Roadway Safety Data Program


# DEVELOPING AND USING STATE-SPECIFIC SAFETY PERFORMANCE FUNCTIONS (SPFS) IN VIRGINIA

## ROADWAY SAFETY DATA AND ANALYSIS

**CASE STUDY**

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# ACKNOWLEDGEMENTS

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| Name | Title | Department | Email/Phone# |
|---|---|---|---|
| Anne Booker | Assistant Regional Traffic Engineer | Virginia DOT | anne.booker@vdot.virginia.gov<br>504.375.0143 |
| Mark Cole | Assistant Division Administrator – Highway Safety | Virginia DOT | mark.cole@vdot.virginia.gov<br>804.786.4196 |
| Jeff Kuttesch | Richmond Area Traffic Engineer | Virginia DOT | jeffrey.kuttesch@vdot.virginia.gov<br>804.524.6114 |
| Young-Jun Kweon | Senior Research Scientist | Virginia DOT | young-jun.kweon@vdot.virginia.gov<br>434.293.1949 |
| In-Kyu Lim | HSIP Data Analysis Team Leader | Virginia DOT | in-kyu.lim@vdot.virginia.gov<br>804.786.3887 |
| Bob Rasmussen | Program Administration Manager III | Virginia DOT | robert.rasmussen@vdot.virginia.gov<br>804.786.6219 |
| Virginia Department of Transportation<br>Traffic Engineering Division<br>1401 East Broad Street<br>Richmond, VA 23219 | | | |

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# ACRONYMS

| | |
|---|---|
| EB | Empirical Bayes |
| FTE | Full-Time Equivalent |
| HSIP | Highway Safety Improvement Program |
| HSM | Highway Safety Manual |
| PSI | Potential for Safety Improvement |
| SPF | Safety Performance Function |
| TSN | Target Safety Needs |
| VCTIR | Virginia Center for Transportation Innovation and Research |
| VDOT | Virginia Department of Transportation |

# EXECUTIVE SUMMARY

The Virginia Department of Transportation (VDOT) emphasizes data-driven decision-making and desires to improve safety and safety data. From this desire, VDOT implemented a comprehensive set of State-specific Safety Performance Functions (SPFs) covering 98 percent of its State-maintained roadway locations. The impetus for VDOT developing their own SPFs and analytical tools arose from the decision that AASHTOWare Safety Analyst™ did not meet their needs. VDOT developed State-specific SPFs using historical crash, traffic, and roadway inventory data. SPF developers worked closely with engineers throughout the development process to see whether each SPF was implementable for all types of improvements (spot, corridor, and systemic). To date, VDOT has developed 24 SPFs covering a majority of roadway facilities, including two-lane roads, intersections, and freeways/multi-lane highways.

After performing network screening, the VDOT central office identifies the top 100 sections and top 100 miles of segments with the largest Potential for Safety Improvement (PSI). The list is then sent to the district engineers who determine which sites to prioritize based on practical experience and knowledge of their area. VDOT has noted several benefits of Virginia's SPF implementation effort. For example, the advanced data-driven process leads to better use of funds, benefits for both systemic and spot improvements are quantifiable, VDOT can better manage public concerns, and VDOT can compare locations to prioritize projects. The SPF development team conducts training (including an annual "roadshow" to all nine districts) and hosts webinars to ensure district engineers understand the methodology and how to use the SPFs. VDOT has not mandated the use of SPFs and PSIs by the districts because the process of introducing a new methodology takes time, but the district engineers know it is the preferred method for network screening.

## INTRODUCTION

The Virginia Department of Transportation (VDOT) emphasizes data-driven decision-making and makes safety data improvement a focus of continuous effort and long-term planning. From this desire to improve safety and safety data, Virginia implemented a comprehensive set of State-specific Safety Performance Functions (SPFs) covering 98 percent of the State-maintained roadway locations in the Commonwealth. An SPF is a mathematical relationship between crash frequency and site characteristics such as traffic volume, segment length, and other roadway attributes. VDOT developed State-specific SPFs using historical Virginia crash, traffic, and roadway inventory data separately for each grouping of roadway locations based on homogeneous roadway characteristics. The SPFs are statistical functional forms and estimate the average crash frequency for a specific location by traffic volume and segment lengths. Actual crash frequency for any location can be compared to the SPF for locations of that type to see if, for the level of traffic volume, the location has more than the predicted number of crashes.

VDOT incorporates the comparisons of actual- to predicted-crash frequencies in its network screening and provides district engineers with a list of the top 100 intersections and top 100 miles of roadway segments drawn from those locations that are above the SPF. In other words, these locations have more crashes than other similar locations for the same level of traffic volume. VDOT has developed algorithms capable of screening the entire roadway network and has recently begun implementing the algorithms for prioritizing Virginia's roadways for safety improvement.

The purpose of this case study is to describe the successes and ongoing challenges related to developing and implementing a comprehensive set of State-specific SPFs in Virginia.

## BACKGROUND

VDOT maintains 58,430 centerline miles of roadway, which comprises approximately 78 percent of the 74,748 centerline miles of public roadway in Virginia. VDOT also maintains data in the Roadway Inventory for 85,824 (95 percent) of the 90,614 intersections in the Commonwealth.

Staff from Virginia Center for Transportation Innovation and Research (VCTIR)—a joint program of VDOT and the University of Virginia—and the VDOT Traffic Engineering Division worked together to develop the Virginia-specific SPFs and conduct training for VDOT District engineers.

Prior to the Virginia-specific SPF development effort, VDOT purchased a license for AASHTOWare Safety Analyst™ in 2009, but subsequently decided that the software did not meet their needs. VDOT differs from most State transportation departments because it

maintains such a large percentage of the roadway miles, including secondary roads. Consequently, the roadway database is extensive. To manage this network, VDOT divides the Commonwealth into nine districts. Using Northern Virginia as a test district, VDOT identified 9,000 errors in the AASHTOWare Safety Analyst™ records that would have required manual review in order to correct the problems. This was the impetus for VDOT to develop their own SPFs and analytic tools.

VDOT developed SPFs using a standard methodology in which staff would collect data, filter the data by facility types and urban/rural designation, then develop the SPFs for specific categories of roadway. VDOT, VCTIR, and Traffic Engineering staff worked together from the beginning of the SPF development program. Whenever the district engineers asked to implement the SPFs for a special purpose/analysis (including spot, corridor, and systemic improvements), the development team and the engineer determined if the SPF was implementable—meaning it could be used in all types of improvements. If VDOT could not use the SPF in a systemic fashion, the SPF was not used. To date, the project has resulted in 24 SPFs covering the majority of roadway locations managed by VDOT. Figure 1 shows which SPFs were developed first through 2014.

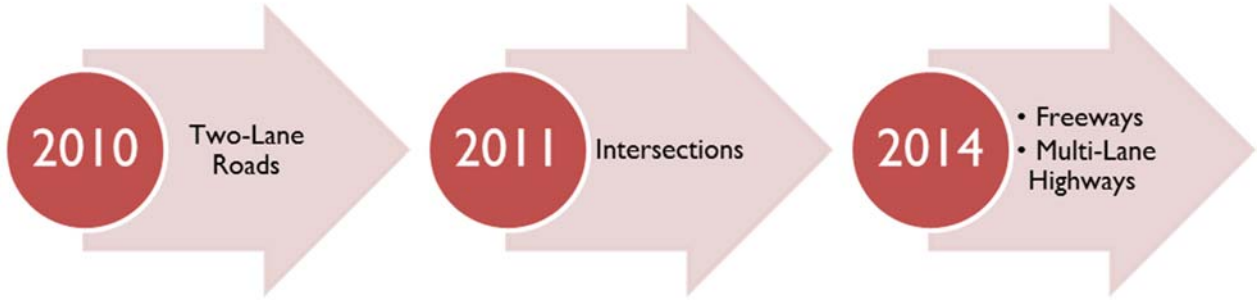


**Figure 1. Timeline of SPF development.**

Through this process, VDOT found that there were fewer obstacles advancing the use of SPFs when decision-makers understand the development process and how SPFs are applied. VDOT continues to strive for all districts to use Virginia-specific SPFs as the primary resource to develop Highway Safety Improvement Projects (HSIP) in Virginia.

## OBJECTIVE

Virginia's SPF implementation effort strives to:

- Identify intersections and segments that have the most potential for improvement.
- Allow district engineers to select appropriate project locations by advanced screening results.

- Select and prioritize projects with more efficiency and therefore, better allocate funds.
- Support before-after analysis to quantify the safety benefit once projects are completed.

## AUDIENCE

This case study may be of interest to the following audiences:

- State Department of Transportation: Safety Engineering, Design, Planning, Maintenance, GIS, and Asset Management Units.
- Local and Regional: City and County Public Works/Engineering/Transportation Departments, Metropolitan Planning Organizations, and Regional Planning Commissions.
- Local Technical Assistance Programs.
- Consultants and private industries involved in safety.

## SPF USE IN SAFETY DECISIONMAKING

VDOT developed their SPFs using the five years of historical crash data (2004-2008). For each facility/location type, VDOT developed two separate SPFs: one for total crashes and the other for fatal+injury crashes. VDOT developed SPFs for the following types of roadway facilities:

- Two-lane roads: Two types (rural and urban segments)
- Intersections: Eight types (rural/urban; three-leg/four-leg; minor-road stop control/signal control intersections)
- Multilane highways: Four types (rural/urban; undivided/divided segments)
- Freeways: Ten types (rural basic-area/interchange-area segments with four/six+ lanes; urban basic-area/interchange area segments with four/six/eight+ lanes)

In network screening, VDOT uses the empirical Bayes (EB) Method to estimate the expected long-term crash frequency at a site. In 2013 and 2014, VDOT used the most recent three years of crash data (2010-2012) to calculate the Potential for Safety Improvement (PSI). The PSI is the expected number of crashes for the site minus the predicted number of crashes based on the SPF for that facility type. A site with a positive PSI warrants examination and those with the highest PSI values should be considered high priority. As with SPFs, VDOT calculates the PSI for total crashes and fatal+injury crashes for each site. The most recent three years (2010-2012) of data were used for calculating PSIs for total crashes and fatal+ injury crashes. Sites with high value in at least two years for both total and fatal+injury PSIs were selected for consideration for Virginia's Highway Safety Improvement Program (HSIP). Those sites were called Target Safety Need (TSN) sites. VDOT identified 2,358 intersections and 2,744 miles of segments as TSN sites for Virginia's HSIP. All nine districts in Virginia have undertaken numerous projects

from the list of TSN sites, most of them being systemic in nature (i.e., low-cost treatments applied across multiple sites with similar characteristics).

## GAINING INTERNAL/LEADERSHIP'S SUPPORT

To gain executive support for the new SPF methodology, the development team met with many high-ranking staff in VDOT, where the development team fielded many questions about the methodology. Those ranking above the State traffic engineer (i.e., the chief engineer level) were largely concerned that traffic engineers had an effective method for picking the most suitable projects and prioritizing those projects. The team used various graphics (e.g., graphs, tables, formulae, maps) when explaining the methodology, which was an effective strategy for gaining buy-in from the high-ranking staff with limited knowledge or experience with highway safety. For example, the team used slides, such as Figure 2 and Figure 3, to explain the methodology.

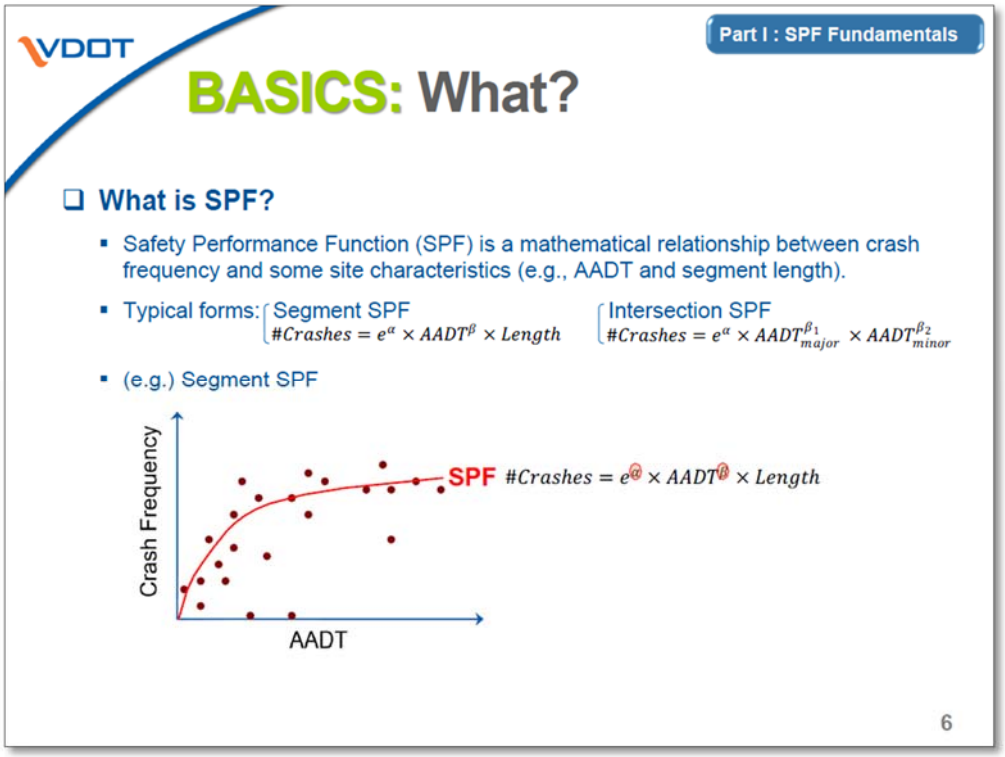


**Figure 2. Example of a slide used by the SPF developers.**

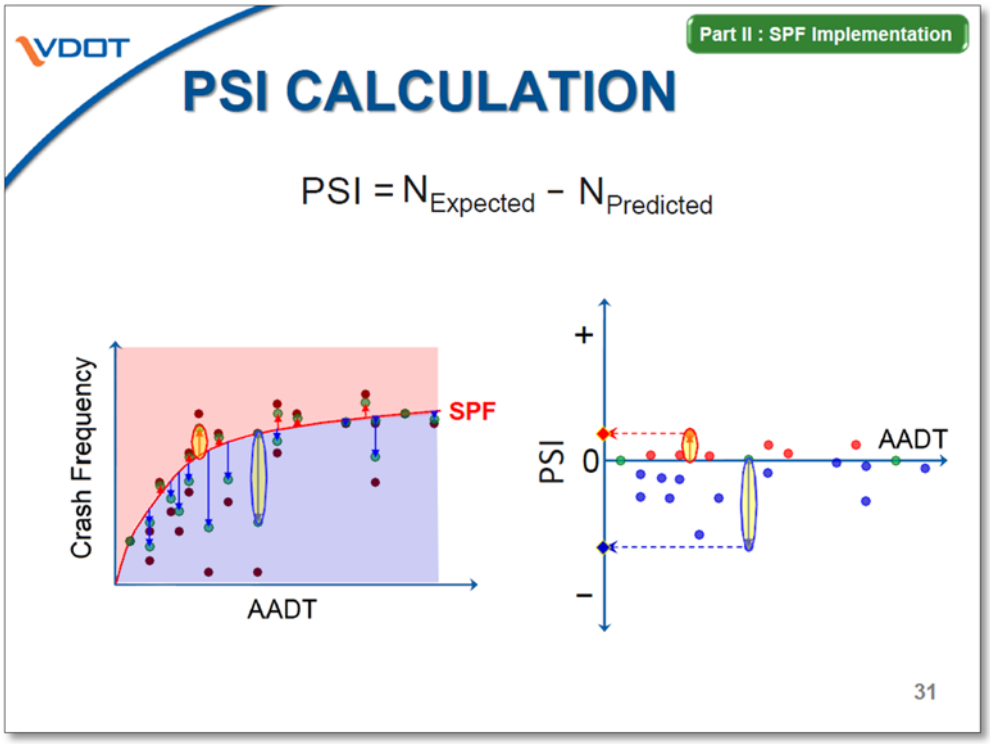


**Figure 3. Example of a slide used by the SPF developers.**

After gaining executive support, the SPF development team met with the district engineers to demonstrate how the methodology works and how the data can be used. At first, the SPF methodology was confusing for many of the district engineers, but several webinars and training sessions have assisted the engineers become more comfortable with using SPFs.

## RESULTS

After performing the network screening and determining the PSI values, the central office identifies the top 100 sections and top 100 miles of segments with the largest PSI. The list is then disseminated to the district engineers who then determine which sites to prioritize based on practical experience and knowledge in the area.

## RESULTS SUMMARY

The Highway Safety Administrator was responsible for promoting the program to executive level staff internally, which included conversations and presentations demonstrating the following SPFs process and benefits.

## Funding

The budget for developing the SPFs is built into staff members' salary and comes from the VDOT budget. The cost to implement and maintain the program is approximately equivalent to a full-time engineering position.

## Benefits

VDOT identified the following benefits of Virginia's SPF Implementation:

- Advanced data-driven process leads to better use of VDOT funds.
- Potential benefits from *both* systemic and spot improvements are quantifiable.
- Districts can better prioritize public concerns by using crash data to determine if treatments are warranted.
- Districts can compare intersections or segments with similar characteristics to help prioritize projects.
- Districts can use PSI information to identify characteristics of safer intersections or segments that may be implemented as countermeasures at other locations with higher PSI values.
- District Staff have a better understanding of SPFs and PSI through training from central office staff

## Barriers and How They Were Overcome

New strategies and technologies are often met with resistance and VDOT found that many district engineers were initially unsure of how to apply SPFs. The SPF development team overcame this barrier by conducting numerous training sessions and webinars. The team also established an annual "roadshow," in which they spend 10 days a year traveling to each of the nine districts to discuss new safety data, review HSIP projects, go through district-level data and the network screening process, and present information on how to fund new safety projects. This annual meeting gives district engineers an opportunity to discuss what they learned using SPFs and how SPFs can be used to support decision making in the future.

## Lessons Learned

VDOT's advice to other States interested in developing State-specific SPFs improving their safety decision-making process is to start slow and be patient. Project staff should expect some reluctance on the part of decision makers adopting new, unfamiliar methodologies. In Virginia, the SPF developers took the time to work with engineers to ensure they fully understood the concepts and how to use the SPFs and PSIs to make better decisions, which in turn made the engineers more accepting of the new practice.

### Next Steps

VDOT has not yet mandated the use of SPFs and PSIs by the Districts. The district engineers know that using SPFs is the preferred method for network screening, but VDOT managers understand that switching to the new method is a process and will take time. VDOT has included an item in its business plan that ensures safety funding is given to highest priority locations using a standardized process in which the central office performs the network screening, identifies locations for improvement, and then develops a way to measure the effectiveness of the treatment.

Beginning this year, VDOT will adopt a "benchmarking" approach to identify sites with negative PSI values (i.e., sites where less crashes occur than are expected). VDOT will compare these locations with sites with similar characteristics, but have a positive PSI, to determine what makes those sites safer.

VDOT learned through a pilot study that HSM SPFs are quite different than the State-specific SPFs, which has been challenging for the district engineers. To address this issue, VDOT plans to launch a project to customize the HSM and conduct trainings for the districts. This training will include State-specific examples using the analytic methods described in the HSM.

In mid-2015, VDOT plans to launch new software that will allow users to search crash data and customize outputs. Users will be able to look at crashes that were associated with different variables (e.g., alcohol, speed, and belted) at a high level. This will allow users to only include relevant variables, which lead to better informed, data-driven decisions. VDOT has also planned to develop SPFs for roadway departure crashes.

## AGENCY CHARACTERISTICS

### Organizational Structure

For the purposes of this case study, VDOT's central staff consists of the Traffic Engineering Division and Executive Staff. These are the practitioners and leaders who, respectively, promoted adoption of HSM-style analytic methods and approved those methods as a part of Departmental policy going forward. The Traffic Engineering Division staff collaborated with the VCTIR researchers to direct development of the Virginia-specific SPFs and the PSI calculations, promote their use by district engineers, and incorporate the analyses into the Department's network screening and project selection procedures. District engineers are responsible for selecting and justifying safety projects in their geographic areas. They have the option to select projects using methods other than strict adherence to the PSI-based prioritizations; however, they must be able to justify their decisions, preferably using a data-driven approach.

### Personnel

The SPF development team worked on the effort as part of their normal duties and did not require assistance from contractors or other outside help. The combined effort to support Virginia's SPF Implementation is equal to having one full-time equivalent (FTE) staff member.

## REFERENCES

The following resources were consulted in development of this case study:

1. Mark Cole and Bob Rasmussen. Telephone Interview. December 15, 2014
2. In-Kyu Lim and Young-Jun Kweon. Telephone Interview. December 15, 2014
3. Anne Booker. Telephone Interview. December 18, 2014
4. Jeff Kuttesch. Telephone Interview. December 18, 2014

## AGENCY CONTACT INFORMATION

Anne Booker
Assistant Regional Traffic Engineer
Southwest Region Operations
Virginia Department of Transportation
1596 Deorah Lane
Salem, VA 24153
Anne.Booker@vdot.virginia.gov
540.375.0143

Mark Cole
Assistant Division Administrator – Highway Safety
Traffic Engineering Division
Virginia Department of Transportation
1401 East Broad Street
Richmond, VA 23219
Mark.Cole@vdot.virginia.gov
804.786.4196

Jeff Kuttesch
Richmond Area Traffic Engineer
Central Region Operations
Virginia Department of Transportation
2201 West Hundred Road
Chester, VA 23831
Jeffrey.Kuttesch@vdot.virginia.gov

804.524.6114

Young-Jun Kweon
Senior Research Scientist
Virginia Center for Transportation Innovation and Research (VCTIR)
Virginia Department of Transportation
530 Edgemont Road
Charlottesville, VA 22903
Young-Jun.Kweon@vdot.virginia.gov
434.293.1949

In-Kyu Lim
HSIP Data Analysis Team Leader
Traffic Engineering Division
Virginia Department of Transportation
1401 East Broad Street
Richmond, VA 23219
In-Kyu.Lim@vdot.virginia.gov
804.786.3887

Bob Rasmussen
Program Administration Manager II
Traffic Engineering Division
Virginia Department of Transportation
1401 East Broad Street
Richmond, VA 23219
Robert.Rasmussen@vdot.virginia.gov
804.786.6219