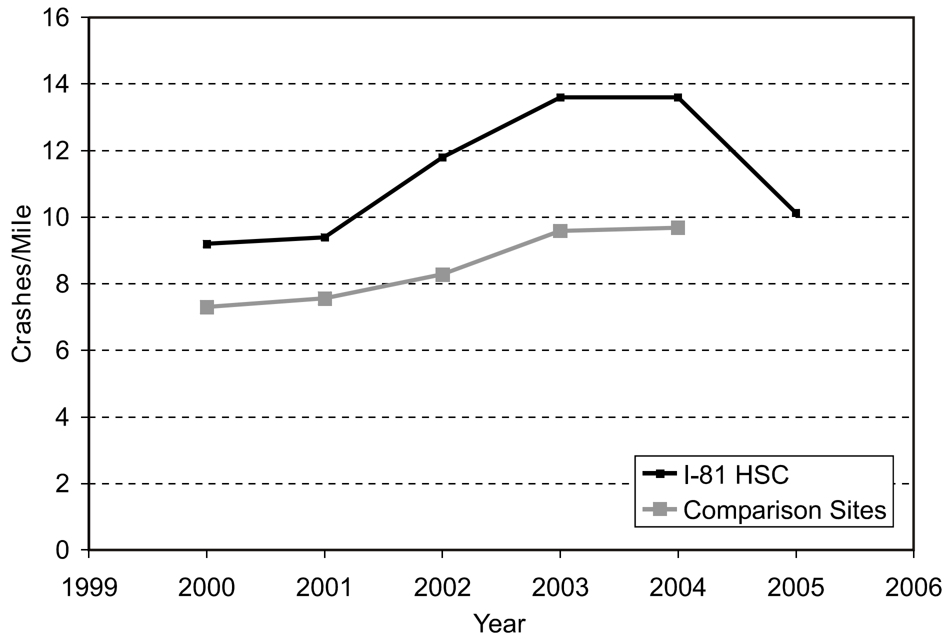

Figure 22. Crash Density at I-81 HSC, 2000-2005

become available. Although these trends are informative, they do not correct for exposure factors such as VMT. In order to correct for exposure, the crash rates were also examined.

Figure 23 shows the crash rate comparison between the I-81 HSC and the comparison sites. Crash rates could not be calculated for 2005 since VMT data have not been finalized for that year. An interesting trend here is that the crash rate on the I-81 HSC actually increased from 2003 to 2004, even though the crash frequency was level. This trend resulted from an estimated

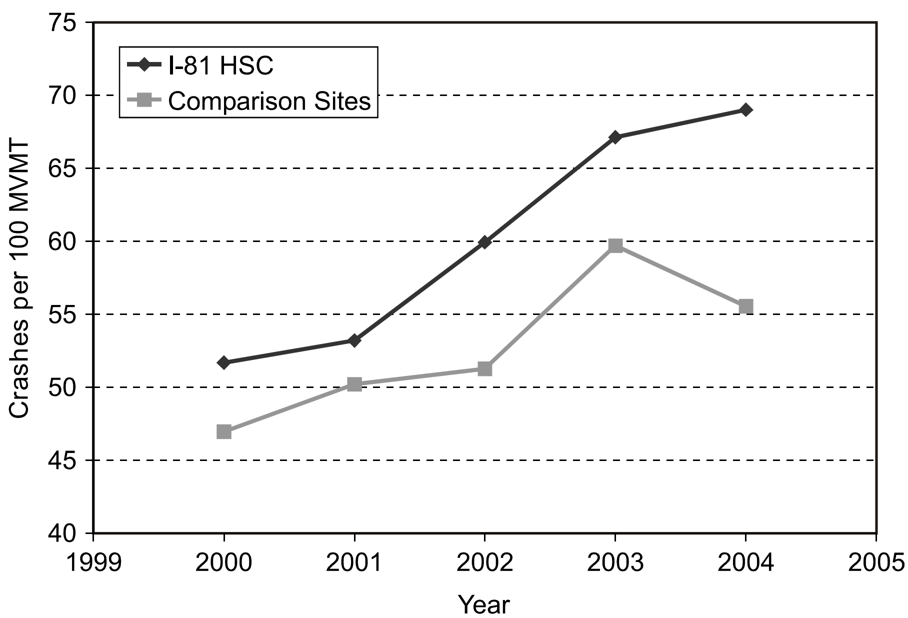

Figure 23. I-81 HSC Crash Rate, 2000-2004

decrease in VMT within the HSC, causing the crash rate to increase. This decrease in VMT may be attributable to the fact that new count stations within the HSC provided more volume data to generate VMT numbers. As a result, it is possible that the 2004 VMT numbers are more accurate than prior years, and the years up to 2004 may have VMTs that are overestimated. This is conjecture but is considered to be a likely explanation. In contrast to the I-81 HSC, the crash rate at the comparison sites actually declined from 2003 to 2004. In those cases, the number of crashes remained relatively level while VMT increased. As a result, the crash rate declined at the comparison sites.

The EB method was used to attempt to assess the impact of the I-81 HSC on crashes. A crash estimation model was built using the data from the HSC and the comparison sites for the period 2000 through 2004 to examine the crash frequency at the sites. The 2005 data were not used since VMT and comparison site data were not yet available. Explanatory variables investigated included:

- segment length
- average segment ADT
- speed limit
- number of lanes.

Although crash data were available going back to 1990, TED staff noted that the quality of the average daily traffic (ADT) estimates improved considerably beginning in 2000. As a result, only the most recent 5 years of data were used for model building purposes. After iterating the model, the model form that produced the best fit was:

$$Crashes = \alpha_y \left(Length\right)^{1.06626} \left(ADT\right)^{0.89824}$$

with annual adjustment factors of:

$\alpha_{2000} = 0.00045$
$\alpha_{2001} = 0.00047$
$\alpha_{2002} = 0.00050$
$\alpha_{2003} = 0.00057$
$\alpha_{2004} = 0.00053$

This model is basically VMT based, with yearly factors showing some of the variations that might be caused by weather or changes in the vehicle fleet. Speed limit and number of lanes were not found to be significant explanatory variables in predicting the number of crashes.

The EB method computes a factor called the index of effectiveness (θ) to show whether a treatment has had a positive safety benefit. The θ value shows the percentage difference between the crashes that actually occurred versus what was predicted. A θ less than 1.0 shows a positive safety benefit, and those greater than 1.0 indicate that more crashes occurred than were predicted based on the control data and pre-existing conditions. When this crash estimation model was applied to the HSC, it predicted that 170.84 crashes should have occurred within the

HSC versus 204 that were recorded within the HSC limits. The θ value for this case had a mean of 1.12 with a 95th percentile confidence interval between 1.105 and 1.136. This implies that approximately 12 percent more crashes occurred at the site than would have occurred without the installation of the HSC.

The EB crash analysis results would appear to imply that the HSC has had a detrimental effect on safety. However, given the limited amount of crash data available for analysis and the potential VMT accuracy issues mentioned earlier, it would be premature to say that this HSC had no benefit.

Summary

The 2005 data available for the I-81 and I-95 Richmond HSCs seem to indicate that crashes declined in 2005, just the opposite of what the EB analysis for the I-81 HSC showed. Crashes, by their nature, are random events and sites exhibit significant variability for year to year. Crash analyses usually rely on at least 3 years of data after a treatment is installed before an accurate determination of the effect is attempted. Performing a crash analysis using only 1 year of data at one site does not provide sufficient information to make a final assessment. Likewise, the change in VMT estimation in the I-81 HSC created by the installation of additional count stations likely impacted the effectiveness analysis. Before a true assessment of the effectiveness of the HSC program can be made, data from all three HSCs should be compiled for at least 3 years. Given the trends that appear to be emerging from the 2005 data, it is possible that the HSC program is providing a safety benefit. Unfortunately, there are insufficient data available to evaluate the impact of the program through 2005.

Consistency of Interstate Identification Methodology Over Time

One concern with performing annual evaluations of crashes is that candidate segments of roads could cycle in and out of the HSC program. The initial selection of interstate candidate sites used crash and VMT data from 2000 through 2002, since they were the most recent data available at the start of the project. Following designation of the initial set of candidate sites, crash and VMT data for the years 2003 and 2004 became available. These data were screened using the interstate methodology to determine whether the sites selected would be different using the most recent 3 years of data.

Table 4 shows how regional average crash rates and EPDO densities changed between the 2000-2002 and 2002-2004 periods. Both average crash rate and EPDO density increased between 10 and 15 percent when the updated data were used. These increases impacted the sites that were identified using the screening process, since the corresponding selection thresholds increased.

Table 5 shows the candidate HSCs that were selected using the 2000-2002 and the 2002-2004 data. Cases where a particular segment of road was not selected are noted, showing the thresholds that prevented selection of the segment. When the 2002-2004 data were used, 13 of 19 (68.4%) of the locations identified using the 2000-2002 data were still selected, at least

Table 4. Comparison of Interstate Regional Averages, 2000-2002 vs. 2002-2004

Region	Period	Total Crashes	Total EPDOs	Average EPDOs/Mile/Year	Average Crashes/100 Million VMT
1	2000-2002	7,821	29,552	20.6	44.2
	2002-2004	9,276	32,659	22.7	49.4
	Change	+1,455 (+18.6%)	+3,107 (+10.5%)	+2.1	+5.2 (+11.8%)
2	2000-2002	21,714	75,875	59.1	81.0
	2002-2004	25,478	86,817	67.7	90.7
	Change	+3,764 (+17.3%)	+10,942 (+14.4%)	+8.6	+9.7 (+12.0%)
3	2000-2002	16,944	60,902	95.8	81.0
	2002-2004	19,648	68,963	108.5	90.2
	Change	+2,704 (+16.0%)	+8,061 (+13.2%)	+12.7	+9.2 (+11.4%)
State	2000-2002	46,479	166,329	49.6	71.1
	2002-2004	54,402	188,439	56.2	79.2
	Change	+7,923 (+17.0%)	+22,110 (+13.3%)	+6.6	+8.1 (+11.4%)

EPDO = equivalent property damage only; VMT = vehicle miles traveled.

Table 5. Changes in Candidate HSCs, 2000-2002 vs. 2002-2004

Region	Road	2000-2002		2002-2004		Change (miles)
		Start Milepost	End Milepost	Start Milepost	End Milepost	
1	I-77	0	17	Does not meet EPDO		-17
	I-81	3	10	Does not meet crash rate or EPDO, likely reflects end of I-81 work		-7
		90	99	94	99	-4
		127	142	125	142	+2
		Did not meet truck crash rate		187	206	+19
		244	251	Does not meet EPDO		-7
		295	302	Does not meet EPDO		-7
		310	319	312	319	-2
	I-581	0	6	0	6	0
2	I-64	181	187.53	181	186	-1.53
		Did not meet crash rate		190.77	196	+5.23
		246	252	246	252	0
		260	297	259	288	-2
				291	297	
	I-95	50	56	Does not meet crash rate		-6
		71	83	71	90	+7
	I-264	1	19	0	19	+1
3	I-66	58	69	58	69	0
	I-95	149	159	150	163	+3
		165	179	165	175	-4
	I-395	0	9.88	0	9.88	0
	I-495	0	5	Does not meet crash rate		-5

EPDO = equivalent property damage only.

partially. In addition, two new sites were identified using the new data. The net reduction in the number of miles identified was 25.3 miles. It is worth noting that the sites that were no longer eligible using the more recent data only marginally met at least one of the selection thresholds using the older data or had a change that was likely to impact crash rates (such as the cessation of work zone activities within the zone). All of the sites where HSCs were installed based on the 2000-2002 data were still identified as candidates using the updated data.

It appears that many of the 2000-2002 candidates that exceeded the thresholds remained candidates when the data were updated. As long as the more marginal candidates are not selected for implementation, it appears that the results of the screening process will remain relatively consistent from year to year.

Potential Methodology for Extending HSC Program to Primary System

In developing the primary HSC process, it became obvious that the procedures would have to be tailored to the specific characteristics of the primary system. The primary system is much more heterogeneous than the interstate system. It consists of roads ranging from two-lane rural facilities to signalized multilane urban arterials to limited access freeways, so the procedure to select HSCs had to be able to account for the inherent differences in these facility and cross-section types. An iterative approach to examining the crash data was used to try to develop a process that was relatively easy to administer, was not biased toward any particular type of facility, and ensured a reasonable geographic distribution of candidate HSCs throughout the state.

Application of Interstate Method

The first approach tested involved applying the interstate thresholds and regions to the primary system. The regional average crash rates and EPDO densities were calculated for the primary system, and the same screening process was applied to each of the regions. The advantage of this approach was that it would provide a greater level of consistency between the interstate and primary HSC program and make administration of the program simpler overall. When this approach was applied to the primaries, it was found to have several deficiencies, however:

- *The EPDO density threshold was biased toward the high-volume, multilane roads found in major urban areas.* As a result, no rural two-lane roads were selected and all candidate HSCs tended to be congregated around major urban areas such as Hampton Roads, Richmond, and Northern Virginia.

- *The truck-involved crash rate threshold was highly unstable.* Many primary roads have a relatively small proportion of truck traffic, creating significant variability in the truck-involved crash rate threshold. This variability was so extreme that it was difficult to apply the threshold in a meaningful manner.

- *The crash rate threshold also exhibited extremely high variability, with some lower volume roads having extremely high rates because of their low volumes.* This also created problems in applying the interstate thresholds.

- *The net combination of these factors caused the candidates identified to be almost exclusively high volume, urban facilities, such as U.S. 29 in Northern Virginia and U.S. 250 in Richmond.* Some districts, such as Culpeper, Lynchburg, and Fredericksburg, had no candidates identified.

Given these problems, it was concluded that the interstate methodology could not be directly applied to the primary system. A technique that better accounted for the variability among primary road sites was needed to ensure a better distribution of candidate sites throughout the state. Further testing using district-based averages revealed similar problems, although the dispersion of candidate HSCs was improved. HSCs still tended to be clustered on high-volume, urban highways however. Additional work using county-based averages identified so many potential candidates that it would be difficult to administer the program. As a result, a new methodology was sought for the primary system.

Application of Critical -Rate–Based Method

The next method evaluated used the concept of critical crash rate to identify sites. With the critical rate method, also called the rate quality control method, the crash rate at a site is compared to an average crash rate at other sites, adjusted based on an assumption of a Poisson distribution of crashes. The critical crash rate method is currently used by VDOT to help identify isolated locations with potential safety problems, but it is not being used to identify potential corridor-wide issues. The critical rate for a site is defined as:

$$R_{ci} = R_a + k\sqrt{\frac{R_a}{M}} + \frac{1}{2M}$$

where R_{ci} = critical crash rate for the section being examined (crashes per 100 million VMT)
R_a = average crash rate for similar facilities (crashes per 100 million VMT)
K = factor for the statistical level of confidence required (a value of 2.576 was used in this study, corresponding to a 99 percent level of confidence)
M = total VMT at the site, expressed in units of 100 million VMT.

The crash rate of the segment is compared to the critical rate of the segment. If the ratio of the crash rate to the critical rate is greater than 1.0, the segment has a potentially significant crash problem.

There are several advantages to using this technique. First, a segment's crash history is compared only to the crash history on other similar segments. This means that four-lane divided highways would not be compared to two-lane roads. Second, the critical rate technique has been used by VDOT to identify problem locations for a number of years, and staff are familiar with its use. Figure 24 is a flowchart describing the application of the critical rate–based primary analysis procedure.

The first step in developing the critical rate method was to define average crash rates for different facility types. Four basic facility types were defined:

1. 2-lane undivided roads
2. > 2 lane undivided roads
3. < 4 lane divided roads
4. 4 or more lane divided roads.

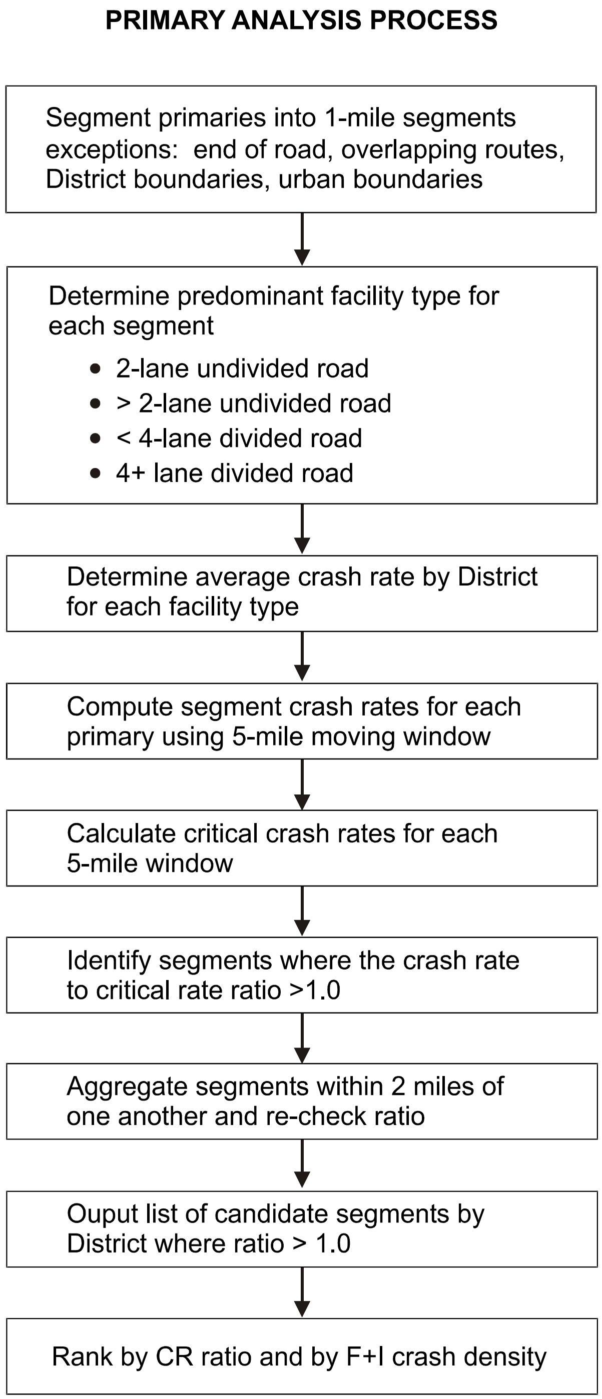

Figure 24. Analysis Process for Identifying Candidate Primary HSCs

The VDOT roadway inventory was used to define these cross sections for the entire roadway network. The primary system was then segmented into 1-mile pieces and assigned the predominant facility type based on the type on the majority of the segment. Not all segments were exactly 1 mile long; however, as the end of a route, overlaps among multiple routes, or urban boundaries may reduce the length of a segment.

Examination of the data showed a great deal of variability in crash rates for the different facilities among the various VDOT districts. Once again, using regional averages would tend to cluster HSC selections in the major urbanized areas. For example, few sites were selected in the Culpeper or Fredericksburg districts when they were combined with the Northern Virginia District. After the alternative comparisons were discussed with TED, a district-by-district average crash rate for each facility type was calculated for the comparisons. This would have the additional benefit of providing districts with a listing of hazardous segments that might be eligible for safety programs other than the HSC program.

The crashes in each segment were identified, and average crash rates were calculated by facility type for each VDOT district. As a result, 36 average rates were calculated (4 facility types × 9 districts). Table 6 shows the average rates by facility type and VDOT district for 2002 through 2004. The variation between districts in the rates can be seen.

Next, crash rates were computed for every 5-mile segment of road within each district based on the same minimum length reasoning used for the interstate HSCs. The crash rates were compared to the critical rates for those segments of roads, and sections with a crash rate to critical rate ratio exceeding 1.0 were identified. Examination of these results indicated that the segments identified appeared to ensure a wide distribution of candidate HSCs throughout the state as well as a manageable number of candidates for detailed examination. Examples of the sites identified as candidates for the Culpeper and Hampton Roads districts are included in Appendix D. Next, the fatal plus injury crash density and rate for the candidate corridor segments were calculated and sorted to determine those with the highest crash severity.

Table 6. Average Primary Crash Rates by District, 2002-2004 Data (Crashes per 100 million VMT)

District	Facility Type			
	2-lane Undivided	> 2-lane Undivided	< 4-lane Divided	4 or more lane Divided
Bristol	162.58	111.79	149.45	74.06
Culpeper	152.04	184.76	186.90	109.99
Fredericksburg	123.16	218.99	49.96	116.84
Hampton Roads	131.52	107.50	153.44	93.58
Lynchburg	137.12	241.00	71.59	69.02
Northern Virginia	177.44	385.38	220.36	186.50
Richmond	142.07	219.52	92.30	167.90
Salem	156.70	157.92	132.18	104.45
Staunton	135.39	94.13	88.30	94.40

Proposed Primary Program Procedures

Administration of a primary HSC program will have to be fundamentally different from that used for interstates because of the number of jurisdictions that are likely to be involved. Enforcement of the traffic regulations within the HSC will fall primarily to local law enforcement, rather than VSP. This means that local governments will have to be involved in the approval and ongoing operation of primary HSCs. The primary system is also approximately 8 times as large as the interstate system, so the number of potential candidates is also going to be larger. The primary system procedures outlined next are suggested measures and would need to be formally adopted by VDOT prior to implementation. Figure 25 is a flowchart of a potential primary HSC process.

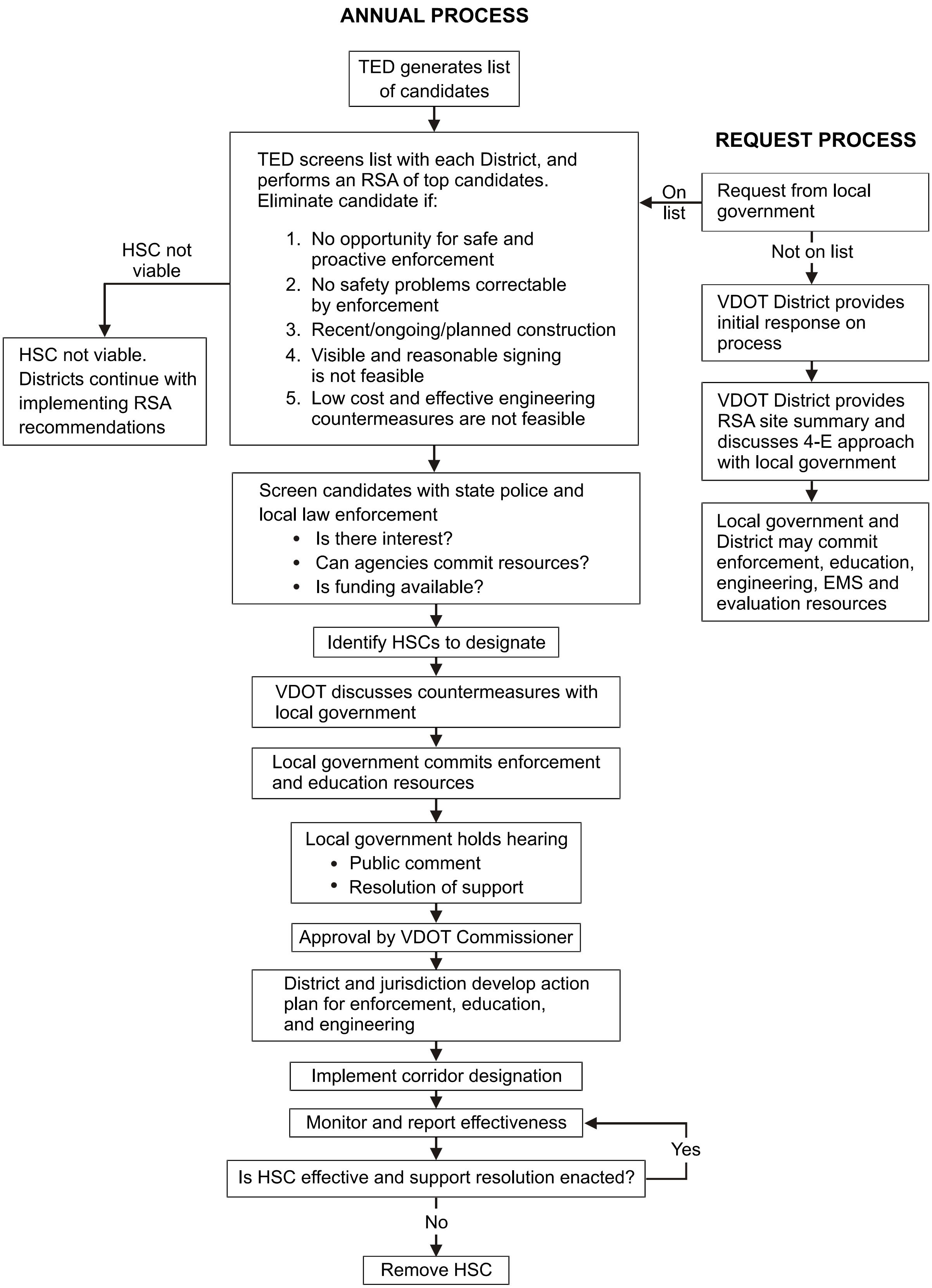

Figure 25. Primary HSC Implementation Process

The proposed process could be initiated in one of two ways: through an annual analysis of primary roads or in response to a specific request from a city or county. Each method is discussed here. The process shown in Figure 25 envisions that TED would develop an annual screening process for primary roads, similar to that adopted for interstates. The list of candidate HSCs would first be shared with each VDOT district, which would be asked to perform an RSA of the sites. Candidate sites would be eliminated if:

- the safety problem could not be addressed through enforcement (e.g., the crashes were due to recurring peak hour congestion or geometric design issues)
- there was no opportunity to enforce the candidate HSC safely and effectively (e.g., shoulder space was not available)
- construction at the site either had been recently completed, was ongoing, or was planned for the near future
- adequate and safe signing could not be easily provided
- low-cost and effective engineering countermeasures could not be installed.

Following district review, TED would approach VSP and local law enforcement to gauge their interest in the HSC. They would be asked whether they had available resources to commit to enforcement. In the event the district or enforcement review eliminated a candidate, it would be reviewed as part of other safety programs, but would be eliminated from further consideration within the HSC program.

An important consideration in the primary program will be whether the HSC signing can be installed adequately and safely. Signing the primary HSCs will be much more difficult than signing interstate HSCs because of driveways, cross streets, increased roadside development, and a more constrained right of way. Whether HSC signs would be installed after every cross street or only after cross streets that exceeded particular volume thresholds will have to be determined. Sign designs will also have to be significantly altered. The interstate sign shown in Figure 8 measures 15 feet wide and 6 feet high. Primary roads, especially ones in urbanized areas, are unlikely to have enough right of way to accommodate these signs easily. Revisions to the sign designs will likely be needed to ensure that HSCs can be installed along urban arterial roads. TED is currently in the process of developing sign designs for primary HSCs to deal with these issues, but it is likely that the traffic control and geometric conditions on the primary roads will act as significant constraints in determining which corridors become HSCs.

The remaining candidates would then be screened to determine which should be designated HSCs. The magnitude of the safety problem, availability of resources, and ability to correct the safety problem would all be factored into the final decisions. The recommended candidates would then be discussed with the appropriate local governments, and the local government would be required to hold a public hearing on the proposed HSC. The locality would also be responsible for passing a resolution of support for the HSC. This resolution would commit the locality to providing enforcement and educational initiatives along the HSC. Further, it would commit the locality to providing VDOT with regular updates on crashes, citations, and educational initiatives within the HSC. Appropriate minimum levels of enforcement and public outreach to be provided by the localities would need to be defined and included in the resolution. Oregon is one state that defines some minimum requirements for enforcement and education provided by the local government. It requires that a minimum of 50 hours of enforcement be provided per month along a HSC in addition to what would normally be provided on the road and that at least four quarterly public information efforts be conducted.[8] Similar values could be used in Virginia to define the minimum level of commitment that local governments would need to provide. The RSA results conducted earlier would also be used to determine what engineering countermeasures should be applied at the site. Following approval, the process for implementing and monitoring the primary HSC would be similar to that used in the interstate process.

A review of a specific corridor might also be initiated in response to a request from a local government. In this case, TED would check whether the requested location was identified as part of the annual screening process. If so, it would simply become part of the annual process of identifying and implementing primary HSCs. If the requested corridor was not previously identified as a potential HSC, the appropriate VDOT district would inform the locality that the requested corridor was not eligible for the HSC process but could be examined through an RSA process. The district could compile crash data and conduct an RSA with the locality to identify 3-E alternatives with the locality. The locality could then commit resources to implementing the 3-E approach without the additional HSC signing and fine structure. Engineering countermeasures identified might be eligible for funding from the Highway Safety Improvement Program or other transportation sources, and education and enforcement efforts might be eligible for annual grants from the National Highway Transportation Safety Administration through the DMV. VDOT could also work with local initiatives to provide targeted enforcement along the requested corridor by providing speed and crash data that might help focus the enforcement efforts on potential problem areas.

SUMMARY

Although the HSC program for the interstate system was successfully developed and implemented, the safety results are not yet conclusive. The 2004 safety and speed data analysis did not show a positive effect at the I-81 HSC site, but the 2005 data from the I-81 and I-95 Richmond HSCs showed promising trends. More data are needed to determine the actual impact of the HSC program on safety. As noted earlier, several mitigating factors might explain the lack of effect seen in the I-81 HSC 2004 analysis:

- *The results of the HSC safety effectiveness analysis were based on only 1 year of post-installation data.* At least 3 years of post-installation crash data are typically used to perform a safety analysis.

- *The addition of new permanent detector stations within the I-81 HSC changed the way that VMT was estimated in the corridor, causing the VMT estimates for 2004 to drop from the prior year.* This is an unusual occurrence and is not reflected in VMTs at other locations along I-81. This may indicate that earlier VMTs may have been overestimated, but it is impossible to know the true effect of this change on the analysis. Given that the crash estimation model relies on VMT as a major input for crash prediction, this fluctuation in VMT may have also had an impact on the results of the analysis. As more data become available, the safety trends seen in the 2005 data may continue, but a final assessment of the safety effectiveness of the HSC program is likely premature at this time.

- *There are potential limits to the speed analysis.* For the I-81 case study, no detectors were in place within the HSC when it went into effect. As a result, it is impossible to know whether there were any observable changes in speeds following installation. Likewise, the quality of the speed data archived by VDOT within the I-95 Prince William HSC was not sufficient to support any reasonable analysis.

- *The Code of Virginia did not specify any dedicated funding to implement the HSC program.* VSP and VDOT executed the program using existing resources, supplemented with grants from DMV. As a result, no high-cost engineering countermeasures were installed at any of the HSC sites and VSP had to conduct enforcement using resources they had available. It is possible that more effect might be seen if dedicated funding were available to fund additional officers, perform more engineering improvements, and maintain a high level of public visibility and education within the HSCs.

One concern with performing annual evaluations of crashes is that candidate segments of roads could cycle in and out of the HSC program. It appears that many of the 2000-2002 interstate candidates that exceeded the thresholds still remained candidates when the data were updated. Thus, as long as the more marginal candidates are not selected for implementation, it appears that the results of the screening process will remain relatively consistent from year to year.

Administration of a primary road system HSC program will have to be fundamentally different from that used for interstates because of the number of jurisdictions that are likely to be involved. Enforcement of the traffic regulations within the HSC will fall primarily to local law enforcement, rather than VSP. This means that local governments will have to be involved in the approval and ongoing operation of primary HSCs. The primary system is also approximately 8 times as large as the interstate system, so the number of potential candidates will be larger. The primary system procedures provided earlier are suggested measures and would need to be adopted formally by VDOT prior to implementation. Following approval, the process for implementing and monitoring the primary HSC would be similar to that used for the interstate process.

CONCLUSIONS

- *Several states have implemented HSC programs.* California, Oregon, New Mexico, New Jersey, and Pennsylvania allow fines to be increased in designated HSCs. Several other states designate HSCs but do not increase fines for violations. Data from these states indicate mixed results for HSCs, ranging from no effect in some locations to a reduction of up to 30 percent in total crashes in some HSCs.

- *The impact of HSCs on safety is inconclusive, although recent preliminary crash data indicate promising results.* The EB analysis of 1 year of crash data at the I-81 site indicated no significant improvement in safety in 2004. The analysis was limited, however, by the availability of only 1 year of post-installation data. Inconsistencies in the VMT estimation might also be introducing error into the statistical analysis. Preliminary 2005 crash data for the I-81 and I-95 Richmond HSCs seem to indicate that the HSCs may have had a positive impact in that year, but the effect of the HSC program cannot be known until VMT and comparison site crash data are finalized. Additional years of data are needed to allow a definitive assessment of the program.

- *Speeds are not significantly impacted by HSCs.* The Richmond HSC did not have a statistically significant decrease in mean vehicle speeds. The speed compliance rate and the percentage of high-speed vehicles also were statistically unchanged, although several of the Richmond sites showed a short-term reduction in the percentage of high-speed vehicles immediately following installation of the HSC.

- *Lack of funding limits the countermeasures that have been applied at the HSCs.* Increases in enforcement have been relatively modest, and engineering improvements have been limited to low-cost measures because of the lack of a dedicated funding stream. The relatively small-scale nature of the countermeasures implemented may partially explain the limited safety effects within the HSCs. The results appear to be consistent with the limited effectiveness of increased fines in work zones reported in other states where enforcement levels do not change. Larger impacts may be achievable if a dedicated funding stream for the program becomes available.

- *The method used to identify potential interstate HSCs cannot be directly applied to the primary system program.* The interstate method does not account for the wide differences in crash experience on the different types of primary roads. The proposed critical-rate–based method addresses the differences in safety on different types of primary roads. By explicitly considering traffic volume and roadway cross section, the critical rate method should identify sites that have a significantly higher crash rate than other similar facilities in a district. This will allow two-lane rural roads and multilane divided highways to be compared using the same methodology.

RECOMMENDATIONS

1. *TED should continue to pursue additional funding to support the HSC program*. The results of the evaluation show that existing efforts have not created demonstrable changes in speeds in the HSCs. A coordinated campaign of increased enforcement, public education, and engineering improvements should be pursued as a way to attempt to improve safety. The lack of dedicated funding for the HSC program has limited enforcement efforts and restricted engineering improvements. A dedicated budget for the program is needed to increase the

level of engineering countermeasures that can be implemented, as well as to increase enforcement presence in the HSCs. By implementing a more aggressive 3-E program, it may be possible to produce larger reductions in speeds and crashes. TED staff are initiating procedures to use FHWA funding of projects within the candidate corridors through the Highway Safety Improvement Program. Additional efforts are needed for DMV and VSP to target NHTSA grants for education and enforcement projects in the designated and candidate corridors.

2. *TED should develop methods to automate the identification and evaluation of HSCs.* The current analytical techniques used for identification and analysis are time-intensive, manual procedures. Automated methods to screen, identify, and analyze HSCs are needed to reduce the time commitment of the program. Although TED is currently seeking a full-time employee to administer the HSC program, automated processes would significantly reduce the time required to identify and select potential candidates. This is particularly important if the screening of candidate HSCs will be performed annually.

3. *TED should proceed with the development of a primary system program and deploy one test case.* The *Code of Virginia* requires that VDOT develop a primary system program. The critical-rate–based methodology and overall program framework recommended in this document should be piloted on a single primary HSC to determine if changes to the program are necessary. The pilot test on a single primary would serve to highlight whether the proposed procedures function well in a primary environment. It would also provide data on the potential safety effects of a primary HSC.

4. *TED should plan the installation of any new count stations within proposed HSCs to support the monitoring and evaluation of HSC effectiveness.* Any new permanent count stations installed in proposed HSCs should be brought on-line at least several months before HSC installation to provide baseline speed data within the HSCs. The count stations should also be located so that speed data are provided for each segment that has relatively homogeneous traffic volume and geometric characteristics.

5. *VDOT and VSP should quantify potential costs and benefits for providing additional enforcement within the HSCs.* VDOT should work with VSP to identify the baseline amount of enforcement that has been occurring within the confines of a proposed HSC prior to designation. By tracking VSP costs before and after installation of multiple HSCs, it should be possible to develop relationships between the costs and amount of enforcement present and any potential reductions in crashes at the sites.

6. *TED should update the analysis of the effects of the HSCs on crashes and speeds as more data become available.* This report provides a detailed analysis of the first year of crashes at the I-81 HSC, as well as preliminary data from 2005 for the I-81 and I-95 Richmond HSCs. The results in the 2005 data appear to contradict what was observed during the first year of the I-81 HSC installation, and analysis using additional years of data is needed to ascertain the impact of HSC designation. This evaluation should be repeated for the two I-95 HSCs and any new HSCs that are brought into the system. Once at least 3 years of data are available following the installation of the HSC, VDOT should determine the effectiveness of

the program and whether the program should be modified. An additional research project may be warranted to perform this assessment.

COSTS AND BENEFITS ASSESSMENT

The HSC program comes with several inherent costs. First, district and central office staff time must be used to identify candidate HSCs, gain public approval, and develop countermeasures to affect the observed safety problems. Funding must also be available to support increased enforcement, educational measures, HSC signing, and engineering countermeasures. At the present time, this funding is coming from existing agency resources or DMV grants. The implication of this arrangement is that potential resources are being diverted from other programs to allow the HSC program to operate.

At this point, it is impossible to determine what safety benefits, if any, the HSC designation may confer. The EB analysis of the 2004 data available shows no conclusive safety benefits to installing the HSC at the I-81 site. No reduction in crashes was observed. Further, no statistically significant change in mean speed, speed limit compliance, or percentage of high speed vehicles was observed. Given that only 1 year of data were available, it is premature to say whether the HSC provides a safety benefit. The preliminary data from 2005 seem to indicate that crash reductions were achieved at both HSC sites where more recent data were available. The potential benefits of the HSC program should be reevaluated when at least 3 years of crash data become available.

The systematic review of crash data that drives the HSC program has a number of tangential benefits. The crash databases and analyses developed for the HSC program have been used to support a variety of other VDOT projects that need safety data, including the I-81 draft environmental impact statement, various local public hearings and safety committees, and other requests for safety improvements submitted to the central office. As an example, the HSC analysis was used to support the installation of shoulder rumble strips along a section of I-77 where there was a high incidence of run-off-the-road crashes.

At this point, however, it is impossible to quantify the benefits of the HSC program because of the limited amount of data available. More data need to become available before the safety benefits of the program can be determined. This issue should be revisited once at least 3 years of data are available following HSC installation at multiple sites.

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APPENDIX A: CODE OF VIRGINIA SECTIONS PERTAINING TO HSCS

§ 33.1-223.2:8. Highway safety corridor program.

The Commissioner shall establish a highway safety corridor program, under which a portion of Virginia primary system highways and interstate system highways may be designated by the Commissioner as highway safety corridors, to address highway safety problems through law enforcement, education, and safety enhancements. In consultation with the Department of Motor Vehicles and the Superintendent of State Police, the Commissioner shall establish criteria for the designation and evaluation of highway safety corridors, to include a review of crash data, accident reports, type and volume of vehicle traffic, and engineering and traffic studies. The Commissioner shall hold a public hearing prior to the adoption of the criteria to be used for designating a highway safety corridor. The Commissioner shall hold a minimum of one public hearing before designating any specific highway corridor as a highway safety corridor. The public hearing or hearings for a specific corridor shall be held at least 30 days prior to the designation at a location as close to the proposed corridor as practical.

The Department shall erect signs that designate highway safety corridors and the penalties for violations committed within the designated corridors.

(2003, c. 877.)

§ 46.2-947. Violations committed within highway safety corridor; report on benefits.

Notwithstanding any other provision of law, the fine for any moving violation of any provision of this chapter while operating a motor vehicle in a designated highway safety corridor pursuant to § 33.1-223.2:8 shall be no more than $500 for any violation which is a traffic infraction and not less than $200 for any violation which is a criminal offense. The otherwise applicable fines set forth in Rule 3B:2 of the Rules of the Supreme Court shall be doubled in the case of a waiver of appearance and a plea of guilty under § 16.1-69.40:1 or § 19.2-254.2 for a violation of a provision of this chapter while operating a motor vehicle in a designated highway safety corridor pursuant to § 33.1-223.2:8. The Commissioner shall report, on an annual basis, statistical data related to benefits derived from the designation of such highway safety corridors. This information may be posted on the Virginia Department of Transportation's official website. Notwithstanding the provisions of § 46.2-1300, the governing bodies of counties, cities and towns may not adopt ordinances providing for penalties under this section.

(2003, c. 877.)

APPENDIX B: EXAMPLE SUMMARY REPORT FOR A CANDIDATE HSC

Region 1 Candidate HSC #7: I-81 from MP 310 to MP 319

Length: 9 miles
Jurisdictions Affected: City of Winchester, Frederick County (Staunton District)

Table B-1. I-81 from MP 310 to MP 319 Crash Summary

Year	Number of Crashes	Average Number of Crashes/Mile/Year	EPDOs	Average EPDOs/Mile/Year	Overall Crash Rate (per 100 MVMT)	Truck Crash Rate (per 100 MVMT)
2000	72	8.0	212	23.6	48.4	61.1
2001	91	10.1	381	42.3	62.7	65.0
2002	90	10.0	375	41.7	56.4	77.6
Total	**253**	**9.4**	**968**	**35.9**	**55.8**	**67.9**
Region	**7,821**	**5.4**	**29,552**	**20.4**	**44.2**	**38.8**

Table B-2. I-81 from MP 310 to MP 319 Crash Severity Summary

Year	PDOs		Injury		Fatal	
	Number	Percent	Number	Percent	Number	Percent
2000	52	72.2	20	27.8	0	0
2001	53	58.2	36	39.6	2	2.2
2002	51	56.7	38	42.2	1	1.1
Total	**156**	**61.7**	**94**	**37.2**	**3**	**1.2**
Region	**4,875**	**62.3**	**2,853**	**36.5**	**93**	**1.2**

Table B-3. I-81 MP 310 to MP 319 Crash Type Summary

Crash Type	Percentage of Crashes
Fixed Object–Off Road	32.7
Rear End	26.5
Sideswipe–Same Direction	23.7
Non-collision	7.2
Deer/Other Animal	7.2
All Other Crashes	2.8

Table B-4. I-81 MP 310 to MP 319 Major Factors in Crashes

Major Factor	Percentage of Crashes
Driver Inattention	61.5
Driver Speeding	23.4
Driver Handicap	6.2
Driver Under the Influence of Alcohol or Drugs	5.9
Road Slick	2.2
All Other Factors	0.7

APPENDIX C: INITIAL RANKING OF CANDIDATES BY REGION

Table C-1. Region 1 Rankings Based on Crash Rate, 2000-2002 data

Ranking	Site	Crash Rate (Crashes per 100 Million VMT)
1	I-581 from MP 0 to 6	91.5
2	I-81 from MP 295 to 302	64.1
3	I-77 from MP 0 to 17	56.1
4	I-81 from MP 310 to 319	55.8
5	I-81 from MP 127 to 142	55.1
6	I-81 from MP 90 to 99	50.4
7	I-81 from MP 3 to 10	50.2
8	I-81 from MP 244 to 251	47.4

Table C-2. Region 1 Rankings Based on EPDO Density, 2000-2002 data

Ranking	Site	Average Number of EPDOs/Mile/Year
1	I-581 from MP 0 to 6	69.7
2	I-81 from MP 310 to 319	35.9
3	I-81 from MP 127 to 142	34.1
4	I-81 from MP 244 to 251	32.1
4	I-81 from MP 3 to 10	32.1
6	I-81 from MP 295 to 302	31.5
7	I-81 from MP 90 to 99	28.4
8	I-77 from MP 0 to 17	26.6

Table C-3. Region 1 Combined Rankings, 2000-2002 data

Ranking	Site	Normalized Rate Score	Normalized EPDO Score	Combined Score
1	I-581 from MP 0 to 6	100.0	100.0	200.0
2	I-81 from MP 295 to 302	70.1	45.2	115.3
3	I-81 from MP 310 to 319	61.0	51.5	112.5
4	I-81 from MP 133 to 142	60.2	48.9	109.1
5	I-81 from MP 3 to 10	54.9	46.1	101.0
6	I-77 from MP 0 to 17	61.3	38.2	99.5
7	I-81 from MP 244 to 251	51.8	46.1	97.9
8	I-81 from MP 90 to 99	55.1	40.7	95.8

Table C-4. Region 2 Rankings Based on Crash Rate, 2000-2002 data

Ranking	Site	Average Number of EPDOs/Mile/Year
1	I-264 from MP 1 to MP 19	202.8
2	I-64 from MP 260 to MP 297	155.6
3	I-95 from MP 71 to MP 83	147.5
4	I-64 from MP 181 to MP 188	106.1
5	I-95 from MP 50 to MP 56	98.2
6	I-64 from MP 246 to MP 252	88.1

Table C-5. Region 2 Rankings Based on EPDO Density, 2000-2002 data

Ranking	Site	Crash Rate (Crashes per 100 Million VMT)
1	I-264 from MP 1 to MP 19	150.0
2	I-95 from MP 71 to MP 83	124.6
3	I-64 from MP 260 to MP 297	117.7
4	I-95 from MP 50 to MP 56	104.4
5	I-64 from MP 246 to MP 252	103.7
6	I-64 from MP 181 to MP 188	95.7

Table C-6. Region 2 Combined Rankings, 2000-2002 data

Ranking	Site	Normalized Rate Score	Normalized EPDO Score	Combined Score
1	I-264 from MP 1 to MP 19	100	100	200
2	I-95 from MP 71 to MP 83	83.1	72.7	155.8
3	I-64 from MP 260 to MP 297	78.5	76.7	155.2
4	I-95 from MP 50 to MP 56	69.6	48.4	118.0
5	I-64 from MP 181 to MP 188	63.8	52.3	116.1
6	I-64 from MP 246 to MP 252	69.1	43.4	112.5

Table C-7. Region 3 Rankings Based on EPDO Density, 2000-2002 data

Ranking	Site	Average Number of EPDOs/Mile/Year
1	I-95 from MP 165 to MP 179	263.2
2	I-495 from MP 0 to MP 5	246.9
3	I-395 from MP 0 to MP 10	229.2
4	I-66 from MP 58 to MP 69	220.2
5	I-95 from MP 149 to MP 159	180.5

Table C-8. Region 3 Rankings Based on Crash Rate, 2000-2002 data

Ranking	Site	Crash Rate (Crashes per 100 Million VMT)
1	I-95 from MP 165 to MP 179	131.6
2	I-66 from MP 58 to MP 69	115.8
3	I-95 from MP 149 to MP 159	113.9
4	I-395 from MP 0 to MP 10	111.7
4	I-495 from MP 0 to MP 5	103.2

Table C-9. Region 3 Combined Rankings, 2000-2002 data

Ranking	Site	Normalized Rate Score	Normalized EPDO Score	Combined Score
1	I-95 from MP 165 to MP 179	100	100	200
2	I-495 from MP 0 to MP 5	78.4	93.8	172.2
3	I-395 from MP 0 to MP 10	84.9	87.1	172.0
4	I-66 from MP 58 to MP 69	88.0	83.7	171.7
5	I-95 from MP 149 to MP 159	86.6	68.6	155.2

APPENDIX D: EXAMPLES OF PRIMARY SITES SELECTED USING CRITICAL RATE METHOD FOR CULPEPER AND HAMPTON ROADS DISTRICTS

Table D-1. Candidate Primary HSCs in Culpeper District, 2002-2004 Data

Rank	Route	Mileposts		Length (Mi)	Crashes			Crash Rate (per 100M VMT)	Critical Rate (per 100M VMT)	Ratio
		Start	End		Total	Injury	Fatal			
1	US 29	138.62	149	10.38	1340	390	3	270.93	122.24	2.216
2	SR 20	40.16	50	9.84	175	64	3	285.4	196.58	1.452
3	US 211	24	31	7	56	29	3	320.33	230.87	1.387
4	SR 53	0	18.28	18.28	299	121	3	238.75	180.82	1.320
5	US 250	73	93	20	439	128	4	233.33	180.24	1.295
6	US 250	97.83	103	5.17	333	128	4	208.88	165.24	1.264
7	SR 20	28	37.59	9.59	225	67	5	219.8	181.06	1.214
8	SR 22	2	11	9	95	44	0	236.51	203.4	1.163
9	US 250	105	110	5	63	29	0	242.22	216.24	1.120
10	US 211	46	51	5	71	25	1	169.9	152.98	1.111
11	US 522	17	22	5	47	20	0	252.98	228.42	1.108
12	SR 22	12	18	6	31	14	1	274.92	251.07	1.095
13	SR 28	0	5	5	109	39	0	214.94	197.63	1.088
14	SR 6	28	34	6	26	9	1	278.74	261.4	1.066
15	US 15	116	122	6	77	32	1	202.14	196.61	1.028
16	US 15	108	113	5	57	21	1	216.02	215.77	1.001

Table D-2. Candidate Primary HSCs in Hampton Roads District, 2002-2004 Data

Rank	Route	Mileposts		Length (Mi)	Crashes			Crash Rate (per 100M VMT)	Critical Rate (per 100M VMT)	Ratio
		Start	End		Total	Injury	Fatal			
1	US 17	57.46	68	10.54	816	339	1	181.36	105.44	1.720
2	SR 10	83	91.32	8.32	257	132	3	264.14	153.72	1.718
3	SR 337	1.62	12.96	11.34	281	144	8	259.95	160.4	1.621
4	SR 178	0	11.51	11.51	64	33	2	301.08	196.9	1.529
5	SR 187	0	5	5	25	11	2	373.67	253.21	1.476
6	SR 125	0	6.24	6.24	54	22	2	291.95	203.41	1.435
7	SR 316	0	9.49	9.49	94	42	2	239.14	179.91	1.329
8	SR 175	0	6	6	105	44	1	225.64	175.9	1.283
9	US 60	230	236.83	6.83	193	87	2	146.76	117.97	1.244
10	SR 199	9	14.13	5.13	182	62	3	160.87	142.66	1.128
11	US 13	5	16	11	187	83	2	165.55	148.29	1.116
12	US 58	459	467	8	294	127	1	123.14	111.81	1.101
13	US 17	39	47	8	217	81	0	129.82	118.38	1.097
14	US 60	243	248	5	101	49	1	161.96	152.33	1.063
15	US 13	81	88	7	119	40	1	124.21	119.56	1.039
16	SR 301	16	25	9	40	17	0	175.82	169.39	1.038
17	SR 30	55	60	5	53	24	1	148.41	145.93	1.017
18	US 13	129	134	5	138	55	4	125.02	124.01	1.008