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Incorporating Safety into the Regional Planning Process in Virginia: Volume II: a Resource Guide

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16. Abstract:

Motor vehicle crashes have an annual societal cost of $230 billion, and one way to reduce this cost is to incorporate safety directly into the long-range transportation planning process. This resource guide presents some ways through which safety and planning may be integrated and is targeted toward Virginia Department of Transportation (VDOT) district planners, metropolitan planning organizations, and planning district commissions.

The guide does not constitute a VDOT policy or regulation; rather, it is a set of best practices designed to accompany, rather than duplicate, the regional transportation planning process. The guide describes eight independent steps for integrating safety into the regional transportation planning process and provides one or more Virginia-specific examples for each step. The steps are as follows:

1. Develop a vision statement, goals, and objectives that directly incorporate safety.
2. Use diverse stakeholders to identify alternatives and evaluate their utility.
3. Use safety-related performance measures to assess deficiencies.
4. Acquire data within the time constraints faced by the planner.
5. Analyze data with available resources and thus select higher impact projects.
6. Prioritize projects to determine the largest expected crash avoidance given limited funds.
7. Identify alternative funding sources for safety-related projects.
8. Monitor the safety impacts of implemented projects.

This guide constitutes Volume II of the two-volume report *Incorporating Safety Into the Regional Planning Process in Virginia*. Volume I describes how the guide was developed.

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FINAL REPORT

INCORPORATING SAFETY INTO THE REGIONAL PLANNING PROCESS IN VIRGINIA: VOLUME II: A RESOURCE GUIDE

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ABSTRACT

Motor vehicle crashes have an annual societal cost of $230 billion, and one way to reduce this cost is to incorporate safety directly into the long-range transportation planning process.[1] This resource guide presents some ways through which safety and planning may be integrated and is targeted toward Virginia Department of Transportation (VDOT) district planners, metropolitan planning organizations, and planning district commissions.

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TABLE OF CONTENTS

ACRONYMS

AADT	average annual daily traffic
ADT	average daily traffic
AMF	accident modification factor
BCI	bicycle compatibility index
BLOS	bicycle level of service
CAT	crash analysis tools
CLRP	Constrained Long-range Plan
CODES	Crash Outcome Data Evaluation System
CRF	crash reduction factor
DMV	Department of Motor Vehicles
DOT	Department of Transportation
EMS	emergency medical services
FHWA	Federal Highway Administration
GIS	geographic information system
HRMPO	Harrisonburg-Rockingham Metropolitan Planning Organization
HSM	*Highway Safety Manual*
HTRIS	Highway Traffic Records Information System
LOS	level of service
MPO	Metropolitan Planning Organization
MUTCD	*Manual on Uniform Traffic Control Devices*
NHTSA	National Highway Traffic Safety Administration
PDC	planning district commission
PDO	property damage only
PLOS	pedestrian level of service
RNS	roadway network system
RSA	road safety audit or road safety assessment
RSAR	road safety audit review
SAFETEA-LU	Safe, Accountable, Flexible Efficient Transportation Equity Act: A Legacy for Users
SHSP	Strategic Highway Safety Plan

SPS	Statewide Planning System
SPSS	Statistical Package for the Social Sciences
SQL	Structured Query Language
STIP	State Transportation Improvement Program
SYIP	Six-Year Improvement Program
TCSP	Transportation, Community, and System Preservation
TMS	traffic monitoring system
TED	[VDOT’s] Traffic Engineering Division
TIP	Transportation Improvement Program
TMPD	[VDOT’s] Transportation Mobility Planning Division
TRB	Transportation Research Board
TWLTL	two-way left-turn lane
VDOT	Virginia Department of Transportation
VMT	vehicle miles traveled
VTRC	Virginia Transportation Research Council

OVERVIEW

The Metropolitan Transportation Planning Final Rule (C.F.R. Parts 450 and 500) requires that the metropolitan transportation planning process address several factors to "increase the safety of the transportation system for motorized and non-motorized users." This resource guide is designed to enhance this integration of safety into the regional transportation planning process; such an enhancement is known as transportation safety planning.[1] The audience for this guide is metropolitan planning organizations (MPOs), planning district commissions (PDCs), localities, and the district and central office work units of the Virginia Department of Transportation (VDOT).

The guide describes eight independent steps for integrating safety into the regional transportation planning process and provides one or more Virginia-specific examples for each step. Planners need not use the entire guide but rather may consult individual steps during the development of the Constrained Long-range Plan (CLRP).

The steps are as follows:

1. Develop a vision statement, goals, and objectives that directly incorporate safety.
2. Use diverse stakeholders to identify alternatives and evaluate their utility.
3. Use safety-related performance measures to assess deficiencies.
4. Acquire data within the time constraints faced by the planner.
5. Analyze data with available resources and thus select higher impact projects.
6. Prioritize projects to determine the largest expected crash avoidance given limited funds.
7. Identify alternative funding sources for safety-related projects.
8. Monitor the safety impacts of implemented projects.

The guide was developed using input from Virginia MPOs and PDCs, VDOT staff, and related literature. The development of the guide is described in Volume I of this report: *Incorporating Safety Into the Regional Planning Process in Virginia: Volume I: Development of a Resource Guide*.[2]

Throughout this guide, mention is often made of a survey of MPOs and PDCs that was undertaken in 2008 to help develop the guide. The survey instrument, the recipients, and the survey responses are provided in Volume I.[2] A brief summary is provided here. The 23-question survey was sent to the 23 MPOs/PDCs in Virginia, and each provided a response; response rates for individual questions varied from 78 to 100 percent. The survey concerned how MPOs and PDCs incorporate safety in the planning process in terms of regional plan development (e.g., establishing goals, identifying alternatives, and measuring performance); outreach to other entities; project selection; and resources and challenges (e.g., availability of crash data). The collective responses to each survey question are provided in Appendix B of Volume I.[2]

Contents At a Glance

The resource guide contains eight numbered sections, which correspond to the eight steps to fulfill the requirement for integrating safety into the regional transportation planning process. Each section answers a fundamental question regarding one of the eight steps. The integration of the steps, the sections of the resource guide, and the fundamental questions asked is shown in Table 1.

A list of acronyms used in the guide (p. vii), a list of references used in the guide (p. 77), an appendix summarizing how the sections of the guide were developed (p. 85) and an index (p. 87) are also provided.

Table 1. Integration of Steps for Integrating Safety, Numbered Section of the Resource Guide, and Question Answered by Section of the Resource Guide

Step in Integrating Safety	Numbered Section of Resource Guide	Question Answered	Page No.
1. Develop a vision statement, goals, and objectives that directly incorporate safety.	1. Vision Statement, Goals, and Objectives	How can I identify measurable safety objectives for a project?	5
2. Use diverse stakeholders to identify alternatives and evaluate their utility.	2. Stakeholders	Who should be involved in the selection of projects?	9
3. Use safety-related performance measures to assess deficiencies.	3. Performance Measures	Are changes in crashes the only indicator of performance?	15
4. Acquire data within the time constraints faced by the planner.	4. Data Needs	Where can I find detailed crash data?	23
5. Analyze data with available resources and thus select higher impact projects.	5. Data Analysis	Where can I find tools to analyze data?	37
6. Prioritize projects to determine the largest expected crash avoidance given limited funds.	6. Prioritization	How can I select projects that must be addressed immediately?	53
7. Identify alternative funding sources for safety-related projects.	7. Funding	How can I identify alternative sources of funds for projects?	61
8. Monitor the safety impacts of implemented projects.	8. Monitoring	How can I ensure a project is addressing its need after construction?	67

How the Sections of the Guide Fit Together

The connecting arrows in Figure 1 show how the results of each of the eight steps to integrate safety into transportation safety planning influences the remaining steps. Steps that are performed concurrently or in close sequential order appear in the same row. These rows are:

- *The first row*. The vision statement, goals, and objectives (Step 1) are set by the stakeholders (Step 2) and may cause additional stakeholders to be added.

- *The second row*. Through the vision statement, goals, and objectives, the stakeholders influence Steps 3 through 7. The performance measures (Step 3) used to evaluate candidate projects require the necessary data to be obtained (Step 4) and data analysis (Step 5). For prioritization of projects (Step 6), safety considerations may be

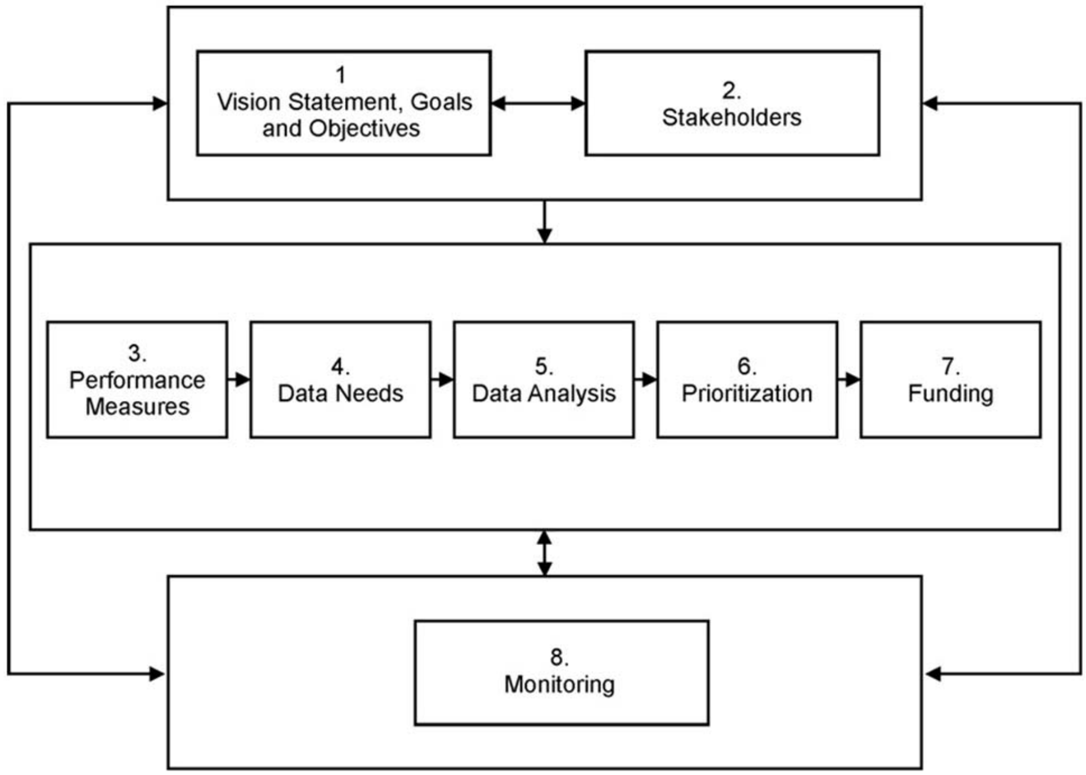

Figure 1. Flowchart Summarizing the Eight Numbered Sections of the Resource Guide

used to rank projects, recognizing that other factors, such as congestion, travel time, and air quality, may also affect project prioritization. Prioritization enables planners to specify the precise role of safety within project selection. Knowledge concerning funding (Step 7) can help identify alternative funding sources for safety-related projects and how to take advantage of such sources.

- *The third row*. Because monitoring and evaluation of projects (Step 8) is intrinsically linked to performance measures (Step 3), Steps 8 and 3 can be performed concurrently.

How to Use This Guide

Each numbered section of the guide, which corresponds to one of the eight steps, as previously mentioned, is divided into four subsections.

1. a *description* of the step
2. a *summary of current practice* regarding the step based on responses to the survey of Virginia MPOs/PDCs described in Volume I[2]
3. at least one *example* of how the step may be performed
4. a list of *selected references that provide additional information* for each step.

SECTION 1: VISION STATEMENT, GOALS, AND OBJECTIVES

Step 1. Develop a vision statement, goals, and objectives that directly incorporate safety. This step requires a minimum of 1 to 2 hours depending on the number of stakeholders involved in developing the vision, goals, and objectives.

1.1. Description of the Step

A *vision statement* describes what a community desires for the future and provides opportunities for public input. It usually comprises the beginning of a planning process and identifies the desired states of prosperity, environmental quality, social equity, and community quality of life.[3] Virginia's vision statement is "to make Virginia's surface transportation system the safest in the nation by 2025."[4] The American Traffic Safety Services Association's vision statement is, in part, to "annually reduce roadway fatalities."[5]

A *goal* is an end result or an end state toward which effort is directed.[6,7] Thus, one goal of a CLRP might be to improve transportation system safety by reducing crash frequency for all users. Goals may also be generalized statements that broadly relate the physical environment to values to which no test for fulfillment can be readily applied, e.g., "to maintain and improve the quality of transportation."[3] Virginia's 2010 goals are "to reduce from 2005 levels, the annual number of injuries and deaths due to motor vehicle crashes in Virginia by 100 deaths and 4,000 injuries by 2010."[4] The American Traffic Safety Services Association cites a goal of zero fatalities.[5]

Objectives are specific and measurable statements that relate to the attainment of goals.[3] Thus, one objective might be to reduce roadway departure crashes by 10 percent over the next 5 years. An objective of Virginia's Strategic Highway Safety Plan (SHSP) is to increase safety belt use among occupants aged 15 through 25.[4]

1.2. Summary of Current Practice Based on the Survey of Virginia MPOs/PDCs

Most survey respondents (21 of 23 MPOs/PDCs) included safety in their CLRP, suggesting that MPOs/PDCs follow the Metropolitan Planning Final Rule and that safety is a priority in the planning process.

Of the 21 respondents who included safety in their CLRP, 19 included safety in the goals and/or objectives and only 8 included safety in the vision statement, suggesting a challenge in explicitly including safety in the vision statement.

The importance of explicitly incorporating safety into the planning process was echoed in an interview with staff of the Central Shenandoah PDC and VDOT's Staunton District. As mentioned in Volume I of this report, interviewees noted that including safety in the vision statement, goals, and objectives would require an MPO/PDC to (1) consider the existing and future conditions of a project, (2) justify its need at the beginning, and (3) estimate the safety consequences of a project.[2]

1.3. Example of How the Step May Be Performed

The SHSP identifies several emphasis areas such as intersection safety, driver behavior, roadside departures, and pedestrian/bicycle safety.[4] This example shows how an MPO/PDC may develop a vision statement, goals, and objectives and then integrate them with specific projects within the pedestrian and bicycle safety emphasis area.

Vision Statement:

Three possible vision statements that could be included in the CLRP are:

1. Every project within the MPO/PDC will reduce the crash risk of all transportation users.

2. We envision a transportation system where it “feels safe” to use any mode of transportation.

3. Zero fatalities: a vision we can live with.[8]

Goals:

Three possible safety-related goals that could be included in the CLRP are:

1. Develop a safe and convenient transportation system serving all modes of travel.

2. Preserve and improve the free flow of traffic and improve the safety of the road system.

3. Reduce annual traffic fatalities and serious injuries by 50 percent by year 2035.[8]

Objectives:

Three possible safety-related objectives are:

1. Prioritize funding requests on the basis of safety by targeting improvement projects to those corridors that exceed the 85th percentile for serious injury crash rate.

2. Decrease pedestrian and bicycle collisions by 20 percent by year 2010.

3. Reduce motor vehicle crash risk by reducing VMT [vehicles miles traveled] by 5 percent over a 5-year period within a specific corridor.

Notice that the vision statements, by themselves, are not directly measurable. They are more likely to be realized if they can be related to more specific goals and objectives that link decisions (e.g., which projects are selected) with outcomes (e.g., changes in crash frequency). The objectives should be measurable, be realistic, and have a time period specified for implementation.[9] The literature illustrates how to link goals to projects[10] and how to determine whether a given goal, such as a 40 percent reduction in fatalities, is feasible within a given time frame.[11]

Integration of Vision Statement, Goals, and Objectives With Specific Projects:

Suppose the CLRP lists several high-priority projects. For each project, the goals and objectives of the project and the CLRP may be included after the project description.[12] An example is shown in Table 1.1 for a single project where the impact of the proposed reconstruction is linked to the goals and objectives cited previously.

Table 1.1. Description of an MPO's Project in the CLRP

Jurisdiction	Rockingham
Urban/ Rural	Urban
ID	64
Project Description	New Major Collector Road: Construct 2-lane major collector connecting Milky Way Drive to proposed Bridgewater Bypass (north of Mt. Crawford Avenue / Dinkel Intersection). Mt. Crawford Avenue will be reconstructed as a standard two-lane urban roadway with sidewalks.
Project Goals	To decrease traffic congestion (by adding an extra lane) and to reduce pedestrian crash risk by providing a separate travel facility. Thus the sidewalk may contribute to Goal 1 (developing a safe transportation system serving all modes of travel).[a]
Project Objectives	The sidewalk may also contribute to Objective 3 (to the extent that the sidewalk encourages walking and hence reduces VMT).[a]

[a] Note that projects may serve multiple goals. For example, because the alternate route to this corridor has 3 (motor vehicle) roadway departure crashes per year, the project may also serve to reduce such crashes.

Role of the MPO/PDC in Setting a Vision Statement, Goals, and Objectives Based on Future Changes:

The MPO/PDC may identify the greatest safety-related needs for the purposes of not only regional planning but also statewide planning. One example is the High Risk Rural Roads Program, which requires states to identify rural roads that are functionally classified as a major, minor, or local collector and that exceed (or are likely to exceed based on increasing traffic volumes) the statewide fatality or severe injury rate for those functional classes.[13] The memorandum explaining the High Risk Rural Roads Program indicates that states should consider safety needs for all eligible facilities "whether state or locally owned"[13]; a list of those eligible intersections and segments is available from VDOT's Traffic Engineering Division (TED).[14] The Federal Highway Administration (FHWA)[13] explicitly noted that it is MPOs and PDCs that may identify those facilities that, in the future, may exceed the statewide average crash rate based on expected growth in traffic volumes, which in turn may result from changes in land development—an area of expertise for MPOs and PDCs.

Thus, the MPO or PDC may be able to use changes in land development to keep state decision makers better informed of potential future crash risks that are not apparent at present.

To this end, the MPO may have a unique capacity to identify objectives that address such future development. For example, a related objective might be as follows:

> "All proposed new developments consisting of more than 100 dwelling units will be served by either a facility that currently has an injury crash rate below the statewide average or a facility that has been improved as a result of recommendations from a road safety audit, road safety audit review, or road safety assessment."

1.4. Selected References That Provide Additional Information for the Step

Examples of Vision Statement and Goal Development

- Meyer, M.D., and Miller, E.J. *Urban Transportation Planning*. McGraw-Hill, New York, 2001.

- Preston, H., and Storm, R. *Minnesota Comprehensive Highway Safety Plan (CHSP)*. St. Paul, 2004. http://www.dot.state.mn.us/trafficeng/safety/chsp/CHSP%20Report%20-%20June2005.pdf. Accessed November 25, 2009.

- Virginia's Surface Transportation Safety Executive Committee. *Virginia's Strategic Highway Safety Plan*: *2006-2010.* Richmond, 2007. http://www.virginiadot.org/info/resources/Strat_Hway_Safety_Plan_FREPT.pdf. Accessed February 20, 2008.

Information on the High Risk Rural Roads Program

- Virginia Department of Transportation, Business Center, Traffic Engineering Division. Highway Safety Improvement Program (HSIP). Richmond, 2009. http://www.virginiadot.org/business/ted_app_pro.asp. Accessed November 25, 2009.

SECTION 2. STAKEHOLDERS

Step 2. Use diverse stakeholders to identify alternatives and evaluate their utility. This step requires 4 to 16 hours per issue depending on how stakeholders are selected and which activities they undertake.

2.1. Description of the Step

A *stakeholder* is an individual, group, or organization that affects, or can be affected by, an organization's actions such as selecting projects to be constructed or initiatives to be implemented. With respect to transportation safety, stakeholders may include individual citizens, community organizations, and the other advocacy groups listed in Table 2.1. One reason so many stakeholders are listed is that each stakeholder may have a particular area of expertise, such as community safety committees, for which local knowledge enables him or her to comment on "neighborhood and school area traffic calming plans, walkability/bikeability assessments of neighborhoods, or EMS plans for the rural areas."[15] Other stakeholders may provide a needed broader perspective; e.g., since children's field of vision is smaller than that of adults,[16] crossings that are likely to be used by children require particular design changes.

Stakeholders play at least two critical roles with respect to planning and safety integration. One role is to identify problems that increase crash risk and provide evidence, positive or negative, for the effectiveness of each countermeasure. As an illustration, consider the problem of fatigued driving: stakeholders might quantify the extent to which driver fatigue influences crash risk and then estimate the impact of diverse countermeasures such as roadside clear zones, shoulder rumble strips, and rest areas. (This role is illustrated in Example 1 in Section 2.3.)

A second role of stakeholders is to prioritize improvements. For example, an EMS provider may offer one perspective on the impact of speed humps as they relate to EMS access and a citizen's advisory committee may offer another perspective on such devices as a traffic calming measure. Participation of both stakeholders helps ensure that the full safety impacts of various decisions are considered. (This role is illustrated in Example 2 in Section 2.3.)

Table 2.1. Examples of Stakeholders

Stakeholder Group	Individual Stakeholders
Public	Individual citizens, advocacy groups (e.g., local community safety committees), private transit providers (e.g., freight, rail, and taxicab operators), local business (e.g., bicycle shops, private developers), neighborhood associations
Federal agencies	Federal Highway Administration, Federal Transit Authority, Federal Rail Administration, Department of Rail and Public Transportation
State agencies	VDOT, PDCs, MPOs, Virginia State Police, EMS, Department of Motor Vehicles, Department of Health, Department of Education, academic institutions
Local and regional agencies	Management, engineers, planners, public affairs, health and education, police and EMS

2.2. Summary of Current Practice Based on the Survey of Virginia MPOs/PDCs

Most survey respondents (22 of 23 MPOs/ PDCs) actively involve stakeholders in their safety planning process; stakeholders include VDOT, PDCs, counties, and citizens. Fewer respondents used other stakeholders such as the Federal Transit Administration, the Department of Motor Vehicles (DMV), private industry, or advocacy groups. Most respondents (18 of 23) use meetings and forums when involving staff from other agencies during the selection of safety projects; slightly less than one-half of respondents use written or telephone communication.

2.3. Examples of How the Step May Be Performed

Example 1. Crashes Related to Driver Fatigue

Stakeholders may identify a potential problem area, such as crashes attributable to driving while fatigued. The planner's role is to provide information that enables stakeholders to (1) define the problem, (2) identify candidate countermeasures, and (3) quantify the impact of such countermeasures to the extent data will allow.

1. Define the Problem:

The problem of fatigued driving may be quantified in two distinct ways:

- *A query with Virginia data showed that the driver condition of "fatigued" or "apparently asleep" was indicated for approximately 3,240 drivers involved in crashes in 2007, which represents 1.3 percent of all drivers involved in a 2007 crash.* A different query with Virginia data showed that of the 28,760 drivers involved in a 2007 crash where some type of driver distraction was noted, 2,370 drivers were classified as having "driver fatigue." Thus the planner might be prepared to indicate that, depending on how crash data are queried, Virginia data suggest that between 2,370 and 3,240 drivers are involved in a crash annually where some indication of drowsy driving is noted and these figures represent approximately 1 percent of all drivers in Virginia crashes.

- *A review of the literature indicates a similar percentage based on national U.S. crash data where 1.5 percent of all crashes "involve drowsiness or fatigue as a principal cause."*[17] However, the same source suggested that this percentage may be low, suggesting instead a percentage of 15 percent based on studies in Britain. Further, a 6-month pilot study of Virginia crashes where one or more drivers had been "inattentive" showed that 17 percent of the crashes involved driver fatigue or drowsiness.[18] Thus the planner might initially indicate that although direct examination of crash data supports the percentage of approximately 1 percent noted previously, it is possible that driver fatigue plays a greater role than this percentage suggests.

2. Identify Candidate Countermeasures:

The National Highway Traffic Safety Administration (NHTSA) and Virginia's SHSP each suggest several countermeasures that can be used to address the problem of driver fatigue, as shown in Table 2.2. The countermeasures are listed in three categories, depending on whether they can be addressed by the driver, vehicle designers, or a state or local transportation agency. Table 2.2 also identifies the effectiveness of each countermeasure based on the literature. Although quantifiable data are best, it is clear that the efficacy of some measures has not been fully documented and thus these unknown impacts are noted in the table.

Table 2.2. Candidate Countermeasures for Driver Fatigue

Category	Countermeasure	Suggested by	Effectiveness
Driver	Napping	NHTSA[a]	Although not as effective as adequate rest, laboratory studies show that 15- to 20-minute naps may improve performance.[19]
	Caffeine	NHTSA	Laboratory tests suggest caffeine may reduce dangerous behaviors for about 1 hour after consumption.[19]
	Medication	NHTSA	These have "limited or no high quality evaluation evidence."[20]
	Manageable shift duties	NHTSA	
Vehicle	In-vehicle alarm systems to detect driver sleepiness	NHTSA	These are identified as an "experimental" technology and have not yet been evaluated.[21]
State or local transportation agency	Rumble strips (centerline and shoulder)	SHSP[b]	Milled shoulder rumble strips have reduced run-off-the-road injury crashes by 18% on rural 2-lane facilities.[22] Centerline rumble strips have reduced crashes on rural 2-lane highways by between 14% and 68% depending on crash type and severity.[23]
	Rest areas and/or parking facilities	SHSP	Direct safety benefits of rest areas could not be pinpointed because of data limitations, but a "preliminary" analysis suggested increased rest area frequency may reduce crashes. [24]
	Education and awareness programs	SHSP	Such programs have been tried widely, but no "valid evaluations" have been performed.[18]
	Roadside clear zones, including proper utility post placement	SHSP	Most (90%) crashes with utility poles (in City of Huntsville, Alabama) occurred within 10 ft of the pavement edge.[25]
	Medians or barriers	SHSP	Facilities with medians generally have a 40% lower crash rate than undivided facilities.[26]
	Installation or addition of guardrail	SHSP	Guardrail may reduce run-off-the-road injury crashes by 47%.[27]

[a] National Highway Traffic Safety Administration. *Drowsy Driving and Automobile Crashes*. Washington D.C., 1998. http://www.nhlbi.nih.gov/health/prof/sleep/drsy_drv.pdf. Accessed August 10, 2009.
[b] Virginia's Surface Transportation Safety Executive Committee. *Virginia's Strategic Highway Safety Plan*: *2006-2010*. Richmond, 2007. http://www.virginiadot.org/info/resources/Strat_Hway_Safety_Plan_FREPT.pdf. Accessed February 20, 2010.

3. Quantify the Impact of Such Countermeasures to the Extent Data Will Allow:

Table 2.2 clearly shows that the effectiveness of several countermeasures is not completely understood. For example, in-vehicle warning systems to alert drivers are an emerging technology that has not yet been evaluated. Thus, countermeasures may need to be prioritized despite the lack of complete information about each. One role a stakeholder may fill is to provide additional information based on his or her expertise regarding the efficacy of a countermeasure in a particular region. For example:

- Private sector freight companies may be able to comment on the supply of parking for commercial vehicle operators.

- VDOT's TED may provide information on the expected costs of rumble strip installation and shoulder widening.

- Federal representatives may be aware of grant programs to encourage collaboration between the public and private sector regarding development of in-vehicle driver warning systems.

- Operators of privately managed facilities, such as commercial truck stops, may be willing to provide information regarding parking use at their sites.

Stakeholders may provide insights that would enable one to understand better the expected impact of countermeasures such as those listed in Table 2.2.[28] For example, *milled* shoulder rumble strips have been shown to be about twice as effective as *rolled* rumble strips at reducing crashes where drivers "drift off the road due to drowsiness, inattention, or distraction" because of the louder noise and stronger vibrations associated with milled strips.[29] In some cases, it may be more productive to provide stakeholders with an initial estimate of impacts, such as that provided in Table 2.2, and then enable stakeholders to provide information that would allow one to modify these impacts to reflect local conditions.

Example 2. Prioritizing Improvements

Stakeholders may also help prioritize improvements. For example, the City of Harrisonburg's Bicycle Plan Review Committee identifies projects to improve bicycle facilities and safety throughout the city.[30] The committee's 11 members are listed in Table 2.3.

Table 2.3. Harrisonburg City Bicycle Plan Review Committee

No.	Stakeholder Group
1	Harrisonburg City Schools
2	Planning and Community Development
3	Individual citizen
4	James Madison University Police Department
5	Planning and Community Development
6	Parks and Recreation Department
7	RMH/Safe Kids[a]
8	Planning Commission
9	Transportation Safety Commission
10	Public Works Department
11	Citizen/Shenandoah Bicycle Company

[a]RMH is thought to mean "Rockingham Memorial Hospital"; however, this acronym is not defined in the plan.

The committee prioritized 11 projects that would need attention within the next 5 years. Each project was ranked as 1 (essential), 2, or 3 (optional). Three such projects and their rankings are described in Table 2.4.

Table 2.4. Prioritized Projects by the City of Harrisonburg's Bicycle Plan Review Committee

Project Title	**Description**	**Projected Cost**	**Priority**
Garbers Church Road Wide Sidewalk or Multi-Use Trail	Construct large sidewalk from Erickson Avenue to Lendale Lane	$725,000	1 (essential)
Old Furnace Road	Multi-use trail paralleling Old Furnace Road from Smithland Road to Vine Street	$462,000	2
South Avenue Bike Lane	Bike lane on South Avenue between South Main Street and South High Street	$3,500	3 (optional)

The precise approach used to prioritize these three particular projects is not known. However, one approach that may be used is the use of performance measures, where the current value of each performance measure for each project is determined and the project that currently has the poorest performance measure is selected for implementation. Three such performance measures—bicycle level of service (BLOS), bicycle and pedestrian crashes, and presence of pedestrian facilities—are shown in Table 2.5 and applied to the three bicycle projects shown in Table 2.4.

Table 2.5. Select Performance Measures for Bicycle-Related Projects Within a Single Locale[a]

Performance Measure	**Garbers Church Road Wide Sidewalk or Multi-Use Trail**	**Old Furnace Road**	**South Avenue Bike Lane**
Bicycle level of service [b, c]	D	C	C
Bicycle and pedestrian crashes	0	0	0
Presence of pedestrian facilities [c]	None	None	None

[a] Other measures, such as community support as shown in Table 2.6, are possible.
[b] This performance measure is fully defined in Step 3. For the purposes of reading this table, a score of "C" indicates a facility that is friendlier to bicyclists than one with a score of "D."
[c] Values were obtained from Virginia's Statewide Planning System (SPS) on October 14, 2009, and reflect conditions exclusively within the City of Harrisonburg.. Crashes were assumed to be zero as no located crashes could be obtained; this may be attributed to the fact that these facilities are not maintained by VDOT.

According to Table 2.5, the project with the poorest current value, based on a review of these three performance measures, is Garbers Church Road, and thus this project may be implemented first as it has the most dire need for improvement. There exists, however, a wide variety of other approaches that may be used to prioritize projects, such as (1) amount of public support; (2) expected impact of each improvement, and (3) other performance measures such as cost per mile. For example, suppose *a region* was prioritizing projects from multiple jurisdictions. In that instance, a performance measure might be *degree of local support*, where points could be awarded, as shown in Table 2.6.

Tables 2.5 and 2.6 show that one contribution a planner can make is to document the approach used to select alternatives. Performance measures can provide stakeholders a common understanding of the pros and cons of each alternative and are detailed in Step 3, as described in Section 3 of the guide.

Table 2.6. Local Support Performance Measure for Bicycle-Related Projects Within Multiple Locales

Role of Project in Local Plan	Points Awarded
Project is not mentioned in local plan	None
Project is mentioned in local plan in a summary manner without supporting details	3
Project is fully described in local plan but impediments to implementation are not discussed	7
Project is fully described and methods for garnering public support and funding are given	10

2.4. Selected References That Provide Additional Information for the Step

Ways to Quantify the Efficacy of Crash Countermeasures

- Federal Highway Administration. *Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes.* Washington, D.C., 2007. http://www.transportation.org/sites/scohts/docs/Roadway%20Departure%20Issue%20Brief.pdf. Accessed November 30, 2009.

- Harkey, D.K., Srinivasan, R., Baek, J., Council, F.M., Eccles, K., Lefler, N., Goss, F., Persaud, B., Lyon, C., Hauer, E., and Bonneson, J.A. *Accident Modification Factors for Traffic Engineering and ITS Improvements.* NCHRP Report 617. Transportation Research Board of the National Academies, Washington, D.C., 2008. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_617.pdf. Accessed October 16, 2009.

Ways to Address Fatigued and Distracted Driving

- National Highway Traffic Safety Administration. *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices,* 4th ed. Washington, D.C., 2009. http://www.nhtsa.gov/staticfiles/DOT/NHTSA/Traffic%20Injury%20Control/Articles/Associated%20Files/811081.pdf. Accessed August 10, 2009.

- Stutts, J., Knipling, R.R., Pfefer, R., Neuman, T.R., Slack, K.L., and Hardy, K.K. Volume 14: A Guide for Reducing Crashes Involving Drowsy and Distracted Drivers. In *Guidance for Implementation of the AASHTO Strategic Highway Safety Plan.* NCHRP Report 500. Transportation Research Board of the National Academies, Washington, D.C., 2005. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_500v14.pdf. Accessed August 10, 2009.

SECTION 3. PERFORMANCE MEASURES

Step 3. Use safety-related performance measures to assess deficiencies. This step requires 20 to 40 hours depending on which performance measures are selected and the extent to which they are applied.

3.1. Description of the Step

A *performance measure* is an objective stated in measurable terms[7] and indicates the effectiveness of a transportation system.[3] Performance measures are used in the prioritization and selection of projects in the CLRP[7] and can be categorized according to the question they answer, as shown in Table 3.1.

Not all performance measures shown in Table 3.1 require crash data, e.g., the bicycle compatibility index (BCI), BLOS, and pedestrian level of service (PLOS) provide information about specific dimensions of crash risk, such as the extent to which automobiles and bicycles can share a particular section of roadway.

Table 3.1. Safety-Related Performance Measures

Question	Performance Measure
What is the system's overall performance in terms of safety?	Crashes per million VMT
	Crashes per million vehicles entering the intersection
	Crashes per population
	Number of fatalities, injury crashes, and property damages per 100 million VMT or ADT
What is the crash risk of specific modes of travel?	Number of pedestrian crashes per year
	Number of bicycle crashes per year
	Number of crashes per 100 million VMT on undivided facilities
To what extent are specific causal factors contributing to crash risk or long-term injury risk?	Number of deer crashes per year (percentages may also be relevant)
	Number of crashes in work zone areas
	Number of alcohol-related crashes
	Number of crashes attributable to design deficiencies such as lack of bicycle lanes, crosswalks, and active control at at-grade railroad crossings and substandard lane widths
	Number of near misses, which are evasive maneuvers such as drivers braking to avoid a conflict or swerving over a double yellow line
	Number of locations with inadequate site distance or sharp curves
	Number of conflict points or access points per mile
	Average response time for EMS
What is the relative accessibility of each mode of travel?	Vehicle accessibility (measured as travel time)
	Bike accessibility (measured as BLOS and BCI)
	Pedestrian accessibility (measured as PLOS)
	Geometric deficiencies (presence of bicycle lanes and crosswalks)

ADT = average daily traffic; BLOS = bicycle level of service; BCI = bicycle compatibility index; PLOS = pedestrian level of service.

3.2. Summary of Current Practice Based on the Survey of Virginia MPOs/PDCs

Survey responses from the large MPOs/PDCs identified other performance measures besides those shown in Table 3.1, such as the [amount of] property damage. However, about one-third of the respondents do not use any performance measures in long-range planning documents. Respondents noted one obstacle to the use of crash data: historically, the location of the crash (e.g., the route and milepost) was not available in cities if those roads were not maintained by VDOT. [Starting with 2008 data, VDOT records a latitude and longitude for crashes, which may help cities locate such crashes if they have their own roadway network file.] Some respondents also indicated the use of a goal or standard associated with these performance measures, such as crashes per 100 million VMT (for crash rate).

3.3. Examples of How the Step May Be Performed

Example 1. Intersection Performance Measures

Several performance measures can be used to assess the current condition of an intersection, such as the four listed in Table 3.2 and Figures 3.1 and 3.2. A prioritization of intersections based on such performance measures is detailed in Section 6 of the guide.

Table 3.2. Performance Measures of an Intersection

Performance Measure	Lee Highway (U.S. 29) and Westmoreland Street
Entering vehicles per day [a]	25,322
3-year crash frequency (fatal and injury crashes) [b]	2
Crashes per million vehicles entering [b, c] the intersection	0.07
Number of curb cuts within 150 ft of the intersection	7

[a] Data were obtained from VDOT's Traffic Management System Database Queried on August 14, 2009, in Arlington County for the year 2007
[b] Crash data were obtained from VDOT's Crash Database for the period 01/01/2005 through 12/31/2007.
[c] Crash rate is computed as 2 crashes divided by (25,322 vehicles/day) (365 days/year) (3 years) and multiplied by 1 million

Example 2. Bicycle and Pedestrian Performance Measures

The Bicycle Review Committee for the City of Harrisonburg[30] rated the Garbers Church Road project as essential, with the project limits being between Erickson Avenue and Lendale Lane. A related project is noted in the CLRP[31] between West Market Street (Route 33) and Route 42. These overlapping projects are described in Table 3.3 and shown in Figures 3.3 and 3.4.

Figure 3.1. Intersection of Lee Highway and Westmoreland Street. Google, Inc. Google Map Application, Mountain View, CA, 2009. http://maps.google.com. Accessed August 3, 2009. The attribution shown in the map reads as follows: "Commonwealth of Virginia, U.S. Geological Survey, Digital Globe, USDA Farm Service Agency, Map Data ©2009 Google."

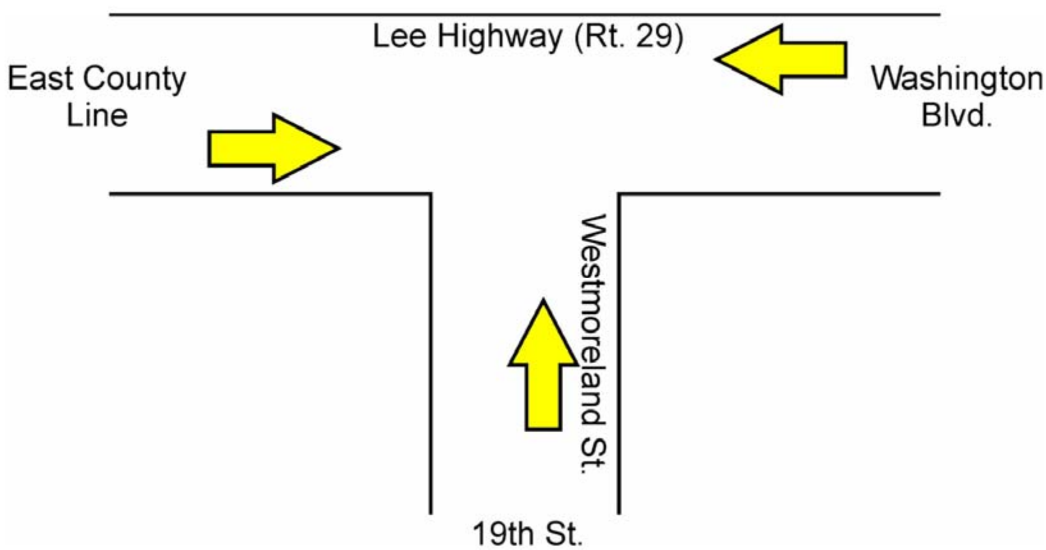

Figure 3.2. Intersection of Lee Highway and Westmoreland Street. Total entering volume for Lee Highway is the link between the East County Line and Washington Blvd, both directions. Total entering volume for Westmoreland St. is the link between 19th street and Lee Highway, northbound only.

Table 3.3. Description of Garbers Church Road Project in Harrisonburg

Element	Description
Project	Improvements to Garbers Church Road from Route 33 to Route 42 to include pedestrian and bicycle facilities and added turning lanes[31] and a wide sidewalk or multi-use trail from Erickson Avenue to Lendale Lane[30]
Performance Measures	Bicycle accessibility
	Pedestrian accessibility
Justification	This would provide a north-south connection and would provide a safe connection for Harrisonburg High School students[30]
Projected Cost	$725,000[30]

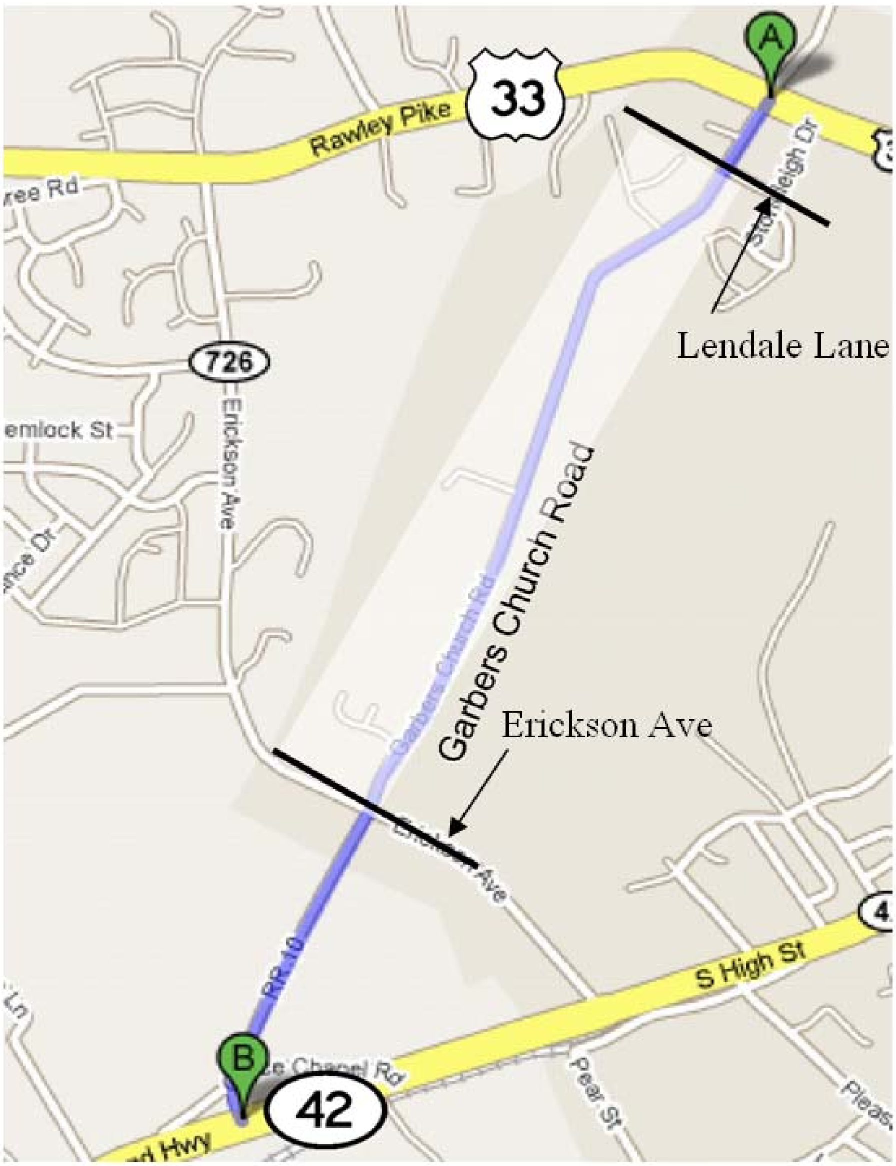

Figure 3.3. Garbers Church Road Project. Project limits are from Route 33 to Route 42[31] or from Erickson Avenue to Lendale Lane.[30] Google, Inc. Google Map Application, Mountain View, CA, 2009. http://maps.google.com. Accessed June 23, 2009.

Figure 3.4. Route 910 (Garbers Church Road) Bordered by Route 33 and Route 42 Using VDOT's GIS Integrator

Two performance measures that can be used to evaluate bicycle and pedestrian facilities are BLOS and PLOS. A BLOS and PLOS calculator is used to obtain the BLOS and PLOS values. Virginia MPOs/PDCs can obtain BLOS values from the Statewide Planning System (SPS) database.

Bicycle and Pedestrian Level of Service:

BLOS indicates a bicyclist's comfort level in using a specific roadway given its geometric and traffic conditions.[32] PLOS indicates a pedestrian's comfort level in using a specific roadway.[33] A BLOS and PLOS calculator[34] uses a list of parameters, such as speed limit and sidewalk width (Table 3.4), to calculate a numerical score.

Table 3.4. Bicycle Level of Service Parameters for a Subsection of Garbers Church Road

Parameter	Value[a]
Through lanes per direction (default value = 1)	1
Width of outside travel lane to outside stripe (feet) (default value = 12)	11
Paved shoulder, bike lane or marked parking area to outside lane stripe to pavement edge (feet) (default value = 0)	0
Bi-directional traffic volume (default value = 12,000)	2,966
Posted speed limit (mph) (default value = 40)	55 mph
Percentage of heavy vehicles (default value = 2)	6
FHWA's pavement condition rating (1[worst] through 5 [best]) (default value = 4)	4[b]
Percentage of road segment with occupied on-street parking (default value = 0)	0[b]
Percentage of segment with sidewalks (default value = 100)	0[b]
Sidewalk width (feet) (default value = 5)	0[b]
Sidewalk buffer/ parkway width (feet) (default value = 10)	0[b]
Buffer/ parkway average (0= no trees, default value = 80)	80[b]
Numerical score from the BLOS Calculator[34]	4.95

[a] BLOS values were obtained for Garbers Church Road in Rockingham County, Virginia, between Route 42 and the southern boundary with the City of Harrisonburg, using data from SPS excerpted on October 14, 2009.
[b] Values were not given in SPS and thus were assumed by the authors.

The numerical score of 4.95 is then assigned a corresponding "A" through "F" level of service based on the ranges shown in Table 3.5. A BLOS/PLOS "A" indicates that a roadway is extremely comfortable for an adult bicyclist/pedestrian; an "F" indicates that the roadway is completely uncomfortable for an adult bicyclist/pedestrian.[33] The BLOS for the subsection of the facility shown in Table 3.4 is "E," based on both the SPS and the BLOS calculator.

Table 3.5. Bicycle[a] and Pedestrian Level of Service[a]

BLOS/PLOS	Model Score
A	≤ 1.5
B	1.5-2.5
C	2.5-3.5
D	3.5-4.5
E	4.5-5.5
F	>5.5

[a] From *Transportation Research Record: Journal of the Transportation Research Board,* No. 1578, Transportation Research Board of the National Academies, Washington, D.C., 1997, Table 3, p. 125. Reproduced with permission of the Transportation Research Board.

Other performance measures that can be used to evaluate bicycle and pedestrian projects are bicycle and pedestrian crashes, roadway deficiencies, and the BCI. These measures have different areas of emphasis: BLOS indicates bicyclists' comfort level, and the BCI evaluates the ability of a roadway to accommodate both motorists and bicyclists. The BCI can be used to determine a bicyclist's decision to use or not use a specific roadway given the current conditions, as shown in Table 3.6.[35]

Table 3.6. Bicycle Compatibility Index (BCI)

BCI	Range	Compatibility Level
A	≤1.50	Extremely High
B	1.51-2.30	Very High
C	2.31-3.40	Moderately High
D	3.41-4.40	Moderately Low
E	4.41-5.30	Very Low
F	>5.30	Extremely Low

3.4. Selected References That Provide Additional Information for the Step

Development of Performance Measures

- Barsotti, E. Bicycle Level of Service/ Pedestrian Level of Service Calculator Form. League of Illinois Bicyclists, Aurora, Ill., 2004. http://www.bikelib.org/roads/blos/losform.htm. Accessed June 15, 2009.

- Sinha, K.C., and Labi, S. *Transportation Decision Making. Principles of Project Evaluation and Programming.* John Wiley & Sons Inc., Hoboken, N.J., 2007.

SECTION 4. DATA NEEDS

Step 4. Acquire data within the time constraints faced by the planner. This step requires 10 to 60 hours depending on the type of data sought, data availability, and staff experience with obtaining these data.

4.1. Description of the Step

Step 4 (data needs) and Step 5 (data analysis) are related: data analysis cannot be performed without obtaining the appropriate data, but one may not know which data to obtain without knowing the methods of analysis. Thus, Steps 4 and 5 may be performed concurrently. The performance measures discussed in Step 3 (see Table 3.1) use a wide variety of data. Not surprisingly, therefore, multiple data sources may be necessary, as indicated in Table 4.1 and described in Section 4.3.

Select examples of the data tools described in Table 4.1 are given here.

Statewide Planning System (SPS):

SPS provides the roadway inventory, traffic characteristics, performance, and crash summary data for individual roadway sections as shown in Figure 4.1.

Crash Analysis Tools:

A database application called "Crash Analysis Tools" (CAT) summarizes crash data for a user-specified period of time and for a user-specified section of a roadway and is based on VDOT's crash records system (Figure 4.2). CAT is a Microsoft Access application that enables users to conduct a corridor segment analysis without detailed knowledge of Standard Query Language (SQL).[9,36] CAT uses two modules to generate different types of information for interstate, primary, or secondary roads. Module 1 analyzes crash density (number of crashes per segment) as shown in Example 1 for this step, and Module 2 analyzes types of collisions.

Note that CAT captures only crashes along a given section of roadway. CAT does not include crashes that (1) occur on ramps, (2) are not locatable, or (3) are near but not along the roadway. For example, in Figure 4.3, CAT will capture Crashes 1, 2, and 3 but will not capture Crash 4, even though Crash 4 is located just 50 feet from Road A. Roadway configurations that involve grade separation should be treated with caution when using CAT.

Table 4.1. Data Types, Tools, Contacts, and Sources

Data Type	Data Tool	Contact	Source
Crashes that may be tabulated by the user	Virginia Statewide Planning System (SPS)	TMPD[a]	VDOT[37]
	Crash Analysis Tools (CAT)	TED[b]	Available from VDOT upon request
	Highway Traffic Record Information System (HTRIS)	VDOT	National Con-Serv Inc[38]
	Roadway Network System (RNS)	VDOT	Not yet available
	VDOT Crash Report Database	TED[c]	Available within VDOT
	5 years of crash data on a CD	TED	Provided by VDOT TED to each MPO/PDC on an annual basis
	VDOT Dashboard	VDOT[d]	http://dashboard.virginiadot.org/
Existing crash tabulations	Crashes by jurisdiction and vehicle type (DMV Crash Facts)	DMV	http://www.dmv.state.va.us/webdoc/pdf/vacrashfacts_08.pdf
	Roadway crash rates (Annual Summary of Crash Data)	TED[e]	http://www.virginiadot.org/business/ted_app_pro.asp (scroll to the bottom of the page)
	Rankings of intersections (by crash severity) and segments (by roadway departure crashes)[8]	TED	Available upon request
Traffic volumes	SPS	TMPD	VDOT[36]
	Traffic Monitoring System (TMS)	TED[f]	Available upon request; see also VDOT[39]
Roadway characteristics (e.g., lane widths, LOS, posted speed limit, number of through lanes)	SPS	TMPD	VDOT[36]
Near misses	Manual collection at various locations	N/A	N/A
Seat belt use	Annual surveys of belt use	DMV Highway Safety Office	See Porter et al.[40] or Lynn and Kennedy[41] for historical examples
Virginia-specific GIS layers	VDOT GIS Integrator	VDOT[g]	Available from VDOT upon request
Roadway video images	VDOT VisiWeb	VDOT[h]	Available from VDOT upon request
Roadway aerial photos	Microsoft Maps	Microsoft	Maps.live.com, live.local.com
	Google Maps	Google	www.maps.google.com
Virginia crash data with injury, health outcome, charge, and cost data	Virginia Crash Outcomes Data Evaluation System (CODES)	DMV and VDH	http://www.vacodes.org/default.asp

TMPD = VDOT Transportation and Mobility Planning Division; TED = VDOT Traffic Engineering Division; DMV = Virginia Department of Motor Vehicles; VDH = Virginia Department of Health.

[a] Although SPS is accessible to VDOT staff, a related resource is the on-line mapping tool available to both VDOT and non-VDOT staff, accessible at http://www.virginiadot.org/projects/prOTIM.asp.

[b] Within VDOT the url is \\0501coitd1\TEDPublic\Crash\2008 Safety Analysis and Crash Database Workshop\VDOT CAT Tools(2002-06).mdb.

[c] Within VDOT the url is http://crash/crash/jsp/ (for crash reports); there is also an Oracle database (an .mdb file) available from VDOT TED that allows manipulation of crash data in a raster format.

[d] Within VDOT the url is http://dashboard3/.

[e] These books are developed every year; the most recent is the *2007 Annual Summary of Crash Data* available at http://www.virginiadot.org/business/resources/HSIP/2007%20Crash%20Summary.pdf.

[f] Within VDOT the url is http://tedweb/tms/jsp/.

[g] Within VDOT the url is http://insidevdot/sites/GIS/default.aspx or http://coapp09/vdotgis/default.htm.

[h] Within VDOT the url is http://coapp75/visiweb/.

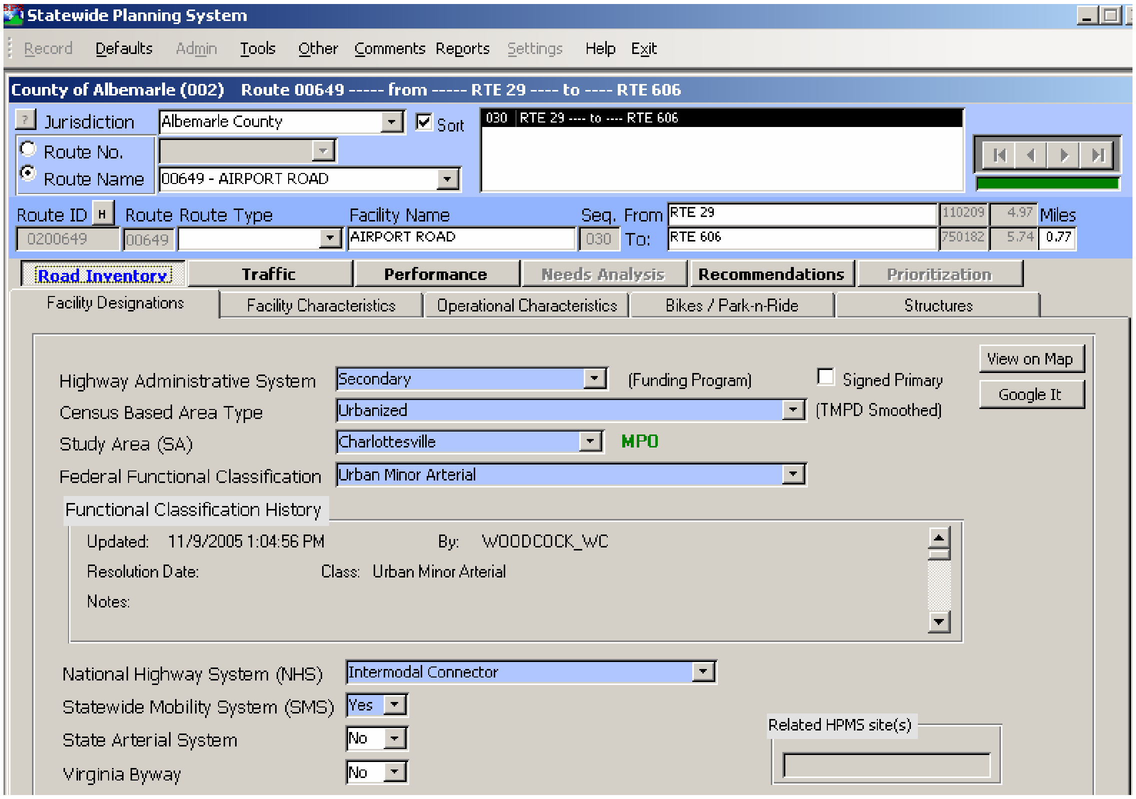

Figure 4.1. Virginia's Statewide Planning System (SPS) Data Tool

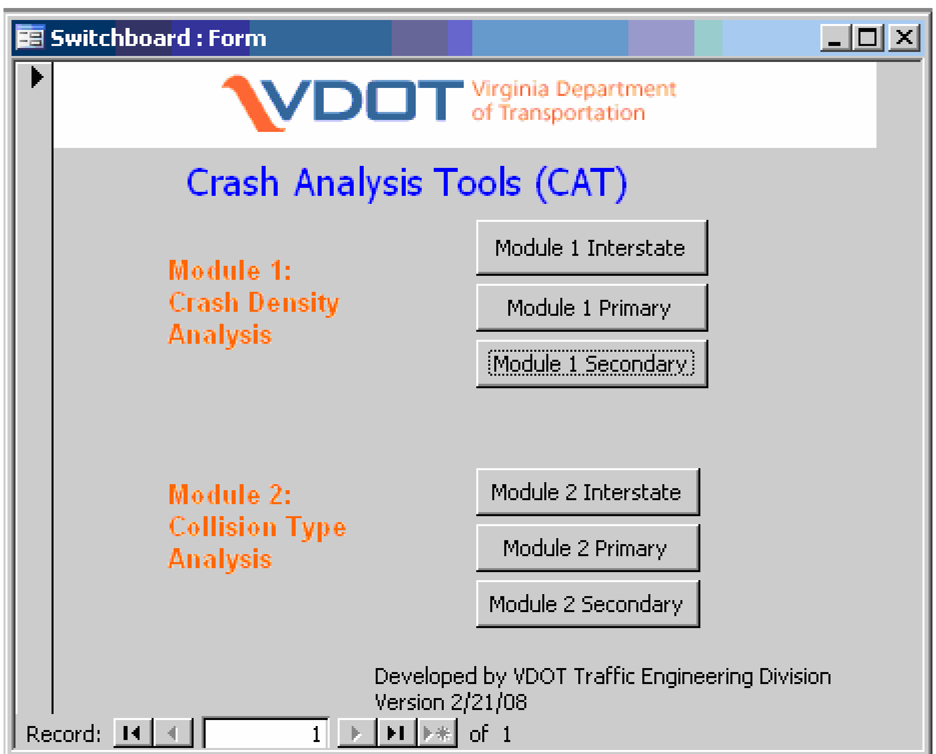

Figure 4.2. VDOT Crash Analysis Tools, Module 1

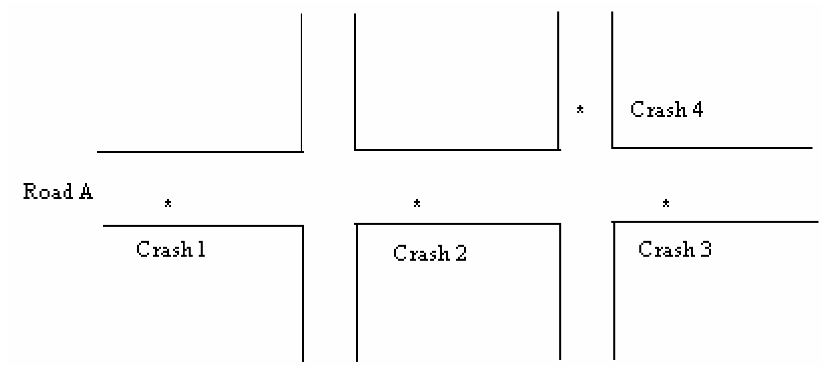

Figure 4.3. Crash Captures by Crash Analysis Tools (CAT) for Road A. CAT will capture Crashes 1, 2, and 3 but will not capture Crash 4, even though Crash 4 is located just 50 feet from Road A.

Crash Report Database:

VDOT's Crash Report Database can be used to obtain individual crash reports for Virginia crashes on roadways and intersections, as shown in Figure 4.4. VDOT also has a database based on Microsoft Access that allows manipulation of crash data based on characteristics in addition to those shown in Figure 4.4.

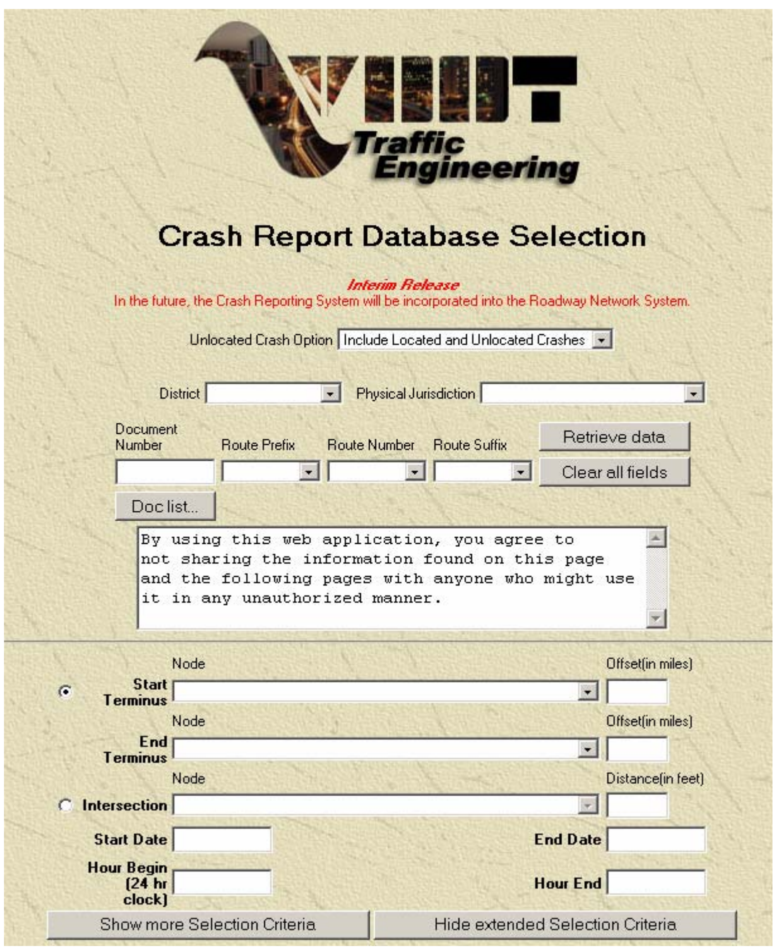

Figure 4.4. VDOT Crash Database. Selection criteria not shown include vehicle type, collision type, surface condition, weather, lighting, traffic control, major factor, functional class, fixed object, and vehicle maneuver.

VDOT Dashboard:

The Dashboard can be used to obtain crashes, injuries, and fatalities in Virginia. The crashes can be located for a particular district, city or county, road system, and focus area. Figure 4.5 shows the crashes, injuries, deaths, and work zone crashes in VDOT's Staunton District, Rockingham County, for primary roads. Although the Dashboard does not provide detailed crash data that can be obtained from other sources (e.g., CAT), it is readily accessible to MPOs and localities outside VDOT's firewall.

Description	Recent 12 Months	3-Year Avg
Angle	110	94
Backed Into	2	2
Deer	64	63
Fixed object in road (from ditch to ditch)	1	1
Fixed object off road (from outside of ditch)	136	116
Head on	10	7
Miscellaneous or other	5	4
Non-Collision, overturned, jacknifed or ran off road (no object)	19	17
Not Stated	0	0
Other Animal	11	7
Pedestrian	2	2
Rear End	152	146
Sideswipe - Opposite direction of travel	12	9
Sideswipe - Same direction of travel	28	33
Train	0	0
Undetermined Cause	0	0
Total	**552**	**500**

Figure 4.5. Virginia Department of Transportation Dashboard Monitoring System

GIS Integrator:

The VDOT GIS Integrator can be used to obtain different data types on Virginia roads. There are various layers that can be selected, e.g., roadway networks, VDOT data, and hydrology among others, as shown in Figure 4.6.

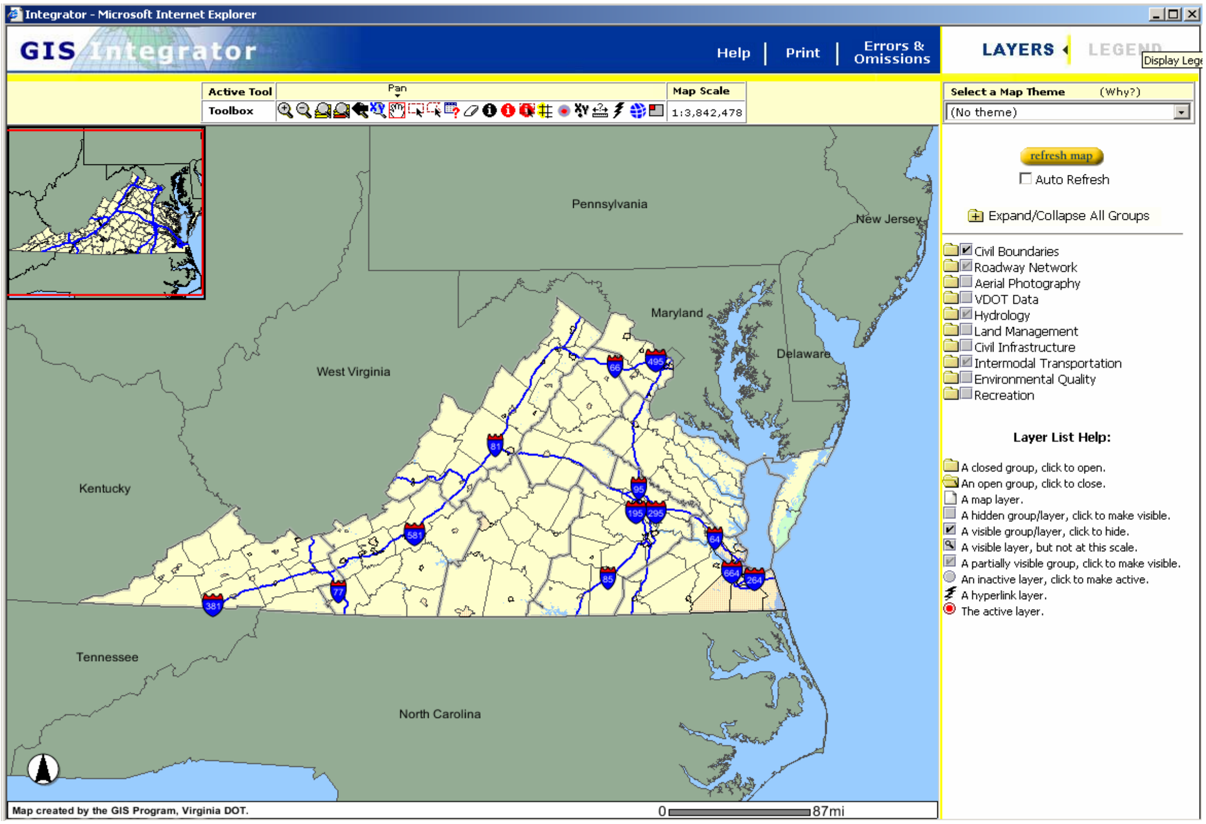

Figure 4.6. VDOT GIS Integrator

VisiWeb:

The VDOT VisiWeb tool provides a videolog of Virginia roadways. It is useful for observing the physical characteristics of a roadway and its surrounding areas without the necessity of taking photographs in the field. Figure 4.7 is an example of a VisiWeb diagram on Route 29 North in Charlottesville, which was identified using the following characteristics:

- survey year of 2008
- Culpeper District
- Albemarle County
- U.S. road system
- 29 N (route number and direction)
- begin at county mile post 21.44.

Clicking the “go to” icon on VisiWeb will display a video of the selected area and its surroundings with play, reverse, and pause viewing options.

Figure 4.7. VDOT VisiWeb Tool

Microsoft Maps:

Microsoft Maps can be used to obtain information about a roadway and the adjacent area, as shown in Figure 4.8, such as degree of access and the presence of major traffic generators.

Figure 4.8. Microsoft Maps

Google Maps:

Google Maps may be used to obtain information on a roadway and its surrounding areas, as shown in Figure 4.9, such as the density and connectivity of the roadway network. Google's "Street View" function is available for many Virginia roadways;[42] this function provides images at the street level and thus may serve as a videolog. The attribution that Google gives at the bottom of the screen must be readable either as a caption or an addition to the graphic.

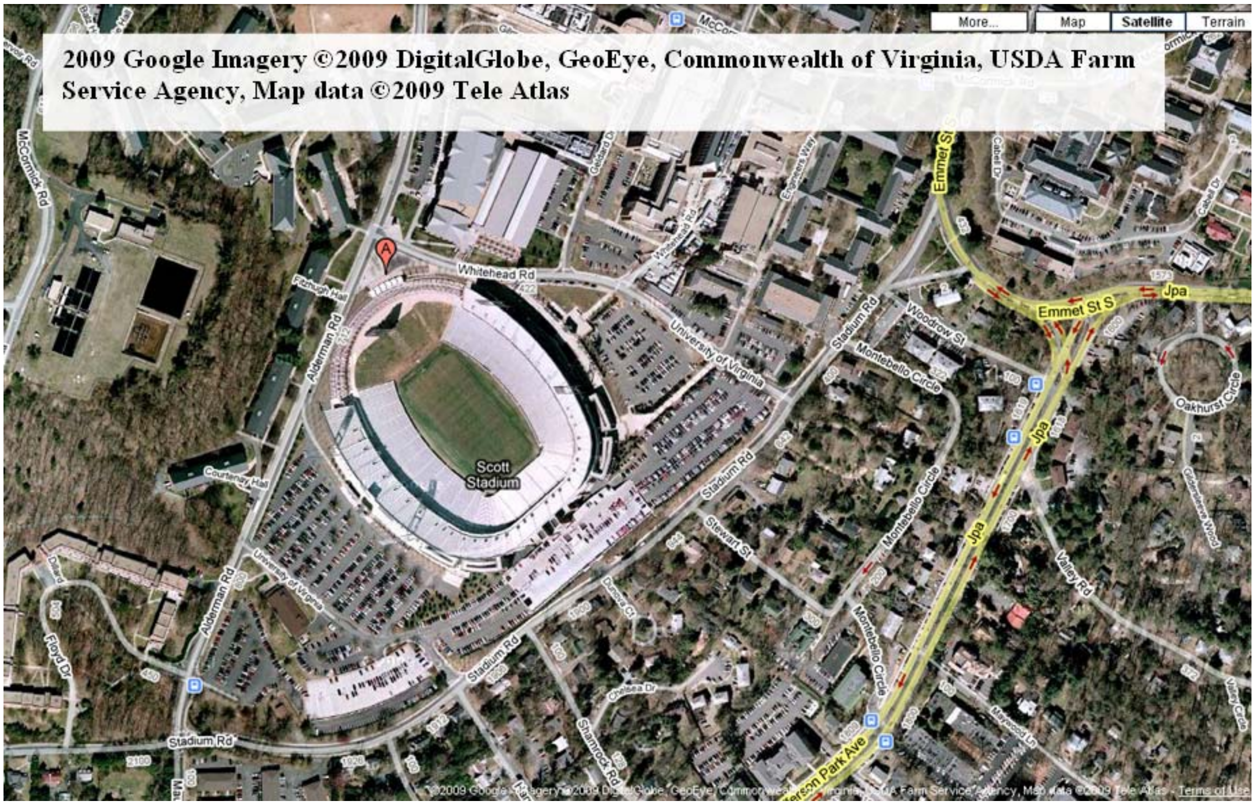

Figure 4.9. Google Maps. Google, Inc. Google Map Application, Mountain View, CA, 2009, http://maps.google.com.

4.2. Summary of Current Practice Based on the Survey of Virginia MPOs/PDCs

Identification of data needs is challenging in part because crash data have generally not been available for roads not maintained by VDOT (e.g., most roads in incorporated cities in Virginia). The survey responses confirmed this finding: lack of data (or difficulty obtaining such data) was the second greatest obstacle cited by survey respondents to integrating safety and planning. MPOs are interested in obtaining crash data; however, three-fourths of respondents use automobile crash data, and two-thirds of respondents noted that expertise in crash data acquisition was needed to integrate safety and planning.

Improving traffic records is a significant component of Virginia's Strategic Highway Safety Plan.[4] Although it is not possible to obtain roadway information for city streets at this time, VDOT is exploring the feasibility of obtaining this information in the future.[15]

4.3. Examples of How the Step May Be Performed

Example 1. Crash Analysis Tools (CAT)

CAT can be used to obtain the number of injuries, fatalities, and property damage only (PDO) crashes occurring on a user-defined roadway section for sections maintained by VDOT. This example uses a 20-mile section of U.S. 250 entered in Module 1 of CAT as shown in Figure 4.10. [The segment runs from mile post 150 to mile post 170, uses 5 years of crash data based on the period 2002-2006, and uses 0.25-mile analysis intervals in both directions.] CAT generates a summary crash table (Figure 4.11) and lists the FR 300 crash report numbers, which can be used to obtain individual crash reports.

Although 5 years of crash data are used in Figure 4.10, it is now possible to use CAT with up to 11 years of crash data; note also that additional analysis of roadway departure crashes is also feasible.[9]

Figure 4.11 can also be exported to Microsoft Excel and plotted to show the relationship between total crashes, deaths, and injuries and each quarter-mile subsection. Figure 4.12 indicates that the most severe subsection is between mile posts 159.5 and 159.75 with more than 100 deaths and injuries over the 5-year period. Note that crashes within the City of Richmond are not reported in the analysis.

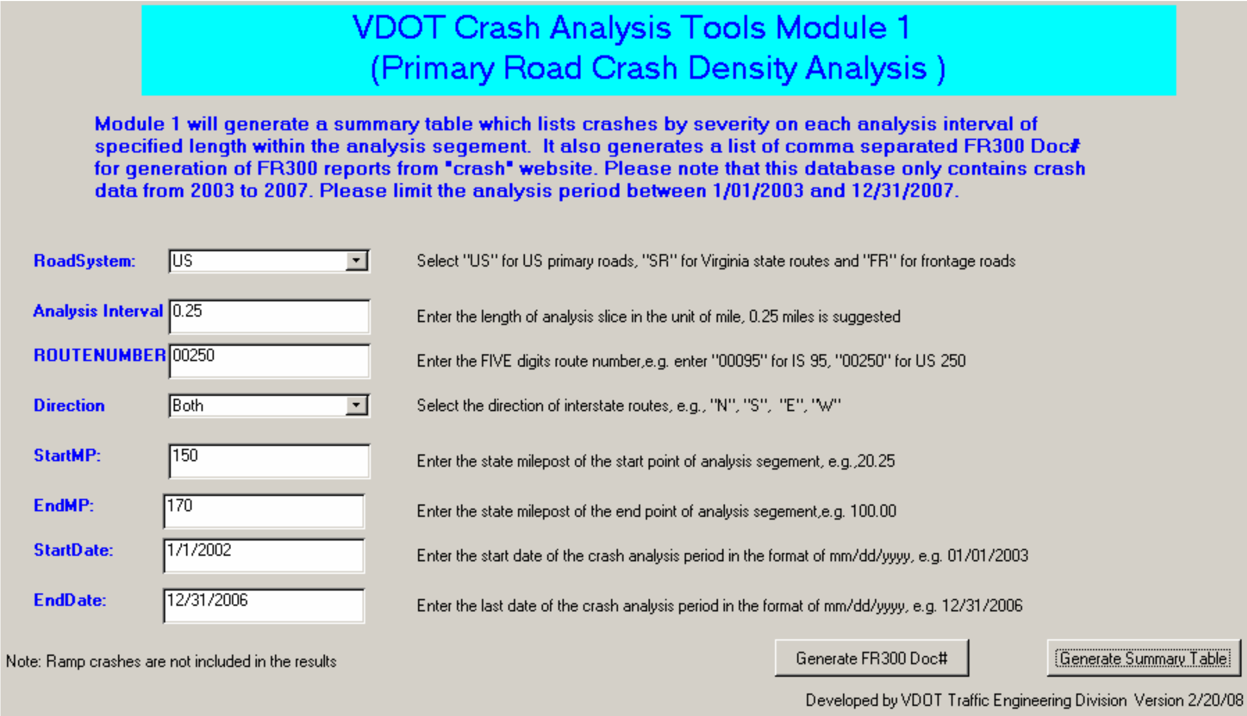

Figure 4.10. VDOT Crash Analysis Tools (Module 1: Primary Crash Density Analysis)

LinkID	Milepost		Slice	Crashes				Injuries and Fatalities		
	Start	End		Fat	Inj	PDO	Total	Fat	Inj	Total
US00250	150	150.25	1	0	1	1	2	0	1	1
US00250	150.25	150.5	2	0	8	9	17	0	13	13
US00250	150.5	150.75	3	0	4	5	9	0	4	4
US00250	150.75	151	4	0	5	10	15	0	7	7
US00250	151	151.25	5	0	1	4	5	0	1	1
US00250	151.25	151.5	6	0	0	3	3	0	0	0
US00250	151.5	151.75	7	0	1	4	5	0	4	4
US00250	151.75	152	8	0	7	17	24	0	10	10
US00250	152	152.25	9	0	1	2	3	0	1	1
US00250	152.25	152.5	10	0	3	6	9	0	4	4
US00250	152.5	152.75	11	0	21	25	46	0	28	28
US00250	152.75	153	12	0	14	37	51	0	19	19
US00250	153	153.25	13	0	53	137	190	0	89	89
US00250	153.25	153.5	14	0	46	97	143	0	63	63
US00250	153.5	153.75	15	0	44	83	127	0	65	65
US00250	153.75	154	16	0	31	72	103	0	36	36
US00250	154	154.25	17	0	36	60	96	0	60	60
US00250	154.25	154.5	18	0	10	27	37	0	13	13
US00250	154.5	154.75	19	0	31	66	97	0	44	44
US00250	154.75	155	20	0	29	95	124	0	39	39
US00250	155	155.25	21	0	9	28	37	0	9	9
US00250	155.25	155.5	22	0	7	16	23	0	10	10
US00250	155.5	155.75	23	0	47	101	148	0	76	76
US00250	155.75	156	24	0	32	54	86	0	47	47
US00250	156	156.25	25	1	30	87	118	1	41	42
US00250	156.25	156.5	26	0	34	44	78	0	43	43
US00250	156.5	156.75	27	1	63	68	132	1	107	108
US00250	156.75	157	28	0	44	58	102	0	77	77
US00250	157	157.25	29	0	45	108	153	0	56	56
US00250	157.25	157.5	30	1	29	56	86	1	36	37
US00250	157.5	157.75	31	1	60	106	167	1	84	85
US00250	157.75	158	32	0	25	37	62	0	37	37
US00250	158	158.25	33	1	24	36	61	1	39	40
US00250	158.25	158.5	34	1	52	80	133	1	72	73
US00250	158.5	158.75	35	0	36	47	83	0	54	54
US00250	158.75	159	36	1	28	37	66	1	38	39
US00250	159	159.25	37	0	45	80	125	0	73	73
US00250	159.25	159.5	38	0	81	130	211	0	118	118
US00250	159.5	159.75	39	0	7	8	15	0	9	9
US00250	159.75	160	40	0	12	31	43	0	16	16
US00250	160	160.25	41	0	16	39	55	0	20	20

Figure 4.11. VDOT Crash Analysis Tools, Module 1, Excerpt of Summary Table

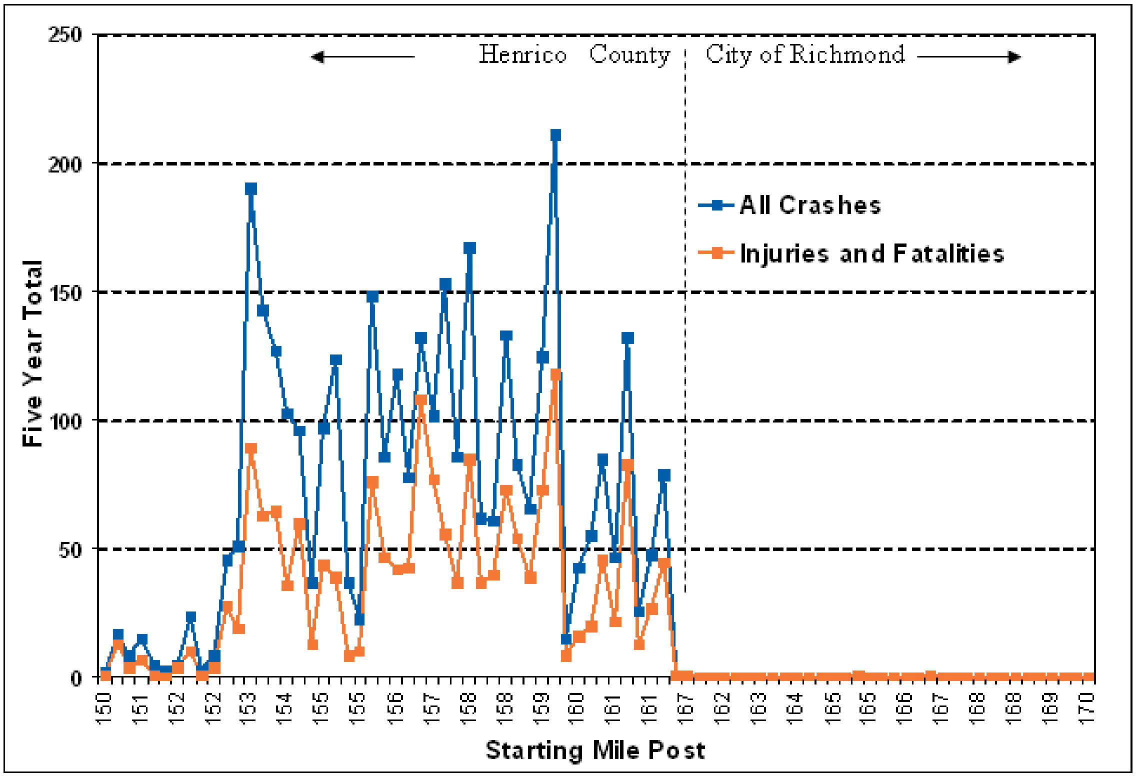

Figure 4.12. U.S. 250 Crash Statistics per Quarter Mile (2002-2006)

Example 2. Statewide Planning System

A project similar to the Garbers Church improvement was selected for construction. To evaluate the performance measures listed in Step 3 (performance measures), the data in Table 4.2 were obtained from the Virginia SPS as shown in Figures 4.13 and 4.14. These performance measures may be used for the purposes of prioritization (Step 6) or monitoring (Step 8).

Table 4.2. Volume, Geometric, and Crash Data for Garbers Church Road

Route	Route 910
Project limits	Route 42 to Route 33 (West Market Street)[a]
Subsection examined	Route 42 to the City of Harrisonburg
Speed	55 mph
Widths	Lane 11 feet, Pavement 22 feet
Bicycle and Pedestrian Facilities	None
BLOS (2007)	E
Crashes (1/1/2003-12/31/2007)	1 rear end

[a] The executive summary of the CLRP describes the selected project as "Improvements to Garbers Church Road, from West Market Street to Route 42, include pedestrian and bicycle facilities and added turning lanes"[12] (see p. vi of the CLRP). As shown in Figure 4.13, the calculations in the table are based on only one subsection of this facility. Data were obtained from SPS on October 15, 2009.

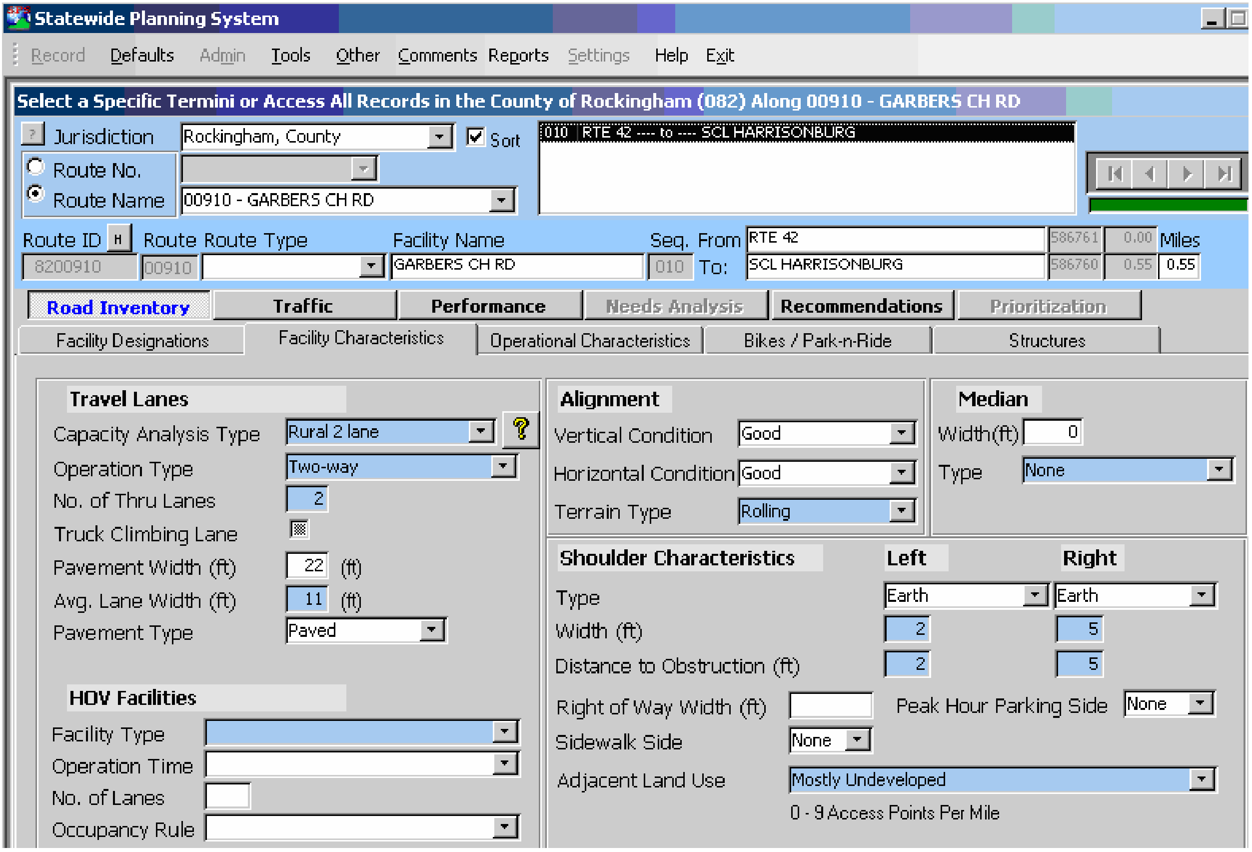

Figure 4.13. Virginia's Statewide Planning System Data Tool: Facility Characteristics

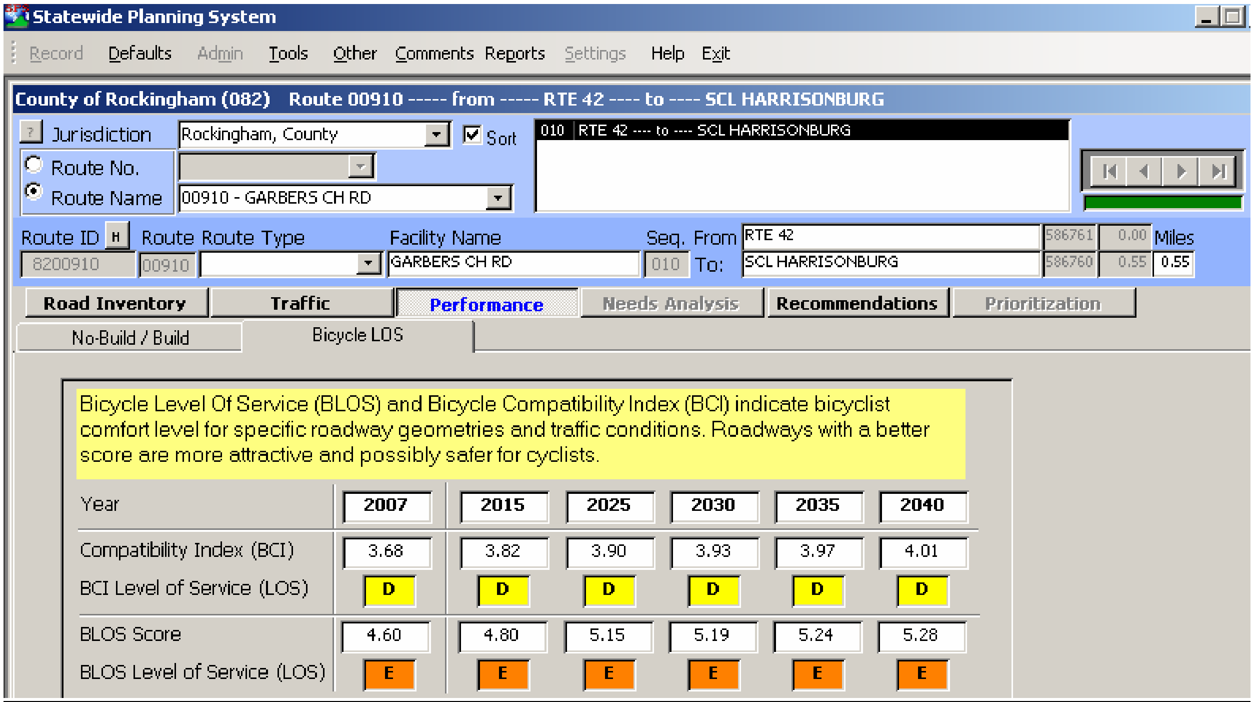

Figure 4.14. Virginia's Statewide Planning System Data Tool: Performance

4.4. Selected References That Provide Additional Information for the Step

Obtaining Crash Data

- Virginia Department of Transportation, Traffic Engineering Division. Crash Analysis Tools. Available upon request from VDOT. Within VDOT, the url for the precise tool used in this manual is \\0501coitd1\TEDPublic\Crash\2008 Safety Analysis and Crash Database Workshop\VDOT CAT Tools(2002-06).mdb. Updates to this tool, as well as documentation, are available in the folder in which this file is stored: \\0501coitd1\TEDPublic\Crash\2008 Safety Analysis and Crash Database Workshop.

- Virginia Department of Transportation, Transportation Mobility Planning Division. Statewide Planning System (SPS), Version 4.03.00. Richmond, 2008. http://insidevdot/sites/StatewidePlanningSystemUsersTeamSite/default.aspx. Accessed June 26, 2009.

SECTION 5. DATA ANALYSIS

Step 5. Analyze data with available resources and thus select higher impact projects. The amount of time required for this step is highly variable and may range from a few hours for a quick evaluation to a full-scale effort for a detailed analysis.

5.1. Description of the Step

The data collected in Step 4 require interpretation to determine locations that require safety improvements. Such locations may include sharp curves, unsafe pedestrian and railroad crossings, narrow lanes, and locations with inadequate sight distance.

The choice of data analysis methods used will depend on the availability of data, staff, and modeling resources and the problem under consideration. Examples of data analysis methods, from least to most sophisticated, may include:

- *Visual inspection of data* (to determine high-crash locations) or roadway geometry (to identify potentially hazardous locations). Section 5.3 (Example 1) illustrates this method.

- *Crash reduction factors* (CRFs) (e.g., widening a 10-foot lane to 12 feet should reduce crashes by 2 percent[27]). Section 5.3 (Examples 2 and 3) illustrates this method.

- *Accident prediction models* (e.g., the number of crashes on two-lane segments is equal to 1.9806 + 0.0440 × Number of commercial entrances + 0.00004 × AADT).[43] The SafetyAnalyst software package may use such models.[44]

- *Statistical methods* (e.g., before-after comparisons of crash rates suggest that installation of roundabouts will reduce intersection crashes by x percent). Some, but not all, methods require a statistical software package such the Statistical Package for the Social Sciences (SPSS) or SAS.

Note also that the Transportation Research Board (TRB) is anticipating the release of the first edition of the *Highway Safety Manual* (HSM) in early 2010.[45] The HSM will be a detailed safety reference that includes four major topics: (1) the fundamentals of highway safety (e.g., human factors and roadway design); (2) a process for identifying and prioritizing safety-related projects; (3) methods for predicting safety impacts by facility type; and (4) the impact of various countermeasures such as improving the shoulder type. The forthcoming HSM has been described as being analogous to TRB's well-known *Highway Capacity Manual* because of the breadth and depth of topics therein.[45] [Although this resource guide and the HSM may have some overlap, this guide is believed to be considerably shorter and more focused on planning.] More information on the HSM is available at http://www.highwaysafetymanual.org/.

5.2. Summary of Current Practice Based on the Survey of Virginia MPOs/PDCs

Slightly less than one-half of the survey respondents identified safety-related problems at the regional level; one-third identified safety-related problems at the project level. Some respondents indicated specific evaluation methodologies (e.g., 10 percent of respondents use safety performance indices based on safety performance functions and 22 percent use before-after crash comparisons). About one-half of respondents noted their staff were "somewhat" (as opposed to adequately or fully) trained in the technical skills necessary to incorporate safety into the planning process.

VDOT is an active member in the deployment of the SafetyAnalyst software package, which helps identify crash patterns and potential countermeasures.[44] As noted in Section 4, VDOT's TED provides crash data tabulated by intersection and roadway departure crashes for Virginia counties; further, VDOT is planning to provide summaries of intersection and route segments where crash reductions appear feasible.[8]

5.3. Examples of How the Step May Be Performed

Example 1. Identifying Hazardous Locations

CAT crash data, such as number of fatalities and injuries, can be integrated with a GIS roadway shapefile to locate areas of high crash concentration and to determine contributing causes such as large demand generators (e.g., a shopping center) or geometric deficiencies (e.g., a gas station in close proximity to a signalized intersection). These locations can be examined to identify countermeasures, such as consolidation of commercial driveways.

Figure 5.1 locates hotspots on U.S. 250 between mile posts 150 and 161 based on 2002 through 2006 injuries and fatalities. (These data were obtained in Step 4, Example 1. A crash summary table [Figure 4.10] was exported to a spreadsheet, saved as a .csv file, and then used with the roadway GIS shapefile to locate motor vehicle fatalities and injuries for each quarter-mile segment.)

The highest number of injury crashes occurs between mile posts 159.25 and 159.5, which is shown in Figure 5.2. This section's crashes, traffic volumes, and geometry may be studied to identify potential countermeasures. Examination of Figure 5.2 alone initially suggests two such geometric features of interest: the entrance and exit ramp to the east (raising the possibility that merging might be a contributor factor) and the presence of a high-volume intersection to the west. A quick review of crash data from SPS shows that virtually no crashes for this section occurred east of the Glenside Drive intersection, suggesting that further study may be concentrated on the intersection as opposed to the exit ramp.

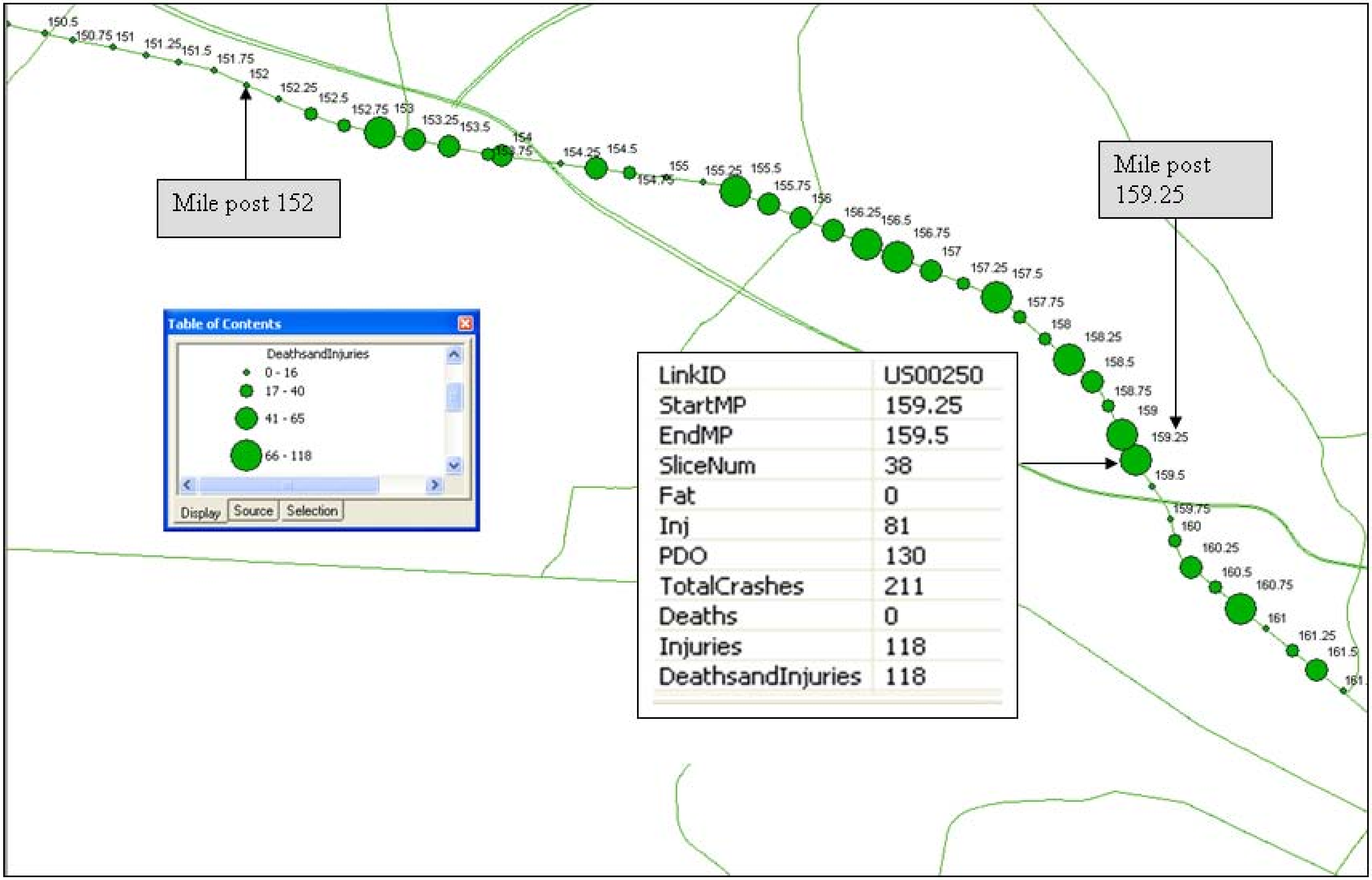

Figure 5.1. U.S. 250 Injuries Between Mile Posts 152 and 161 for Years 2002-2006 Using GIS and CAT. Numbers reflect deaths and injuries from motor vehicle crashes in both directions.

Figure 5.2. U.S. 250 Mile Post 159.25 to Mile Post 159.5 Between Glenside Drive and I-64. Google, Inc. Google Map Application, Mountain View, CA, 2009. http://maps.google.com. Accessed June 23, 2009.

Example 2. Reducing the Number of Through Vehicle Lanes to Reduce Crash Risk

Road diets—defined as a reduction in the number of through lanes open to motorized vehicles—have the potential to reduce automobile crashes. This example describes one application of a road diet in Virginia and estimates the expected crash reduction based on evidence from other states. Such a reduction, however, is realistic only if the necessary conditions, such as a reduction in access points and speed, are implemented in conjunction with the road diet. Therefore, this example considers three aspects of planning for a road diet:

1. Identify conditions under which road diets may reduce crashes.
2. Assess the safety benefits of a specific road diet.
3. Interpret the results.

1. *Identify conditions under which road diets may reduce crashes.*

The literature indicates six conditions under which road diets may be favorable.

- The road diet will reduce conflict points.[46,47,48]

- The road diet will improve sight distance for turning and crossing traffic along the corridor.[46,47,48]

- The road diet will enhance pedestrian safety by enabling them to cross one lane at a time; further, pedestrians can use the center lane as a refuge because the volume and speed of traffic may be reduced.[47,48]

- Traffic calming will result because there will be fewer opportunities for vehicle passing on the facility.[47,48]

- Average daily traffic (ADT) is less than some threshold amount. While citing a successful 30,000 ADT conversion in Washington State, Burden and Lagerwey[46] suggested that communities establish their own ADT thresholds, noting that the 20,000 to 23,000 range is "achievable" in most locations. Other sources have suggested successful operations for ADTs as high as 20,000[47] or 24,000.[48]

- Lane widths are carefully considered as their impact on crash risk depends on the type of facility.[49] Because it is possible that narrowing lanes can increase the crash rate, initiatives should be studied carefully at each site where they are considered.[50]

2. *Assess the safety benefits of a specific road diet.*

A 2-mile section of Lawyers Road between Reston Parkway and Myrtle Lane in Fairfax, Virginia (Figure 5.3), is being converted from a four-lane undivided facility to one with one through lane in each direction, a center two-way left-turn lane (TWLTL), and two bicycle lanes (Figure 5.4).

Table 5.1 shows the current and projected (for 2015 and 2030) ADT and crashes for the facility; the crashes presume that conditions will not change from the existing four undivided through lanes shown to the left of Figure 5.4. Generally there are approximately twice as many non-injury crashes as there are injury crashes.

Varying crash reductions attributable to road diets have been noted. Cited reductions include 47 percent (Iowa) [27], 19 percent (California and Washington State),[27] 32.3 percent (also in Iowa),[51] 34 percent (in Seattle, Washington),[47] and almost 100 percent (Pennsylvania[46]). Pawlovich et al.[52] cited decreases of 25.2 percent (crashes per mile) and 18.8 percent (crash rate). Huang et al.[53] reported a 6 percent decrease in California and Washington State but cautioned that a separate analysis that considered confounding factors yielded no significant impact.

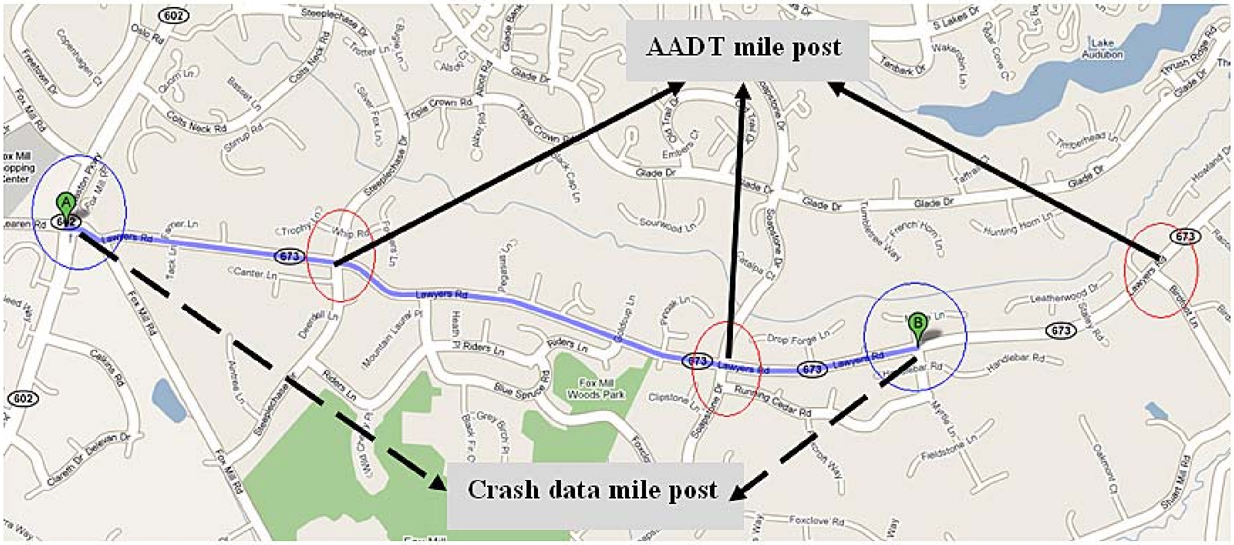

Figure 5.3. Lawyers Road Between Reston Parkway and Myrtle Lane in Fairfax, Virginia. Google, Inc. Google Map Application, Mountain View, CA, 2009. http://maps.google.com. Accessed June 21, 2009. *Broken arrows* define crash data collection points, and *solid arrows* define AADT data collection points.

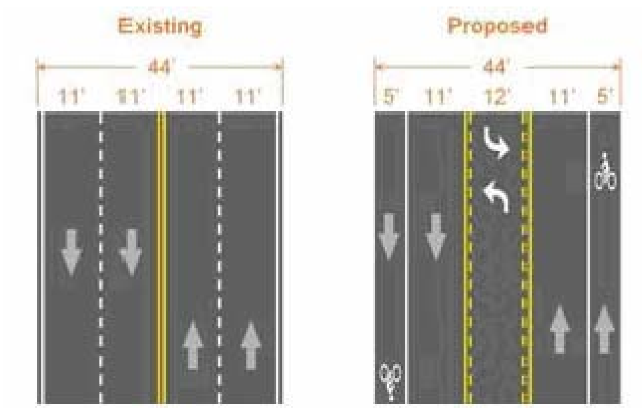

Figure 5.4. Lawyers Road Lane Configuration. VDOT Newsroom. Road Diets for Lawyers. Roadhttp://www.virginiadot.org/newsroom/northern_virginia/2009/road_diet_for_lawyers41216.asp. Accessed August 24, 2009.

Table 5.1. Volume, Crash, and Geometric Data from Lawyers Road

Segment Start	Segment End	Year	Crashes per Year				ADT
			Fatal	Injury	PDO	Total	
Reston Parkway (MP 0.19)	Steeplechase Drive (MP 0.71)	Base (average of 2004-2007)[a]	0[a]	2.25[a]	4.25[a]	6.5[a]	9,878[a]
		Near-term forecast (2015)[b]	0[b]	2.33[b]	4.40[b]	6.73[b]	10,226[c]
		Long-range forecast (2030)[b]	0[b]	2.54[b]	2.79[b]	7.33[b]	11,141[c]
Steeplechase Drive (MP 0.71)	Soapstone Drive (MP 1.61)	Base (average of 2004-2007)[a]	0.50[a]	4.75[a]	11.75[a]	17[a]	9,815[a]
		Near-term forecast (2015)[b]	0.53[b]	5.04[b]	12.46[b]	18.02[b]	10,406[c]
		Long-range forecast (2030)[b]	0.56[b]	5.36[b]	13.26[b]	19.19[b]	11,080[c]
Soapstone Drive (MP 1.61)	Birdfoot Lane and Myrtle Lane (MP 2.6)	Base (average of 2004-2007)[a]	0[a]	1.50[a]	2.25[a]	3.75[a]	9,140[a]
		Near-term forecast (2015)[b]	0[b]	1.58[b]	2.38[b]	3.96[b]	9,651[c]
		Long-range forecast (2030)[b]	0[b]	1.69[b]	2.54[b]	4.23[b]	10,317[c]

PDO = property damage only; ADT = average daily traffic; MP = mile post.
[a] Base year data are the average for years 2004-2007 inclusive. For example, there were 17 PDO crashes for this period, yielding an average of 4.25 crashes per year. Crashes were obtained from the Crash Analysis Tools (CAT).
[b] Forecast year crashes presume crash risk is directly proportional to volume and no geometric changes. For example, because volume is expected to increase from 9,878 (base year) to 10,226 (near-term forecast) for the section from Reston Parkway to Steeplechase Drive, PDO crashes are expected to increase from 4.25 to 4.25(10,226/9,878) = 4.40.
[c] Forecast AADTs were obtained from the SPS in September 2009.

Table 5.2 presents CRFs from Bahar et al.[54] These CRFs pertain to urban environments where four-lane undivided roadways are converted to a three-lane facility with the center lane being a TWLTL. Table 5.2 also gives the 95 percent confidence interval for each CRF.

Table 5.2. Crash Reduction Factors for Converting a Four-Lane Undivided Facility to a Facility with Two Through Lanes and One Two-Way Left-Turn Lane

Crash Severity	CRF (%)	Standard Error	95% Confidence Interval
All crashes	37	1[a]	35 to 39[b]
Fatal or injury	0	2[a]	-4 to 4[b]
PDO	46	1[a]	44 – 48[b]

[a]Low standard errors indicate that CRFs are very accurate.[54]
[b]Assuming a 95% confidence interval (i.e., ±2 standard deviations), the confidence interval for PDO crashes will be CRF ± (2 x standard error) = 46 ± (2 x 1) = 44 to 48.

Assuming crash risk is proportional to ADT, Equations 1 and 2 can be used to estimate the road diet's impact on crashes between Reston Parkway and Steeplechase Drive in years 2015 and 2030.

$$\text{Crash Reduction}_{2015} = (\text{Avg. Crashes from 2004 - 2007})\left(\frac{\text{Volume in 2015}}{\text{Avg. Volume from 2004 - 2007}}\right)(\text{CRF}_{\text{PDO}}) \quad \text{[Eq. 1]}$$

$$\text{Crash Reduction}_{2030} = (\text{Avg. Crashes from 2004 - 2007})\left(\frac{\text{Volume in 2030}}{\text{Avg. Volume from 2004 - 2007}}\right)(\text{CRF}_{\text{PDO}}) \quad \text{[Eq. 2]}$$

Because the CRF is 0.46 (Table 5.2) and because the volume increases from 9,878 at present to 10,226 in 2015 (Table 5.1), Equation 3 estimates a crash reduction of 2 crashes in 2015.

$$\text{Crash Reduction}_{2015} = (4.25)\left(\frac{10{,}226}{9{,}878}\right)(0.46) \cong 2.02 \text{ crashes reduced} \qquad \text{[Eq. 3]}$$

Equation 4 similarly estimates a reduction of 2.21 crashes in year 2030, given a further increase in volume to 11,141 as shown in Table 5.1.

$$\text{Crash Reduction}_{2030} = (4.25)\left(\frac{11{,}141}{9{,}878}\right)(0.46) \cong 2.21 \text{ crashes reduced} \qquad \text{[Eq. 4]}$$

Table 5.3 summarizes the crash reductions estimated for all crash severities and total crashes for the three sections of Lawyers Road for 2015 and 2030. Note that the sum of fatal, injury, and PDO crash reductions does not equal the total crash reductions (in Table 5.3). This results because Table 5.2 showed that fatal and injury crash reductions could not be reliably estimated. To simplify the interpretation of this analysis, stakeholders may choose to focus on either the PDO crash reductions or the total crash reductions.

Table 5.3. Crash Reductions from the Alternative Configuration of Lawyers Road

			Crash Reductions			
Segment Start	**Segment End**	**Year**	**Fatal**	**Injury**	**PDO**	**Total**
Reston Parkway (MP 0.19)	Steeplechase Drive (MP 0.71)	Near-term forecast (2015)	0[a]	0[a]	2.02[b]	2.49
		Long-range forecast (2030)	0[a]	0[a]	2.21	2.71
Steeplechase Drive (MP 0.71)	Soapstone Drive (MP 1.61)	Near-term forecast (2015)	0[a]	0[a]	5.73	6.67
		Long-range forecast (2030)	0[a]	0[a]	6.10	7.10
Soapstone Drive (MP 1.61)	Birdfoot Lane and Myrtle Lane (MP 2.6)	Near-term forecast (2015)	0[a]	0[a]	1.09	1.47
		Long-range forecast (2030)	0[a]	0[a]	1.17	1.57

PDO = property damage only.
[a] Table 5.3 shows zero injury and fatal crash reductions because the confidence interval in Table 5.2 includes zero.[54] A more detailed study may alter the CRF if warranted by closer examination of environmental, traffic mix, geometric, and operational conditions.
[b] For example, with no change in lane configuration, the section from Reston Parkway to Steeplechase Drive is expected to have 4.40 PDO injury crashes per year in 2015 as shown in Table 5.1. Equation 3 suggests that with a CRF of 46%, the alternative configuration will eliminate 2.02 PDO crashes. Thus, this section is expected to see only 4.40 – 2.02 = 2.38 PDO crashes in 2015.

3. Interpret the results.

Table 5.3 suggests that the road diet may eliminate roughly 11 crashes each year based on the volumes for 2015 and 2030. These results are realistic to the extent that the six conditions noted at the beginning of Example 2 hold.

- *The road diet reduces conflict points,*[47,48] such as unsignalized driveways, and by extension vehicle conflicts such as stopped left-turning vehicles in a through lane, lane-changing collisions between two through lanes, and turning movement conflicts.

- *The road diet improves sight distance for turning traffic*. If the TWLTL somehow adversely affected this sight distance, the crash reductions might not materialize.

- *The road diet enhances pedestrian and bicycle safety*. Knapp and Giese[48] suggested that three-lane facilities may offer an advantage relative to four-lane undivided facilities for *pedestrians and bike activities* because of (1) a reduction in conflicts between vehicles and pedestrians; (2) pedestrians needing to cross fewer travel lanes (thereby making it easier to judge available gaps for crossing[47]); and (3) dedicated bicycle lanes.

- *Traffic calming will result*.[47,48] For example, sideswipe crashes may decrease since motorists no longer need to swerve around vehicles waiting to turn left in a through lane, and left-turn crashes may decrease because motorists encounter only one lane of oncoming traffic.

- *Forecast ADTs remain manageable.* (The values shown in Table 5.3 are easily below the maximum values cited elsewhere.[46,47,48]) Further, because the intended function of a four-lane road is to serve through traffic rather than turning traffic,[48] safety may be threatened if the turning volumes are higher than expected.

- *Lane widths are appropriate for the function of the roadway*. The 11-foot through lanes and 12-foot TWLTL may be monitored to ensure sideswipe collisions do not increase.

To the extent the six assumptions hold, converting the four-lane facility to a three-lane facility with TWLTL and a bike lane can potentially reduce crash risk.

Example 3. Widening Lanes to Reduce Crash Risk

One CLRP described the identification of a dozen roads that may have safety deficiencies under the no-build alternative:

> Also, criteria were established to identify "transitional roads" which are a future safety concern. Transitional roads are those that, while not forecast to be congested, are experiencing a transition from low to moderate or high traffic volumes on narrow (and often curvy) two-lane rural roads. The criteria for transitional roads are narrow (less than 11-foot) travel lanes and greater than a five percent annual growth rate in traffic volumes.[12]

Although the criteria chosen (less than 11-foot travel lanes and an increase in volume of 5 percent per year) may be valid, an improvement to the CLRP would be to quantify the impact of these geometric deficiencies on crash risk. One way to quantify this impact is through the use of CRFs. Although such an assessment is not necessary for all projects, it may help prioritize those projects for which their merits are being debated for other reasons. As an illustration, this step demonstrates how to use crash, geometric, and traffic data (available from Virginia's SPS) to determine the impacts of two projects shown in the case study plan[12]: widening the travel lanes for Route 679 and widening the travel lanes for Route 689. In both cases, lane widths are less than 12 feet. The findings of this analysis are that although each project can reduce crash risk, their benefits are not equivocal: the Route 689 widening should reduce approximately 4 times as many crashes as the Route 679 widening.

The steps for performing this analysis are (1) collect data for the selected projects; (2) obtain CRFs or AMFs; (3) estimate the crash impacts; and (4) interpret the results.

1. Collect data for the selected projects.

Two of the transitional routes identified by the CLRP are described in Table 5.4, based on Appendix B of the CLRP.[12] These routes are shown in Figures 5.5 and 5.6, respectively. Although the CLRP indicates that both segments have lane widths less than 11 feet, SPS indicates that a portion of Route 679 has lane widths of 12 feet and the remaining portion has lane widths of 8 feet. Geometric data, crash data, and year 2030 projected volumes from Virginia's SPS regarding Routes 679 and Route 689 are given in Table 5.5.

2. Obtain crash reduction factors or accident modification factors.

A CRF is the expected percentage reduction in crashes resulting from a treatment; for example, a CRF of 37 percent means that the treatment will reduce crashes by 37 percent. An AMF is the expected crash reduction from applying the treatment; thus a treatment with a CRF of 37 percent has an AMF of 63 percent.

CRFs or AMFs are available from published sources[27,54] for a variety of treatments such as adding lighting, changing signal phasing, and flattening horizontal curves. It is possible that different values for a given CRF will be found if multiple literature sources are consulted; in those situations, the analyst may consider the methods used to obtain the CRF, the date of publication, the amount of underlying data, and the specificity of the treatments cited therein when deciding which CRF should be used.

Table 5.4. Two Transitional Routes Identified in the HRMPO Plan[a]

Jurisdiction	ID	Project Description	Length (miles)	Total Cost (2005 $)
Rockingham	73	Upgrade Pleasant Valley Rd. (Rt. 679) to a 2-lane minor arterial from Rt. 704 to Cross Keys Rd. (Rt. 276)	3.00	3,764,640
Rockingham	78	Upgrade Shen Lake Rd. (Rt. 689) to a 2-lane major collector between Port Republic Rd. (Rt. 659) and Spotswood Trail (Rt. 33)[b]	2.01	2,336,233

HRMPO =Harrisonburg-Rockingham Metropolitan Planning Organization.
[a] Excerpted from Appendix B of the HRMPO Constrained Long Range Plan (CLRP), p. 64.[12]
[b] Because there is no Rt. 659 in Rockingham County, it is assumed that the Rt. 659 refers to Rt. 253 (which is Port Republic Road). Because Rt. 689 does not intersect with Rt. 33, it is assumed the endpoint is Rt. 276, as shown in Figure 5.5.

Figure 5.5. Route 689 Bordered by Route 253 (West) and Route 276 (East), Using VDOT's GIS Integrator

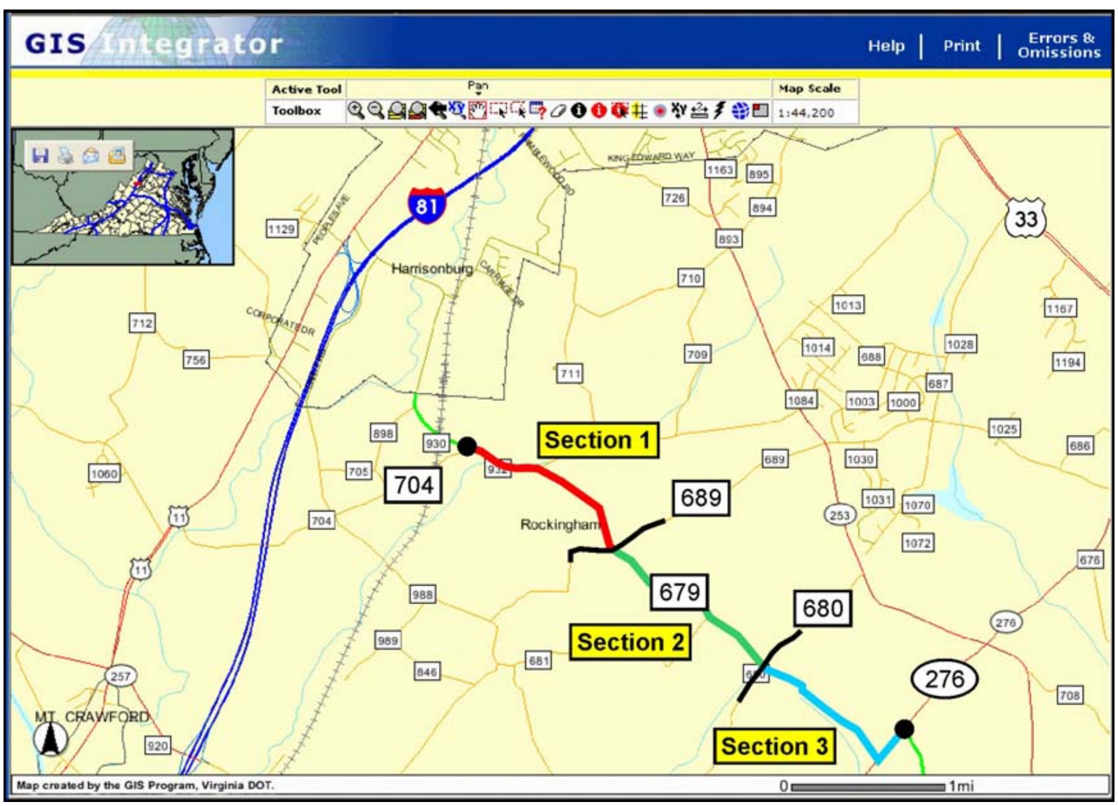

Figure 5.6. Route 679 Bordered by Route 704 (West) and Route 276 (East), Using VDOT's GIS Integrator

Table 5.5. Volume, Geometric, and Crash Data for Route 679 and Route 689

Route	Start and End Points	Section No.	Length (miles)	Lane Width (feet) (2009)	No. of Crashes (1/01/03-12/31/07)	Two-Way ADT (2007)	Two-Way ADT (2030)
679	704 and 689	1	0.79	12	7	1,745	2,987
	689 and 680	2	1.31	12	15	510	785
	680 and 276	3	0.98	8	11	498	782
689	253 and 687	1	0.74	10	15	4,470	8,032
	687 and 276	2	1.28	10	10	3,738	6,605

Equation 5 calculates an AMF for widening lanes on rural two-lane roads. Harkey et al.[27] suggested that 35 percent of the crashes may be attributable to the lane deficiency [if site-specific data are not readily available].

$$AMF = (AMF_{After} / AMF_{Before} - 1)0.35 + 1 \quad \text{[Eq. 5]}$$

where Table 5.6 is used to calculate AMF_{After} and AMF_{Before}.

For example, consider the section of Route 679 between Routes 680 and 276. Table 5.5 indicates an expected 2030 ADT of 782. Assuming no improvements to these 8-foot lanes, Equation 6, based on Table 5.6, indicates that AMF_{Before} is 1.16. Equation 7, also based on Table 5.6, shows that AMF_{After} will be 1.00 assuming the lanes are widened to 12 feet.

$$AMF_{Before} = 1.05 + 0.000281(ADT - 400) = 1.05 + 0.000281(782 - 400) = 1.16 \quad \text{[Eq. 6]}$$

$$AMF_{After} = 1.00 \quad \text{[Eq. 7]}$$

Application of Equation 8, which was based on Equation 5, indicates that the AMF is 0.95.

$$AMF = (1.00 / 1.16 - 1)0.35 + 1 = 0.95 \quad \text{[Eq. 8]}$$

Table 5.6. Computations for AMF_{After} and AMF_{Before}[a]

Lane Width	Accident Modification Factor (AMF)			Where Used in This Example
	ADT < 400	ADT between 400 and 2,000	ADT > 2,000	
9 ft[b]	1.05	1.05 + 0.000281(ADT - 400)	1.50	Eq. 6 to obtain AMF_{Before}
10 ft	1.02	1.02 + 0.000175(ADT - 400)	1.30	Not used
11 ft	1.01	1.01 + 0.000025(ADT - 400)	1.05	Not used
12 ft	1.00	1.00	1.00	Eq. 7 to obtain AMF_{After}

[a] Based on Harkey, D.K., Srinivasan, R., Baek, J., Council, F.M., Eccles, K., Lefler, N., Goss, F., Persaud, B., Lyon, C., Hauer, E., and Bonneson, J.A. *Accident Modification Factors for Traffic Engineering and ITS Improvements.* NCHRP Report 617. Transportation Research Board of the National Academies, Washington, D.C., 2008.[27]

[b] It is assumed that the AMF for 8-foot lane widths equals the AMF for 9-foot lane widths.

3. Estimate the crash impacts.

Table 5.5 indicated that 11 crashes occurred over the 5-year period (2003-2007 inclusive) on this segment. If it is assumed that crash risk is proportional to ADT, Equation 9 may be used to estimate the change in crashes in year 2030 based on widening these lane widths to 12 feet.

$$\text{Crash Reduction} = (\text{Crashes 2003 to 2007})\left(\frac{\text{Volume in 2030}}{\text{Volume in 2007}}\right)(1-\text{AMF}) \qquad \text{[Eq. 9]}$$

For example, Equation 10 shows the reduction for this particular segment as about 1 crash.

$$\text{Crash Reduction} = (11\text{ crashes for 2003 to 2007})\left(\frac{782\text{ vpd in 2030}}{498\text{ vpd in 2007}}\right)(1-0.95) = 0.86 \qquad \text{[Eq. 10]}$$

Table 5.7 summarizes these crash reductions for Route 679 and Route 689.

Table 5.7. Estimated Crash Reductions Resulting from Widening Routes to 12 Feet

Route	Start and End Points	AMF	Crashes in 2030		
			Without widening	**With widening[a]**	**Reduction**
679	704 and 689	1.0[b]	11.98	11.98	0.00
	689 and 680	1.0[b]	23.09	23.09	0.00
	680 and 276	0.95	17.27	16.45	0.82
	Total crashes reduced for Route 679				0.82
689	253 and 687	0.92	26.95	24.78	2.18
	687 and 276	0.92	17.67	16.24	1.43
	Total crashes reduced for Route 689				3.61

[a] Presumes lane widths are widened from values shown in Table 5.5 to 12 feet.
[b] No change because lanes are already 12 feet.

4. Interpret the results.

Table 5.7 suggests that although a lane widening should improve safety for both Route 679 and Route 689, the expected reduction in crashes for Route 689 (3.61 crashes) is more than 4 times the expected reduction in crashes for Route 679 (0.82 crash) over a 5-year period. This result is not surprising given that Route 689 has a higher traffic volume than Route 679 and is deficient for its entire length; Route 679 has a substandard lane width for only a portion of its length.

There are several ways the estimated crash reductions from Table 5.7 can be used in the planning process, as shown in Table 5.8.

Table 5.8. Ways to Use the Estimated Crash Reductions in the Planning Process

Application to Planning Process	Rationale
Do not use Table 5.7.	There are sufficient resources to improve both Route 679 and Route 689.
	There are other reasons for improving both routes.
Redo Table 5.7 with different ADT.	Upon review of these results, MPO or VDOT staff noted that the 2030 ADT forecast in the CLRP differs substantially from the 2030 ADT obtained herein.
Schedule the Route 689 improvement ahead of the Route 679 improvement.	The analysis shows that the Route 689 widening will reduce about 4 times as many crashes as the Route 679 widening.
Modify Table 5.7 to include additional AMFs.	Upon review of these results, MPO or VDOT staff decides to examine the impact of additional improvements to the same routes, such as reduction of horizontal curvature.

Importance of Context When Analyzing the Impact of Potential Countermeasures

Whether narrowing lanes or widening lanes reduces crash risk depends on the context in which the change is proposed.[55] In Example 3, widening lanes to 12 feet reduces crash risk because these are through travel facilities that have substandard geometry. By contrast, crash risk can be reduced by narrowing lanes in some situations, such as residential neighborhoods where traffic calming may reduce excessive speeds. Thus, understanding the type of demand for a given facility may help identify the most appropriate countermeasures.

Note also that the crash reductions anticipated in Example 2 result from a variety of impacts: better access management (which may be assessed based on the reduction in conflict points), replacement of the undivided centerline with a TWLTL, and dedicated facilities for bicycle use. If only speed reductions are desired, less substantive changes can be made with techniques such as narrowing lanes (by constructing a center island using tubular markers), deploying speed feedback signs, and painting speed limit markings with a red background. The efficacy of such changes may be limited; for example, the speed limit markings with a red background yielded speed reductions of 1 to 4 mph in a rural Ohio community 1 year after installation, leading researchers to suggest that more "physical" alterations, such as roundabouts, may be required to achieve greater speed reductions.[56]

5.4. Selected References That Provide Additional Information for the Step

Crash Reduction Factors

- Bahar, G., Masliah, M., Wolff, R., and Park, P. *Desktop Reference for Crash Reduction Factors.* Federal Highway Administration, Washington, D.C., 2007. http://www.transportation.org/sites/scohts/docs/Crash%20Reduction%20Factors%20Desktop%20Reference%2012-19-07.pdf. Accessed July 17, 2009.

- Harkey, D.K., Srinivasan, R., Baek, J., Council, F.M., Eccles, K., Lefler, N., Goss, F., Persaud, B., Lyon, C., Hauer, E., and Bonneson, J.A. *Accident Modification Factors for Traffic Engineering and ITS Improvements.* NCHRP Report 617. Transportation Research

Board of the National Academies, Washington, D.C., 2008. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_617.pdf.

Development of Future Resources

- Task Force on the Development of the Highway Safety Manual. *Highway Safety Manual Overview Presentation.* Transportation Research Board of the National Academies, Washington, D.C., 2008. http://www.highwaysafetymanual.org/PastPresentations/Generic%20HSM%20November%202008.pdf. Accessed October 15, 2009.

SECTION 6. PRIORITIZATION

Step 6. Prioritize projects to determine the largest expected crash avoidance given limited funds. This step requires 10 to 20 hours depending on the type of prioritization method used and whether it is applied to a small number of projects

6.1. Description of the Step

FHWA's Office of Safety implies that safety should be a dominant consideration in project selection, noting that:[57]

> Safety should be considered first, every time and at every stage of a project. Make safety your first consideration in every investment decision.

However, transportation investments are made to achieve multiple objectives (e.g., greater economic development, congestion reduction, and desired land use changes), and a risk of not explicitly recognizing such diverse objectives is that one or more will implicitly guide the project selection process.

Accordingly, one way to strengthen the role of safety in the planning process is to recognize safety explicitly as one of the few or many factors used in project selection. Table 6.1 lists 18 such factors. By clearly documenting the prioritization process, planners can ensure that (1) stakeholders are able to participate in a constructive fashion and (2) safety is given due consideration in project selection.

Table 6.1. Factors That May Influence Project Prioritization

Safety	Travel time	Volume of vehicles served
Congestion	Mobility	Level of service
Cost-effectiveness	Air quality	Speed
Security	Public and community support	Impacts on low income residents
Current conditions	Economic development	Impacts on minority developments
Accessibility to transit	Availability of funds	Geometric/ design deficiencies

Several methods can be used to prioritize projects:

- *Benefit/cost analysis* where a project's future value is assigned a monetary value and compared to the expected capital costs. The benefit/cost is a ratio of the equivalent net present value of benefits to that of costs incurred over the analysis period.[7]

- *A point system* where prioritization criteria are assigned a score. Effective evaluation criteria can be achieved by using performance measures, goals, and objectives used in an MPO's CLRP.[58] The value assigned to prioritization criteria will vary within MPOs. For instance, an MPO in a congested area may have higher values for congestion and transit projects than an MPO in a less congested area. Two point systems are presented in Table 6.2, showing that the degree of detail and number of factors in the prioritization process may be varied.

Table 6.2. Example Prioritization Methods

Category	Prioritization System A (points in parentheses)[a]	Prioritization System B (points in parentheses) [b]
Safety	Crashes (20) Bicycle LOS (10)	Crashes (20) Equivalent property damage only (20) Crashes per million entering vehicles (20)
Roadway type	--	Functional classification (5)
Congestion	Vehicle LOS (10)	Entering vehicles per day (20) Vehicle LOS (5)
Compatibility with other planning processes	--	Presence in long-range plan (1) Presence in current TIP (1)
Roadway design	Geometric deficiencies (10)	--
Maximum points	50	92

TIP = Transportation Improvement Program.
[a] Presented in Section 6.3, Example 2.
[b] Adapted from Young.[59]

- *Road safety audit (RSA) and road safety audit reviews (RSAR),* which are formal examinations of the crash risk of existing or proposed transportation-related investments.[60,61] The distinction between an RSA and an RSAR is that an RSA evaluates a planned [but presumably unbuilt] facility whereas an RSAR evaluates an already constructed facility.[62] Some literature uses the term *road safety assessment* to denote an audit of a constructed facility that is open to traffic.[63] Select characteristics used in an RSA are given in Table 6.3 and adapted from Morgan.[64]

Table 6.3. Select Intersection Characteristics for a Road Safety Audit[a]

Characteristic	Examples of Desired Conditions
Structural	• Pavement and sidewalks are free of potholes and obstructions. • Lighting is adequate and utilities do not present a roadside safety hazard. • Drainage is adequate to reduce the risk of hydroplaning.
Alignment	• Sight distance is adequate given curvature and vegetation. • There are no surprises for motorists, bicyclists, or pedestrians such as abrupt bicycle lane terminations or a hidden driveway.
Intersections	• Pedestrian signals are provided as necessary. • Turning radii are adequate for vehicles. • Bus stops are located in a safe manner.
Traffic signals	• The yellow plus all red phase is sufficiently long to clear the intersection. • Signals heads are easily visible and located on the far side of the intersection.
Signs and markings	• Signs do not overload the user and are easily understood. • Pavement markings are visible at night during inclement weather. • Parking does not increase risk of injury for bicyclists, pedestrians, motorists, or transit users.
Driver behavior	• Drivers yield to pedestrians and obey traffic control. • Near misses are minimized.
Crashes	• Few crashes are observed. • Crashes do not suggest a deficiency. (For example, a large number of rear-end crashes might suggest inadequate intersection clearance time.)

[a] Structural, alignment, intersections, traffic signals, and signs and marking characteristics were developed based on a review by Morgan.[64] Driver behavior and crashes characteristics were based on comments from Read.[15]

6.2. Summary of Current Practice Based on the Survey of Virginia MPOs/PDCs

MPOs and PDCs value safety: 83 percent of survey respondents indicated safety was a factor in placing a project in the CLRP, and about 50 percent of the respondents noted safety was a factor in scheduling projects in the Six-Year Improvement Program (SYIP). However, about one-half of the respondents did not know if safety played a role in scheduling in the SYIP. Further, when asked how often safety was the only reason or one of several reasons for placing a project in the SYIP or STIP, roughly 40 percent of the respondents indicated they did not know the answer.

6.3. Examples of How the Step May Be Performed

Two examples of prioritization are presented: one based on intersections and one based on route segments. The examples demonstrate that prioritization is possible given the data that are available but are not necessarily the "best" method of prioritization.

Example 1. Prioritization of Intersections

This example illustrates how to identify which of three intersections has the greatest crash and injury risk based on three performance measures:

1. entering vehicles per day
2. crashes per million vehicles entering annually
3. number of fatal and injury crashes (3-year crash frequency).

Because this example focuses only on injury and fatal crashes, property damage only (PDO) crashes are excluded. (Although the most severe crashes are fatalities, typically one does not analyze fatal crashes alone because they are rare.)

The three intersections are ranked to determine the intersection with the greatest crash risk based on a point scale adapted from Young.[59] The three intersections listed in Table 6.4 are prioritized based on a total of 60 points: entering vehicles per day (20 points), number of injuries (20 points), and crashes per million entering vehicles (20 points).

Table 6.4. Intersection Data from Lee Highway

Data	**Lee Highway (U.S. 29) and Westmoreland St.**	**Lee Highway (U.S. 29) and Lexington St.**	**Lee Highway (U.S. 29) and George Mason Dr.**
Entering vehicles per day[a] (points)	25,322 (15)	25,170 (15)	37,025 (19)
3-year fatal and injury crash frequency[b] (points)	2 (1)	5 (1)	14 (5)
Crashes per million entering vehicles[c] (points)	0 (1)	0.22 (2)	0.44 (3)
Total points	17 points	18 points	27 points

[a] Data were obtained from VDOT's Traffic Management System Database.
[b] Crash data were obtained from VDOT's Crash Database.
[c] In 2007 the number of crashes for each column were 0, 2, and 6, respectively. Note this is a different time period that that used in Table 3.2; hence the rate shown differs from Table 3.2. For example the crash rate of 0.44 in Column 4 was computed as 6 crashes divided by (37,025 vehicles/day) (365 days/year), multiplied by 1 million.

The weighting criteria used for the intersections are shown in Table 6.5.[59] Table 6.4 ranks the intersection of Lee Highway (U.S. 29) and George Mason Drive as the intersection with the greatest safety risk, and thus it should be addressed first if it is not possible to treat all three intersections at the same time

Table 6.5. Application of Point Scale to the Intersection Data from Lee Highway

Entering Vehicles per Day	Points	No. of Crashes	Points	Crashes per Million Entering Vehicles Annually	Points
39,000+	20	45+	20	4+	20
35,001-39,000[a]	19[a]	43-45	19	3.51-4.00	19
32,001-35,000	18	40-42	18	3.01-3.50	18
29,001-32,000	17	37-39	17	2.51-3.00	17
25,501-29,000	16	34-36	16	2.01-2.50	16
22,001-25,500	15	30-33	15	1.91-2.00	15
20,501-22,000	14	28-29	14	1.81-1.90	14
19,001-20,500	13	25-27	13	1.61-1.80	13
17,501-19,000	12	24	12	1.41-1.60	12
16,001-17,500	11	23	11	1.21-1.40	11
14,001-16,000	10	21-22	10	1.11-1.20	10
12,001-14,000	9	20	9	1.01-1.10	9
11,001-12,000	8	18-19	8	0.91-1.00	8
10,001-11,000	7	16-17	7	0.81-0.90	7
8,751-10,000	6	15	6	0.71-0.80	6
7,501-8,750	5	13-14[a]	5[a]	0.61-0.70	5
5,751-7,500	4	12	4	0.51-0.60	4
4,001-5,750	3	11	3	0.41-0.50[a]	3[a]
2,000-4,000	2	6-10	2	0.21-0.40	2
0-2,000	1	0-5	1	0-0.20	1

[a] Rows indicate point values for the intersection of Lee Highway (U.S. 29) and George Mason Drive.

Example 2. Prioritization of Projects

A documented process may provide a score for each project based on a variety of criteria such as crash frequency; bicycle, pedestrian, or vehicle level of service; and the difference between observed and posted speeds. The documentation should show how total scores are obtained such that readers can see how projects are selected. A prioritization process based on two projects is shown in Table 6.6

Table 6.6. Stone Spring Road and Old Furnace Road Data

Data	Stone Spring Road (Rockingham County)[a]	Old Furnace Road (Rockingham County)[b]
Crashes (1/1/2005-12/31/2007)	7	6
Posted speed	25 mph	55 mph
Estimated free flow speed	24.7 mph	57 mph
Vehicle LOS	C	A
Bicycle LOS	D	B
Presence of sidewalk	None	None
Presence of bicycle facility	None	None

[a] Data based on SPS for the section between the City of Harrisonburg and Route 253 as of October 15, 2009.
[b] Data based on SPS for the section between the City of Harrisonburg and Route 717 West as of October 15, 2009.

The ranking criteria may include (1) safety, (2) vehicle level of service, and (3) geometric deficiencies.

1. Safety (0 to 30 points):

An MPO can use two factors to evaluate the safety score: number of crashes (20 points) in Table 6.7 and BLOS (10 points) in Table 6.8. For example, since Stone Spring Road had 7 crashes, it receives 15 points (Table 6.7), and because Stone Spring Road has a BLOS of C, it receives 6 points (Table 6.8) for a total of 21 points. Note that Table 6.7 distinguishes urban and rural crashes, which is the practice in some regions.

Table 6.7. Score Based on Number of Crashes

No. of Crashes County Limits	Safety Score	No. of Crashes City Limits	Safety Score[a]
≥ 10[b]	20	≥ 15[b]	20
7-9[c]	15[d]	10-14[c]	15
4-6	10[c]	5-9	10[c]
1-3	5	1-4	5
0	0	0	0

[a] Although safety was evaluated using crashes and BLOS, other methods include geometric deficiencies, inadequate site distance, unsafe pedestrian and rail road crossings,[12] and the measures shown in Table 3.1 or Table 6.1.
[b] These rows were developed based on the MPO's judgment[12] that high-crash locations may be defined as 10 crashes every 3 years in the county or 15 crashes every 3 years in the city.
[c] These rows were developed based on the authors' judgment and HRMPO's use of 4 levels per factor.
[d] This is the score given to Old Spring Road because of its 7 crashes in Table 6.5.

Table 6.8. Score Based on Bicycle Level of Service

BLOS[a]	LOS Score[b]
F	10
E	8
D	6[c]
C	4
B	2
A	1

[a] An MPO may use BLOS and other prioritization factors in Table 6.1 to determine a safety score that would suit the needs of the MPO.
[b] Point values are based on an assumption that BLOS is linearly related to crash risk. A review of relevant literature (e.g., Klobucar and Fricker, 2007) does not indicate a precise relationship between LOS and crash risk (except that it is believed that a BLOS of A yields a facility that has less crash risk than a facility with an LOS of F).
[c] This is the score given to Old Spring Road because of its BLOS of D in Table 6.5.

2. *Vehicle level of service (0 to 10 points):*

A poor LOS will receive a higher score in the prioritization criteria, indicating that projects with a poor LOS should be considered before those with a good LOS. A LOS F indicates that a roadway is more congested than one with a LOS A.

Table 6.9. Score Based on Vehicle Level of Service

Vehicle LOS	LOS score
F	10
E	8
D	6
C	4[a]
B	2
A	1

[a] This is the score given to Old Spring Road because of its vehicle LOS of C in Table 6.5.

3. Geometric deficiencies (0 to 10 points):

A roadway can be prioritized based on the lack of sidewalks and bicycle lanes as shown in Table 6.10 but only if the improvement will address the deficiency. Because the proposed projects do not include bicycle/pedestrian facilities per se, in this case no points are awarded.

Table 6.10. Score Based on Geometric Deficiencies

Bicycle Facility	Score[a]	Sidewalks	Score
Paved	0	Paved	0
Unpaved	2	Unpaved	2
None	5	None	5

[a] Point scores are based on the authors' assumption that pedestrians and bicyclists prefer to use paved facilities. A range of values is possible for unpaved facilities; the value of two points was arbitrarily chosen for this table.

Summary

The sums of the ranking criteria 1 through 3 are scored for each project and ranked as shown in Table 6.11. According to this prioritization process, the Stone Spring Road project should be considered for construction before the Old Furnace Road project.

Table 6.11. Prioritization and Ranking of Projects Within an MPO

Project	Safety (0-30)	Vehicle LOS (0-10)	Geometric Deficiencies (0-10)	Total Score (0-50)	Rank
Stone Spring Road (county) Widen to 4-lane facility	21	4	0	25	1
Old Furnace Road (718) (county) Upgrade to 2-lane major collector	12	1	0	13	2

6.4. Selected References That Provide Additional Information for the Step

Road Safety Audits, Road Safety Audit Reviews, and Road Safety Assessments

- Morgan, R. Road Safety Audits: Practice in Australia and New Zealand. *Institute of Transportation Engineers Journal*, Vol. 75, No. 7, 2005, pp. 22-25. http://www.ite.org/membersonly/itejournal/pdf/2005/JB05GA22.pdf. Accessed June 21, 2008.

- Wilson, E.M., and Lipinski, M.E. *Road Safety Audits: A Synthesis of Highway Practice*. NCHRP Synthesis 336. Transportation Research Board of the National Academies, Washington, D.C., 2004.

SECTION 7. FUNDING

Step 7. Identify alternative funding sources for safety-related projects. This step requires 30 to 40 hours depending on the effort needed to demonstrate that a project meets the criteria for a particular funding source.

7.1. Description of the Step

Many projects listed in the CLRP are funded from some component of the SYIP and are not discussed further in this step. There are, however, some lesser-known alternative funding sources, some of which are shown in Table 7.1; the reader may consult Grimes et al.[65] for a comprehensive list. Table 7.1 lists information for the funding sources that was current as of 2009; at any given point in time, a particular funding source may change from being earmarked to requiring competitive proposals or vice versa.

Note that the programs shown in Table 7.1 can yield safety benefits even though they are not dedicated exclusively to safety projects. A related initiative is the VDOT Strategically Targeted Affordable Roadway Solutions (STARS) Initiative, which aims to implement lower cost projects (in the range of $2 million to $5 million) relatively quickly.[66]

7.2. Summary of Current Practice Based on the Survey of Virginia MPOs/PDCs

The survey respondents ranked the greatest obstacle to integrating safety and planning as a lack of dedicated safety funding. Three funding sources—enhancements, safe routes to school, and the Highway Safety Improvement Program—were each used by between one-third and one-half of respondents. Funding sources shown in Table 7.1 are often targeted to specific purposes that can be aligned with improvements noted in the CLRP. For example, the Harrisonburg-Rockingham MPO lists funding sources that can be used for bicycling/walking improvements; two such sources are the Virginia Recreational Trails Program and the National Scenic Byways Program.[12]

7.3. Example of How the Step May Be Performed

There are at least four ways to obtain funding for safety-related projects.

1. *Reduce maintenance expenses where demand has decreased.*

   See Step 8 (Section 8 of the guide) for an innovative approach (T. Short, personal communication, May 28, 2009).

2. *Identify safety-related improvements as part of the land development process when residential or commercial developers seek a rezoning request.*

Table 7.1. Examples of Alternative Funding Sources for MPOs and PDCs

[Agency] and Fund	Dollar Amount	Contact Information
[U.S. DOT] Transportation, Community, and System Preservation (TCSP) Program	$61.25 M (2009)	Office of Planning, Environment, and Realty Phone: 202-366-2048 http://www.fhwa.dot.gov/tcsp/pi_tcsp.htm
[U.S. DOT] Public Lands Highway Program	$102 M (2009)	Office of Program Administration Phone: 202-366-4653 http://www.fhwa.dot.gov/discretionary/plhcurrsola3.cfm
[U.S. DOT] Scenic Byways Programs	$43.5 M (2009)	1200 New Jersey Avenue, SE HEPN-50 Washington, DC 20590 Phone: 804-786-2264 nsb-director@byways.org http://www.bywaysonline.org/program/us_code.html http://www.fhwa.dot.gov/safetealu/factsheets/scenic.htm
[VDOT] Congestion Mitigation and Air Quality (CMAQ) Program	$39.5 M (2008)	Virginia Department of Transportation 1401 E. Broad Street, Room 414 Richmond VA 23219 Phone: 804-786-6675 http://www.fhwa.dot.gov/environment/cmaqpgs/ http://www.fhwa.dot.gov/legsregs/directives/notices/n4510675.htm
[VDOT] Highway Safety Improvement Program (HSIP) under SAFETEA-LU, which includes: • Bike and Pedestrian Safety Program (BPSP) • Highway Safety Program (HSP) • Rail Grade Crossing Safety Program (H-RGCP) • High Risk Rural Roads Program	$45.9 M (2009)	Highway Safety Improvement Programs Manager Virginia Department of Transportation Traffic Engineering Division 1401 East Broad Street Richmond, VA 23219 HSIProgram@VirginiaDOT.org Phone: 804-786-9094 [HSP and BPS Programs: 804-786-6610] [H-RGC Program: 804-786-2822] http://www.fhwa.dot.gov/safetealu/summary.htm www.virginiadot.org/business/trafficeng-default.asp
[VDOT] Safe Routes to School		Safe Routes to School Coordinator Virginia Department of Transportation Transportation and Mobility Planning Division 1401 E. Broad St. Richmond, VA 23219 Phone: 804-371-4868 http://www.virginiadot.org/programs/ted_Rt2_school_pro.asp http://www.fhwa.dot.gov/safetealu/factsheets/saferoutes.htm
[VDOT] Revenue Sharing	$30 M (annually since 1999)	Phone: 804-786-1519 http://www.virginiadot.org/business/local-assistance-access-programs.asp
[VDOT] Transportation Enhancement Program	$19.2 M (2010)	Phone: 1-800-444-7832 EnhancementProgram@VDOT.Virginia.gov http://www.virginiadot.org/business/prenhancegrants.asp
[DMV] (Federal 402 Performance Based Funds)	$6.3 M (2008)	Highway Safety Office (DMV) http://www.dmv.state.va.us/webdoc/safety/highway_safety_plan.pdf
[DCR] Virginia Recreational Trails Fund	$25,000 to $100,000 per project	Virginia Recreational Trails Program Department of Conservation and Recreation 203 Governor Street, Suite 326 Richmond, VA 23219-2010 Phone: 804-786-4379 http://www.dcr.virginia.gov/recreational_planning/trailfnd.shtml

U.S. DOT = U.S. Department of Transportation; DCR = Virginia Department of Conservation and Recreation.

3. *Incorporate safety improvements into existing operational, maintenance, and 3R [resurfacing, restoration, and rehabilitation] projects*.[15]

   For example, the main motivation for a given resurfacing project may be pavement deterioration; however, at the same time, it may be possible to consider needed geometric improvements such as the addition of turn lanes, a shoulder widening, or a horizontal curvature improvement.[67]

4. *Identify other funding sources for safety-related projects*.

   The State Transportation Improvement Program (STIP) is the predominant source of funds for transportation improvements. The STIP is a combination of the SYIP and each MPO's Transportation Improvement Program (TIP). However, projects may be eligible for other sources of funding that have specific requirements, as shown in the following example.

Potential Project

The Arboretum Trail Project, suggested by the City of Harrisonburg's Bicycle Plan, will connect Neff Avenue to University Boulevard, providing a convenient trail between the James Madison University (JMU) campus and off campus apartment complexes.[30] This project may also reduce crash risk for bicyclists and pedestrians.

Potential Funding Source

The Transportation and Community System Preservation (TCSP) Program administered by the U.S. Department of Transportation under Section 1117 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) (P.L. 109-203) could be used to provide additional funds for the Arboretum Trail Project. The TCSP Program provides funding for projects that address relationships between transportation, community, and system preservation. Section 1117 of SAFETEA-LU authorized the program through FY 2009. Additional information can be found at http://www.fhwa.dot.gov/tcsp/pi_tcsp.htm.

The TCSP program requires project proposals to achieve the following:

1. Improve the efficiency of the transportation system.
2. Reduce the impacts of transportation on the environment.
3. Reduce the need for costly future public infrastructure.
4. Ensure efficient access to jobs, services and centers of trade.
5. Encourage private sector development patterns.

Linking the Project and the Funding Source

If submitted, it appears that the Arboretum Trail Project would qualify for TCSP Program funds as it would:

- Provide a continuous bicycle and pedestrian network. This network would benefit the community of students, faculty, and staff of JMU as well as other citizens of the residential complexes. Currently there are portions of the trail in place, but they lack a connection to Neff Avenue (Requirement 1).

- Reduce the transportation impacts to the environment to the extent that bicycling and walking replace travel by auto and thus reduce mobile source emissions and water runoff (Requirement 2).

- Provide two alternative means of transportation (bicycling and walking) that reduce infrastructure costs to the extent that more expensive roadway improvements or transit operating improvements are not needed because of bicycling and walking use (Requirement 3).

- Provide efficient access to JMU for students and staff by providing a faster route to the campus (Requirement 4).

- Encourage residential developers to consider pedestrian and bicyclist access in future developments (Requirement 5).

Comment

Each of the four approaches noted at the beginning of Section 7.3—reducing maintenance expenses, integrating safety with the land development process, integrating safety and operations projects, and identifying an alternative source of funds—ultimately uses monies that could have served some other purpose. Accordingly, it may be necessary to estimate the impact of the proposed project on crash risk. Tools to estimate these impacts include AMFs (Step 5). For 3R projects in particular, the Resurfacing Safety Resource Allocation Program[67] shows expected crash reductions and allows the user to "optimize" the expected crash reduction benefits based on several candidate 3R projects.[67]

7.4. Selected References That Provide Additional Information for the Step

Virginia-Specific Examples of Combining Congestion and Safety

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National Examples of Combining Operations and Safety

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NCHRP Report 486. Transportation Research Board of the National Academies, Washington, D.C., 2003. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_486_full.pdf. Accessed October 14, 2009.

SECTION 8. MONITORING

Step 8. Monitor the safety impacts of implemented projects. This step requires 10 to 50 hours for an evaluation of the types given in the examples. More detailed evaluations will require more time.

8.1. Description of the Step

Monitoring of the transportation system is a fundamental component of transportation planning. Within the context of urban transportation planning, Meyer and Miller wrote that monitoring can do the following:

> identify where *problems* occur (or are likely to occur) in the transportation system, where *opportunities* exist for improving the effectiveness and efficiency of current services even thought they might not be related to identifiable problems, and how well the transportation *program goals* are being achieved (emphasis in the original).[3]

Because system monitoring entails a retrospective examination of safety-related performance and is used to quantify the efficacy of safety-related programs, the mathematical techniques associated with system monitoring may be similar to those used in a before-after study. However, the literature portrays monitoring as being broader than a before-after study, with a three-pronged emphasis on (1) goals, (2) opportunities, and (3) problems as noted in the quotation.

1. Goals: How well are goals being achieved?

Monitoring may mark progress toward specified goals by relating safety performance to objectives subsumed within those goals. When in 2001 the U.K.'s Highways Agency established a target of reducing fatalities and injuries by 33 percent by year 2010, the agency established a monitoring program to disseminate detailed crash data and related safety program information.[68]

Because crashes have a variety of causal factors, it may be productive to collect a variety of performance measures that can address short-term and long-term performance. For example, suppose a region seeks to reduce run-off-the-road departure crashes on its secondary facilities as discussed in Section 5.3. Although the most important result is the reduction of injuries and fatalities, this end result does not provide sufficient information as to the efficacy of roadway departure crash strategies. For example, if injury crashes decrease by 5 percent from one year to the next, one cannot discern whether this decrease results from a given program, random variation, or some other factor such as a reduction in total travel.

Accordingly, a monitoring program might consist of three related performance measures, as shown in Table 8.1. Although the first measure reports the overall effectiveness of the program, the second and third measures serve as a diagnostic tool to understand why such injury crashes may be changing.

Table 8.1. Performance Measures for Monitoring a Roadway Departure Crash Reduction Program

No.	Performance Measure	Scope	Strengths and Weaknesses
1	Change in roadway departure injury crashes	Long term (at least 6 years of before-after data) at the jurisdiction level	Easily understood by stakeholders but requires substantial time to collect
2	Number of lane miles built with substandard width	Medium term (2 to 6 years) at the program level	Directly affected by local and state actions but not the only factor affecting crash risk
3	Number of times a vehicle crossed the double yellow line	Short-term data collection effort at specific sites	Requires manual data collection effort at specific locations

2. Opportunities: Where do opportunities exist to improve the effectiveness of current services?

Monitoring may pinpoint opportunities for improvement. For example, the VDOT Northern Virginia District Transportation Planning Section undertook a Mobility Improvement Study (MOBIS) that identified safety and mobility problems in transportation corridors.[69] One such corridor was a 9-mile section of Braddock Road, a highly congested urban facility with 53 intersections, speed limits of 40 to 45 mph, and four to eight travel lanes. The analysis of crash data coupled with field visits led to consideration of specific improvements at each intersection. For example, the use of offset opposing left-turn lanes was examined in order to increase visibility at the Backlick Road intersection, and an extension of the left-turn lane was considered to reduce left-turn crashes at the Ravensworth Road intersection. Figure 8.1 shows that both intersections have higher injury crash rates than the average for the entire corridor.

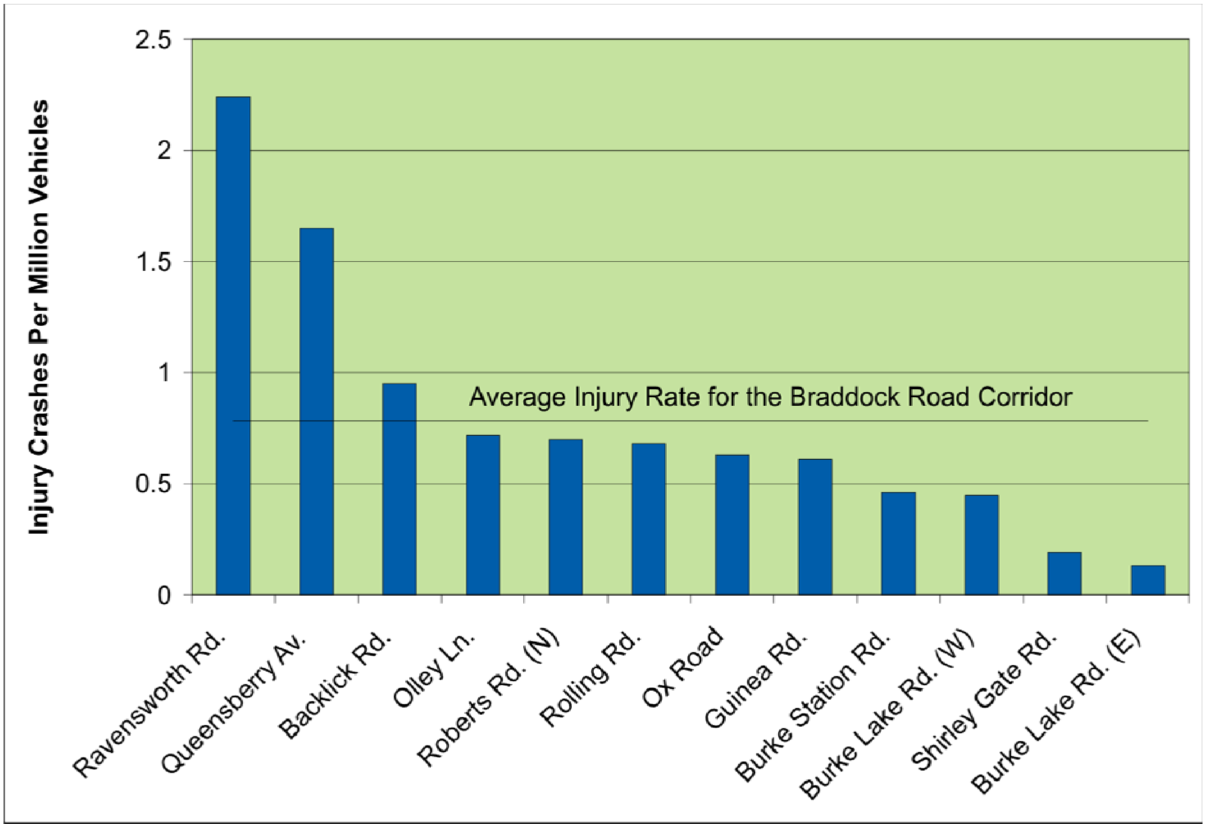

Figure 8.1. Injury Crash Rates for the Braddock Road Corridor Created by Reviewing VDOT Data[69]

3. Problems: Where are problems that are likely to occur?

System monitoring may be undertaken for current or future problems. For example, Agent and Green reported that the installation of signals that did not meet any of the warrants of the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) was associated with an average rear-end crash increase of 222 percent, compared with an increase of 49 percent for signals that met at least one of the warrants.[70] Thus, monitoring may be as straightforward as identifying existing locations that do not meet acceptable practices.

Monitoring may also identify problem areas that are likely to arise in the future. One illustration is the PLANSAFE model, which forecasts crashes by transportation analysis zone.[71] Many of the independent variables encompassed by the model are directly or indirectly related to land development; these include total population, commuting behavior, income, density, and VMT. Thus, one application of PLANSAFE is to run the model in conjunction with a 20-year travel demand forecast and then identify locations where safety countermeasures are likely to be required. (The authors cautioned that the model should not be used to choose land development strategies; rather, the model should be used to identify when safety countermeaures are needed.[71] For example, it would be inappropriate to use the model to determine whether a compact growth scenario should be pursued by a region; however, it would be appropriate to use the model to determine when in the future and where within the region a given growth scenario would increase pedestrian crash risk such that appropriate countermeasures could be studied.)

8.2. Summary of Current Practice Based on the Survey of Virginia MPOs/PDCs

Almost two-thirds of the MPOs/PDCs noted they use public perception to evaluate the safety impacts of projects in the CLRP; about one-half of those respondents also use other techniques such as before-after comparisons of crash rates and safety performance indices. Most respondents noted they do not regularly perform retrospective analyses of safety-related projects, and about one-third noted they never perform such an analysis. The survey suggested at least two obstacles to such monitoring: the lack of sufficient staff necessary to analyze project impacts and a lack of access to necessary data.

8.3. Examples of How the Step May Be Performed

Three examples show how monitoring enhances transportation safety planning:

1. Measure progress toward the *goal* of reducing crashes.
2. Identify *opportunities* to improve the effectiveness of traffic control.
3. Determine if *problems* result from cost reductions.

In practice, each example requires additional study beyond that presented here. That said, the examples illustrate tangible ways in which monitoring may enhance the integration of safety and planning.

Example 1. Measure Progress Toward the Goal of Reducing Crashes

System monitoring may assess progress toward a goal of reducing crash risk on interstate facilities at the jurisdiction level. As an illustration of such monitoring, consider crashes on I-81 Northbound within Harrisonburg, Virginia, and Rockingham County, Virginia. This corridor is of interest for two reasons. First, it receives emphasis in the region's long-range transportation plan, which includes "I-81 ramp/safety improvements" as one safety-related initiative.[12] Second, Virginia's SHSP points out that roadway departure crashes are an emphasis area; such crashes are severe "because of the speed differential involved with vehicles striking a fixed object or an oncoming vehicle."[4] Roadway departure crashes, such as those involving a fixed object or an overturned vehicle, account for roughly one-half of the total crashes on I-81 North within these two jurisdictions.

A variety of policies may reduce crash risk, and monitoring might assess the effectiveness of such policies. One such policy is the establishment of lower or higher speed limits. On January 19, 2001, the speed limit for I-81 between mile posts 242.33 and 248.96 was lowered from 65 mph to 60 mph; the remainder of I-81 within Rockingham County and the City of Harrisonburg retained a speed limit of 65 mph. Figure 8.2 shows this section and the 10-year crash frequency. The "before" period reflects crashes occurring between January 19, 1996, and January 19, 2001, when the speed limit was 65 mph for the entire section. The "after" period reflects crashes occurring between January 19, 2001, and January 19, 2006, when the speed limit for the aforementioned section was lowered to 60 mph.

System monitoring may also identify ways to improve progress toward a given goal. For example, Figure 8.3 shows a drop in crashes from 2000 to 2001 in the section where speed limits were lowered, followed by an increase in crashes in later years. It is possible, of course, that random variation explains the shape of the crash frequencies such that the speed limit change has had no effect. However, it is also possible that other factors are affecting the utility of this speed zone. If these other factors are within the control of the state, MPO, or localities, such as the availability of law enforcement, they may merit further consideration.

For MPO or PDC staff wishing to replicate these types of analyses to examine high-crash corridors, note that crash rates for corridors under study may be compared to statewide averages. For example, in 2005, the average injury rate for I-81 for the entire Commonwealth of Virginia was 23.1 persons injured per 100 million VMT.[72] By comparison, the injury rate for the entire I-81 section shown in Figure 8.2 was 15.4 injuries per 100 million VMT.

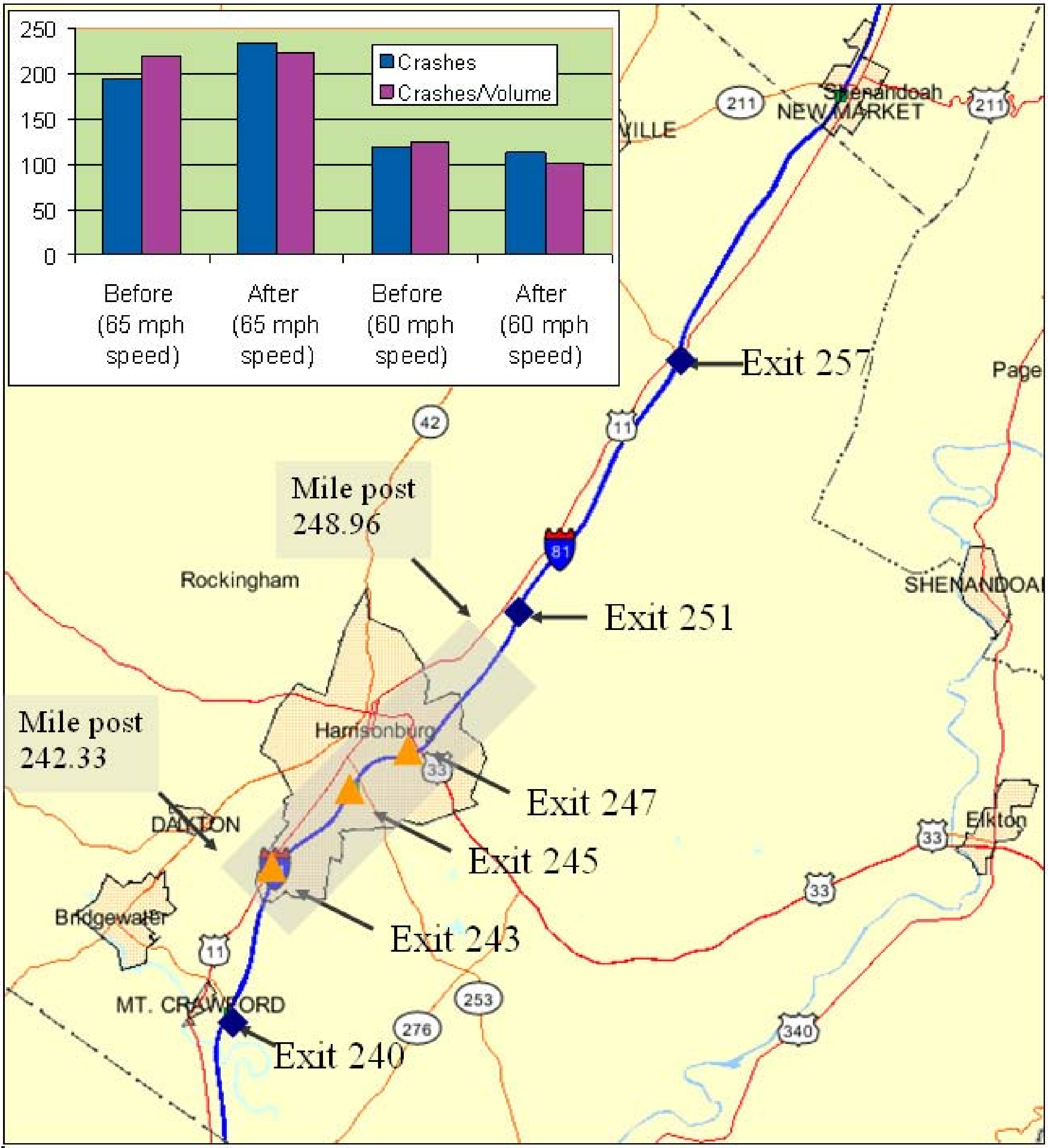

Figure 8.2. Total Crashes on I-81 North for the Period January 19, 1996–January 19, 2006. Volume data were obtained for mile posts 252.93 to 258.49 and 243.56 to 246.39.

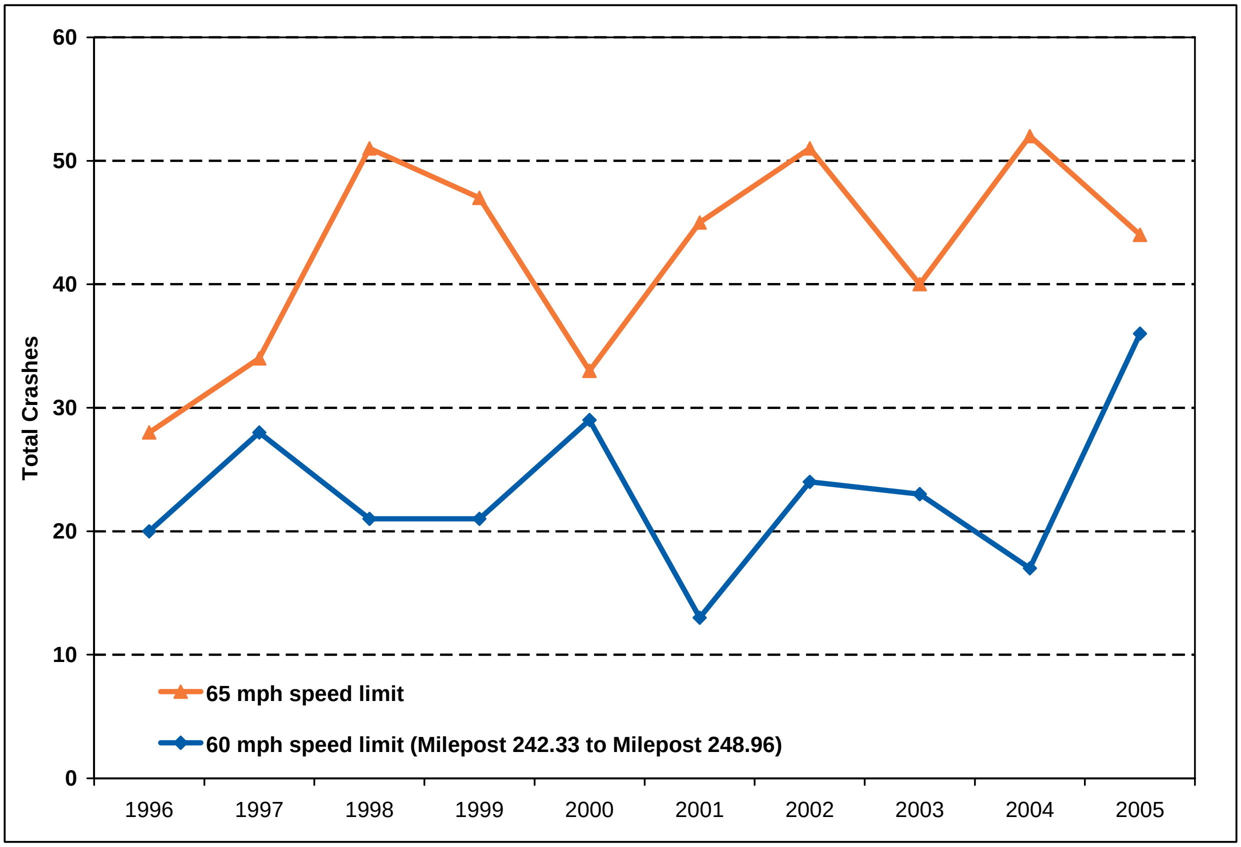

Figure 8.3. Crash History for I-81 North. Note that 1996 data do not include the period January 1-18.

Example 2. Identify Opportunities to Improve the Effectiveness of Traffic Control

An asset management example of monitoring was provided in a meeting with VDOT Staunton District and Shenandoah Valley PDC staff (T. Short, personal communication, May 28, 2009). In the City of Covington, the annual maintenance cost for each traffic signal is approximately $3,000 to $8,000. The high costs result because the older signals require parts from a limited supply of higher priced vendors when repairs are needed. Traffic volumes have decreased because of the city's population losses, suggesting that it may be possible to replace some traffic signals with stop or yield signs. Replacing the signals with such signs would provide a cost savings that could be directed to safety-related projects. One such signal is at the intersection of Monroe Avenue [U.S. 60] and Riverside Drive [S.R. 154], shown in Figure 8.4.

The MUTCD may be used to establish a monitoring process.[73] The MUTCD names eight warrants that can help determine whether a signal is needed based on factors such as vehicle and pedestrian volume, peak hour volume, the existence of a school crossing, the need for a coordinated signal system, crash experience, and the need to redirect travel demand to a particular link on the roadway network. Meeting the criteria for a signal warrant is not, by itself, a sufficient condition to justify a signal; further, failure to meet all warrants is not a sufficient condition to justify signal removal. However, meeting the criteria for at least one warrant is a relatively solid indicator as to whether a signal is needed or not at a particular location.

Figure 8.4. Intersection of Riverside Drive (Minor Approach) and Monroe Avenue (Major Approach) in Covington, Virginia. Photograph taken by Jeremy Schroeder, Covington, Virginia, August 2, 2009.

The first warrant may be applied when either Condition A (8-hour vehicular volume) or B (interruption of continuous traffic) is met. An excerpt of Condition A is[73]:

> The need for a traffic control signal shall be considered if an engineering study finds that . . . for each of any 8 hours of an average day…The vehicles per hour given . . . [in Table 8.2] . . . exist on the major-street and the higher-volume minor-street approaches.

Figure 8.5 shows one lane for the east-west minor approach (Riverside) and two lanes for the north-south major approach (Monroe). Eight-hour volume data are shown in Table 8.3. Table 8.3 shows that for year 2008, only 5 of the 8 hours met both criteria for Warrant 1. Because Warrant 1 requires that the criteria be satisfied for all 8 hours, a traffic signal at this location is not needed based on this warrant for Condition A. A separate analysis could be undertaken to verify that Condition B is also not satisfied.

Table 8.2. Warrant 1: Eight-Hour Volume Requirements for Condition A[a]

No. of Lanes for Moving Traffic on Each Approach		**Criterion 1: Vehicles per Hour on Major Street (Total of Both Approaches)**	**Criterion 2: Vehicles per Hour on Higher Volume Minor Street Approach (One Direction Only)**
Major Street	**Minor Street**		
1	1	500	150
2 or more[b]	1[b]	600[b]	150[b]
2 or more	2 or more	600	200
1	2 or more	500	200

[a] Excerpt of Table 4C-1 from the MUTCD with annotation added.
[b] The conditions shown in this row apply to the intersection being studied.

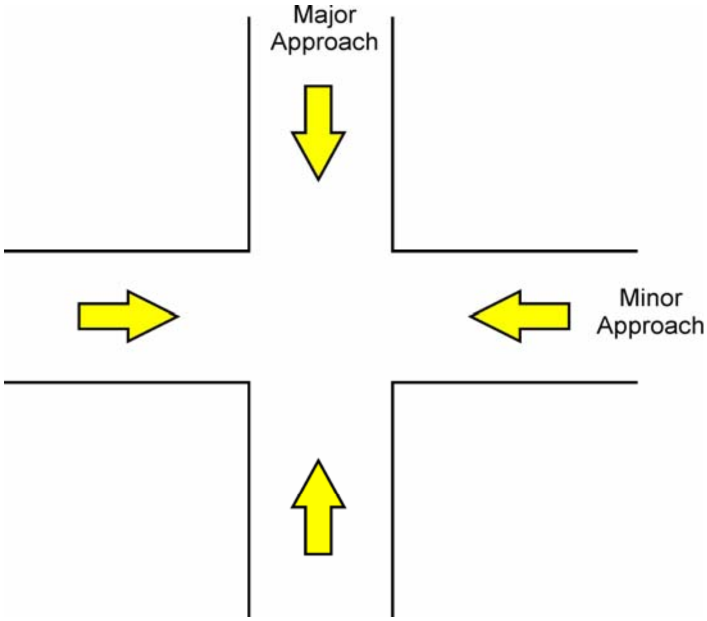

Figure 8.5. Minor Approach (Riverside Drive) and Major Approach (Monroe Avenue)

Table 8.3. Intersection Volumes for 2008

	2008[a] Data (Real data)				
	Riverside Drive [SR 154]		**Monroe Avenue [U.S. 60]**		
Hour	**Minor NB**	**Minor SB**	**Major EB**	**Major WB**	**Both Hourly Criteria Met?**
8-9	123	138	234	261	No
9-10	119	154[b]	258	312	No
10-11	110	127	288	209	No
11-noon	133	151[b]	352[c]	254[c]	Yes
Noon-1	182	191[b]	340[c]	307[c]	Yes
1-2	208[b]	171	292[c]	384[c]	Yes
2-3	142	191[b]	324[c]	307[c]	Yes
3-4	174	187[b]	331[c]	319[c]	Yes

[a] Traffic volume data obtained from VDOT's Traffic Management System Website [Node 115555].
[b] The higher minor street volume exceeds 150 (see Table 8.2, Criterion 2).
[c] The total of both major approach volumes exceeds 600 (see Table 8.2, Criterion 1).

Example 3. Determine If Problems Result From Cost Reductions

It is possible that removing the traffic signal at an intersection will have an adverse impact on safety. Accordingly, a monitoring process can be established to determine whether a safety-related problem has arisen. Although the eight signal warrants are germane, the seventh warrant (crash experience) directly incorporates the concept of monitoring.

Three conditions must be met to satisfy the crash experience warrant[73]:

1. Other alternatives, such as better signing, removal of vegetation, or improved pavement markings, have failed to reduce crash frequency and/or crash severity.

2. For each of any 8 hours, the major and minor approach volumes should be greater than 80 percent of the volumes shown in Table 8.2.

   Consider Table 8.3 for year 2008 for the hour from 8 to 9 A.M. The major approach volume is 234 + 261 = 495. This exceeds 80 percent of the major approach volume criterion in Table 8.2, since 80 percent of 600 = 480. Criterion 2 is also met since the higher minor approach volume (138 shown in Table 8.3) exceeds 80 percent of the 150 vehicles per hour shown in Table 8.2). [There are other ways to satisfy this condition; see the MUTCD[73] for details.]

3. Five or more reportable crashes related to the lack of a traffic signal should have occurred during the previous 12 months.

   Table 8.4 shows that two crashes occurred in 2010 (prior to the signal's removal) and, for the purposes of illustration, that three crashes occurred in 2011 after the signal was removed. Note that in 2011 the warrant criterion is not satisfied as there were not five crashes attributed to the lack of a traffic signal.

Table 8.4. Intersection Crash Data for 2008 and 2011

2008 Crash Data[a]		**Fictitious 2011 Crash Data**[b]	
Crash No.	**Summary**	**Crash No.**	**Summary**
1	PDO angle crash, driver charged with disregard traffic signal	1	PDO angle crash, driver charged with failure to yield
2	PDO angle crash, driver charged with failure to maintain control	2	Injury Rear-end crash, driver charged with driver inattention
		3	PDO angle crash, driver charged with speeding

[a] Crash data were obtained from VDOT and reflect crashes within 150 feet of the intersection.
[b] Data are fictitious and were created for the purpose of illustration.

Because the third criterion is clearly not met, the crash warrant is not satisfied and thus there does not appear to be a safety-related problem at the intersection. However, the initial increase from two to three crashes may raise a concern. Two factors that may be further considered are as follows:

1. *Is the increase in crash frequency due to random variation?*

   If, for example, 3 years of before data showed annual crash frequencies of 1, 2, and 3 whereas 3 years of after crash data showed annual crash frequencies of 3, 0, and 4, one might suspect the differences are random.

2. *Are the crashes attributable to traffic control?*

   For example, in 2011, it is possible, but not necessarily the case, that Crash 1 (failure to yield) may be related to the type of traffic control. To make this determination, a site visit would be needed to determine if sight distance was a problem; one would also study the intersection to see if other types of crashes (or near misses) transpired.

Monitoring is also helpful for assessing the appropriateness of CRFs, which are the expected percentage reduction in crashes resulting from some treatment. For example, data from Harkey et al.[27] suggested that, based on a study of one-way streets in Philadelphia, removing an "unwarranted" traffic signal in an urban environment may

- reduce rear-end crashes by 29 percent
- reduce severe injury crashes by 53 percent.

The conditions in Covington (less urban, two-way streets) clearly differ from those where the CRFs were developed (more urban, one-way streets). If the data shown for 2008 in Table 8.4 are representative of data for other years, there are no (or very few) rear-end crashes or injury crashes. Thus, the available data do not suggest that removing the signal will necessarily yield safety benefits at the intersection. It still may be beneficial to remove the signal, but the case for removing it would appear to be that the signal is not warranted and thus the cost savings its removal will generate could be used for safety improvements elsewhere.

(Another type of traffic control not discussed is a roundabout, which, when designed appropriately, has the potential to provide safety benefits by eliminating left-turn, right-angle, and head-on collisions[74] and may reduce speeds.[56] However, the reader should consult the literature, which provides additional design and safety considerations relevant to roundabouts.)

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APPENDIX: HOW THE GUIDE WAS DEVELOPED

The eight steps shown in Figure 1 were compiled from several sources as detailed in *Incorporating Safety into the Regional Planning Process in Virginia: Volume 1: Development of a Resource Guide.*[2] These sources were as follows:

- *safety engineering literature*, such as crash reduction factors[27,54] that indicate how various treatments should affect crash risk
- *planning literature*, such as bicycle LOS concepts[34]
- *Virginia practices*, such as an MPO's CLRP[12] and the state Highway Safety Plan[4]
- *the survey distributed to 23 Virginia MPOs and PDCs* in November 2008 as part of the development of the guide.[2]

A seminal TRB publication entitled *Incorporating Safety Into Long Range Transportation Planning (*NCHRP Report 546)[71] identified useful integration practices. Table A1 relates the steps in the resource guide to this publication, the Virginia MPO/PDC survey, and examples of relevant literature.

Table A1. Information Used to Generate Each Step Discussed in the Resource Guide

Step in Integrating Safety	**Numbered Section of Resource Guide**	**Best Practice As Provided in NCHRP Report 546**[a]	**Virginia MPO/ PDC Survey Question**[b]	**Example of Relevant Literature**
1. Develop a vision statement, goals, and objectives that directly incorporate safety.	1. Vision Statement, Goals, and Objectives	1,2	2	Meyer and Miller[3]
2. Use diverse stakeholders to identify alternatives and evaluate their utility.	2. Stakeholders	10	9,10	HRMPO[12]
3. Use safety-related performance measures to assess deficiencies.	3. Performance Measures	3	4, 5	Landis et al.[33]
4. Acquire data within the time constraints faced by the planner.	4. Data Needs	5,4	1(part of),11	VDOT[36]
5. Analyze data with available resources and thus select higher impact projects.	5. Data Analysis	5,4	3,13	Harkey et al.[27]
6. Prioritize projects to determine the largest expected crash avoidance given limited funds.	6. Prioritization	6,7,8	8,6	Trigueros[58]
7. Identify alternative funding sources for safety-related projects.	7. Funding	6	12, 14	HRMPO[12]
8. Monitor the safety impacts of implemented projects.	8. Monitoring	9	7,15	FHWA[73]

HRMPO = Harrisonburg-Rockingham Metropolitan Planning Organization

[a] In NCHRP Report 546, Washington et al. outlined 10 practices for linking safety and planning:[71]

1. Does the vision statement for the planning process include safety?
2. Are there at least one planning goal and at least two objectives related to safety?
3. Are safety related performance measures part of the set being used by the agency?
4. Are safety related data used in problem identification and for identifying potential solutions?

5. Are safety analysis tools used regularly to analyze the potential impacts of prospective strategies and actions?
6. Are evaluation criteria used for assessing the relative merits of different strategies and projects including safety related issues?
7. Do the products of the planning process include at least some actions that focus on transportation safety?
8. To the extent that a prioritization scheme is used to develop a program of action for an agency is safety one of the priority factors?
9. Is there a systematic monitoring process that collects data on the safety related characteristics of transportation system performance and feeds this information back into the planning and decision making process?
10. Are all of the key safety stakeholders involved in the planning process?

[b] The question number refers to one of the 18 questions in the survey of Virginia's 23 MPOs and PDCs as described in Volume I of this report.[2]

INDEX

The numbers refer to section numbers; e.g., accident modification factors may be found in Section 5.3, Example 3.