District Highway Safety Guidance Manual

December, 2014

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DEPARTMENT OF TRANSPORTATION

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District Highway Safety Guidance Manual

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December, 2014

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Chapter 1 — Introduction

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1.1 Introduction

Highway safety is a key priority for the Pennsylvania Department of Transportation (PennDOT). PennDOT's strategic agenda and mission encompass providing a safe intermodal transportation system, and reducing highway fatalities is identified as the goal of PennDOT's strategic focus area in safety. Under this strategic focus area, safety to customers is to be maximized through educational activities, infrastructure improvements, and enforcement.

The magnitude of the highway crash problem in Pennsylvania is staggering:

- Over the past 10 years, more than 14,600 people have lost their lives on Pennsylvania's state and local roads.
- Over the past 10 years, more than 1.3 million people in Pennsylvania, or almost 8 percent of the State's population, have been injured in highway crashes on State and local roads.
- The estimated economic losses associated with highway crashes in Pennsylvania exceed $14.5 billion annually, or more than $1,148 per Pennsylvanian.

PennDOT has been and continues to be a recognized leader among states in implementing safety improvements and activities to reduce future crash potential. Safety provisions have been incorporated throughout the design, maintenance, construction, and operation functions of the Department. In addition, PennDOT has developed a Strategic Highway Safety Plan (SHSP). This plan establishes a comprehensive approach to safety and includes education, engineering, enforcement and EMS strategies to reduce the highway fatalities and major injuries in Pennsylvania.

Within PennDOT, specific organizations and personnel have direct safety functions and responsibilities to improve highway safety. Specific organizations and personnel have direct safety functions and responsibilities: the Highway Safety and Traffic Operations Division (HSTOD), District Traffic Engineers, District Highway Safety Engineers, District Safety Press Officers, and District Pedestrian and Bicycle Coordinators. This manual, while potentially useful to all organizations and personnel, provides specific guidance to those groups and staff who have direct safety functions and responsibilities.

1.2 Purpose and Objective

The purpose of the *District Highway Safety Guidance Manual* is to provide a single, comprehensive, and consolidated guidance and information document that Central Office and District safety personnel who have direct safety functions and responsibilities can use to successfully identify and perform safety-related activities.

Prior to this manual, safety guidance to Districts was primarily in the form of strike off letters. These letters were stand-alone documents issued over the last several years. By their nature, they created a number of challenges, including difficulty in determining if one had all pertinent letters on a given subject, difficulty in determining if a particular strike off letter had been modified or superseded, and difficulty in determining whether a strike off letter exists for a given subject area.

The objectives of this manual are as follows:

- Incorporate pertinent information from all previously issued safety strike off letters into the manual, superseding previously issued strike-off letters.
- Provide guidance to Districts regarding preparation of the safety component of District Business Plans; District Safety Plans; and safety activities related to implementing provisions of the Moving Ahead for Progress in the 21st Century (MAP-21) legislation .
- Provide guidance on countermeasure selection, characteristics, and effectiveness associated with spot and systematic deployment.
- Provide guidance on safety-related activities associated with design, maintenance, and permit applications.
- Provide guidance on special safety activities such as road safety audits.

1.3 Scope and Intended Audience

The manual will provide guidance related to the following safety areas:

- All Section 148 Highway Safety Improvement Plan (HSIP) activities and requirements that pertain to District functions.
- Local road District safety activities associated with Local Technical Assistance Program (LTAP) coordination.
- Driver behavior activities associated with the Federal 402 program.
- Project design team activities – safety functions of the District Traffic Engineer as part of the District Design Team.
- Utility permit safety activities.
- Maintenance safety activities.
- Other specific safety activities such as road safety audits, context sensitive design, skid testing and results, and risk management.

The primary audience of this manual is personnel who have direct responsibilities for performing safety functions in the above safety areas. They include:

- Staff of the Highway Safety & Traffic Operations Division (HSTOD).
- District Traffic Engineers.

- District Highway Safety Engineers.
- District Safety Press Officers.
- District Pedestrian and Bicycle Coordinators.

Other personnel, particularly those who have overall responsibility for the above functions, may also benefit from the guidance in this manual.

1.4 Overview of the Crash Data System

PennDOT operates and maintains a crash data system that serves as the foundation for developing and implementing the HSIP. All reportable crashes are forwarded to the HSTOD electronically or in hard copy for processing and incorporation into the Crash Data System. As reportable crashes are added to the Crash Data System, Districts obtain electronic access to the information in the reports through the Crash Data Access and Retrieval Tool (CDART) system. In the summer of each year, when all crashes from the previous year have been processed and incorporated into the Crash Data System, year-end reports are developed and forwarded to the Districts for their use. The year-end reports are supplemented by a continuously updated CDART system, which includes the most current crash data information. District safety personnel use this information to identify crash problems and locations; analyze safety problems; and develop safety programs using the CDART. In addition, after the most current year-end crash data is available, two statewide annual reports are prepared: the *State of Highway Safety* annual report (P:\bhste_shared\highway-safety\state of highway safety report - 2011) and the *Pennsylvania Crash Facts and Statistics* annual report (http://www.dot.state.pa.us/Internet/Bureaus/pdBHSTE.nsf/BHSTEHomepage?OpenFrameset).

1.5 Vision, Goals, and Mission

PennDOT's vision, goals, and mission for its highway safety program are identified in the SHSP.

1.5.1 Vision

Pennsylvania works continuously toward zero deaths and injuries on our roads.

1.5.2 Goals

Reduce average fatalities and major injuries by 50 percent over the next two decades.

1.5.3 Mission

Improve highway safety by developing and implementing education, enforcement, engineering and emergency medical service strategies.

1.6 Federal Safety Requirements — MAP-21

The Moving Ahead for Progress in the 21st Century Act, abbreviated MAP-21, succeeded SAFETEA-LU as the federal highway funding mechanism as of July 6, 2012. This Act maintains the HSIP program while continuing to support an array of driver behavior safety sections.

1.6.1 Highway Safety Improvement Program Provisions

Section 1112 of MAP-21 includes the program and policy language for HSIP, which is codified as Section 148 of Title 23 of the United States Code (23USC148). Brief descriptions of the program's major features are included below. Additional HSIP information can be found at http://safety.fhwa.dot.gov/hsip/.

Funding

MAP-21 provides approximately $4.8 billion for HSIP over the 2013 and 2014 federal fiscal years based on a state apportionment formula written into the legislation. Pennsylvania receives over $92 million annually for the HSIP.

Highway Safety Improvement Program Requirements

To obligate "core" safety funds, a State must have an HSIP in effect. Under this plan, the State develops and implements a Strategic Highway Safety Plan (SHSP) that identifies and analyzes highway safety problems and opportunities; produces a program of projects or strategies to reduce identified safety problems; evaluates the plan regularly; and submits an annual report to the U.S. Secretary of Transportation.

Strategic Highway Safety Plan

The Strategic Highway Safety Plan (SHSP) is developed by the State DOT after consultation with a highway safety representative of the Governor, regional transportation planning organizations (e.g., metropolitan planning organizations (MPO)), major transportation mode representatives, State and local traffic enforcement, persons responsible for administering Section 130 at the State level (i.e., Operation Lifesaver), motor carrier safety program representatives, motor vehicle administrators, and other major State and local safety stakeholders.

The SHSP:

- Analyzes and makes effective use of State, regional or local crash data.
- Addresses engineering, management, operation, education, enforcement, and emergency medical services in evaluating highway projects.
- Considers safety needs, and high fatality segments, of public roads in the State.
- Considers results of State, regional or local transportation and highway safety planning processes.
- Describes a program of projects or strategies to reduce or eliminate hazards.
- Is approved by the Governor or responsible State agency.
- Is consistent with the requirements of the statewide planning process, Section 135(g).

As part of the SHSP, a State shall:

- Have in place a crash data system with the ability to perform safety problem identification and countermeasure analysis.
- Identify hazardous location sections or elements that constitute a danger to motorists, bicyclists, and pedestrians.
- Establish the relative severity of these locations.
- Adopt strategic and performance-based goals.
- Advance the capabilities of the State for traffic records data collection, analysis, and integration.
- Determine priorities for the correction of hazardous road locations, sections, and elements as identified through crash data analysis.
- Establish an evaluation process to assess results achieved by improvement projects.

PennDOT has met the federal requirements of this provision by developing Pennsylvania's SHSP in 2006 and updating the plan in 2009 and again in 2012. These plans may be accessed on PennDOT's shared p-drive: P:\bhste_shared\highway-safety\SHSP\2012 SHSP.

Set-Asides

- A $220 million per year set-aside for rail grade crossing safety (elimination of hazards and the installation of protective devices at railway-highway crossings). If a State has met all of its needs for protective devices at crossings, the U.S. Secretary of Transportation may permit the State to use the set aside funds for other Section 130 needs. PennDOT's highway-rail grade crossing program is administered by PennDOT Bureau of Project Delivery.

Reporting Requirements

MAP-21 requires two annual State reports that describe progress in implementing safety projects, including an assessment of whether the HSIP is accomplishing its intended purpose to reduce fatalities and serious injuries on public roads and an assessment of the Highway-Rail Grade Crossing program. PennDOT provides its annual State report to the U.S. Department of Transportation (USDOT) by August 31 of each year. Districts have access to these reports through the shared p-drive: P:\bhste_shared\highway-safety\FHWA Annual Reports.

1.6.2 Driver Behavior Safety Programs

MAP-21 has established a number of major legislative sections related to improving driver behavior and data enhancements as referenced in the following sections of the law:

- Section 154 – Open Container Law
- Section 164 – Repeat Offender Law
- Section 402 – Highway Safety Programs
- Section 405(b) – Occupant Protection Grants
- Section 405(c) – State Traffic Safety Information System Improvement Grants
- Section 405(d) – Impaired Driving Countermeasures Grants
- Section 405(e) – Distracted Driving Grants
- Section 405(f) – Motorcyclist Safety Grants
- Section 405(g) – State Graduated Driver Licensing Grants

These sections also provide funding for general driver behavioral safety activities and specific initiatives to increase safety belt usage, reduce impaired driving, and improve data quality. Each section includes eligibility requirements for funds.

For more information on these grant programs, visit www.nhtsa.dot.gov.

1.7 State Safety Requirements

The Pennsylvania Vehicle Code, Title 75, includes several sections that are pertinent to the highway safety improvement program:

- Section 3746 – Immediate Notice of Crash to Police Department – Drivers of vehicles involved in an crash should notify police if the crash involves injury or death to any involved person or damage to any vehicle involved to the extent that it cannot be driven under its own power in its customary manner without further damage or hazard to the vehicle, other traffic elements, or the roadway, and therefore requires towing.
- Section 3751 – Reports by Police – Every police department that investigates a vehicle crash for which a report is required will forward an initial written report to PennDOT.

- Section 3752 – Crash Report Forms – PennDOT will prepare and, upon request, supply to all law enforcement agencies and other appropriate agencies and individuals forms for written crash reports.
- Section 3753 – Department to Compile, Tabulate, and Analyze Crash Reports – PennDOT will establish a central crash records agency, which will be the repository for all reportable traffic crashes. The agency will have primary responsibility for the administration and supervision of storing, processing, and satisfying the information needs of all official agencies having responsibility for the transportation system.
- Section 3754 – Crash Prevention Investigations – PennDOT, in association with the Pennsylvania State Police, may conduct in-depth crash investigations and safety studies of the human, vehicle, and environmental aspects of traffic crashes for purposes of determining the causes of traffic crashes and the improvements which may help prevent similar types of crashes or increase the overall safety of roadways and bridges. In depth crash investigations and safety studies and information, records, and reports used in their preparation shall not be discoverable nor admissible as evidence in any legal action or proceeding, nor shall officers or employees of these agencies charged with the development, procurement, or custody of in-depth crash investigations and safety study records be required to give depositions or evidence contained in such in-depth crash investigations or safety study records or reports in any legal action or other proceeding.

Specific language for each of these sections can be found in Chapter 37 of the Vehicle Code at http://www.dmv.state.pa.us/pdotforms/vehicle_code/chapter37.pdf . The entire Vehicle Code can be found at http://www.dmv.state.pa.us/vehicle_code/index.shtml.

In addition to legal requirements specified in the Vehicle Code, the Design Manual Parts 1, 1A, and 2 identify the roles of the Traffic Engineer and the Safety Engineer in the design process. This manual provides specific role guidance to the Traffic Engineer and Safety Engineer on safety considerations for design projects.

1.8 Funding

Sources for transportation safety improvement funding include a combination of Federal, State, and local funds. Federal funding is estimated based on available Federal legislation and obligation authority. State funds are based on current revenues. As a result, funding levels will likely vary to some degree from year to year.

At the beginning of each fiscal year, the Districts will receive a letter from the Office of the Deputy Secretary for Highway Administration that will apprise them of the level of funding that will be distributed to them for safety improvement programs.

Certain countermeasures such as lighting and traffic signals on State highways require commitments from municipalities to energize, operate, and maintain. Before these types of

countermeasures are considered for programming, the municipality in which the location resides must commit to accepting these responsibilities.

1.9 Resource Documents

This manual is one of several documents published by PennDOT, the Federal Highway Administration (FHWA), and independent transportation engineering organizations that provide useful information and guidance on transportation safety. The following is a list of documents that should be used as additional reference for in-depth information on a variety of transportation-related topics.

1.9.1 State Documents

- Publication 23 – Maintenance Manual.
- Publication 46 – Traffic Engineers Manual.
- Publication 170 – Highway Occupancy Permit Manual.
- Publication 212 – Official Traffic Control Devices.
- Publication 383 – Traffic Calming Handbook.
- Publication 450 – Roadside Development Inspection Guide.
- Publication 461 – Roadside Planting Guidebook.
- Design Manual (Parts 1, 1A, and 2).
- Bicycle and Pedestrian Master Plan.
- Risk Management Manual (under development).

The published documents listed above, as well as many others, can be accessed from the "Forms and Publications" section of the PennDOT website (www.dot.state.pa.us).

1.9.2 Federal and National Documents

Transportation Research Board (TRB)

- NCHRP Report 500 – Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volumes 1 through 18.
- NCHRP Report 486 – Systemwide Impact of Safety and Traffic Operations Design Decisions for 3R Projects.

These and other publications containing informative technical materials and guidelines can be found at the Transportation Research Board website: http://www.trb.org/.

American Association of State Highway and Transportation Officials (AASHTO)

- AASHTO Roadside Design Guide, 4th Edition.
- AASHTO Policy on Geometric Design of Highways and Streets, 6th Edition.
- Federal Highway Administration (FHWA) Highway Safety Manual, 1st Edition.
- AASHTO Highway Safety Design and Operations Guide, 3rd Edition.

These and other publications containing informative technical materials and guidelines can be found at the AASHTO website: http://www.transportation.org/.

Governors Highway Safety Association (GHSA)

- Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices, 6th Edition.

These and other publications containing informative technical materials and guidelines can be found at the GHSA website: http://www.ghsa.org/

1.10 Procedures for Modifications or Additions to this Document

PennDOT recognizes that the regulations and policies affecting its safety procedures are continuously changing and that this manual must be a dynamic document to remain current. Whenever modifications or additions are required to improve the present procedures, the following procedure shall be followed:

1. Bureau Directors and District Engineers/Administrators should submit suggestions for new/revised manual content to HSTOD in electronic form. HSTOD will process and evaluate the submissions. Suggestions for changes and/or new material should include:
    a. The title and page number of the existing material to be revised, if applicable.
    b. The recommended revised/new content and the chapter(s) into which it should be incorporated.
    c. The reasons for recommending modifications or new content.

2. HSTOD will review the recommended changes or additional procedures and transmit copies to the various affected Bureau Directors and District Engineers for their comments.
3. The affected Bureau Directors and District Engineers shall provide their comments on the proposed recommended changes or additional procedures to the Chief of the Highway Safety and Traffic Operations Division, who will take appropriate action. Only those changes which have the support of the District Engineers and affected Bureau Directors will be incorporated into the updated manual.
4. When modifications or additions are made to pages in this manual, a revision date will be indicated in the date area in the header (i.e., upper left corner). The revision will be distributed by HSTOD by transmittal letter. Changes will be issued on an annual basis.

District Highway Safety Guidance Manual

Chapter 2 — Plans, Programs, and Activities

December, 2014

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2.1 Introduction

Highway safety actions exist throughout the Pennsylvania Department of Transportation (PennDOT) programs and activities. At the center of the highway safety effort is the Strategic Highway Safety Plan (SHSP). The SHSP was completed in 2006 and updated in 2009 and 2012. It may be accessed on PennDOT's shared P-drive: P:\bhste_shared\highway-safety\SHSP\2012 SHSP.

The following plans complement the SHSP:

- Annual Section 402 Safety Plans – These are primarily oriented towards improving driver, occupant, and pedestrian safety behaviors. They are prepared by the Highway Safety and Traffic Operations Division (HSTOD).
- Annual District Safety Plans – These are focused on infrastructure-based safety improvements on the State highway system at high crash locations. They are prepared by the Districts.
- Highway Safety Improvement Program (HSIP)
- Commercial Vehicle Safety Plan (CVSP)

Programs are developed to implement the projects, grants, actions, and activities identified in these plans.

In addition, programs to improve local roads and highway-rail crossings and provide safe routes to school are underway. Safety activities are also incorporated into PennDOT's design development process, maintenance operations, driveway and utility permitting processes, risk management activities, and traffic engineering studies. The District Traffic Engineer, District Safety Engineer, Safety Press Officer, District Pedestrian and Bicycle Coordinator, and the District Grade Crossing Engineer/Administrator are the primary focal points for developing programs and conducting safety activities in these areas.

2.2 Strategic Highway Safety Plan Implementation

The 2012 Strategic Highway Safety Plan (SHSP) has been developed to maintain and build on momentum achieved by Pennsylvania's 2006 and 2009 strategic plans. The SHSP serves as a blueprint to reduce fatalities and major injuries on Pennsylvania's roadways. Pennsylvania's comprehensive approach was to engage state and national experts by conducting a Highway Safety Summit to collect input and establish a Highway Safety Steering Committee. Safety stakeholders and partners from both the public and private sector, representing the 4 E's of highway safety (*E*ngineering, *E*ducation, *E*nforcement, and *E*mergency Medical Services), contributed to the development of our plan.

The SHSP identifies PennDOT's vision, mission and goals for its highway safety program.

2.2.1 Vision

Pennsylvania works continuously toward zero deaths and injuries on our roads.

The "vital seven" safety focus areas have been chosen because implementing improvements in these areas will have the most impact on overall highway fatalities. They are:

- Reducing Impaired (DUI) driving.
- Increasing Seat Belt Usage.
- Infrastructure Improvements.
- Reducing Speeding & Aggressive Driving.
- Reducing Distracted Driving.
- Mature Driver Safety.
- Motorcycle Safety.

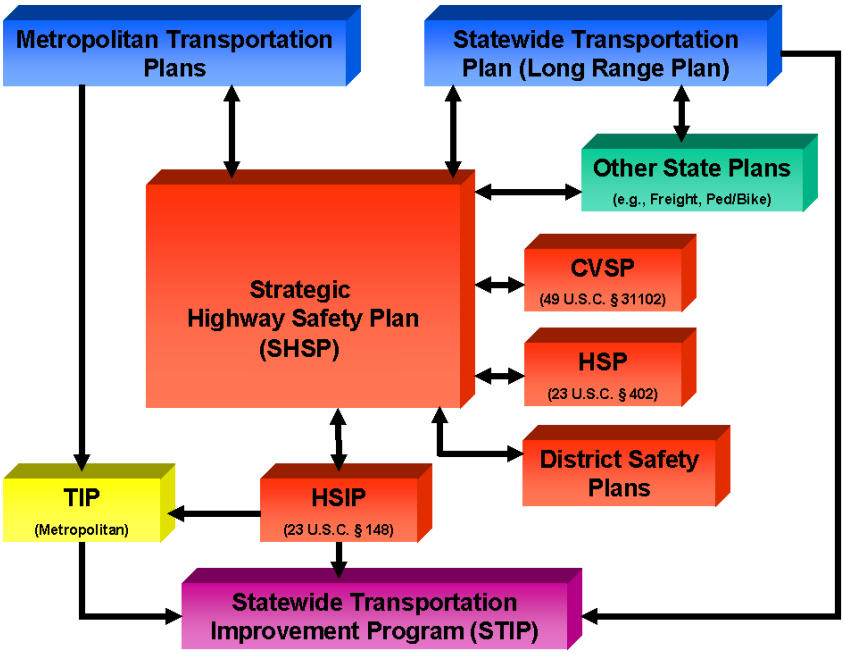
2.2.2 Goals

Reduce average fatalities and major injuries by 50 percent over the next two decades.

2.2.3 Mission

Improve highway safety by developing and implementing education, enforcement, engineering and emergency medical service strategies.

The relationship between the SHSP and other plans is shown in Figure 1.



Adapted from: *Strategic Highway Safety Plans: A Champion's Guide to Saving Lives*, FHWA

Figure 2-1: Relationship between Strategic Highway Safety Plans (SHSP) and Existing Planning and Programming Processes

Summary reports on the progress made towards implementing activities and reducing fatalities within the SHSP safety focus areas are prepared annually. They may be accessed on PennDOT's shared P-drive: P:\bhste_shared\highway-safety\SHSP.

2.3 The Highway Safety Improvement Program (HSIP)

Section 148 of Title 23, United States Code, and Part 924 of Title 23, Code of Federal Regulations, establish the requirements for a Highway Safety Improvement Program (HSIP). These Federal provisions state that the Highway Safety Improvement Program in each State shall consist of components for planning, implementation, and evaluation of safety programs and projects. These components shall be comprised of processes developed by the States and approved by FHWA. Where appropriate, these processes shall be developed cooperatively with officials of the various units of local governments. The processes may incorporate a range of alternate procedures appropriate for the administration of an effective highway safety improvement program on individual highway systems, portions of highway systems, and in local political sub-divisions, but combined shall cover all public roads in the state. The process in Pennsylvania for developing an HSIP, selecting candidate projects, programming and implementing the projects, evaluating the safety impacts of the safety improvements, and incorporating lessons learned from the process into future processes is described in Figure 2-2.

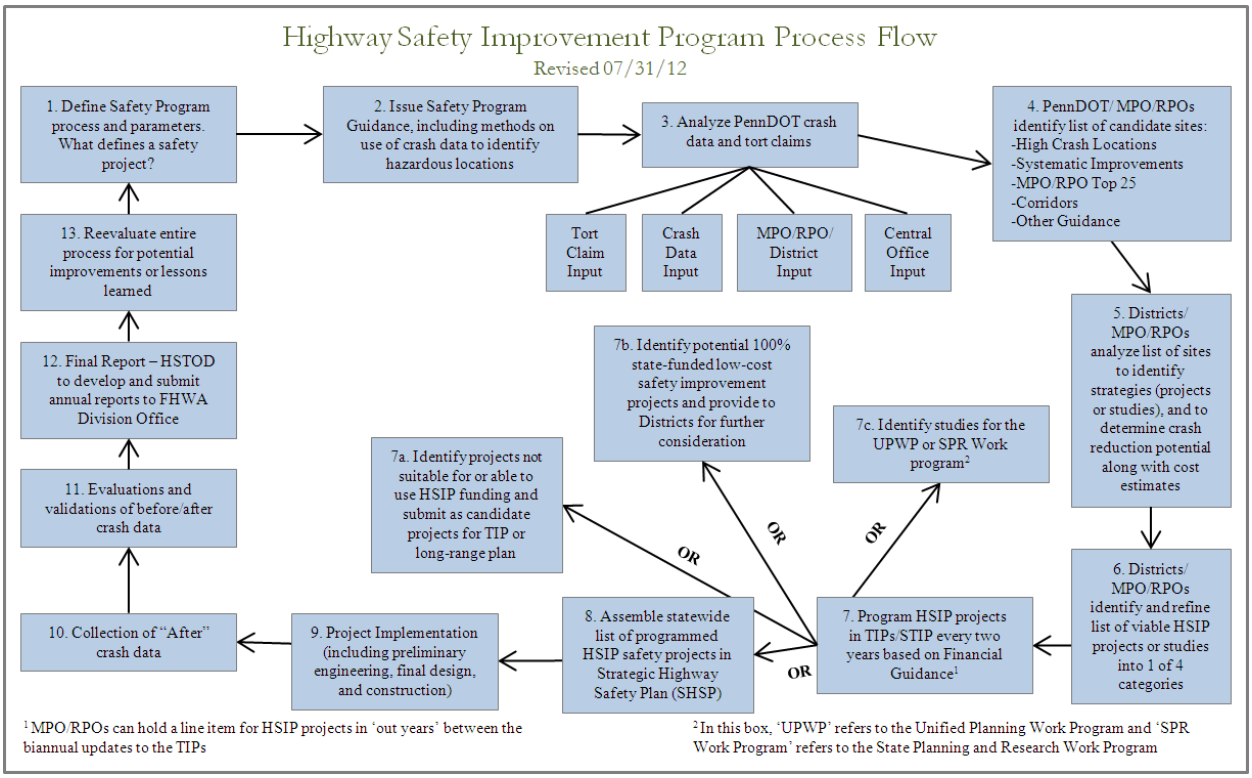


Figure 2-2: Highway Safety Improvement Program Process Flow

The HSIP portion of the Commonwealth's Twelve Year Program process is encompassed in Steps 4 through 7 of Figure 2-2. On a bi-annual basis, the 12-year program is updated to reflect new projects and existing, and program funds available for Section 148 and other safety projects. The safety portion of this process is described below and illustrated in Figure 2-3.

A. In the first three (3) months of every odd numbered year (January through March), the District Highway Safety Engineer gathers information from the Statewide High Crash Location List and the Planning Organization High Crash Location Lists, and input from HSTOD, the Risk Management Engineer and the Metropolitan Planning Organization (MPO)/Rural Planning Organizations (RPOs) and assembles a list of candidate safety improvement project sites. These sites are based upon an analysis of crash data and actions that are needed to help achieve the District's fatality goal. Ideally, the candidate list will include those projects that have the greatest potential to save the highest numbers of lives. Priority candidates should include:

    1. Groupings of priority, low-cost safety improvements by County or District that cannot be implemented in the 100 percent State-funded program.

    2. Locations that are in the top 5 percent of high crash locations listings.

B. The candidate listings are forwarded to HSTOD at the end of March of odd numbered years. HSTOD obtains review and input from FHWA and forwards feedback to the Districts on the candidate listings by May of odd numbered years.

C. In late summer (August-September) of odd numbered years, the Center for Program Development and Management issues guidance to Districts on updating the TIP, including available funding levels for Section 148 project additions.

D. Once the District guidance is received from the Center for Program Development and Management, the District Programming Engineer and the District Highway Safety Engineer will assemble a set of proposed safety improvements for the Section 148 funds available. This set of improvements will incorporate input from both the District Risk Management Engineer and MPO/RPOs as well as feedback from HSTOD. Ideally, this set of safety improvements is selected to maximize the number of lives that can be saved for the funds available. As part of the compilation, the District Highway Safety Engineer should estimate the potential number of lives saved from the assembled list of proposed safety improvements. The tentative list should be shared with the District Risk Manager and the MPO/RPOs for input.

E. In the December (odd numbered year)-January (even numbered year) time frame, the District Planning and Programming Engineer will meet with Center of Program Development and Management staff to obtain input on the Districts draft TIP update. HSTOD safety personnel may attend a portion of the meeting to provide input on the proposed Section 148 safety projects.

F. Using the input from the meeting with the Center for Program Development and Management staff, the District Planning and Programming Engineer will finalize the draft TIPs in conjunction with the MPO/RPOs.

G. The MPO/RPOs will transmit the draft TIP in the spring of even numbered years to the Center for Program Development. After the TIP public and approval comment period by the MPOs/RPOs, STC, and FHWA, the TIP is finalized by the end of September of even numbered years.

H. Section 148 candidate projects are added to the TIP from the HSIP line items. Then design authorization may commence.

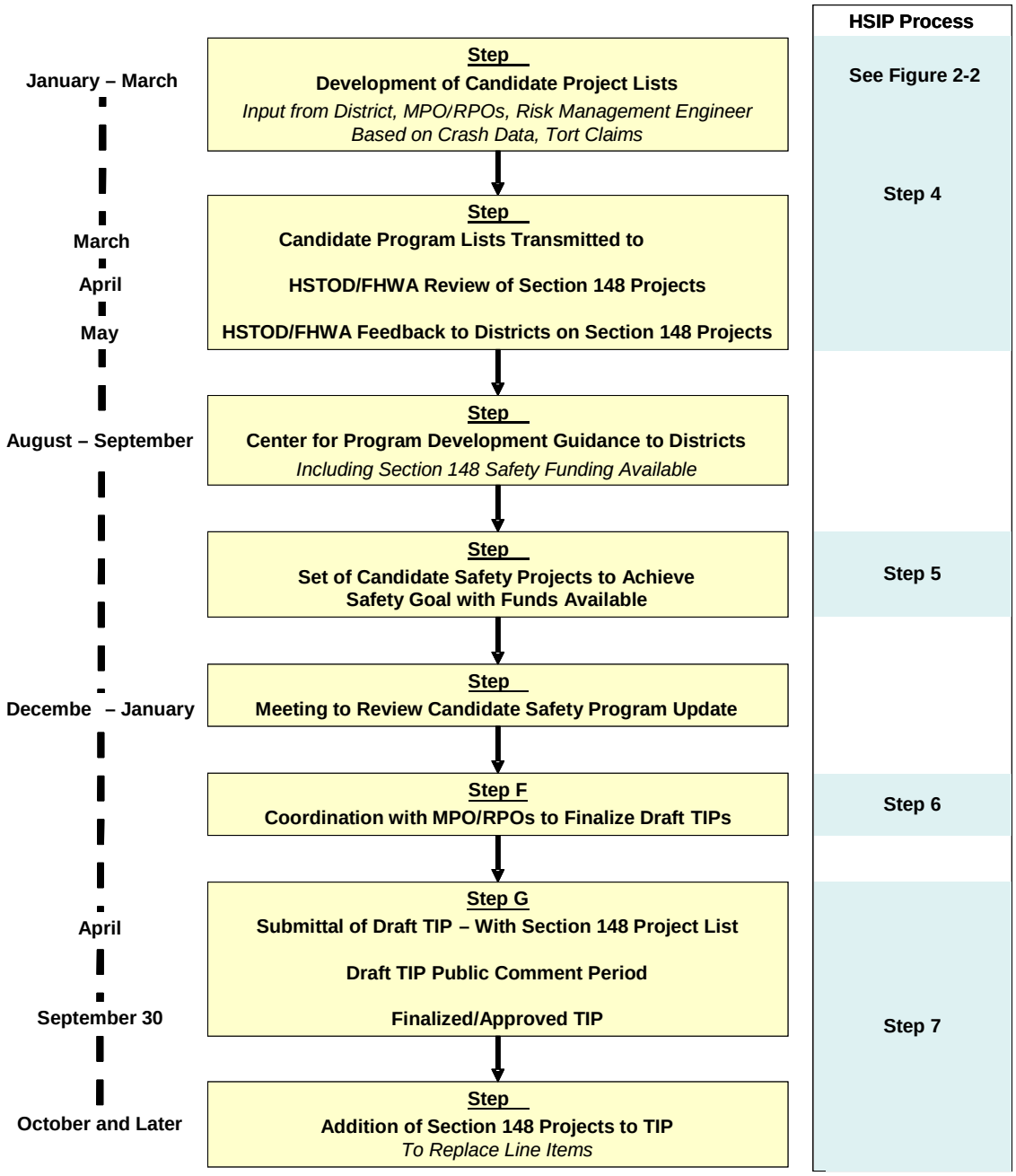


Figure 2-3: District Safety Planning Timeline for 12-Year Program Section 148 Projects

2.4 Commercial Vehicle Safety Plan (CVSP)

The Commercial Vehicle Safety Plan (CVSP) is developed annually and administered by the Pennsylvania State Police. The goal of the CVSP is to reduce crashes, injuries, and fatalities involving large trucks and buses. Major activity areas include the following:

- Driver/vehicle inspections.
- Traffic enforcement with or without inspections.
- National compliance reviews.
- Education and outreach.

2.5 Section 402, Pennsylvania Highway Safety Grant Program (HSGP)

Pennsylvania's Highway Safety Grant Program (HSGP) is an annual program developed to reduce highway fatalities and severe injuries. It is directly aligned with the SHSP in five of the safety focus areas: aggressive driving, impaired driving, safety belts, crash data improvements, and pedestrian safety. Candidate grant application information is compiled annually by HSTOD in the late spring of each year. A Safety Advisory Committee comprised of internal PennDOT safety organizations, safety advocates from other State agencies and non-profit safety organizations, and representatives from the National Highway Traffic Safety Administration (NHTSA) and FHWA develops the HSGP using crash data information, evaluation results from the previous grant years, and the compiled grant application information. HSTOD is the process owner for the HSGP. Once a draft HSGP is developed, it is presented to PennDOT's Program Management Committee for review and final approval. The final HSGP is transmitted to NHTSA annually in August or September for approval and funding eligibility.

The HSGP is funded completely by NHTSA funds from sources including Sections 402, 405, 408, 410, and other intermittent funding programs NHTSA makes available to Pennsylvania.

The HSGP is a data-driven, needs-based program with resources directed towards those problems and areas with the greatest chance of reducing the frequency of fatalities and major injuries. Grants and contracts are issued to government entities, non-profit safety organizations, and other jurisdictions to implement HSGP programs. Grant applications are based upon problem identification and contain an action plan of proven approaches targeting specific problems and locations. To ensure program integrity, cost effectiveness, and accountability, grantees are required to submit quarterly progress reports to HSTOD. These reports identify results of efforts against pre-established measurement factors.

The approximately 85 statewide annual grantees and contractors have been organized geographically into regional teams designed to maintain safety throughout the State. The network of regional safety teams has been named the Pennsylvania Statewide Safety Network.

Each of Pennsylvania's 67 counties obtains services from grants administered through the HSGP. To facilitate providing services, all grantees and other partners are grouped into six geographical regional planning and implementation teams as shown in Figure 2-4. The planning teams bring together essential Highway Safety Grantees and other partners approximately six times per year to plan and coordinate activity. Overseeing each region is a statewide steering committee comprised of each regional team leader, PennDOT program managers assigned to each regional team, the PSP internal media personnel, and critical contractual entities. Their purpose is to develop a data-driven implementation plan for their region that can lower the number of fatalities.

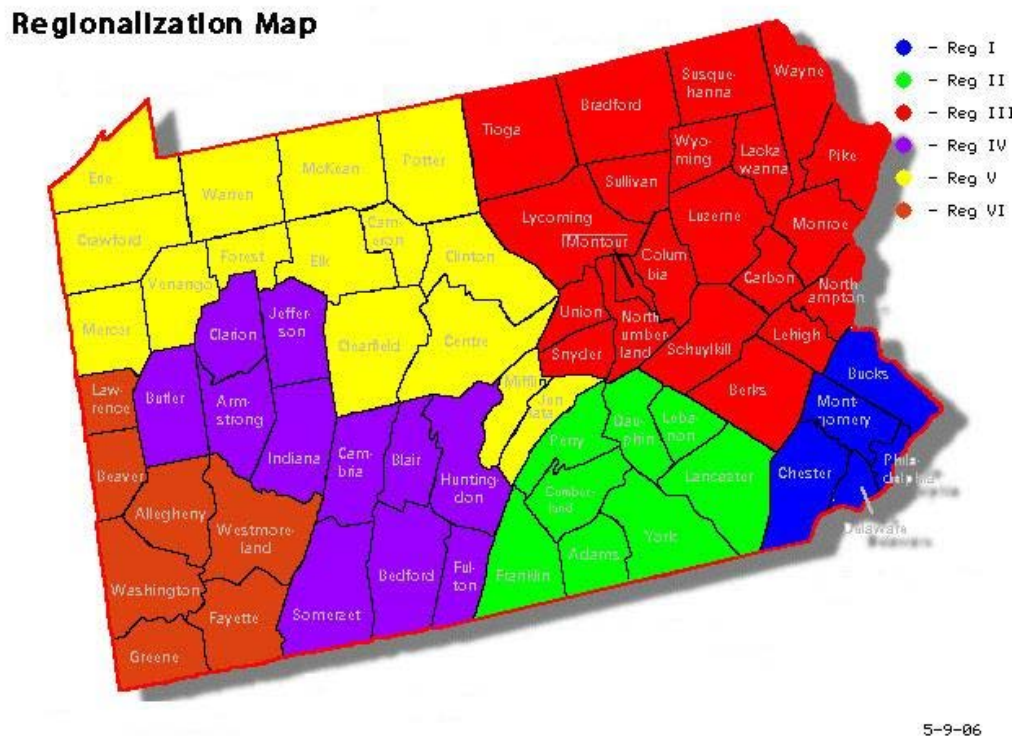


Figure 2-4: PennDOT Geographic Regions

2.6 District Safety Plans

District Safety Plans are prepared on an annual basis as part of the District business planning cycle. The District Safety Plans establish a District Safety goal defined in a terms of a specified reduction in the District fatalities and the projects and programs the District intends to develop and implement to achieve the goal.

The introduction to the District Safety Plan includes historic fatality information and the District safety goal, which is expressed in terms of fatalities. The District Safety Champion is also identified in this section of the plan.

At its core, the District Safety Plan should include lists of planned safety projects and initiatives chosen by using crash data and working with the planning partners as per the safety project selection guidance to mitigate safety problems at high-risk intersections and roadways in the State. The projects and initiatives are divided into separate sections (or lists) in the District Safety Plan based on the following categories:

- Transportation Improvement Program (TIP) (Non-HSIP, Section 148) Safety Projects.
- Section 148 (HSIP) Projects (project list).
  - Planning worksheet for Section 148 projects.
- Low Cost Safety Improvement Projects ($10 Million Gov. Budget Initiative).
  - Systematic Implementation of Safety Improvements (50 percent of District budget).
- Other Maintenance Safety Projects.
- Local Road Safety Projects and Initiatives.
- Safety Press Officer Planned Activities.

The District Safety Plans are completed and placed on PennDOT's shared P-drive by March 31 of each year. HSTOD reviews the Districts Safety Plans and provides feedback to the Districts on possible improvements by April 1 of each year.

The timeline for developing District Safety Plans is provided in Figure 2-5.

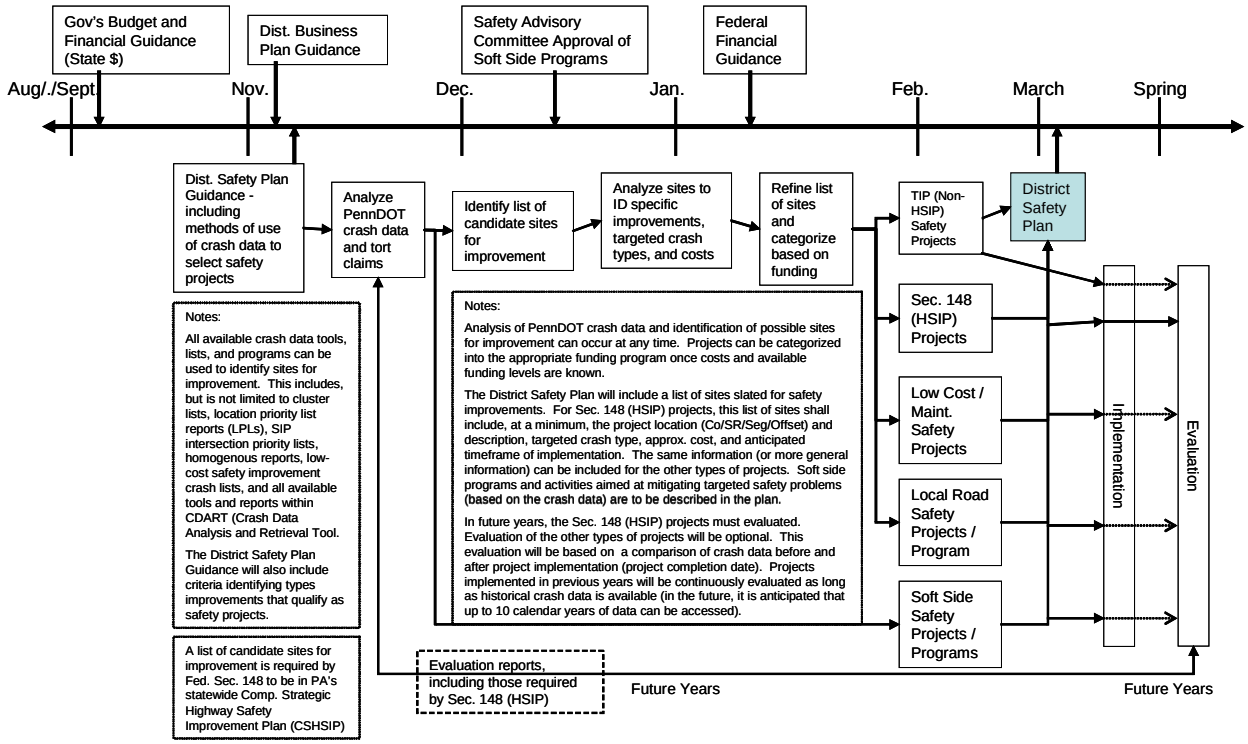


Figure 2-5: Annual District Highway Safety Planning Timeline/Process

The current guidance for developing the District Safety Plan may be accessed on PennDOT's shared P-drive: P:\bhste_shared\highway-safety\District_Safety_Planning\backup guidance\project selection guidance. An example of the guidance for the 2007 plan development is provided in Appendix A.

2.7 Section 130 Grade Crossing Program

The Section 130 Grade Crossing Program is managed by the Bureau of Design, Grade Crossing and Utility Relocation Section. The Bureau of Design annually solicits recommendations from the Districts on potential grade crossing improvements for the available funding, usually during the summer months with the program being assembled by the District Grade Crossing Engineer/Administrator in the fall. Within the Districts, the Grade Crossing Engineer/Administrator is the primary point of contact to assemble proposed projects for the funds available. The Grade Crossing Engineer/Administrator uses the Federal Railroad Administration's (FRA) crash prediction model and evaluates crossings that are in the top 25 percent of locations generated from the model. The District Grade Crossing Engineer/Administrator also uses Publication 371, *The Grade Crossing Manual*, as a resource for assembling candidate improvements. The District Traffic Engineer and/or the Highway Safety Engineer, at the Grade Crossing Engineer/Administrator's request, may provide complementary safety assistance. The assistance may be in two forms as follows:

- Compilation of crash data for highway-rail crossings within the District to identify crossings that have had a history of crashes involving or not involving trains and may benefit from crash-reducing countermeasures.
- Technical safety assistance to the Grade Crossing Engineer/Administrator at candidate crossings with crash histories to identify appropriate countermeasures to reduce future crash potential.

2.8 Safe Routes to School Program

The Federal Safe Routes to School Program (SRTS) is a new program generated under SAFETEA-LU. It is being administered through a Safe Routes to School Coordinator located in the Center for Program Development and Management.

The Program Center has a contract with the State Association of Township Supervisors (PSATS) to coordinate the education, encouragement, enforcement, and evaluation aspects of the program. These activities are required in SAFETEA-LU and a certain portion of the federal funding is set aside for these purposes. Safety Press Officers will be involved with this process.

The Program Center tentatively will be soliciting for noninfrastructure projects through PSATS in the fall of 2012. Eligible applicants will include schools and school districts, which will be required to apply jointly with their municipality. Applicants will also be asked how they plan to

fulfill the education, encouragement, enforcement, and evaluation requirements of the Safe Routes to School Program.

District input may be solicited prior to programming decisions as follows:

- Safety Press Officer input on safety education and encouragement activities that will be coordinated primarily by PSATS.
- District Traffic Engineer and/or Highway Safety Engineer review and recommendations regarding any proposed SRTS infrastructure projects on or affecting State highways.

2.9 Safety Activities in Improving Safe Driver Behavior

Two overarching activities within Pennsylvania that have a significant impact on safe driving behavior are:

- Driver licensing actions administered by the Bureau of Driver Licensing that impact safe driving behavior. Three primary actions include issuing licenses to new qualified drivers, removing or restricting licenses of drivers who have acquired significant physical or mental conditions that affect their ability to drive safely, and sanctioning or suspending drivers who have been cited for serious or multiple Vehicle Code violations.
- Enforcement actions by State and local police directed toward drivers violating various provisions within the Vehicle Code that are related to risky driving behavior.

In addition to these overarching activities, the SHSP has identified four driver-related strategic focus areas:

- Reducing Impaired (DUI) Driving
- Increasing Seat Belt Usage
- Reducing Speeding & Aggressive Driving
- Reducing Distracted Driving

Education and enforcement activities within these three areas are pursued jointly by the District Safety Press Officer and grantees funded through the Section 402 Highway Safety Plan. Specific countermeasures are provided in Chapter 5 of this manual.

2.10 Safety Activities for Pedestrians and Bicyclists

PennDOT's current Statewide Bicycle/Pedestrian Master Plan may be accessed on PennDOT's website at http://www.dot.state.pa.us/Internet/Bureaus/pdBikePed.nsf/. A significant number of safety activities are directed toward implementing the safety strategies identified within the Master Plan.

A unique program that PennDOT initiated is the "Yield to Pedestrian Channelizing Devices" Pedestrian Safety Program. PennDOT has established a contract through the Department of General Services to make "Yield to Pedestrian Channelizing Devices" available through the Districts to municipalities that have crosswalks qualifying for the initiative. The application process, District Bicycle/Pedestrian Coordinator role, and application form, are provided in Appendix B. These devices are provided to municipalities by PennDOT for installation and maintenance on crosswalks with combinations of pedestrian activity and substantial vehicle flow.

Pedestrian and bicycle safety enhancements associated with the design of new, reconstruction, rehabilitation, and resurfacing projects are also incorporated into the design process. The use of the Bicycle/Pedestrian Checklist located in Appendix S of Design Manual, Part 1A is used to identify potential safety enhancements.

Education and enforcement activities supporting pedestrian and bicycle safety are pursued jointly by the District Bicycle/Pedestrian Coordinator, District Safety Press Officer and Section 402 Program grantees.

2.11 Highway Safety Activities on Local Roads

Approximately 16 percent of fatalities and 27 percent of the crashes that occur in Pennsylvania occur on local roads. There are approximately 82,000 miles of local roads in Pennsylvania. Local road crashes are incorporated into PennDOT's crash data system. However, since most local roads do not have a measuring system along them, only County, municipality, and route can be used to generally identify crash locations from the crash record system. Safety improvement needs are primarily identified through the Department's Local Technical Assistance Program (LTAP), working in conjunction with municipalities. Three areas in which the LTAP provides safety assistance to municipalities are as follows:

- Safety technical assistance to a limited number of diversified municipalities with high crash numbers or rates under the Local Safe Roads Communities Program.
- Safety training courses to municipalities that cover a variety of safety problems that are particular concerns to municipalities.
- On-call technical assistance to municipalities for specific safety problems.

Whenever an LTAP Engineer is planning to conduct training or assist a municipality regarding a safety issue, the District Municipal Supervisor and the District Safety Engineer will be apprised of the visit and invited to participate. The District Safety Engineer, at his/her discretion, may participate in the municipal meeting or training. The LTAP Engineer may consult the District Safety Engineer to address specific municipal safety concerns, particularly if the location is an intersection with joint municipal/state ownership. Additional information on the LTAP program may be found on the LTAP website at https://www.dot7.state.pa.us/LTAP/.

2.12 Highway Safety Activities on State Highways

The major categories of safety activities on State highways are as follows:

- Safety enhancements associated with the design of new, reconstruction, rehabilitation, and resurfacing projects.
- Safety enhancements associated with maintenance operations and activities.
- Safety enhancements associated with permitting of utilities and occupancy permits.
- Safety enhancements associated with implementation of specific safety provisions within SAFETEA-LU, such as the Safe Routes to School Program.
- Safety enhancements associated with the highway safety improvement program at high crash locations. These enhancements fall into three approaches, which are discussed in detail in Chapter 5 of this manual. They include:
  - The traditional approach of identifying high-crash locations and determining cost-effective countermeasures for each location.
  - The systematic approach of identifying promising cost-effective countermeasures and then identifying sets of locations where it is cost effective to apply the countermeasure.
  - The corridor approach of identifying sections of highway that have significant numbers of severe crashes, of either all or specific types, and applying a coordinated set of engineering, enforcement, and education initiatives to affect the problem.

2.13 Plan and Reporting Summaries

2.13.1 Plan Preparation Summaries

Three annual plans are to be developed for the safety program as follows:

- The safety component to the District Business Plan is due annually in August. District Business Plan preparation guidelines are issued in the spring of each year and provide information on safety components to address in the Business Plan. *(District responsibility)*
- The District Safety Plans are due annually on March 31 of each year. Guidance documentation for preparation of the District Safety Plan is provided in early winter of each year. The current guidance for developing the District Safety Plan may be accessed on PennDOT's shared P-drive: P:\bhste_shared\highway-safety\District_Safety_Planning\backup guidance\project selection guidance. An example of the guidance for the 2007 plan development is provided in Appendix A. *(District responsibility)*
- The final Section 402 Highway Safety Plan is due annually in August. *(HSTOD responsibility)*

2.13.2 Reporting Summaries

Reports are required of Grantees, Districts, and HSTOD as follows:

- Grantees – Progress reports in implementing approved grants, submitted quarterly to HSTOD by the 30th of October, January, April, and July.
- Districts – Reports on 100 percent State funded projects completed and open to traffic during the past quarter are due to HSTOD on a quarterly basis (e.g., 30th of October, January, April and July). A sample format for the quarterly report is provided in Figure 2-6.
- HSTOD – Annual report to the FHWA Administrator by August 31 of each year. This annual report is posted on the U.S. Department of Transportation (USDOT) web site and describes at least 5 percent of locations identified by PennDOT that exhibit the most severe safety needs. This report also contains an assessment of potential remedies to the locations identified, estimated costs associated with these remedies, and impediments to implementation other than cost associated with those remedies. Previous annual reports may be accessed on PennDOT's shared P-drive: P:\bhste_shared\highway-safety\FHWA Annual Reports.
- HSTOD – Annual report to the FHWA Administrator by August 31 of each year that describes the progress being made to implement highway safety improvement projects under Section 148, assess the effectiveness of these improvements, and describe the extent to which the improvements contribute to the goals of the following elements. Previous annual reports may be accessed on PennDOT's shared P-drive: P:\bhste_shared\highway-safety\FHWA Annual Reports.

- Reducing the number of fatalities on roadways.
- Reducing the number of roadway related injuries.
- Reducing the occurrences of roadway related crashes.
- Mitigating the consequences of roadway related crashes.
- Reducing the occurrences of crashes at highway-rail grade crossings. (This portion of the report is prepared by the Bureau of Project Delivery.)

Sample Quarterly Report
District Low Cost / Maintenance Safety Projects
1st Quarter 05-06 (7/1/05 - 9/30/05)

MPMS#	SPN	Project Location							Type of Improve-ment	Targeted Crash Type	Completion Date
		Dist	CO	SR	Beg Seg	Beg Offset	End Seg	End Offset			
34576	45-403-00-343-etc	7	12	30	120	0	140	0	CLRS	HO/SS	8/15/2005
34576	45-403-00-343-etc	7	14	25	450	1012	490	454	GDRL	HFO	9/1/2005
34576	45-403-00-343-etc	7	16	45	50	1115	50	1115	ACWM	Curve	9/3/2005
34576	45-403-00-343-etc	7	18	84	200	0	250	0	SHDLR	ROR	9/30/2005

Figure 2-6: District Quarterly Report

District Highway Safety Guidance Manual

Chapter 3 — Safety-Related Functions

December, 2014

District Highway Safety Guidance Manual

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3.1 Overview of District Safety-Related Functions

In addition to core functions that directly support the development and implementation of the Strategic Highway Safety Plan (SHSP) that are addressed in Chapter 2, there are additional safety functions that contribute towards improving overall safe travel in the Commonwealth. They include the following:

- Safety in the design development process.
- Safety in maintenance operations.
- Safety in the utility pole permitting process.
- Safety in the risk management process.
- Safety in promoting safe travel practices by drivers, occupants, pedestrians, motorcyclists, and bicyclists.

The general relationship between District safety personnel involvement and safety function is shown in Table 3-1.

Table 3-1: District Safety Personnel Involvement in Safety Functions

	District Traffic Engineer	District Highway Safety Engineer	District Safety Press Officer	District Pedestrian and Bicycle Coordinator
Section 148 Projects – District Safety Plan	✓	✓		
Low-Cost SIP – District Safety Plan	✓	✓		
Other Maintenance Safety Projects – District Safety Plan		✓		
Local Roads Safety Projects – District Safety Plan		✓		
SPO Planned Activities – District Safety Plan			✓	
Safety in the Design Process	✓	✓		✓
Safety in Maintenance Operations	✓	✓		
Safety in the Utility Permitting Process		✓		
Safety in the Risk Management Process		✓		
Safety in Promoting Safe Travel Practices	✓		✓	✓

3.2 Safety in the Design Development Function

The design development process for all new and reconstructed projects is detailed in Design Manual, Parts 1, 1A, and 2. Highway safety is identified throughout the Design Manual. Within the process, the District Traffic Unit has been identified to participate in design development in a number of stages. Table 3-2 shows the key stages and potential safety-related activities for each stage.

Table 3-2: Safety-Related Activities in the Design Development Process

Design Manual Reference	Traffic Safety Relationship	Safety Opportunity
Part 1, Chapter 3, Design Project Management, Section 3.0B	The District Traffic Unit is identified as a member of the Design Team.	The District Traffic Unit representative on the Design Team can identify safety issues and crash concerns that should be addressed during the design process of a project.
Part 1, Chapter 5, Scoping, Section 5.0	Engineering and environmental scoping recommends assembling of a package of background information for scoping that includes safety-crash reports.	The District Traffic Unit can identify any locations within the proposed limits of work that appear on any of the high crash location or cluster lists identified in Chapter 4 of this manual. If locations having crash histories are present, the crashes can be analyzed to determine if there are patterns that may be cost effectively impacted by modifying or adding design features to the highway.
Part 1, Chapter 7, Preliminary Engineering Procedures	Section 7.1 Preliminary Engineering Activities Section D Engineering Parameters states that a thorough analysis involves extensive gathering and evaluation of information regarding reported safety problems areas (including crash clusters).	The District Traffic Unit can perform any further safety analyses as needed beyond that performed in scoping to address high crash locations and concerns in the limits of work. This may include contacting the State or local police to identify safety concerns they have identified.
Part 1, Chapter 7.2, Final Design Plan Development	Section 7.2 Traffic Coordination states that the District Traffic Unit is involved in traffic signal plans, sign and sign lighting plans, incident management plans, traffic control plans, and pavement marking plans.	The District Traffic Unit can ensure that any existing crash or safety problem is considered in the development of the traffic signal plans, sign and sign lighting plans, incident management plans, traffic control plans, and pavement marking plans. Lighting improvements may be considered;

Design Manual Reference	Traffic Safety Relationship	Safety Opportunity
		however, the municipality in which the intersection resides must agree to operate, energize, and maintain the lighting once it is in place.
Part 1, Chapter 2, Minor Project Design	Section 2.1 Minor Project Design Process identifies an engineering and environmental (E&E) scoping field view as a key activity.	The District Traffic Unit can identify any locations within the proposed limits of work that appear on any of the high crash location or cluster lists identified in Chapter 4 of this manual. If locations having crash histories are present, the crashes should be analyzed to determine if there are patterns that may be cost effectively impacted by modifying design features of the highway.
Part 1, Chapter 7, Design Review Procedures	Section 7.2D requires that all projects be reviewed by a qualified District Safety Review Committee before contract letting.	Regardless of whether the District Traffic Unit is on the Safety Review Committee, the District Traffic Unit may provide information to the committee regarding high crash locations, clusters, and safety concerns relayed from police or local jurisdictions along with potential cost effective countermeasures that may be considered during the design process.
Part 1X, Appendix O, Safety Review Procedures	Section D.1 provides purpose and procedure for safety reviews including safety review submission and a project design criteria report that summarizes crash histories within the limit of work.	Regardless of whether the District Traffic Unit is on the Safety Review Committee, the District Traffic Unit may provide information to the committee regarding high crash locations, clusters, and safety concerns relayed from police or local jurisdictions along with potential cost effective countermeasures that may be considered during the design process.
Part 1X, Appendix O, Safety Review Procedures	Section D.2 Safety Audits provides guidance on selecting projects and conducting safety audits recommending that the audit team leader be the District Traffic Engineer.	The District Traffic Engineer as head of the audit team may suggest design projects that are suited for performing safety audits.

3.2.1 Incorporating Safety into Resurfacing, Restoration, and Rehabilitation Projects

Pavement management systems and other inputs are used to schedule pavement restorations. Incorporating minor, cost-effective safety improvements into the design of resurfacing, restoration, and rehabilitation projects is an important step in improving the overall quality and performance of the highway. Refer to Publication 242, Appendix G as well as the following for suggested actions to ensure that safety is considered in these types of projects.

Identify Targeted Safety Improvements

Using the limits of work established for the project, identify any sections that have crashes in excess of the thresholds established for the various crash types/countermeasures identified in Chapter 5 of this manual. If any are identified, perform additional analysis to determine if cost-effective countermeasures can affect the problem and the appropriateness of incorporating the safety improvement into the project.

Consider Selective Cost-Effective Geometric Improvements

Depending on the crash history, geometric improvements that can resolve an existing highway deficiency, particularly those associated with crashes, should be considered. Examples of geometric improvements include:

- Inclusion of left turn lanes at intersections that have a history of left turn movement crashes.
- Pavement cross slope improvements, particularly if the pavement drains poorly and has a tendency to pond water.
- Additional inlets or an increase in cross-drainage capacity when water accumulation on the pavement occurs because of adjacent drainage issues.
- Cross-section improvements such as lane and shoulder widening and paving the shoulders when pavements or shoulders are narrow and there is a potential for safety improvement, The potential for safety improvement can be determined through the crash analysis procedures defined in Chapter 5 of this document..
- Sight distance improvements (e.g., vegetation clearing, slope flattening, vertical curve lengthening) on sections where sight distance is significantly restricted.
- Intersection reconfiguration (horizontal or vertical alignment), for intersections with a potential for safety improvements, that can be associated with the geometric features of the intersection.
- Super-elevation improvement on curves that are severely lacking in super-elevation.

Consider Traffic Control Device Enhancements and Better Route Guidance

Minor traffic control improvements can substantially improve the safety of a highway. Examples of traffic control device enhancements include:

- Edge line and centerline rumble strips to alert drivers drifting out of their lane.
- Improved curve warning systems for sharp curves.
- Durable and/or wider pavement markings (experimental, not proven), reflective pavement markers, and median barrier delineation for improved route guidance, particularly at night.
- Upgraded signs and traffic signals as needed.

Consider Improvements to Reduce the Frequency and Severity of Run-Off-Road Crashes

Minor fixed object modifications or removal can substantially reduce the potential for run-off-road severe crashes on a section of highway. Examples of improvements to reduce run-off-road crashes or severity of these crashes include:

- Bridge rail and bridge transitions to guide rail upgrades.
- Modifying culvert end sections to be traversable and/or extended.
- Minor slope flattening, clearing, and re-grading, particularly if deep non-traversable ditches parallel the highway.
- Edge drop mitigation using paved shoulders and safety edges.
- Guide rail enhancements (e.g., installations, replacements, and upgrades where needed).
- Removal of unwarranted guide rail.
- Headwall replacements with inlets.
- Mailbox (control of replacement).
- Vulnerable tree removal or delineation.
- Vulnerable utility pole delineation, removal or relocation.
- Other obstacle removal or delineation.
- Median barrier installation.
- Safety dikes (e.g., clear zones created on the far side of T-intersections by relocating utility poles, making ditch slopes traversable, removing other fixed objects to lessen the severity of crashes if a motorist fails to stop at the intersection side road).

Consider Access Managements Concepts and Additional Enhancements to Improve Safety

Examples of access and additional enhancements that can improve safety include:

- Commercial or private drive reconfiguration, relocation, or consolidation for existing driveways that pose a safety concern, particularly in sections with a high number of driveway related crashes.
- Lighting on sections or at intersections that have a substantial night crash history if municipalities agree to energize, operate, and maintain the lighting systems.

3.3 Safety in Maintenance Operations

A number of maintenance operations and activities may benefit from a safety perspective if maintenance personnel are provided with appropriate data regarding safety concerns and low-cost improvements. Maintenance operations and activities that can benefit from safety analyses include the following:

- Snow removal.
- Tree removal or delineation.
- Fixing shoulder drop-offs or shoulder upgrading.
- Slope flattening.
- Shoulder widening and paving.
- Sign and marking improvements at stop control intersections.
- Sign and marking improvements on curves.
- Guide rail improvements/replacement/removal where not needed.
- Drainage improvements.
- Protecting bridge ends (e.g., transition guide-rail).
- Addressing slippery pavement.
- Improving intersection sight distance (e.g., clearing brush).

Data information that can help identify priority safety candidate locations for maintenance operations and activities along with potential low-cost improvements are shown in Table 3-3.

Table 3-3: Identifying Priority Safety Candidate Locations for Maintenance Operations and Activities

Maintenance Operation/Activity	Data Information to Identify Priority Safety Candidate Locations
Snow Removal	Sections of roadway that have had both a high number and disproportionate level of crashes on snow covered pavements. A suggested threshold would be: • Ten or more snow covered crashes within 5,000 feet and a ratio of snow covered to total crashes of at least 25 percent above the mean for the County for the previous year (short-term concern), and/or • Forty or more snow covered crashes within 5,000 feet and a snow covered to total crashes ratio of at least 20 percent above the mean for the County for the previous 5 years. Information provided in both tabular form and GIS map. Once developed, the Highway Safety Engineer can meet with appropriate County Managers or Assistants to provide them with the information identify and discuss section problem areas and potential adjustments to snow removal operations to reduce potential in the future. These activities should take place ideally in July, August, or September.

Maintenance Operation/Activity	Data Information to Identify Priority Safety Candidate Locations
Tree Removal	Sections of rural highway with concentrations of tree crashes. A suggested first priority threshold would be: • Five or more tree crashes within 1,000 feet on 55 mph rural highways in 5 years, and • Twenty or more tree crashes within 3,000 feet on 55 mph rural highways. Information provided in both tabular form and GIS map. Once developed, the Highway Safety Engineer can meet with appropriate County Managers or Assistants to provide them with the information, identify and discuss problem areas, discuss solutions using the tree analysis included in Chapter 5 of this manual, and discuss potential actions that can be taken to reduce potential crashes in the future.
Shoulder Drop-Offs	Sections of roadway that have had crashes where shoulder drop-offs have been identified as a causation factor. GIS maps developed showing: • Previous year of data, and • Previous 5 years of data. Ideally, GIS maps should also show sections of roadway where the Roadway Management System (RMS) indicates 2 inch or greater drop-offs. Once developed, the Highway Safety Engineer should meet with appropriate County Managers or Assistants, ideally in the early Spring, provide them with the information, identify and discuss problem areas, and discuss solutions, including potential actions that can be taken to reduce potential shoulder drop-off crashes in the future.
Slope Flattening	Sections of rural highway that have had 10 or more single vehicle rollovers not involving other fixed objects over the past 5 years in 3,000 feet. Information provided on both tabular form and GIS map. Once developed, Highway Safety Engineer should meet with appropriate County Managers and/or Assistants to provide them with the information, possibly review sites on the photolog system during the meeting, identify and discuss problem areas, and discuss solutions and potential actions that can be taken to reduce potential crashes in the future.
Shoulder Widening and Paving	Sections of rural 55 mph highway that have had concentrations of 30 or more run off the road crashes within 3,000 feet in 5 years and shoulder widths of 4 feet or less. Information provided in both tabular form and GIS map. Once developed, the Highway Safety Engineer can meet with appropriate County Managers or Assistants to provide them with the information, possibly review sites on the photolog system during the meeting, identify and discuss problem areas, and discuss solutions and potential actions that can be taken to reduce potential crashes in the future.
Sign and Marking Improvements at Stop Control Intersections	Stop control intersections that have 5 or more crashes in rural areas and 20 or more crashes in urban areas in 5 years. Information provided in both tabular form and GIS map. Once developed, the Highway Safety Engineer can meet with appropriate County Managers or Assistants to provide them with the information, discuss package of sign and marking improvements provided in Chapter 5 of this manual, possibly review sites on the videolog system during the meeting, identify and discuss problem areas, and discuss solutions and potential actions that can be taken to reduce potential crashes in the future.

Maintenance Operation/Activity	Data Information to Identify Priority Safety Candidate Locations
Sign and Marking Improvements on Curves	Rural curves that have had eight or more crashes within 1,000 feet in the past 5 years (five or more if the annual average daily traffic (AADT) is less than 3,000).[1] Information provided in both tabular form and GIS map from HSTOD since curve crash data is currently not available in CDART. Each of the curves need to be field evaluated to determine the degree of curvature in comparison to operating speed to determine the appropriate sign and marking enhancements. Once developed, the Highway Safety Engineer can meet with appropriate County Managers and/or Assistants to provide them with the information, discuss signing package of sign and marking improvements provided in Chapter 5 of this manual for curves, possibly review sites on the photolog system during the meeting, identify and discuss problem areas, and discuss solutions and potential actions that can be taken to reduce potential crashes in the future.
Guide Rail Replacements	The target is obsolete guide rails that have had high frequencies of severe crashes: sections of highway from RMS that have obsolete strong post cable guide rail systems coupled with guide rail crash data from the crash data file that identifies sections of obsolete guide rail that have eight or more crashes within 1,500 feet in 5 years. Information provided in both tabular form and GIS map. Once developed, the Highway Safety Engineer can meet with appropriate County Managers or Assistants to provide them with the information, guide rail replacement strategies in the County, possibly review sites on the photolog system during the meeting, identify and discuss problem areas, and discuss solutions and potential actions that can be taken to reduce potential obsolete guide rail crashes in the future
Drainage Improvements	Sections of roadway that have had high numbers of icy crashes during favorable weather conditions. A suggested threshold would be: • Two or more icy pavement crashes during good weather conditions within 1,000 feet within the previous year of data, and • Four or more icy pavement crashes during favorable weather conditions within 5,000 feet for the previous 5 years. Information provided in both tabular form and GIS maps. Once developed, the Highway Safety Engineer can meet with appropriate County Managers or Assistants, ideally in July, August, or September, to provide them with the information, possibly review sites on the photolog system during the meeting, identify and discuss problem areas, and discuss solutions and potential actions that can be taken to reduce potential for icy pavement crashes in the future.
Protecting Bridge Ends (e.g., transition guide-rail)	Bridge ends that have had one or more crashes within the past 10 years. Information provided in both tabular form and GIS maps. Once developed, Highway Safety Engineer can meet with appropriate County Managers or Assistants, ideally in July, August, or September, to provide them with the information, possibly review sites on the photolog system during the meeting, identify and discuss problem areas, and discuss solutions and potential actions that can be taken to reduce potential for crashes with bridge ends in the future.

[1] Unfortunately, PennDOT does not yet have a database of curvature.

Maintenance Operation/Activity	Data Information to Identify Priority Safety Candidate Locations
Slippery Pavement	Sections of roadway that have had eight or more wet pavement crashes in the past 5 years and have a wet-to-total crash ratio of at least 20 percent greater than the mean ratio for the County. In addition, skid test results indicate a skid number of 30 or less. Information provided in both tabular form and GIS maps. Once developed, the Highway Safety Engineer should meet with appropriate County Managers or Assistants to provide them with the information; possibly review sites on the videolog system during the meeting; identify and discuss problem areas, including potential countermeasures identified in Chapter 5 of this manual; and determine potential actions that can be taken to reduce potential for wet pavement crashes in the future.
Intersection Sight Distance Improvements	Rural stop control intersections that have had five or more angle crashes involving a vehicle pulling out from a stop sign. While these intersections will be covered by sign and marking improvements, the high number of angle crashes may indicate a potential sight distance problem. Information provided in both tabular form and GIS maps. Once developed, the Highway Safety Engineer can meet with appropriate County Managers or Assistants to provide them with the information; possibly review sites on the videolog system during the meeting to identify sight distance concerns; identify and discuss problem areas and potential countermeasures, particularly those associated with brush control; and determine potential actions that can be taken to reduce potential for angle crashes in the future.

3.4 Safety in Utility Pole Permitting Processes

Publication 16M, Design Manual, Part 5 establishes a comprehensive utility pole safety plan. It also may be accessed on PennDOT's shared P-drive. The plan has four key elements:

- Prevent the installation or replacement of utility poles in hazardous locations through an effective permit process.
- As part of the betterment/construction project development, relocate/remove utility poles having a crash history or a high potential for being struck.
- As an independent process, identify and investigate the feasibility of removing /relocating any utility poles that have a history of multiple hits and are not part of any betterment/construction project as in element #2.
- Increase the utility industry's awareness of the magnitude of the utility pole crash problem and the fact that they can do something about it.

Within each of the key elements, action items are identified to implement the element. The plan also identifies responsibilities of the District Executive, Permit Unit, Utility Relocation Unit Administrator, Highway Safety Engineer, Design-Squad Leader, Right of Way, and Chief Counsel's Office for successful plan implementation. As a first step in implementing these

elements, the District Highway Safety Engineer should develop the following lists of high utility pole crash locations:

- Sections of roadway with five or more pole hits in 1,000 feet in 5 years. Ideally, these sections should be separated by urban and rural areas. The rural areas will have more severe crashes due to higher speeds and also will have more flexibility in terms of identifying relocation solutions (Elements 1 and 2).
- Sections of roadway where two or more utility pole crashes have occurred within 100 feet within 5 or 10 years (i.e., identifying poles with probable multiple crash involvement).

Once assembled, the District Highway Safety Engineer should meet with the Utility Relocation Unit Administrator to establish a plan for implementing each of the key elements.

3.5 Safety in Risk Management

Risk management has three major processes: risk identification, risk mitigation, and claims handling. The District Highway Safety Engineer and the District Risk Manager need to coordinate functions in risk identification and risk mitigation. PennDOT has a Risk Management Manual under development that will provide guidance to Districts on managing lawsuits and actions that can be taken to reduce future lawsuits.

3.5.1 Risk Identification

The first step in determining risks associated with highway tort liability is to identify the types of highway elements or factors that correlate to claims or lawsuits that have been filed against PennDOT. Examples of deficiencies that have historically produced a significant number of tort claims include:

- Shoulder drop-offs.
- Incorrect or missing traffic control devices.
- Damaged, outdated, or missing traffic barriers.
- Isolated drainage-related icy spots and slippery pavements.

The history of past claims against PennDOT is an excellent source for identifying risks if these claims accurately identify the system deficiency that led to the claim and pin point the location of the deficiency on the highway system.

The PennDOT crash record system also can be a very useful tool in the risk identification process because it can be used to segregate crashes by type, cause, location, and severity. When these data are reviewed in conjunction with the history of past claims, a list of potential problem locations or areas in need of improvement can be prepared. Maintenance records provide information about the type and character of recent repair and replacement activities. Damage to

such items as guide rails and sign supports may occur without crash reports being filed. Excessive repair activity may indicate the need for a more permanent solution. Sometimes damaged elements are merely replaced in kind whereas the frequency of damage indicates the need for different hardware or a changed location.

Citizen concerns are also an excellent source to use in the identification process and should be handled by employees designated to receive, record, and follow up on the correction of all such reports. An established procedure for handling complaints and reports is also an important element in the risk management process from a legal standpoint. Once a complaint is registered by the agency, the agency is on notice of the potential defect that it represents. If a crash occurs because of that defect prior to it being addressed by the agency, the courts may find the agency negligent and therefore liable for the damages that result.

3.5.2 Risk Mitigation

Traditional highway safety programs tend to be reactive, whereby locations with a high number of crashes are identified and then corrected. The risk management process uses a more proactive approach by identifying potential problems. This process attempts to prevent crashes from happening at locations that may or may not have a crash history. Traditional safety improvement programs constitute an important component of the agency's overall safety effort by implementing large-scale site-specific and system-wide improvements. The risk management process serves as adjunct to the agency's overall safety improvement program by primarily addressing many of the smaller maintenance and operational improvements that tend to be the focus of tort claims.

Risk management targets problems that have the highest tort liability exposure. These problems do not tend to be associated with multiple crashes at the same physical location, but rather relate to crashes that are spread throughout the highway system. As an example, consider the problem of edge drop-offs. This maintenance deficiency problem has the known potential for large tort payouts if a crash occurs. However, an edge drop-off at a particular site does not normally cause a high number of crashes. Therefore, this location is unlikely to show up as a high crash location in a safety improvement program.

The cost effectiveness of risk management improvements is extremely difficult if not impossible to measure because of the almost infinite variety in the ratio of claims to damages, circumstances surrounding the incidents, inconsistency in the courts, and other factors. Their low costs coupled with the improved maintenance quality that they provide the motoring public should offset any concern over the lack of measurable benefits.

The District Highway Safety Engineer should meet with the Risk Management Engineer at least quarterly to coordinate common functions and more often as needed as the District Safety Plan is being prepared.

3.6 Safety in Promoting Safe Travel Practices

The Safety Press Officer (SPO) is part of a regional highway safety team structure in which the SPO works within regionally specified priority areas such as those listed below. These priority areas are addressed by the various members of the regional highway safety teams, through a variety of enforcement and education methods such as, but not limited to, those suggested potential activities shown below under each specific crash category. Specifically for the SPO, these methods include developing media events directly related to activities prescribed by the regional highway safety teams.

3.6.1 Aggressive Driving

- Conduct aggressive driving education at every high school within your District.
- Host a safety summit on aggressive driving to identify key partners to help identify problematic areas and solutions with in your District.
- Meet with State Police monthly to review Prophecy and PennDOT CDART data to identify crash clusters.
- Set up monthly radio talk shows to get out an aggressive driving message on the location of problematic areas.
- Conduct monthly-targeted enforcement media campaigns in crash cluster locations.
- Utilize the District's speed minder in combination with police enforcement and a media component.
- Contact your top ten employers in each county of your District to develop a targeted aggressive driving employer campaign (e.g., public address system announcements, e-mail).
- Conduct an SOS (Stand-Out-Speeder, e.g., drivers traveling at speeds at or greater than 80 mph) Campaign. Work with the State Police to have offender's names released to the media for their speeding offence to be published.
- Conduct a CAMO cops media campaign to target SOSers.
- For short-haul coal truck drivers, meet with coal receiving facilities and company owners to identify aggressive truck drivers and routes.
- Conduct meetings with area District Justices to share PennDOT goals, enforcement programs, and problematic areas. Enforcement partners should take part in the meetings.
- Use variable message boards to alert motorists of increased enforcement and to expect a citation if speeding.
- Conduct an educational and enforcement campaign with the State Police. Highlight the State Police SPARE program (i.e., aircraft enforcement).
- Work with County Maintenance Forces, and State and local police to identify the need for launch pad construction in targeted areas.
- Conduct regional targeted enforcement press events with neighboring Districts.
- Write two press releases per month on aggressive driving.

3.6.2 Alcohol and Drugs - Driving Under the Influence

- Meet with State Police monthly to review Prophecy data and PennDOT CDART to identify driving under the influence (DUI) crash clusters.
- Meet with Pennsylvania Liquor Control Enforcement (PLCE) to identify problematic taverns along high crash corridors (e.g., "cops in shops").
- Meet with DUI Task Forces and law enforcement liaison (LEL) to target DUI crash locations and to conduct media events.
- Conduct a media event to show case DUI Task Force equipment.
- Set up sobriety check points at high schools to simulate the "real thing" (involve the media).
- Promote the 1-888-UNDER-21 reporting number.
- Set up the DUI Bug at a local high school.
- Set up monthly radio talk shows to get out the DUI message.
- Conduct evening parent informational meetings about teen driving and DUI. This should be done in partnership with school officials, the County coroner, and law enforcement.
- Invite the media to attend a DUI checkpoint.
- Write two press releases per month on DUI-related topics.
- Plan to place undercover police at sporting events and share results with media.
- Park the DUI Task Force trailer along heavily traveled highways when not in use. (Note: Watch for vandals!)
- Coordinate "cops in shops" and roving DUI patrols in high crash areas.
- Join or create university anti-alcohol coalitions to plan media and education events on underage drinking.
- Host a local fact finding committee on underage drinking and DUI.

3.6.3 Seatbelts

- Conduct your own seatbelt surveys on high crash roadway to determine usage at various times. Use variable message boards to display usage on low usage roadways.
- Speak with parent groups about the need for their teens to buckle-up.
- Provide seatbelt messages for schools to broadcast on morning and after school announcements and at all sporting events.
- Conduct high-profile seatbelt enforcement campaigns at high schools and on local roads.
- Collaborate with Buckle up PA to promote the Click-It or Ticket Campaign.
- Conduct a seatbelt survey at your district office for both private vehicles and State vehicles. Share the results with your District Executive.
- Write monthly press releases to promote seatbelt use.
- Work with police officers to encourage them to enforce the seatbelt law.
- Meet with top 10 employers to get them to implement a seatbelt policy for company drivers and/or to place Click-It or Ticket stickers on their cargo trailers.

3.6.4 Truck Safety

- Conduct no-zone safety campaigns at every high school. Collaborate with local trucking companies to provide a truck and trailer. Ask your District office to provide a plow truck for students to sit behind the steering wheel.
- Collaborate with State Police truck enforcement during truck inspections to provide media coverage of enforcement.
- Meet with top 10 trucking companies to discuss crash clusters with in your district. Identify any problem they may be encountering with transportation.
- Conduct an Operation Safe Plow media campaign (i.e., a media event before every major snow event to illustrate the dangers around snowplows and large trucks).
- Speak at trucking company safety meetings to discuss PennDOT safety goals and how they can contribute.
- Place message boards along heavily traveled corridors.
- Place CB Wizard in target areas.

3.6.5 Pedestrian Safety

- Meet with every community within your District to identify pedestrian safety needs. Begin with high pedestrian crash areas first. Walk the community to determine if pedestrian channel devices are appropriate. Make sure municipality will agree to paint existing crosswalks before channel devices will be given out.
- Plan pedestrian safety events to highlight the new devices. After one month of exposure, conduct a pedestrian safety education and enforcement campaign and invite the media. Track before and after results of compliance. Publish all enforcement results.
- Plan media events to promote Home Town Street Programs and Safe Route to School Programs.

3.6.6 Work Zone Safety

- Collaborate with State and local police departments to plan work zone safety enforcement and media events (e.g., Operation Yellow Jacket, Sneak Peak). Publish enforcement results.
- Monitor work zone speeds with your District Traffic Unit to get a baseline speed before enforcement campaigns. Conduct a follow-up speed study to determine program effectiveness.
- Work with your District Construction Unit to plan for enforcement areas within construction projects.
- Send out monthly press releases to highlight enforcement measures in each construction project.
- Collaborate with State and local police departments to implement the work zone near miss reports. Follow up with media to report results.

3.6.7 Motorcycle Safety

- Collaborate with the Motorcycle Safety Foundation and local shop owners to promote motorcycle and all-terrain vehicle (ATV) safety. Conduct a press event to highlight the hidden dangers of operating motorcycles at high speeds.

3.6.8 Railroad Safety

- Become certified as an Operation Lifesaver instructor.
- Conduct railroad safety programs at schools and invite the media in for a press event on railroad safety.
- Conduct a high-rail or train ride-along and invite the media to attend to highlight motorists' behavior at highway grade crossings.
- Collaborate with State and local police departments to conduct an educational and enforcement campaign at high-risk highway grade crossings. Share the enforcement results with the media.

3.6.9 School Bus Safety

- Conduct targeted school bus safety enforcement initiatives in high-risk and high-complaint areas for violations.

3.7 Primary Functions of the District Highway Safety Engineer

The primary function of the District Highway Safety Engineer is to improve infrastructure safety on the State Highway System within his/her District specifically addressing the application of effective countermeasures at high crash locations. Some of the key activities are as follows:

- Develop, manage, and monitor the implementation of the annual District Highway Safety Plan.
- Coordinate with the District design teams to ensure that safety is being considered and incorporated into all projects during the design process in accordance with the safety provisions in the Design Manual.
- Provide the District Maintenance Engineer and County Maintenance Managers with appropriate crash data and countermeasure information regarding safety concerns and low-cost improvements that may improve maintenance operations and activities from a safety perspective.
- Participate as a member of the District Safety Review Team in the design function.
- Provide utility pole crash data and vulnerable utility pole countermeasure technical assistance as needed to the Utility Relocation Administrator to ensure that safety is adequately considered during the utility permitting process.

- Provide grade crossing crash data and grade crossing countermeasure technical assistance as needed to the Grade Crossing Engineer to ensure that safety is adequately considered during the development of the annual Grade Crossing Improvement Program.
- Coordinate with the Safety Press Officer in the development and implementation of safety corridors within the District.
- Analyze high crash locations on local roads using local road crash data provided by HSTOD and coordinate with the Local Technical Assistance Program (LTAP) Engineer to promote safety at these locations and on local roads within the District.
- Coordinate with the Risk Management Engineer to insure that the risk management process is successfully implemented.
- Review and provide recommendations regarding any SRTS projects on or affecting State highways.

3.8 Primary Functions of the District Safety Press Officer

The primary function of the District Safety Press Officer is to improve safe driving behavior within his/her District specifically targeting aggressive driving, impaired driving, and safety belt usage. Initiatives are coordinated with the Comprehensive County Safety Coordinators and the Regional Safety Teams. Some of the key activities are as follows:

- Become proficient in using the CDART system and understanding the magnitude and characteristics of the crash data for driver-related crashes particularly aggressive, DUI, and unbelted injury crashes within the District.
- Establish close liaisons with the Regional Safety Teams, the Comprehensive County Safety Program Coordinators, the DUI Task Force, and the LEL within the District.
- Serve as a back up to the Communication Relations Coordinator (CRC) and perform other communication functions such as winter emergency duties as determined by the CRC and the District Engineer.
- Develop a good understanding of the safety grants active within the District and identify media, coordination, or education activities that can complement these grants and improve effectiveness in terms of reducing crashes.
- Identify major gaps between grant areas and identified problem areas and develop initiatives with the police to provide targeted enforcement and education safety activities to the gap areas.
- Ensure that all media events and press releases are first cleared with the Press Office before release.
- Set up monthly radio talk shows on aggressive driving, impaired driving, safety belts, and other relevant safety topics.
- Coordinate and/or lead corridor safety programs for corridors exhibiting significant numbers of severe crashes, aggressive driving crashes, impaired driving crashes, injuries associated with unbelted drivers and occupants, pedestrians, trucks, or other important safety concerns.

- Establish and implement an annual safety media plan for the District that complements education and enforcement activities underway and addresses the major driver behavioral concerns in the District.
- Conduct meetings with District Justices, police chiefs, and municipal officials to share safety goals, identify and implement joint activities to promote safety.
- Use the District speed minder and variable message boards to alert motorists of speed or other targeted enforcement activity on a high crash route.
- Coordinate with the County maintenance authorities, and State and local police to identify the need for launch pad construction for targeted enforcement in high crash areas.
- Prepare and conduct media events, issue press releases, and coordinate interviews with appropriate officials to promote safety, particularly in the emphasis areas.
- Provide review and input for safety education activities proposed for non-infrastructure SRTS proposed projects.

Implementation of suggested items shown below must be agreed upon by your District Executive and by the PennDOT Central Office Press Officer. The following items are given for guidance only, which will be revised based on input from your District Executive and the PennDOT Central Office Press Officer.

Aggressive Driving:

- Conduct Aggressive Driving education at every high school within your District
- Host a Safety Summit on Aggressive driving to identify key partners to help identify problematic areas and solutions with in your district.
- Meet with State Police monthly to review Prophecy and PennDOT C-DART data to identify crash clusters.
- Set up monthly radio talks shows to get out an Aggressive Driving message on the location of problematic areas.
- Conduct monthly Targeted Enforcement Media Campaigns in crash clutter locations.
- Utilize the districts speed minder in combination with police enforcement and a media component.
- Contact your top 10 employers in each county of your District to develop a targeted Aggressive Driving Employer Campaign. (PA announcements, E-mail)
- Conduct a SOS Campaign (Stand-Out-Speeders) 80mph +. Work with PSP to have offender's names released to the media for their speeding offence to be published.
- Conduct a CAMO Cops Media Campaign to target SOSers.
- Short Haul Coal Truck Drivers - Meet with Coal receiving facilities and company owners to identify Aggressive Truck Drivers and routes
- Conduct meetings with area District Justices to share PennDOT goals, enforcement programs and problematic areas. Enforcement partners should take part in the meetings.
- Use variable message boards to alert motorist of increased enforcement and to expect a citation if speeding.
- Conduct and Educational and Enforcement Campaign with PSP. Highlight the PSP SPARE program (Air Craft Enforcement)

- Work with County Maintenance Forces, State and Local Police to identify the need for launch pad construction in targeted areas
- Conduct Regional Targeted Enforcement Press events with neighboring Districts
- Write 2 press releases per month on Aggressive Driving

DUI:

- Meet with State Police monthly to review Prophecy data and PennDOT C-DART to identify DUI crash clutters.
- Meet with PA Liquor Control Enforcement (PLCE) to identify problematic taverns along high crash corridors (Cops in Shops).
- Meet with DUI Task Forces and LEL to target DUI crash locations and to conduct media events.
- Conduct a media event to show case DUI Task Force equipment.
- Set up a Sobriety Check Points at a high schools to simulate the "real thing" (involve the media). Promote the 1-888-UNDER-21 reporting number.
- Set up the DUI Bug at a local high school.
- Set up monthly radio talks shows to get out the DUI message.
- Conduct evening parent informational meetings about teen driving and DUI. This should be done in partnership with school officials, county coroner and law enforcement.
- Invite the media to attend a DUI Check Point.
- Write 2 press releases per month on DUI related topics.
- Plan undercover cops at sporting events and share results with media.
- Park the DUI Task Force Trailer along heavily traveled highways when not in use. NOTE: Watch for vandals!
- Coordinate Cops in Shops and Roving DUI Patrols in high crash areas.
- Join or create University Alcohol Coalitions to plan media and education events on underage drinking.
- Host a local DUI fact-finding committee on underage drinking.

Seatbelts:

- Conduct your own seatbelt surveys on high crash roadways to determine usage at various times. Use variable message boards to display usage on low usage roadways.
- Speak with parent groups about the need for their teens to buckle-up.
- Provide seatbelt messages for schools to broadcast on morning and after school announcements. Provide seatbelt messages for schools to broadcast at all sporting events.
- Conduct high profile seatbelt enforcement campaigns at high schools and on local roads.
- Collaborate with Buckle up PA to promote the Click or Ticket Campaign.
- Conduct a seatbelt survey at your district office for both private vehicle and State vehicles. Share the results with your DE.
- Write monthly press releases to promote seatbelt use.
- Work with Police Officers to encourage them to enforce the seatbelt law.

- Meet with top ten employers to get them to implement a seatbelt policy for company drivers.
- Meet with top ten employers to get them to place Click-it or Ticket stickers on their cargo trailers.

Truck Safety:

- Conduct No-Zone safety campaigns at every high school. Collaborate with local trucking companies to provide a truck and trailer. Ask your district office to provide a plow truck for students to sit behind the steering wheel.
- Collaborate with PSP Truck Enforcement during truck inspections to provide media coverage of enforcement.
- Meet with top ten trucking companies to discuss crash clutters with in your district. Identify any problem they may be encountering with transportation.
- Conduct an Operation Safe Plow Media Campaign. This is a media event before every major snow event to illustrate the dangers around snowplows and large trucks.
- Speak at Trucking Company safety meetings to discuss PennDOT safety goals and how they can contribute.
- Place message boards along heavy traveled corridors.
- Place CB Wizard in target areas

Pedestrian Safety:

- Meet with every community within your district to identify pedestrian safety needs. Begin with high pedestrian crash areas first. Walk the community to determine if pedestrian channel devices are appropriate (Walk the Streets). Make sure municipality will agree to paint existing crosswalks before channel devices will be given out.
- Plan pedestrian safety events to highlight the new devices. After one month of exposure, conduct a Pedestrian Safety Education and Enforcement Campaign and invite the media. Track before and after results of compliance. Publish all enforcement results.
- Plan media events to promote Home Town Street Programs and Safe Route to School Programs.

Work Zone Safety:

- Collaborate with State and local PDs to plan work zone safety enforcement and media events. (Operation Yellow Jacket, Sneak Peak) Publish all enforcement results.
- Monitor work zone speeds with your Traffic Unit to get a baseline speed before Enforcement Campaigns. Conduct a follow-up speed study to determine program effectiveness.
- Work with your Construction Unit to plan for enforcement areas with in construction projects.
- Send out monthly press release to highlight enforcement measures in each construction project.
- Collaborate with PSP and Local PDs to implement the work zone near miss reports. Follow up with media to report results

Motorcycle Safety:

- Collaborate with the Motorcycle Safety Foundation and local shop owners to promote motorcycle and ATV safety. Conduct a press event to highlight speeds of motorcycles and the hidden dangers to riders

Railroad Safety:

- Become certified as an Operation Lifesaver Instructor.
- Conduct railroad safety programs at schools and invite the media in for a press event on railroad safety.
- Conduct a high-rail or train ride along and invite the media to attend to highlight motorists' behavior at highway grade crossings.
- Collaborate with PSP and local PDs to conduct an educational and enforcement campaign at high-risk highway grade crossings. Share the enforcement results with the media.

School Bus Safety:

- Conduct targeted school bus safety enforcement initiatives in high risk and high complaints areas for violations.

Note: All programs should contribute to the PennDOT Fatality reduction goal and should be measurable.

3.9 Primary Functions of the District Bicycle/Pedestrian Coordinator

The primary safety function of the District Bicycle/Pedestrian Coordinator is to improve bicycle and pedestrian safety within his/her District, specifically addressing the application of effective countermeasures at high pedestrian or bicycle crash locations and improving the safe walking, peddling, and driving behaviors of pedestrians, bicyclists, and drivers. Some of the key activities are as follows:

- Coordinate with the District design teams to ensure that pedestrian and bicycle safety issues are identified, considered, and incorporated into all projects during the design process in accordance with the safety provisions in the Design Manual. Use the Bicycle/Pedestrian Facilities Checklist located in Appendix J of the Design Manual, Part 1A to identify potential safety enhancements.
- Become proficient in using the CDART system and understanding the magnitude and characteristics of the crash data for pedestrian and bicycle crashes within the District.
- Coordinate and/or lead corridor pedestrian safety programs for corridors exhibiting significant numbers of severe pedestrian crashes.
- Coordinate with the Safety Press Officer (lead) in the development and implementation of press releases, media events, education and enforcement initiatives that promote pedestrian or bicycle safety.

- Coordinate the "Yield to Pedestrian Channelizing Devices" Pedestrian Safety Program in the District. PennDOT provides these devices to municipalities for installation and maintenance on crosswalks with combinations of pedestrian activity and substantial vehicle flow.
- Ensure that District permitting processes for utilities and highway occupancy permits identify and address pedestrian and bicycle safety issues.

District Highway Safety Guidance Manual

Chapter 4 — Crash Data

December, 2014

District Highway Safety Guidance Manual

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4.1 Introduction

Highway crashes can be classified as reportable or non-reportable. Reportable crashes are those that require State or local police to complete a police crash report. According to Title 75, Pennsylvania's consolidated statutes, Section 3746(a), a reportable crash is one that that occurs on a highway or traffic way that is open to the public by right or custom, involves at least one motor vehicle in transit, and meets one or more of the following definitions:

- Injury to or death of any person.
- Damage to any vehicle to the extent that it cannot be driven under its own power in its customary manner without further damage or hazard to the vehicle, other traffic elements, or the roadway, and therefore requires towing.

Every police department that investigates a reportable vehicle crash prepares a written report. This report is completed either at the time and scene of the crash or thereafter by interviewing the participants or witnesses. Within 15 days of the crash, the police department forwards an initial written report of the crash to PennDOT. If the initial report is not complete, a supplemental report is submitted at a later date. The reports may be transmitted in either paper or electronic format.

Police agencies are required to use the Crash Reporting Form provided by PennDOT. A sample of the form can be found in Appendix C.

http://www.dot6.state.pa.us/crsapp/html/AA500RefManual/AA-500_Crash_Reporting_Online_Reference.htm

4.2 Crash Reporting System (CRS)

All PARs for reportable crashes are sent by the police to PennDOT's Highway Safety and Traffic Operations Division (HSTOD), Crash Information Systems and Analysis Unit for processing and incorporation into the Crash Reporting System (CRS). Crash Data Analysts verify the location, vehicles, and drivers for each case that is processed, while also reviewing inconsistencies and reconciling the issues identified. Approximately 25% of the cases are processed by the system without any input from the analysts. The Unit also has a quality control program in place to improve the accuracy and quality of information in the CRS.

The CRS not only includes information extracted from the Crash Reporting Forms, but also includes:

- Roadway characteristic and traffic volume information for the crash site extracted from the roadway management system (RMS).
- Attributes pertinent to the driver(s) extracted from the driver's license system.

Key data elements captured for each reported crash may be found in Appendix C.

CRS encompasses all reportable crashes received by the Unit from 1997 to the present and contains all crash records that have been approved by the Records Division. With over 1,200 police agencies across the Commonwealth reporting crash data, there is never a time when one can assume that all reports have been submitted for any year. However, there is a point in the year, usually in the spring, at which "year end" batch calculations are executed and reports are generated for the previous year. At that time, one can expect that a majority of crash records for the previous year are complete and in the system. The current year and other years specifically noted are considered incomplete and extreme caution should be followed when using data from these years to create reports or maps, or to make engineering decisions. The Message Center box located in the lower right-hand corner of the CDART home screen and each report will show whether the data for a year is considered incomplete.

4.3 Crash Data Analysis and Retrieval Tool (CDART)

The Crash Data Analysis and Retrieval Tool (CDART) is a user-friendly crash analysis tool developed for the highway safety community to assist users in creatively solving crash problems through the analysis of crash data. Only authorized personnel have access to the system. The approach CDART uses provides access to data and knowledge regarding crash types and locations.

Rather than just reading numbers from a standard, printed report, users can access crash information in a variety of ways and create reports for the data that address specific needs. Users are not limited just to the data that is handed to them on reports.

CDART is an evolving tool and provides the flexibility to quickly respond to new user needs. For example, as users begin to use the tool and find that when routinely needed data is not in a format currently available in one of the CDART reports, they can contact HSTOD and discuss specific needs. It may be very easy for the report to be added. In addition, users are encouraged to suggest ways to improve the tool continuously.

A training module and training courses are available for new employees entering the safety field. HSTOD may be contacted to receive information regarding future training sessions and copies of the training module.

CDART can be used to generate a variety of reports including:

- Public Request/Press Inquiry.
- Crash Resume.
- Crash Detail List.
- Crash Summary.
- Crash Flag Summary.
- Dynamic Crash Cross Tab.
- Grouped by Segment.
- Grouped by Segment Range.
- Standard Cluster.
- Intersection Cluster.

The training session and training module provide more detailed information on each of these reports. All CDART reports include a heading that displays the sort selections made for the report, the date range, the area of interest, and the User ID of the person who generated the report. All reports have a footer that includes the required confidentiality statement, the date the report was printed, and page number. Any important notes for the report are printed on the last page.

Caution must be exercised when counting and summarizing crash information from CDART reports due to the one-to-many relationships between crash-level data and other data as interpreted by CDART. When viewing counts on CDART reports or when totaling information on reports, the following items must be kept in mind:

- Crash data elements such as time, road condition, weather, and collision type are recorded only once for each crash.
- Crash data elements relating to people, vehicles, and road segments involved in a crash occur in the CDART database multiple times per crash to record all information for each person, vehicle, or segment of the roadway.
- Number of fatal crashes does not equal the number of fatalities (deaths).
- Number of injury crashes does not equal the number of people injured (injuries).
- Number of deaths in an unbelted crash does not indicate how many people died without a seat belt on.
- Number of deaths in a DUI crash does not tell you how many drinking drivers were killed.

4.4 Fatal Analysis Reporting System (FARS)

In addition to entering information on all received reportable crash reports into CRS, the Crash Information Systems and Analysis Unit also enters data for all crashes involving a

highway fatality into a national highway fatality database managed by the National Highway Traffic Safety Administration (NHTSA). This database, the Fatality Analysis Reporting System (FARS), includes crashes involving fatalities for all States for the past 10 years.

4.5 Accessing Crash Data and Information

District personnel can access crash data from the following sources:

- General crash information and statistics for Pennsylvania highways can be obtained from the annual *Pennsylvania Crash Facts and Statistics* reports located at http://www.dot.state.pa.us/Internet/Bureaus/pdBHSTE.nsf/BHSTEHomepage?OpenFrameset under Crash Information Systems and Analysis, Crash Facts and Statistics Books.

- General national and Pennsylvania-specific highway fatality information and statistics may be accessed from http://www.nhtsa.gov/FARS. This website provides various highway fatality report documents based upon information in the FARS database. The website also provides a query system where users can query the fatality database and obtain fatality information for a variety of fatal crash characteristics. The query system may also be used to identify Pennsylvania-specific highway fatality characteristics. Unfortunately, FARS does not have adequate location-specific information to determine locations that have concentrations of fatalities.

- Specific reports and data relationships can be generated from CDART (http://164.156.155.62/cdart/). Once a week, data is extracted and uploaded from CRS to CDART. CDART contains all crash records that have been approved in CRS. However, CDART contains only a critical number of all the elements within the Crash Reporting System. Therefore, CDART may be capable of addressing a number, but not all, of the crash data needs at the District level. CDART can be used at the District level by District personnel who are proficient in accessing the CDART system.

- Information generated from CRS may be needed in those cases where CDART does not provide the level of specificity or detail required by District personnel to address a specific safety concern. In these cases, Districts need to transmit a written or electronic request for crash information to the Crash Information Systems and Analysis Unit for processing. The requestor should describe the specific information needed and provide a contact person for any questions that arise in processing the request. The requestor should consult the CRS data elements listed in Appendix C to ensure that the parameters being requested are within the data capabilities of CRS.

4.6 Location of Crashes

The reporting police officer has three options for indicating the location of a crash:

- Provide two landmarks and the distance to the crash location measured from the first landmark toward the second landmark.
- Provide latitude and longitude coordinates at the crash scene by using a GPS device.
- Provide postal/street address.

When the crash report is received by PennDOT, the information is used to determine the exact location on the linear referencing system used for Commonwealth-owned roads and to assign or verify the latitude and longitude values. Since a linear referencing system does not exist on all local roads, geographically locating crashes on local roads as well as grouping them by location in reports can be difficult. The reporting officer includes all elements of the crash but may record the location using a local road name. If the location cannot be determined by the linear referencing system then the crash cannot be plotted onto CDART maps or may not be included in some of the CDART reports. Only crashes that occur on State highways can be plotted.

Since roadways are linear, the linear referencing system allows data to be assigned to a distance along each roadway measured from the beginning of the route or nearest segment beginning. (State-owned roadways have been divided into segments, usually one-half mile increments.) Crashes are assigned to a specific segment(s) and offset (measured in feet).

- If the crash occurs in a mid-block location, the crash record will indicate the segment and offset of the crash.
- If the crash occurs at an intersection, the crash record includes a segment of each road at the intersection.
- If the road is a divided highway, both the primary and secondary segments touching the intersection are assigned to the crash.
- If the local name of a road changes at the intersection, multiple segments for the road may be recorded for the crash.

When CDART was developed, a rule was established that the primary roadway assigned to a crash would be the lowest numbered roadway. For example, crashes that occur at the intersection of Routes 26 and 3014 would have Route 26 assigned as the primary roadway. This in no way affects corridor studies on a specific route. For example, a study of Route 3014 that restricts the report to show only the primary roadway will include crashes that occurred near Route 26.

4.7 The Cost of Crashes

The costs of crashes may vary depending on specific factors involved. Two key measurements are needed for cost analysis:

- The average cost of specific crash types expressed in dollars. This is needed to determine if an improvement may be cost effective.
- Expected deaths and serious injuries per 100 crashes for various crash types. This is needed to determine the extent to which an improvement helps achieve a serious injury and fatality goal.

The monetary costs of crashes are based upon a Federal Highway Administration (FHWA) memorandum issued on February 28, 2013, entitled *Guidance on Treatment of the Economic Values of a Statistical Life (VSL) in U.S. Department of Transportation Analyses*. The injury cost proportions of fatal costs are shown in Table 4-1.

Table 4-1: Injury Cost Proportions of Fatal Costs

Severity	Descriptor	Proportion of AIS 6 Costs (2013 FHWA Memorandum)
AIS 1	Minor	0.003
AIS 2	Moderate	0.047
AIS 3	Serious	0.105
AIS 4	Severe	0.266
AIS 5	Critical	0.593
AIS 6	Fatal	1.000

The FHWA injury estimates are based upon the abbreviated injury scale (AIS). Since PennDOT's definition of injury severity is slightly different than the AIS, the converted costs for the PennDOT injury scale is shown in Table 4-2. These costs are taken from the annual *Pennsylvania Crash Facts & Statistics* document, which can be found at: http://www.dot.state.pa.us/Internet/Bureaus/pdBHSTE.nsf/InfoFbListing?OpenForm
Note that the costs presented in Table 4-2 are from the 2012 edition of the document, and are in terms of 2008 dollars.

Table 4-2: PennDOT Injury Scale - Costs per Injury

Severity	Descriptor	Cost per Injury (2008 Dollars)
K	Fatal	$6,258,621
A	Major	$1,369,921
B	Moderate	$91,545
C	Minor and Unknown	$7,260
PDO	Property Damage Only	$2,904

4.8 Key Crash Attributes Used in Safety Analyses

There are two key crash data attributes that are used in safety analyses when countermeasures or strategies are considered to reduce crashes and help achieve a safety goal.

4.8.1 Average Crash Cost

The average crash cost is the cost of a crash that a given countermeasure or strategy is designed to change or eliminate for a given location type or situation. As an example, centerline rumble strips are applied on rural two-lane highways to reduce head-on and opposing flow side-swipe crashes during all periods of the day. On a statewide basis there may be 1,050 head-on and side-swipe crashes in which there were 50 fatal crashes, 200 major injury crashes, 300 moderate injury crashes, 200 minor injury crashes, and 50 unknown injury crashes. In addition 250 crashes involved no injury and were property damage only. The average cost of these crashes is calculated as follows:

$$\frac{(50 \times 6{,}258{,}621) + (200 \times 1{,}369{,}921) + (300 \times 91{,}545) + (250 \times 7{,}260) + (250x2{,}904)}{1{,}050}$$

Average crash cost = $587,600 (head-on/side-swipe crashes on rural two-lane highways).

The average crash cost will vary depending on the severity of crashes.

The average crash cost associated with a given countermeasure is primarily used in conjunction with the number of targeted crashes that the countermeasure is intended to reduce and the cost of the countermeasure. Based on this data, a benefit cost analysis will determine if the countermeasure is cost effective.

4.8.2 Fatalities per 100 Crashes

The "fatalities per 100 crashes" term is used to predict the impact of implementing a given countermeasure in reducing fatalities. Since the overall safety goal is expressed in terms of reducing fatalities, this is a very important attribute. In the past there have been occasions where it has been assumed that if a location had a fatal crash in the previous 3 to 5 years and a countermeasure could be applied to prevent the reoccurrence of a fatality, then one could estimate that a fatal crash could be prevented if the countermeasure was applied. This method of estimating fatality reduction impact yields an unrealistically large reduction of fatalities. Fatalities are rare events where additional fatalities at the same location, even without the countermeasure, seldom occur due to the involvement of a number of independent variables in a crash (e.g., type of vehicle, age of driver, and point of impact) that can significantly affect the outcome of a crash. A more reliable method of predicting the fatality impact of implementing a countermeasure is to first identify the types of crashes that the countermeasure is intended to reduce. Then, using statewide numbers of similar crash types determine the number of fatalities per 100 crashes of the same crash type. Finally, multiply the predicted number of annual crashes that the countermeasure is intended to reduce by the fatalities per 100 crashes for the crash type being reduced.

For example, in the years 2008 to 2012, Pennsylvania had an average of 665 fatalities and 48,278 crashes involving a single vehicle running off of the road per year. This yields a rate of 1.38 fatalities per 100 crashes ($\frac{665\ fatalities}{48{,}278\ crashes \div 100}$). If shoulder rumble strips (CMF=0.84) are to be applied on a highway network with 500 run-off-road crashes per year, it is assumed that 80 crashes will be prevented ($500\ crashes\ \times (1 - 0.84)$). Finally, it can be assumed that based on the statewide rate, an average of 1.1 fatalities per year will be prevented by implementing the shoulder rumble strip countermeasure ($\frac{1.38\ fatalities}{100\ crashes} \times 80\ crashes$).

4.9 Concentrations of Crash Locations

Since highway crashes are relatively rare events, it is important to have the capability to identify locations that have concentrations of crashes where the potential for future crashes is high.

Crashes are not uniformly distributed throughout the highway system. Some of the factors that affect the distribution of crashes along highways include:

- Randomness of driver events, such as drowsy drivers drifting off of tangent sections of highway or vehicles having tire blowouts.
- Differences in traffic volume exposure.
- Differences in crash frequencies dependent on changes in highway geometrics.

- Concentrations of crashes at intersections because the conflicts between vehicles are much greater than those that occur in highway segments.

Given these factors, it is important to be able to identify high-crash sections of highway or areas where cost-effective strategies and countermeasures may be considered for deployment to reduce the potential for future similar crashes. All roadway-based improvements are considered on a segment, intersection, or corridor basis since improvements are location specific on the highway system. Education and enforcement countermeasures can be considered on a segment, intersection, corridor, or area-wide basis. Area-wide is usually defined by municipal boundaries, since these boundaries usually define the limits within which municipal police will conduct enforcement.

Crashes usually are not distributed uniformly on a municipal-wide basis. Some of the factors that affect the distribution of crashes by area include:

- Differences in population exposure by area.
- Differences in traffic volume AADT by area and/or roadway type.
- Differences in driver-related and vehicle-related demographics by area.

The three predominant types of enforcement are related to aggressive driving, DUI, and safety belt usage. Municipalities may be identified for education and enforcement initiatives based upon previous crash histories and comparisons of these types of targeted crashes. Municipalities can be ranked from highest to lowest frequency of targeted crashes or fatalities. Table 4-3 shows an example of this for total aggressive driving crashes.

Table 4-3: Driver-Related Factors – Aggressive Driving – Area-Wide Frequency

District	County	Municipality	# of Crashes	# of Fatalities	# of Crashes per 1,000 Residents	# of Crashes per Million VMT	% of Total Crashes	% of Total Fatalities	Fatalities per 100 Crashes	% of Crashes Also Alcohol-Related	% of Fatalities Also Alcohol-Related	% Crashes Also Unbelted	% of Fatalities Also Unbelted	% of Crashes Also Alcohol-Related and Unbelted	% of Fatalities Also Alcohol-Related and Unbelted

Notes on generating these tables:

- Create different tables for urban and rural municipalities.
- The targeted crash types may include aggressive driving total, aggressive driving segment, aggressive driving intersection, DUI, and unbelted occupants.
- Using the urban/rural distinctions and all types of targeted crashes, 10 tables can be produced.
- If DUI or unbelted occupants is the targeted crash type, the then aggressive driving total replaces it in the secondary percentage crash columns where the target crash type name appears.
- The information should be arranged in an Excel spreadsheet, where the municipality with the highest number of targeted crashes is listed first.

High-crash segments are usually identified using targeted crashes that a given countermeasure is designed to impact. There are two means of defining high-crash segments:

- Segments that meet or exceed a minimum threshold of targeted crashes within a specified time period per designated unit length.
- Segments that not only meet a minimum threshold of crashes per unit length, but also possess comparisons of other attributes including severity of crashes and trends.

The latter method is defined as the Location Priority Listing (LPL). A description of the LPL is provided in Appendix C.

High-crash intersections can be considered sub-sets of the highway segments except that the location is a point source rather than a section of highway. The LPL for intersections uses the volume(AADT) of the mainline and minor route rather than the VMT for the crash analysis component.

The types of high-crash locations pertinent to each emphasis area within the Strategic Highway Safety Plan are provided in Table 4-4. Additional cluster information is provided in Appendix C. A substantial number of clusters are identified in Appendix C to take into consideration highway ownership (State or local highway), urban or rural area (differences in severity), conditions under which a given countermeasure can be applied, and crash types that a given countermeasure impacts. Details pertaining to the characteristics of each high-crash location type are provided in Chapter 5.

Table 4-4: Types of High-Crash Locations

Crash Type	Area-Wide Information	Cluster Information	Limiting Crash Types
Aggressive Driving			
Aggressive Driving – Segments	✓	✓	Aggressive driving crashes between intersections.[1]
Aggressive Driving – Intersections	✓	✓	Aggressive driving crashes at intersections.[1]
Increasing Seatbelt Use			
Unbelted Crashes	✓	✓	Crashes where one or more front seat occupants are unbuckled.
Reducing Impaired (DUI) Driving			
Alcohol-Related Crashes	✓	✓	Crashes where a blood alcohol content (BAC) level of 0.04 or greater or a police report that driver had been drinking are specified.
Improving Pedestrian Safety			
Pedestrians	✓	✓	Crashes involving one or more pedestrians.
Safety Infrastructure Improvements			
Signalized Intersections	✓	✓	Crashes that occur at or are related to a signalized intersection.
Stop Controlled Intersections		✓	Crashes that occur at or are related to stop control intersections.
Curves		✓	Crashes that occur on a police reported curve.
Trees		✓	Crashes where the first harmful event is “hit tree.”
Utility Poles		✓	Crashes where the first harmful event is “hit utility pole.”
Guide Rails		✓	Crashes involving hitting a strong post cable or strong post W-beam, less than 24 inches guard rail.
Head-On – Two-Lane		✓	Head-on or opposing flow sideswipe crashes on two lane highways.
Head-On – Four-Lane		✓	Head-on or opposing flow side swipe crashes on four-lane highways.
Rear End		✓	Rear-end crashes not occurring at or related to signalized intersections.
Wet Pavement		✓	Wet pavement crashes and wet/total crash ratio of 0.30 or greater.

Crash Type	Area-Wide Information	Cluster Information	Limiting Crash Types
Run-Off-Road – Narrow Pavement		✓	Crashes on two-lane roads with pavement widths less than 20 feet.
Run-Off-Road – Narrow Shoulder		✓	Single vehicle crashes on two- and four-lane roads with shoulder widths less than 4 feet.
Run-Off-Road – Paved Shoulders Available		✓	Single vehicle crashes on two- and four-lane rural roads with 4 feet or greater paved shoulders.

[1] Aggressive driving cases have been separated into two distinct categories – those that occur between intersections and those that occur at intersections. The breakout was created because the type of aggressive driving and enforcement is different for each case. Aggressive driving between intersections usually involves speeding and tailgating. Aggressive driving at intersections involves running red light and proceeding without clearance.

4.10 Requests for Crash Data

Requests for crash data may be received in various formats and from a variety of people, including:

- Public requests.
- Press/media requests (e.g., television, radio, newspaper).
- Safety-related studies/research (e.g., consultants, contractors, government agencies).
- Legal actions (subpoenas/lawsuits).
- Right-to-know law requests.

There are three ways in which a data request can be fulfilled:

- District may directly fulfill request.
- District seeks HSTOD approval and then may fulfill request.
- HSTOD must fulfill the request.

The appropriate method depends on the type of request. Table 4-5 provides a snapshot of what data can be released, and by whom. Further detailed guidance is provided after the table. If in doubt as to the requestor's intent or what can or cannot be released at the District level, seek guidance from HSTOD.

Table 4-5: Responsibilities for Releasing Crash Data

Who is Requesting Crash Reporting System (CRS) Data Output ➔ **Types of Crash Data Output** 🡻	**Public Requests**	**Consultant/ Contractor Requests (PennDOT Hired)**	**Consultant/ Contractor Requests (Not PennDOT Hired)**	**Federal/State/ Local Government Requests (Or Their Consultant/ Contractor)**
CRS - CDART Standard Output	**Who May Review and Handle These Types of Requests (taking into consideration the guidance after the table)**			
Public Request/Press Inquiry	HSTOD or District	HSTOD or District	HSTOD or District	HSTOD or District
Crash Resume	Not Released	HSTOD or District	HSTOD	HSTOD or District
Crash Detail List	Not Released	HSTOD or District	HSTOD	HSTOD or District
Crash Summary	Not Released	HSTOD or District	HSTOD	HSTOD or District
Crash Flag Summary	Not Released	HSTOD or District	HSTOD	HSTOD or District
Dynamic Cross Tab	Not Released	HSTOD or District	HSTOD	HSTOD or District
Grouped by Segment	Not Released	HSTOD or District	HSTOD	HSTOD or District
Grouped by Segment Range	Not Released	HSTOD or District	HSTOD	HSTOD or District
Standard Cluster	Not Released	HSTOD or District	HSTOD	HSTOD or District
Intersection Cluster	Not Released	HSTOD or District	HSTOD	HSTOD or District
Crash Maps (various)	Not Released	HSTOD or District	HSTOD	HSTOD or District
CRS - Miscellaneous Crash Data Output	**Who May Review and Handle These Types of Requests (taking into consideration the guidance after the table)**			
Police Traffic Crash Reports/Images	HSTOD	HSTOD	Not Released	HSTOD
Published Crash Facts & Statistics (PennDOT Website)	HSTOD or District	HSTOD or District	HSTOD or District	HSTOD or District

Who is Requesting Crash Reporting System (CRS) Data Output ➔ Types of Crash Data Output 🡻	Public Requests	Consultant/ Contractor Requests (PennDOT Hired)	Consultant/ Contractor Requests (Not PennDOT Hired)	Federal/State/ Local Government Requests (Or Their Consultant/ Contractor)
Non-Location Statistical Output (statewide, countywide or municipality-wide)	HSTOD or District	HSTOD or District	HSTOD or District	HSTOD or District
Electronic Crash Database	Not Released	HSTOD	HSTOD	HSTOD
Other Miscellaneous Special Requests	HSTOD	HSTOD	HSTOD	HSTOD

4.10.1 Public Requests

Either HSTOD or District Offices may release the standard CDART – *Public Request/Press Inquiry Report* that is approved for public distribution and shows a summary of crash type, severity level, and injury by year. District personnel should not release any other standard CDART reports to this category of requestors.

Other common (non-location specific) statistical crash data requests may generally be fulfilled by HSTOD or District Offices. Examples include: data contained in, or similar to, that found in the *Crash Facts & Statistics* publication (www.dot.state.pa.us), and statewide, countywide or municipal-wide statistical distributions.

All public requests for copies of police or driver traffic crash reports will be referred to HSTOD. Copies of these reports/images will not be furnished to the public except under the following conditions:

- Police reports filed in accordance with Section 3751 of the Vehicle Code are available only to persons involved in the crash and their attorney or insurer[1] and to government agencies and persons determined by PennDOT to be engaged in crash prevention or highway safety research.

- Driver reports filed in accordance with Section 3747 of the Vehicle Code are available only to the driver or occupant who filed the report or his/her attorney and to

[1] Only if they can furnish proof that the crash report is missing or lost and is, therefore, unavailable from the reporting police department.

government agencies and persons determined by PennDOT of be engaged in crash prevention or highway safety research.

Approved information that is released to the public shall not include any of the confidentiality notices mentioned earlier.

Requests must be in writing (e.g., letter, fax, or e-mail). The request must identify a specific person to whom the information will be given, the person's address, telephone number, e-mail address, and the intended use of the information.

4.10.2 Media Requests

Requests from the media should be directed to the appropriate press office (District or Central Office) for guidance on handling the request. Consultation with HSTOD, the Office of Chief Counsel, or both may be necessary if requests are for sensitive or complex information. HSTOD handles electronic crash database requests utilizing the media CRS data application process.

4.10.3 Safety-Related Study or Research Requests

Consultant or Contractors (Hired by PennDOT)

In order to fulfill PennDOT objectives on its own projects, crash data from CRS and CDART are generally made available for this need. Refer to the above listed guidance under Federal/State/local government agencies as it applies for these types of requests as well.

If PennDOT determines that providing police crash reports (including electronic image versions) to its own consultant or contractor is necessary to conduct the project scope of work, then the appropriate police crash reports may be provided with the following stipulations:

- HSTOD and District Offices may handle their own consultant/contractor requests. There is no need for HSTOD to manage this activity centrally.

- If applicable, the crash reports should be sanitized by "blocking out" sensitive information on the report (e.g., names, addresses, phone numbers, driver's license numbers, and vehicle identification numbers).

- The crash reports shall be transmitted to the consultant or contractor with a cover letter that includes the confidentiality notice and the fact that these reports are only provided for their use on a specific PennDOT project.

Consultants or Contractors (Not Hired by PennDOT)

There are instances when consultants or contractors not hired by PennDOT are doing legitimate work that requires them to utilize crash data. It is in PennDOT's best interest to provide limited data as the safety impacts to our highways is at stake. One example of this would be an engineering consultant doing work for a private developer. In such a case, the engineering decisions that the consultant makes ultimately affects the safe operation of our highways.

In most cases, providing these requestors with the following CDART standard reports (previous engineering extract report) will meet their needs. HSTOD and the District Offices may provide these CDART reports:

- Crash Resume Report.
- Crash Summary Report.

Districts will consult with HSTOD on other crash data requests from these requestors.

Requests must be in writing (e.g., letter, fax, or e-mail). The request must identify a specific person to whom the information will be given, the person's address, telephone number, e-mail address, and the intended use of the information.

Federal, State, or Local Government Agencies, Including Police and Persons/Organizations under Agreement with These Government Agencies.

Generally, crash information from CRS and CDART may be released to government agencies or government-associated contractors and researchers as long as the information is needed to fulfill legitimate governmental functions, conduct traffic safety research or studies, or develop traffic safety programs.

However, the information released will be limited to only the data and information relative to a specific need or to fulfill a specific function as defined by the requestor.

The identity and organizational affiliation of all requestors should be verified. Requests must be in writing (e.g., letter, fax, or e-mail). The request must identify a specific person to whom the information will be given and the intended use of the information.

HSTOD may generally release information from CRS and CDART to requestors in this category. HSTOD also handles electronic crash database requests utilizing the CRS data application process.

District Offices may release information from the standard CDART reports to requestors in this category; HSTOD may also approve and delegate District Offices to respond with other crash data output.

If PennDOT determines that providing crash reports (including electronic images versions) to government agencies is necessary to fulfill a legitimate need, then the appropriate crash reports may be provided with the following stipulations:

- HSTOD shall administer and handle these requests. If approved, HSTOD may delegate District Offices to respond to the requestor, if appropriate.
- If applicable, the crash reports should be sanitized by "blocking out" sensitive information on the report (e.g., names, addresses, phone numbers, driver's license numbers, and vehicle identification numbers).
- The crash reports shall be transmitted with a cover letter that includes the confidentiality notice and the fact that these reports are only provided for use on their specific, designated project.

Keep in mind that only necessary and pertinent information should be provided to the requestor to fulfill their need. Outputs that cannot or will not be provided should not be discussed. Be sure that the requestor is fully aware of the confidentiality of the data and how the data should be treated; utilize the confidentiality notices listed earlier.

As always, if HSTOD or the District Offices have questions or concerns with a particular request, guidance from the Office of Chief Counsel can be sought. Sometimes the issue involves how the requestor's needs can be met while protecting PennDOT's data sensitivity interests at the same time.

4.10.4 Legal Action Requests (Subpoenas/Lawsuits)

Requests for crash data from outside attorneys, paralegal firms, private investigation firms, and insurance companies may be linked to lawsuits or potential lawsuits involving PennDOT. It is important to ask these requestors if their request pertains to active litigation (lawsuit) involving PennDOT.

- If it does, they are not to be provided with any information as their request for information is to follow the formalized legal discovery process as part of the lawsuit. Notify the District Risk/Tort Coordinator for handling.

- If they indicate that there is not a present lawsuit against PennDOT (but that they are assessing their options) or that there is a lawsuit but PennDOT is not involved, HSTOD or District Offices may provide the requestor with the CDART Public Request/Press Inquiry Report. No other CDART report output should be provided. The appropriate regional tort litigation office of the Office of the Attorney General (OAG) should be provided with a copy of the crash information that is provided to these requestors.

Requests must be in writing (e.g., letter, fax, or e-mail). The request must identify a specific person to whom the information will be given, the person's address, telephone number, e-mail address, and the intended use of the information.

If subpoenas are received that ask for crash data, police traffic crash reports, or other safety-related information, work with appropriate risk/tort and legal staff as follows:

- Subpoenas received by District or County staff shall be submitted to the District Risk/Tort Coordinator for handling. The Risk/Tort Coordinator may work with HSTOD, the Office of Chief Counsel, or both, as needed.
- Subpoenas received by HSTOD staff shall be submitted to the Bureau Risk Manager for handling. The Risk Manager may work with the Office of Chief Counsel as needed.

If HSTOD or District Offices receive requests for crash-related information through the discovery process as part of a PennDOT lawsuit (e.g., interrogatories, production of documents), the District Risk/Tort Coordinator or HSTOD risk management staff will work directly with the OAG attorney in handling the requested information.

If HSTOD or District Offices receive internal requests for crash data from PennDOT attorneys (e.g., Office of Chief Counsel, Office of Attorney General) or from Department of Government Services (DGS), Bureau of Risk and Insurance Management (BRIM), these requestors may be provided with whatever crash information they need to administer PennDOT lawsuits and claims. Districts should work through the Risk/Tort Coordinator and HSTOD staff with their risk management staff.

If HSTOD or the District Offices have questions or concerns with a particular request, they can always seek guidance from the Office of Chief Counsel.

4.10.5 Right to Know Law (RTKL) Requests

Requestors often state phrases such as: "under the Right to Know Law (RTKL)," "under the Freedom of Information Act (FOIA)," or, generally, that they have a right to know or a right to such information. Responding to these type requests must follow PennDOT RTKL protocol and are time sensitive in nature by law.

If any such request is verbal, direct the requestor to either PennDOT's web site (www.dot.state.pa.us) for information on the Department's Right to Know Law policy or to the District Right to Know Law Coordinator. If the request is written, forward it to the District Right to Know Law Coordinator (typically also the Tort Coordinator) who will in turn forward the request to the Central Office Right to Know Law office.

Typically, RTKL requestors are granted the same type of data that is provided for public requests shown above (i.e., CDART – *Public Request/Press Inquiry Report*, or general

statistical data). If information other than the standard public request type information is requested, then the Office of Chief Counsel, working with HSTOD, will provide direction.

4.10.6 Summary

This guidance establishes the procedure to be followed in handling requests for traffic crash reports and other data output relating to crashes. The procedure is an attempt to balance the public's right of access to public information with PennDOT's rights and interests as the public steward for the Commonwealth's traffic crash records. If there is any uncertainty about how to respond to a specific crash data request, seek guidance from the HSTOD or the Office of Chief Counsel in Central Office.

CDART includes only information on reportable crashes. According to Title 75, Section 3746(a) a reportable crash is an incident that occurs on a highway or traffic way that is open to the public by right or custom and involved at least one motor vehicle in transit. An incident is reportable if it involves injury to or death of any person, or damage to any vehicle to the extent that it cannot be driven under its own power in its customary manner without further damage or hazard to the vehicle, other traffic elements, or the roadway, and therefore requires towing.

Crash data alone does not indicate the level of safety at a given roadway location; it is only one piece of the puzzle. Crashes are the end result of a complex string of decisions made by people which lead to events affecting their vehicles. A crash does not always indicate an engineering problem. When reviewing the crash data included in CDART, keep in mind the following:

- Crash data does not include near misses.
- Crash data does not include non-reportable crashes.
- Crash data may not contain all the information; some elements are unknown.
- Crash data is dynamic.
- PennDOT receives crash reports in paper and electronic formats; however, the reports are not in chronological order.
- By law, police agencies may submit crash report forms up to 15 days after the crash event. However, often this takes longer.
- PennDOT does not process reports in chronological order. For efficiency, data analysts may process reports by region or geographic area rather than date sequence.

It is important to understand the data that is stored within CDART and the limits of the data in order to properly make use of it. Be aware of the timeliness of the data, how crash locations are geographically established and entered in CDART, and how the crash data is interpreted and stored within CDART.

District Highway Safety Guidance Manual

Chapter 5 — Studies and Countermeasures

December, 2014

District Highway Safety Guidance Manual

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5.1 Introduction

The goal of a highway safety improvement program is to reduce the potential for highway fatalities and major injuries at individual locations as well as systematically, statewide. This reduction should be done cost effectively through the application of appropriate countermeasures and strategies. Crash data needs to be analyzed to determine crash types and locations where countermeasures and strategies might be cost effectively applied. Studies are needed at these locations to identify appropriate countermeasures to reduce the potential for fatalities. This chapter has three major components:

1. Approaches to performing crash analyses and safety impact evaluations.
2. A description of various safety study types.
3. Methods to identify cost-effective applications of countermeasures and strategies and means to estimate the potential for reduced fatality occurrence both at specific sites and statewide.
4. Relationships between crash characteristics, application consideration, and effectiveness of major countermeasures and strategies.

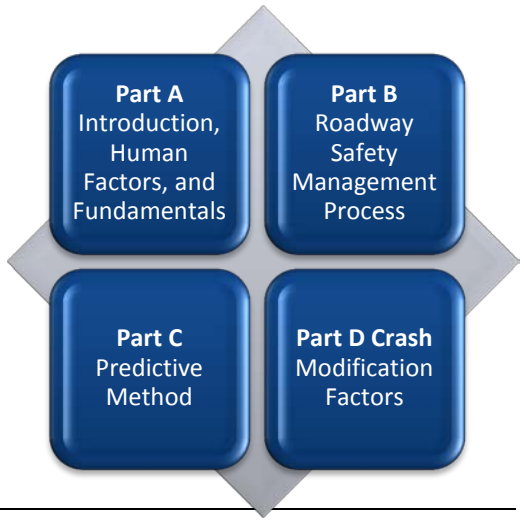
5.2 Crash Analysis and Safety Impact Evaluation

5.2.1 Background

The American Association of State Highway and Transportation Officials (AASHTO) *Highway Safety Manual*, 1st Edition, 2010 (HSM) presents the best available state of the practice in safety analysis, and provides quantitative ways to measure and make safety decisions relating to estimating safety performance. It is a toolbox that provides different analysis approaches, and methods and performance measures, to support decisions in the project development and road management processes.

The HSM is organized into four parts:

- Part A provides the fundamentals of safety and includes a discussion of human factors as it relates to the project development process.
- Part B covers the basic elements of road safety management: network screening (identifying locations with potential for safety improvement), diagnosis and countermeasure selection (alternatives for potential improvement of safety performance), economic analysis and prioritization (for example, benefit-cost analysis), and safety evaluation (evaluating the impact of implemented projects).



- Part C presents the advance predictive method for two-lane rural highway, rural multilane and urban and suburban arterial facilities. For urban arterials, only facilities up to four lanes (two lanes in each direction) are currently included in the analysis tools. HSM safety prediction relies on safety performance functions (SPFs) that express the predicted crash frequency for a basic segment or intersection defined by the type of facility under a specific set of base conditions.
- Part D presents the impact of countermeasures on safety performance, using crash modification factors (CMFs). Several projects are underway and will start in the near future to serve as additional or updated content for the next edition of the HSM.

The HSM is intended for use by professionals charged with planning, design, construction, operations, and maintenance of a road or highway system. In effect, use of the HSM can assist PennDOT accomplish what its customers and stakeholders expect, which is providing the highest level of safety performance when utilizing funding and other resources provided to PennDOT.

5.2.2 Crash Analysis and Safety Impacts Evaluation

HSM Part C provides a predictive method for estimating expected average crash frequency (including severity and crash types) of a network, facility, or individual site, through use of statistical models, or safety performance functions (SPFs), that have been developed for specific roadway types and specific to time period, traffic volume and geometric design characteristics. Specifically, the chapters in HSM Part C provide the predictive method for segments and intersections for the following facility types:

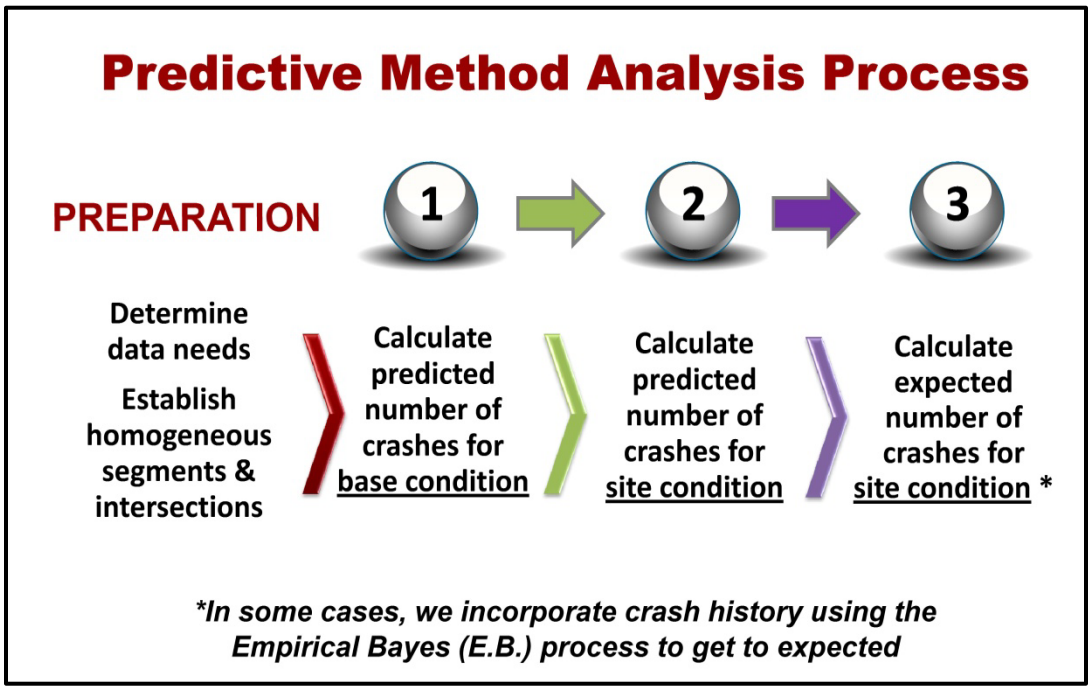
- Rural Two-Lane, Two-Way Roads (HSM Chapter 10)
- Rural Multilane Highways (HSM Chapter 11)
- Urban and Suburban Arterials (HSM Chapter 12)

Segments and intersections can be evaluated based on differing site types within each primary roadway type such as undivided or divided in the case of segments, or type of stop-control and number of legs for intersections. The predictive method can be used for the determination of the expected crash frequency and used throughout the entire project development process for situations such as:

- Roadway network screening to identify safety program priority locations
- Definition of project safety need, as part of environmental purpose and need determination
- Evaluating existing facilities' safety performance under past or future traffic volumes
- Identifying and estimating the effectiveness of proposed countermeasures prior to implementation
- Evaluating the effectiveness of countermeasures after a period of implementation
- Evaluation of Design Exceptions
- Informing the identification, evaluation, selection and design of project alternatives

Predicting expected average crash frequency as a function of traffic volume and roadway characteristics can be used for making decisions relating to designing, planning, operating, and maintaining roadway networks. The approach is applicable for both safety-specific studies and as an element of a more traditional transportation study or environmental analysis.

HSM Predictive Crash Analysis Methodology - The crash frequency for each segment and intersection is predicted using an iterative 18-step method in Highway Safety Manual. For specific instruction on how to perform the analysis, refer to the HSM (chapters 10-12) corresponding to the roadway being studied as noted above. However, in summary, these steps can be grouped into a preparatory stage and three major calculation steps. The figure below illustrates the major components of the Predictive Method Analysis Process.



The preparatory phase consists of data collection (geometric, volume, observed crash data), dividing the facility into individual sites, and selecting an appropriate study period. The analysis process consist of (Step 1) initially calculating multiple- and single-vehicle fatal/injury and property damage only crashes which are then added to obtain base predicted average vehicle crashes. The next step (Step 2) is to adjust the base predicted vehicle crashes with crash modification factors (CMFs) based on the roadway characteristics. Additional analyses are performed to predict bicycle and pedestrian crashes. Calibration factors are then applied to adjust the predicted crashes for local conditions. Finally (Step 3), if historical data is available, a statistical process known as the Empirical Bayes Method is applied within the predictive method to combine predicted average crash frequency with the observed (historical) crash frequency. A weighting of the two estimates (predicted and observed) is utilized to reflect the statistical reliability of the model.

This analysis can be conducted at any stage(s) of a project, from the preliminary planning stage through to operation of an existing facility. The level of effort required to perform safety analysis at differing points of project development can be customized to be commensurate with the point in the process and the level of complexity of the project under development. Each District will have staff experienced in conducting Highway Safety Manual analyses in place to assist

determining the level of effort required and to provide guidance/assistance in performing crash analysis procedures using the HSM methods.

HSM Predictive Crash Analysis Tools – Upon release of the 2010 AASHTO HSM, it was apparent that the AASHTO HSM Part C Predictive Method Worksheets (provided in Chapters 10, 11, and 12 of the HSM) were challenging to complete and time consuming. A set of three spreadsheets to help new users understand how to apply the crash predictive methods included in Volume 2 of the Highway Safety Manual were developed under NCHRP Project 17-38, *Highway Safety Manual Implementation and Training Materials*. The spreadsheets demonstrated the crash prediction procedures for rural two-lane two-way roads (HSM Chapter 10), rural multilane highways (HSM Chapter 11), and urban and suburban arterials (HSM Chapter 12).

As part of the implementation of these tools many states have identified the need for enhancement and customization to the tools increased usage. Several states have developed enhanced/updated versions of the spreadsheets and have even released their versions for use by other agencies as part of their commitment to reducing the likelihood and severity of crashes on public roadways. Copies of enhanced spreadsheets developed through collaboration of Virginia DOT and Alabama DOT are available for use in performing PennDOT crash analysis and can be found at the following location: http://www.safetyperformance.org/resources/hsmxlsextended/ PennDOT is currently in the process of developing versions of the tools specific to PennDOT for use in HSM predictive crash analysis. These PennDOT specific spreadsheet tools will be made available for use upon completion.

Safety Impact Evaluation - The extent of crash analysis and safety impact evaluation will largely depend on where the project falls within the project development process. The predictive method may be applied to estimate the total predicted and expected crash frequencies by crash severity and collision type for a study area, proposed countermeasure, alternative scenarios, individual design element for use in design exception analysis, or project design. The predicted/expected crash frequencies may be calculated for past, present, and/or future conditions and should consider the given geometric design, traffic volume and period of time scenario(s) as specified by the project scope.

Highway Safety Manual, Part C methodology training including Part C predictive analysis tools will be provided on and on-going basis. District staff will be available to assist in safety scope definition and provide guidance on how to prepare crash analysis and safety impact evaluations for PennDOT Projects. Additional guidance on performing HSM analysis, including where to purchase a copy of the HSM, may be found at the following website: http://www.highwaysafetymanual.org/. The FHWA also provides resources which can be found at their website: http://safety.fhwa.dot.gov/hsm/.

5.2.3 Crash Rate Analysis

While it is the intent of PennDOT to transition to the use of the HSM predictive crash analysis methods to perform crash analysis for all safety evaluations, in certain situations the amount and quality of data may limit the ability to apply these methods in an efficient manner. In these

situations it may be necessary to utilize the more traditional crash rate analysis methods to evaluate the safety of a facility or site. When the ability to utilize the predictive methods is in question, the project manager should consult with the District Traffic Engineer who will then coordinate with the HSTOD for determination of the appropriate type of safety crash analysis.

The traditional approach to analyzing crash data may only be used only upon direction of District Safety Staff or HSTOD and when the data to perform HSM analysis is insufficient or to collection of the required data would result in significant schedule or cost impacts to the project under development.

Should the traditional crash rate analysis be the method that is determined to be appropriate for the location to be studied, the following describes the approach that should be used:

***Crash Rate*[1] –** is calculated from the number of all reportable crashes per million vehicle miles traveled along a specific segment of roadway, or in the case of an intersection from all reportable crashes per million entering vehicles. The crash rate calculations for roadway segments and intersections are as follows:

Eqn. 5-1 $$\mathbf{R_{(s)}} = \frac{(\boldsymbol{C}\times\mathbf{1{,}000{,}000})}{(\mathbf{365}\times\boldsymbol{N}\times\boldsymbol{V}\times\boldsymbol{L})}$$

Where:

$R_{(s)}$	=	Roadway segment crash rate per *million vehicle miles traveled*
C	=	Number of crashes at the location during study period (generally 3-5 years)
N	=	Number of years of data
V	=	Average Daily Traffic (ADT)
L	=	Length of road segment (miles)

Eqn. 5-2 $$\mathbf{R_{(i)}} = \frac{(\boldsymbol{C}\times\mathbf{1{,}000{,}000})}{(\mathbf{365}\times\boldsymbol{N}\times\boldsymbol{V})}$$

Where:

$R_{(i)}$	=	Intersection crash rate per *million entering vehicles*
C	=	Number of crashes at the location during study period (generally 3-5 years)
T	=	Time period when crashes are occurring (days) (ex: 1825 days = 5 years)
V	=	Average Daily Traffic (ADT) volume of entering traffic
L	=	Length of road segment (miles)

Comparing crash rates to the statewide summary crash rate statistics – until such time that the data systems have been updated on both the state and local (county, township, municipal) to allow for analysis to be performed for all PennDOT roadways using the HSM predictive methods, summary crash rate information for state facilities will be maintained by HSTOD for comparison to

[1] Analysis using HSM analysis should be used whenever possible. Crash rate analysis may be considered after consultation with and approval by District Safety Staff or HSTOD and only if it is determined that HSM analysis methods cannot be used.

calculated crash rates. The District Traffic Engineer will be able to provide tables summarizing average crash rates for various classifications of roadway according to its urban or rural classification, access control, divider type, total width, and ADT range. The summary statistics are useful for determining how the crash rate on a section of road compares to the crash rates of other similar roadways within the Commonwealth. If the crash rate on a study section of roadway is significantly higher than the calculated statewide average rate, the study section should be considered for additional crash analysis (as determined by the District Traffic Engineer and/or HSTOD) including collection of data as necessary to complete HSM predictive method analysis.

5.3 Safety Studies

5.3.1 Overview

Safety studies are performed to identify engineering, education, and enforcement improvements that can cost effectively lower the potential for future crash occurrence. Studies are normally performed for highway locations or areas that have exhibited an increased frequency of crashes. In addition, studies can also be performed for locations that do not have a history of crashes but have the potential for a substantial increase in crashes.

Since crashes are relatively rare events and many independent variables can influence whether a crash occurs, there are locations which may exhibit few crashes but, based upon characteristics of the roadway, should have a much higher number of crashes. An example may be a high-volume, 55 mph, rural, two-lane highway with no shoulders and only minimal crashes. The actual observed crashes for this type of highway may be significantly lower than the expected crashes, but the potential for future crashes based upon the characteristics of the roadway may be significantly greater. In these instances, it is critical that the characteristics of the roadway and traffic flow are analyzed carefully to determine if there are other factors contributing to the lower number of crashes before a determination is made to improve the shoulders on the roadway.

There are five basic types of safety studies that are performed:

1. Area-wide safety studies.
2. Corridor safety studies.
3. High-crash location studies.
4. Systematic application of low-cost countermeasure studies.
5. Roadway Safety Assessments.

Crash data to perform these studies can be generated by Districts using the CDART system. There will be limited situations where studies will require information that cannot be generated from CDART. In these cases, HSTOD will generate the data from the Crash Records System and provide it to the Districts.

5.3.2 Area-Wide Safety Studies

Area-wide studies are usually performed on a police or municipal jurisdiction level and are associated with education and enforcement initiatives designated to reduce the potential for future aggressive driving or DUI crashes or to increase safety belt usage. Areas are selected based upon the relative frequency of total and severe targeted crashes, frequency of targeted crashes per capita, and the interest and capability of police jurisdictions to perform enforcement to reduce the targeted crashes. Once a municipality or jurisdiction is identified for targeted education and enforcement, the 5-year targeted crashes should be analyzed to determine characteristics of the crashes that can be applied to lower the potential for future targeted crashes. Crash information that is relevant to defining the application of education and enforcement initiatives are:

- Targeted total and severe (i.e., fatal and incapacitating injury) crashes by time of day and day of week to determine time periods most likely for targeted crash occurrence.
- Maps of targeted total and severe crashes that indicate locations which have concentrations of targeted crashes.
- Age and gender of aggressive or DUI drivers involved in either aggressive or DUI total and severe crashes.
- Age and gender of unbelted drivers and front-seat unbuckled occupants (both totals and severe injuries and fatalities) involved in crashes.

This information can be used to determine times and sections of roadway where targeted visible enforcement needs emphasis.

A model work plan for the targeted education and enforcement initiative is provided in Appendix D.

5.3.3 Corridor Safety Studies

Corridor safety studies are usually conducted on high-volume arterials between five and twenty miles in length which exhibit a high frequency of severe and fatal crashes.

The goal of the corridor safety study is to reduce fatal and incapacitating injury crashes on designated high-volume arterials exhibiting high frequencies of severe crashes using low-cost, near-term solutions combined with enforcement, education, and emergency medical service initiatives.

Corridor safety studies are usually conducted using a team approach. The corridor team is normally comprised of at least the following representatives:

- District Highway Safety Engineer.
- District Safety Press Officer.
- County Maintenance Manager or designee.
- Representative of State or local police responsible for enforcement on the corridor.

Additional team members may also include the District Traffic Engineer, Local Emergency Medical Services (EMS) coordinator, a representative of local governments within the corridor, a Metropolitan Planning Organization (MPO) representative, and a highway design representative.

Once a corridor has been identified for a study, the Safety Engineer and the District Safety Press Officer should perform an analysis of the crash data along the corridor to identify crash patterns that can be addressed by low-cost countermeasures and education/enforcement actions. All cluster lists need to be reviewed to identify specific locations within the corridor that appear on one or more of the cluster lists.

After the crash analysis is completed, the corridor safety team is convened to review and discuss the crash analysis, findings, and safety concerns along the corridor from each member's perspective. The team then conducts a field review of the corridor, usually in one or two vehicles, to review areas of concern defined from the crash analysis and team discussions and any other safety aspect identified during the field review. The team then reconvenes and reaches consensus on a set of countermeasures and initiatives that have strong potential to reduce future severe crashes.

The District Safety Engineer and the District Safety Press Officer take the results of the team field review meeting and prepare a cost estimate and an assessment of the probable safety impacts and cost effectiveness of implementing the recommended improvements. A brief report and tentative implementation schedule are prepared and used for programming consideration of cost-effective improvements.

Act 229 Highway Safety Corridors

In 2002, Act 229 provided authority to sign and double fines in designated highway safety corridors where motorists are exposed to increased levels of enforcement and increased penalties for moving violations related to unsafe driving behavior to improve safety.

Act 229 defines a highway safety corridor as "the portion of a highway determined by a traffic study to be targeted for the application of signs, increased levels of enforcement, and increased penalties specifically for the purpose of eliminating or reducing unsafe driving behaviors that are known to result in crashes and fatalities."

A segment of a highway may be designated as a highway safety corridor in which increased penalties will apply for violations identified in 75 Pa.C.S. § 3326(c) (relating to duty of driver in construction and maintenance areas or on highway safety corridors) if the following conditions are satisfied:

1. A crash analysis of candidate locations indicates that, for the preceding 5 years, crashes related to targeted driving behaviors exceeds thresholds for the number of crashes or the rate of crashes for homogeneous roadways as determined by PennDOT.
2. The corridor meets the geometric requirements needed to allow for safe patrolling by law enforcement officers as well as a safe area to stop violators for the issuance of a traffic citation or warning.
3. The corridor has adequate space for the installation of the traffic signs specified in this chapter.
4. There is a written commitment from the local and State law enforcement agencies responsible for highway patrol along the corridor to provide visible, sustained enforcement activity within the limits of the marked corridor.

The decision to apply corridor safety signing strategies is a District Office decision based on satisfying the above requirements. It is recommended that before proceeding, Districts consult with the Safety Management Division of HSTOD for additional insight and guidance on this initiative.

Key Steps for Implementing Act 229 Highway Safety Corridors

Phase 1 – Preparatory

1. Identify what corridor signing is in place and what additional corridors may be candidates for Act 229 highway safety corridor signing.
2. Form a corridor safety team and perform an analysis of the crash data along the corridor to identify crash patterns that can be addressed by low-cost countermeasures and education or enforcement actions. (This is done by the District Safety Engineer and the District Safety Press Officer.)

3. Determine if there are Smooth Operator or safety belt grants that could influence the corridors and if adjustments to the grants may be in order to increase targeted enforcement in the corridor.
4. Conduct a field review of the corridor with the corridor safety team, usually in one or two vehicles, to review areas of concern defined from the crash analysis and team discussions and any other safety aspect identified during the field review. Reconvene the team to reach consensus on a set of countermeasures and initiatives that have strong potential to reduce future severe crashes.
5. Compile the field review results, share the information with the District Engineer/Administrator, and determine a course of action for the candidate corridor. (This is done by the District Safety Engineer and the District Safety Press Officer.)
6. Arrange a meeting with officials (e.g., Mayor's Office, Township Manager's Office, and Chief of Police) for those municipalities encompassing the candidate corridor. Invite the State Police Troop Commander who manages the corridor.

Phase II – Meet with Local Officials

1. Apprise the local officials of the concentration of targeted driver-related crashes on the candidate corridor.
2. Request a written commitment to enhance enforcement on the corridor. Indicate that PennDOT will place special Act 229 signing on the corridor if a written commitment of at least 10 to 15 hours of visible and active enforcement targeting the driver performance associated with targeted crashes is provided on the corridor. Determine if any supplementary signing (e.g., Don't Tailgate, Slow down – Save a Life, Buckle Up – It's the Law, Targeted Enforcement Area) should supplement the Act 229 signs.
3. Advise the meeting participants, if a written commitment for enforcement will be provided, that the data and the increased enforcement should be shared with the media in a joint press conference.
4. Collectively agree on the corridors, develop a coordinated strategy and schedule to sign the highway, announce the information to the media, and begin visible enforcement. Also, agree to a 6 to 12 month follow-up meeting to evaluate the impact of the initiative and determine whether further actions are needed.

Phase III – Implementation

1. Meet with magistrates that service the corridor, explain the driver safety crash concerns on the corridor, review the Act 229 provisions, and ask for their input and cooperation when visible enforcement begins.
2. Install the corridor signs.
3. Begin visible enforcement.
4. Hold a joint press event.
5. Periodically meet with police and magistrates to monitor enforcement levels and obtain any insight from police on observed changes in driving habits as a result of the added enforcement and signing. If anything newsworthy results, provide a press release.

Phase IV – Evaluation

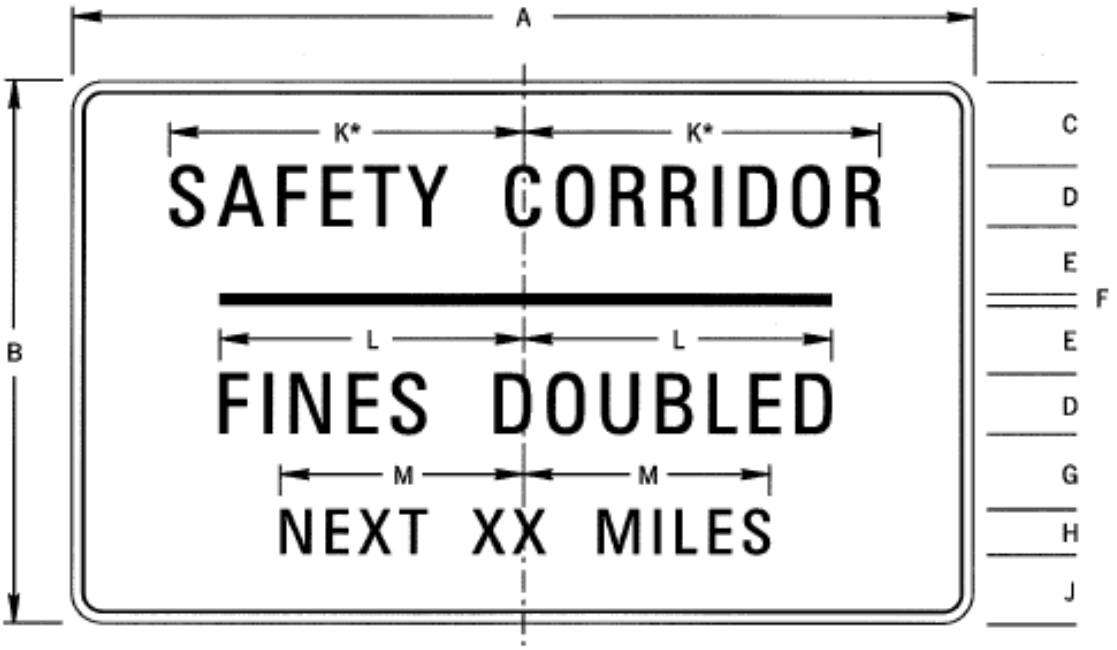
1. After the full year-end crash data is available, perform a before and after comparison of crashes on the corridor comparing the changes in targeted crashes that the enforcement is intended to reduce (i.e., aggressive driving, speeding, unbelted) to the same before period.
2. Meet with the police, share the evaluation information, and determine if any adjustments need to be made.

Act 229 Traffic Signs

Signs shall be installed as follows:

- Sign W35-1 – Safety Corridor – Fines Doubled Next XX Miles – Shall be installed as close as practical to the beginning of the highway safety corridor and after each interchange along the corridor.
- Sign W35-2 – End Fines Doubled Corridor – Shall be installed immediately at the end of each highway safety corridor.

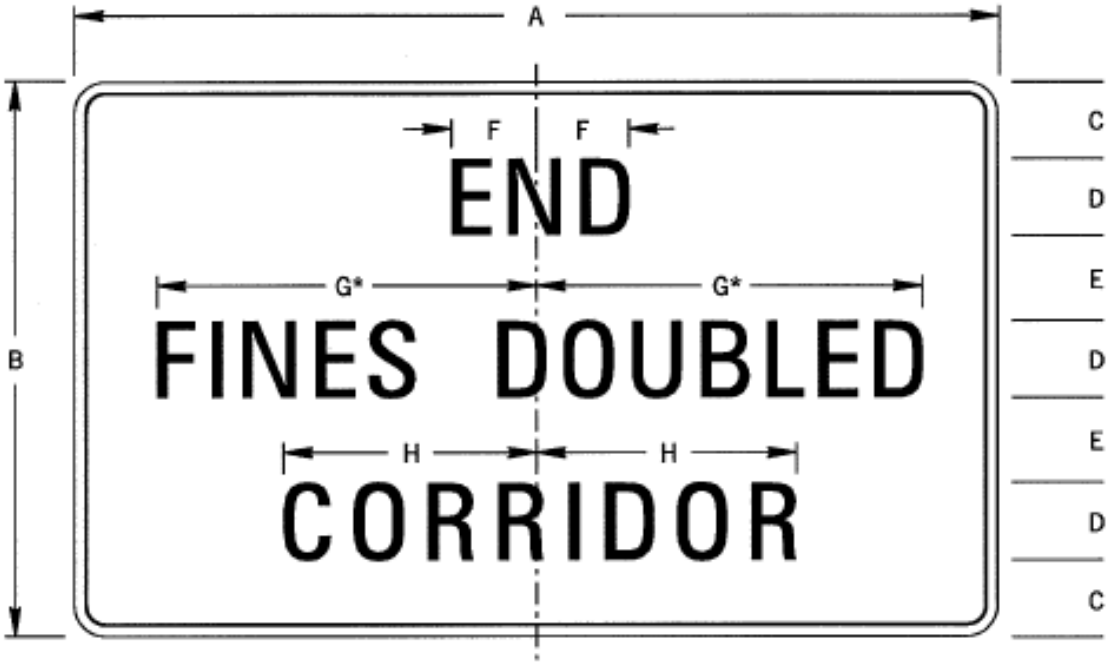
The signs shall be manufactured in accordance with the standards set forth in the following figures.



DIMENSIONS – IN											
SIGN SIZE A x B	C	D	E	F	G	H	J	K	L	M	BOR-DER
60" x 36"	5.6	4E	4.5	0.8	5	3E	4.6	27.2	24	17.9	0.6
120" x 54"	7	8E	5	1	7	6E	7	57.4	48.2	35.8	1.3

* REDUCE SPACING 20% FOR 60" x 36" SIZE ONLY

Figure 5-1: Sign W35-1 Standards



DIMENSIONS – IN							
SIGN SIZE A x B	C	D	E	F	G	H	BOR-DER
60" x 36"	5	5E	5.5	7	27.9	18.8	0.6
108" x 54"	8	8E	7	11.2	48.2	30.1	1.3

* REDUCE SPACING 30% FOR 60" x 36" SIZE ONLY

Figure 5-2: Sign W35-2 Standards

5.3.4 High-Crash Location Studies

Traditional safety improvements for the highway safety improvement program are based upon selecting, studying, and identifying appropriate improvements for high-crash locations. The District Safety Engineer is the focal point within the District for conducting such studies. The model process for identifying, studying, and defining appropriate improvements to reduce the potential for future crashes at high-crash locations is as follows:

1. Identify candidate locations. The Statewide high Crash Location List and the Planning Organization High Crash Location Lists are the principal data sources to identify high crash locations. Locations that appear at or near the top of the listings are the priority locations for study and analysis.
2. Analyze crash data. Once a high-crash location is identified, all crashes defined in the past 5 years are analyzed to determine if any patterns of crashes emerge. Crashes are usually plotted on a diagram of the high crash locations. For each crash, the following is identified:

a. The location within the diagram that the crash occurred.

b. The type of crash.

c. Common information about each crash plotted such as time of day, crash report number, and causation factor.

In addition to the crash diagram, the crashes are further analyzed to determine if any factors such as type of crash, weather conditions, causation factors, and time of crash occurrence can be associated with crash patterns. See Section 5.2 for more information on performing a crash analysis/safety impact evaluation.

3. Gather external information regarding previous crashes from police investigating officers, EMS responders, and maintenance personnel who can provide additional insight on crash characteristics.

4. Perform a field review of the crash site to evaluate the physical characteristics of the crash site that may contribute to any of the crash patterns identified. Geometric features that should be reviewed include:

   a. Intersection type.

   b. Traffic control devices.

   c. Horizontal and vertical alignment.

   d. Sight distance.

   e. Lane and shoulder width.

   f. Pavement and shoulder surface condition.

   g. Median type and condition.

   h. Roadside recovery area, including fixed objects.

   i. Access points.

   j. Available lighting.

   k. Pedestrian facilities.

   In addition to the evaluation of the roadway characteristics, traffic flow characteristics should also be observed to determine if any (e.g., significant variance in speeds) may contribute to an increased potential for crashes.

5. Before finalizing a solution, conduct additional studies depending on the complexity of the location. These studies may include spot speed studies, surface friction tests, traffic conflict studies, and more precise sight distance measurements.

6. Identify appropriate countermeasures that may reduce the potential for future crashes using the crash patterns and characteristics resulting from the crash analysis, the information obtained from the field review, observations, any external relevant crash information, and information generated from any additional studies. Appropriate

countermeasures may be selected from a list of available countermeasures found in Table 5-1.

7. Using the crash reduction factor (CRF) in Table 5-1 for selected countermeasures and the crash patterns associated with the countermeasures, estimate the annual number of crashes that may be reduced for each countermeasure. For each countermeasure identified, develop an estimate of the costs to implement the countermeasure at the high crash location.
8. Perform a benefit/cost (B/C) analysis for each countermeasure. Multiply the estimated number of annual crashes that the countermeasures are projected to prevent by the average crash cost from Table 5-1. Divide this by the estimated annual cost of the countermeasure (i.e., estimated construction cost divided by the expected life (years) of the countermeasure). Countermeasures that yield a B/C ratio above 2.0 are considered very good safety investments. Countermeasures that yield a B/C ratio between 1 and 2 are considered marginal to good investments.
9. For each countermeasure selected, determine the estimated fatality reduction by multiplying the estimated annual crashes reduced by the fatalities per 100 crashes for the appropriate crash type found in Table 5-1.

5.3.5 Systematic Studies and Process for Low-Cost Improvements

Unlike a traditional analysis, the systematic process starts with selecting an improvement type that may be reduced by implementing a low-cost countermeasure at high-crash locations. The answer that is sought is the number of locations where the countermeasure can be deployed cost-effectively. The B/C is given or set, and the number of targeted crashes per location (threshold crash level) needed to make the improvement cost-effective must be determined. The formula is as follows:

$$T = \frac{AnnualCost \times B/C}{Effectivenss \times AverageCrashCost}$$

Where:

- T = Threshold level of targeted crashes per location in order to consider the strategy cost-effective. In Table 5-1, T is the threshold level of target crashes needed over a 5-year period to achieve a B/C ratio of 2.0.
- Annual Cost = Annual cost of the improvement. For construction improvements, Annual Cost is the construction cost annualized over the expected life of the improvement. For an education or enforcement improvement, Annual Cost is the annual cost of a full year of enforcement or education.
- B/C = Set benefit/cost ratio used to determine the threshold level of targeted crashes per unit length. It is usually between 1.0 and 2.0. In this case, a value of 2.0 is used.
- Effectiveness = Estimated effectiveness or crash reduction factor of the countermeasure in reducing targeted crashes derived from information in Table5-1.

- Average Crash Cost = Average cost of targeted crashes provided in Table 5-1.

A 5-year crash history is used in the analysis to provide more data on crash occurrences. Once the threshold is established, the crash data system is searched to determine locations that equal or exceed the threshold level.

Systematic deployments of specified low-cost improvements are based upon selecting relatively low-cost improvement types that can be applied to a large number of defined high-crash locations such that the cumulative effect will significantly help a District achieve a District-wide reduction of fatalities and severe injuries. The District Safety Engineer is the focal point within the District for conducting such studies. The model process for selecting improvement types for systematic deployment and determining the level of deployment and impact on fatalities is as follows:

1. Identify candidate improvement types. The number of locations within each of the various crash cluster listings within the District coupled with the CRF, the estimated unit cost of a typical improvement, and the fatalities per 100 crashes are reviewed collectively to determine improvement types which have the better potential to maximize reduction in fatalities for the same level of funding. Improvement types that have the best potential to save lives per unit of funding can be selected for systematic deployment.
2. Analyze crash data. Once the improvement types are identified, locations that have targeted crashes at or above the threshold level for a given improvement type are analyzed to determine if the improvement is appropriate to implement. Generally two factors will determine appropriateness:
    a. Analysis of crashes at the location to determine if other improvement types are more appropriate to implement.
    b. Field review of the site to evaluate the crash site's physical characteristics, which may contribute to the crashes, and determine whether the improvement type is appropriate for the location.

Upon completion of the field reviews and a determination of the crash locations where the improvement types are appropriate for implementation, a tabulation of locations, costs, and expected overall annual fatality reductions is made for each improvement type identified. This assessment may be made on either a County or District basis.

Systematic deployment of cost-effective, low-cost improvements involves a wide variety of strategies and countermeasures deployed on a segment or intersection basis. Each improvement impacts a specific type of crash. The major types of crash categories by safety focus area within the Strategic Highway Safety Plan are as follows:

Aggressive Driving

- Aggressive driving – segments.
- Aggressive driving – intersections.

Safety Infrastructure Improvements

- Signalized intersections.
- Stop controlled intersections.
- Curves.
- Trees.
- Utility poles.
- Guide rails.
- Head-on and opposing sideswipe.
- Rear end.
- Wet pavement.
- Run-off-road – narrow pavements, narrow shoulders, and paved shoulders available.

Increasing Seatbelt Usage

- Unbelted crashes.

Reducing Impaired (DUI) Driving

- Alcohol-related crashes.

Mature Driver Safety

Motorcycle Safety

Improving Pedestrian Safety

- Pedestrians.

To associate improvement types to crash types, State or local road location, urban or rural area, and often some other relevant feature, such as wet pavements or narrow shoulders, need to be considered.

The listings of systematic improvement types, crash types prevented, crash reduction factor, location criteria, threshold crash level, average crash costs, and fatalities per 100 crashes is provided in the following table.

Table 5-1: Systematic Improvements and Related Crash Types

Systematic Improvement Type	Crash Type Prevented	Location Criteria	Crash Reduction Factor	Section Length	Suggested Five-Year Threshold Crash Level	Average Crash Costs ($)	Fatalities Per 100 Crashes
Aggressive driving segment education and enforcement	Mid-block aggressive driving	State urban	5-25 (dependent on level of enforcement)	3,000 ft.	8 aggressive driving crashes	99,145.69	1.29
Aggressive driving segment education and enforcement	Mid-block aggressive driving	State rural	5-25 (dependent on level of enforcement)	3,000 ft.	8 aggressive driving crashes	196,770.48	2.95
Aggressive driving segment education and enforcement	Mid-block aggressive driving	Local urban	5-25 (dependent on level of enforcement)	Entire road	8 aggressive driving crashes	73,552.47	0.78
Aggressive driving segment education and enforcement	Mid-block aggressive driving	Local rural	5-25 (dependent on level of enforcement)	Entire road	8 aggressive driving crashes	124,961.98	1.59
Aggressive driving intersection education and enforcement	Intersection aggressive driving	State urban	5-25 (dependent on level of enforcement)	Intersection.	8 aggressive driving crashes	71,168.95	0.71
Aggressive driving intersection education and enforcement	Intersection aggressive driving	State rural	5-25 (dependent on level of enforcement)	Intersection	8 aggressive driving crashes	145,678.08	1.97
Aggressive driving intersection education and enforcement	Intersection aggressive driving	Local urban	5-25 (dependent on level of enforcement)	Intersection	8 aggressive driving crashes	47,025.97	0.30
Aggressive driving intersection education and enforcement	Intersection aggressive driving	Local rural	5-25 (dependent on level of enforcement)	Intersection	8 aggressive driving crashes	48,817.33	0.28
Minor signal safety upgrades	Signalized intersection	State urban	30	Intersection	25 crashes	67,710.01	0.60

Systematic Improvement Type	Crash Type Prevented	Location Criteria	Crash Reduction Factor	Section Length	Suggested Five-Year Threshold Crash Level	Average Crash Costs ($)	Fatalities Per 100 Crashes
Minor signal safety upgrades	Signalized intersection	State rural	30	Intersection	15 crashes	114,097.00	1.27
Minor signal safety upgrades	Signalized intersection	Local urban	30	Intersection	25 crashes	53,271.67	0.33
Minor signal safety upgrades	Signalized intersection	Local rural	30	Intersection	15 crashes	48,084.18	0.34
Lighting	Signalized intersection	State urban	50 of night unlit crashes	Intersection	15 night unlit crashes	97,594.20	1.09
Lighting	Signalized intersection	State rural	50 of night unlit crashes	Intersection	15 night unlit crashes	173,703.42	2.28
Lighting	Signalized intersection	Local urban	50 of night unlit crashes	Intersection	15 night unlit crashes	74,666.67	0.66
Lighting	Signalized intersection	Local rural	50 of night unlit crashes	Intersection	15 night unlit crashes	28,428.57	0.00
Skid surface improvements	Signalized intersection	State urban	50 of wet crashes >=45	Intersection	8 wet pavement crashes >=45 and a wet/total crash ratio >.30	66,783.91	0.65
Skid surface improvements	Signalized intersection	State rural	50 of wet crashes >=45	Intersection	8 wet pavement crashes >=45 and a wet/total crash ratio >.30	76,928.07	0.70
Signing and marking	Stop control intersection	State urban	30	Intersection	5 intersection crashes	81,187.52	0.90
Signing and marking	Stop control intersection	State rural	30	Intersection	5 intersection crashes	166,004.78	2.39

Systematic Improvement Type	Crash Type Prevented	Location Criteria	Crash Reduction Factor	Section Length	Suggested Five-Year Threshold Crash Level	Average Crash Costs ($)	Fatalities Per 100 Crashes
Signing and marking	Stop control intersection	Local urban	30	Intersection	5 intersection crashes	46,216.68	0.26
Signing and marking	Stop control intersection	Local rural	30	Intersection	5 intersection crashes	42,070.80	0.14
Lighting	Stop control intersection	State urban	50 of night unlit crashes	Unlit Intersection	5 night intersection crashes	133,990.10	1.90
Lighting	Stop control intersection	State rural	50 of night unlit crashes	Unlit Intersection	5 night intersection crashes	218,739.85	3.15
Lighting	Stop control intersection	Local urban	50 of night unlit crashes	Unlit Intersection	5 night intersection crashes	67,694.92	0.56
Lighting	Stop control intersection	Local rural	50 of night crashes	Unlit Intersection	5 night intersection crashes	55,938.53	0.47
Skid surface improvements	Stop control intersection	State urban	50 of wet crashes >=45	Intersection	8 wet pavement crashes >=45 and a wet/total crash ratio >.30	109,691.10	1.34
Skid surface improvements	Stop control intersection	State rural	50 of wet crashes >=45	Intersection	8 wet pavement crashes >=45 and a wet/total crash ratio >.30	159,180.13	2.39
Signing and marking improvements	Curve crashes	State urban	30	3,000 ft.	8 or more curve crashes	140,393.64	1.95
Signing and marking improvements	Curve crashes	State rural	30	3,000 ft.	8 or more curve crashes	233,989.67	3.57

Systematic Improvement Type	Crash Type Prevented	Location Criteria	Crash Reduction Factor	Section Length	Suggested Five-Year Threshold Crash Level	Average Crash Costs ($)	Fatalities Per 100 Crashes
Signing and marking improvements	Curve crashes	Local urban	30	Entire road	12 or more curve crashes	83,698.92	0.94
Signing and marking improvements	Curve crashes	Local rural	30	Entire road	12 or more curve crashes	125,351.48	1.56
Tree removal	Tree crashes	State urban	100 of tree crashes	3,000 ft.	5 tree crashes	209,770.74	3.32
Tree removal	Tree crashes	State rural	100 of tree crashes	3,000 ft.	5 tree crashes	305,231.56	4.66
Tree removal	Tree crashes	Local urban	100 of tree crashes	Entire road	5 tree crashes	113,867.29	1.41
Tree removal	Tree crashes	Local rural	100 of tree crashes	Entire road	5 tree crashes	161,055.54	2.21
Tree delineation	Night tree crashes	State urban	10 of night tree crashes	3,000 ft.	4 night tree crashes	253,275.25	4.16
Tree delineation	Night tree crashes	State rural	10 of night tree crashes	3,000 ft.	4 night tree crashes	350,492.97	5.47
Tree delineation	Night tree crashes	Local urban	10 of night tree crashes	Entire road	4 night tree crashes	126,572.24	1.63
Tree delineation	Night tree crashes	Local rural	10 of night tree crashes	Entire road	4 night tree crashes	162,152.86	2.19
Utility pole relocation	Utility pole crashes	State urban	See Table 5-9	3,000 ft.	5 pole crashes	137,235.88	1.80
Utility pole relocation	Utility pole crashes	State rural	See Table 5-9	3,000 ft.	5 pole crashes	187,694.29	2.65
Utility pole relocation	Utility pole crashes	Local urban	See Table 5-9	Entire road	5 pole crashes	74,778.56	0.77

Systematic Improvement Type	Crash Type Prevented	Location Criteria	Crash Reduction Factor	Section Length	Suggested Five-Year Threshold Crash Level	Average Crash Costs ($)	Fatalities Per 100 Crashes
Utility pole relocation	Utility pole crashes	Local rural	See Table 5-9	Entire road	5 pole crashes	90,092.39	0.96
Utility pole delineation	Night utility pole crashes	State urban	10 of night pole crashes	3,000 ft.	4 night pole crashes	163,212.28	2.30
Utility pole delineation	Night utility pole crashes	State rural	10 of night pole crashes	3,000 ft.	4 night pole crashes	215,540.18	3.16
Utility pole delineation	Night utility pole crashes	Local urban	10 of night pole crashes	Entire road	4 night pole crashes	87,345.77	1.03
Utility pole delineation	Night utility pole crashes	Local rural	10 of night pole crashes	Entire road	4 night pole crashes	101,894.03	1.17
Old guide rail upgrade	Strong post cable guide rail crashes	State urban	0, less severity	1,000 ft.	5 strong post cable guide rail crashes	106,550.00	1.25
Old guide rail upgrade	Strong post cable guide rail crashes	State rural	0, less severity	1,000 ft.	5 strong post cable guide rail crashes	105,150.16	1.28
Guide rail delineation	Night strong and weak post W-beam guide rail crashes	State urban	10 of night strong and weak post W-beam guide rail crashes	1,000 ft.	4 night strong and weak post W-beam guide rail crashes	173,821.87	2.95
Guide rail delineation	Night strong and weak post W-beam guide rail crashes	State rural	10 of night strong and weak post W-beam guide rail crashes	1,000 ft.	4 night strong and weak post W-beam guide rail crashes	289,530.93	4.89
Guide rail delineation	Night guide rail crashes	Local urban	10 of night guide rail crashes	Entire road	4 night guide rail crashes	77,361.70	0.91

Systematic Improvement Type	Crash Type Prevented	Location Criteria	Crash Reduction Factor	Section Length	Suggested Five-Year Threshold Crash Level	Average Crash Costs ($)	Fatalities Per 100 Crashes
Guide rail delineation	Night guide rail crashes	Local rural	10 of night guide rail crashes	Entire road	4 night guide rail crashes	40,828.63	0.22
Wider centerline markings	Head on and opposing sideswipe crashes	State urban restricted access	Unknown	15,000 ft.	5 head on and opposing sideswipe crashes	569,245.35	11.34
Wider centerline markings	Head on and opposing sideswipe crashes	State urban open access	Unknown	15,000 ft.	5 head on and opposing sideswipe crashes	153,418.85	2.17
Centerline rumble strips	Head on and opposing sideswipe crashes	State rural restricted access	25 of head on and opposing sideswipe crashes	15,000 ft.	3 head on and opposing sideswipe crashes	721,955.36	14.29
Centerline rumble strips	Head on and opposing sideswipe crashes	State rural open access 22’ or greater	25 of head on and opposing sideswipe crashes	15,000 ft.	3 head on and opposing sideswipe crashes	554,777.60	9.93
Wider centerline markings	Head on and opposing sideswipe crashes	State rural open access 18-20 ft.	Unknown	15,000 ft.	3 head on and opposing sideswipe crashes	374,017.06	6.56
Wider centerline markings	Head on and opposing sideswipe crashes	State urban restricted access undivided	Unknown	15,000 ft.	5 head on and opposing sideswipe crashes	371,384.62	5.77
Centerline rumble strips	Head on and opposing sideswipe crashes	State rural restricted access undivided	25 of head on and opposing sideswipe crashes	15,000 ft.	3 head on and opposing sideswipe crashes	792,146.34	12.20
Wider centerline markings	Head on and opposing sideswipe crashes	State urban open access undivided	Unknown	15,000 ft.	5 head on and opposing sideswipe crashes	161,163.63	2.30

Systematic Improvement Type	Crash Type Prevented	Location Criteria	Crash Reduction Factor	Section Length	Suggested Five-Year Threshold Crash Level	Average Crash Costs ($)	Fatalities Per 100 Crashes
Centerline rumble strips	Head on and opposing sideswipe crashes	State rural open access undivided	25 of head on and opposing sideswipe crashes	15,000 ft.	3 head on and opposing sideswipe crashes	485,146.56	8.60
Centerline rumble strips	Head on and opposing sideswipe crashes	State rural restricted access divided	25 of head on and opposing sideswipe crashes	15,000 ft.	3 head on and opposing sideswipe crashes	706,229.51	14.75
Centerline rumble strips	Head on and opposing sideswipe crashes	State rural open access divided	25 of head on and opposing sideswipe crashes	15,000 ft.	3 head on and opposing sideswipe crashes	342,506.49	6.49
Median barrier/edge rumble strips	Head on and opposing sideswipe crashes	State urban freeways	25 of head on and opposing sideswipe crashes	15,000 ft.	3 head on and opposing sideswipe crashes	569,245.35	11.34
Median barrier/edge rumble strip	Head on and opposing sideswipe crashes	State rural freeways	25 of head on and opposing sideswipe crashes	15,000 ft.	3 head on and opposing sideswipe crashes	721,955.36	14.29
DOT markers	Rear-end non-intersection crashes	State rural with AADT < 18000	Unknown	6,000 ft.	5 non-intersection rear end crashes	97,347.42	1.26
Skid surface improvements	Wet pavement crashes	Rural non-intersection state	50 of wet pavement crashes	3,000 ft.	8 wet pavement crashes and wet/total crash ratio >.30	169,311.69	2.46

Systematic Improvement Type	Crash Type Prevented	Location Criteria	Crash Reduction Factor	Section Length	Suggested Five-Year Threshold Crash Level	Average Crash Costs ($)	Fatalities Per 100 Crashes
Lane widening	Single vehicle run-off-road – narrow pavement	2 lane rural with pavements 18-20 ft.	See Table 5-10	3,000 ft.	20 single vehicle run-off-road crashes with pavement widths 18-20 ft.	159,057.03	2.11
Lane widening or experimental edge pavement markings	Single vehicle run-off-road – narrow pavement	2 lane rural with pavements < 18 ft.	See Table 5-10, 5-11, and 5-12	3,000 ft.	20 single vehicle run-off-road crashes with pavements <18 ft.	146,687.82	1.82
Shoulder widening	Single vehicle run-off-road – narrow shoulder	State rural restricted access with shoulders < 4 ft.	See Table 5-10, 5-11, and 5-12	3,000 ft.	20 single vehicle run-off-road crashes with shoulders <4 ft.	133,759.59	1.92
Shoulder widening	Single vehicle run-off-road – narrow shoulder	State rural open access with shoulders < 4 ft.	See Table 5-10, 5-11, and 5-12	3,000 ft.	20 single vehicle run-off-road crashes with shoulders <4 ft.	162,286.06	2.19
Shoulder rumble strips	Single vehicle run-off-road crashes – paved shoulders available	Rural non Interstate state with 4 ft. or > paved shoulders	20 of run-off-the-road crashes	3,000 ft.	8 single vehicle run-off-road crashes	167,381.52	2.38
Safety belt education and enforcement	Unbelted crashes	State urban	5-25 (dependent on level of enforcement)	3,000 ft.	12 unbelted crashes	211,311.80	3.09
Safety belt education and enforcement	Unbelted crashes	State rural	5-25 (dependent on level of enforcement)	3,000 ft.	12 unbelted crashes	477,509.61	7.92

Systematic Improvement Type	Crash Type Prevented	Location Criteria	Crash Reduction Factor	Section Length	Suggested Five-Year Threshold Crash Level	Average Crash Costs ($)	Fatalities Per 100 Crashes
Safety belt education and enforcement	Unbelted crashes	Local urban	5-25 (dependent on level of enforcement)	Entire road	12 unbelted crashes	114,684.89	1.27
Safety belt education and enforcement	Unbelted crashes	Local rural	5-25 (dependent on level of enforcement)	Entire road	12 unbelted crashes	201,315.99	2.69
Sobriety checkpoints	Alcohol-related crashes	State urban	5-25 (dependent on level of enforcement)	3,000 ft.	5 alcohol-related crashes	265,919.78	4.12
Sobriety checkpoints	Alcohol-related crashes	State rural	5-25 (dependent on level of enforcement)	3,000 ft.	5 alcohol-related crashes	472,193.37	7.69
Sobriety checkpoints	Alcohol-related crashes	Local urban	5-25 (dependent on level of enforcement)	Entire road	5 alcohol-related crashes	128,627.11	1.61
Sobriety checkpoints	Alcohol-related crashes	Local rural	5-25 (dependent on level of enforcement)	Entire road	5 alcohol-related crashes	213,061.94	2.92
Pedestrian mid-block safety-signing and marking	Pedestrian crashes	State urban	10-25 pedestrian crashes	3,000 ft.	4 pedestrian crashes	579,407.47	8.81
Pedestrian mid-block safety-signing and marking	Pedestrian crashes	State rural	10-25 pedestrian crashes	3,000 ft.	4 pedestrian crashes	977,789.92	15.83
Pedestrian mid-block safety-signing and marking	Pedestrian crashes	Local urban	10-25 pedestrian crashes	Entire road	4 pedestrian crashes	149,266.97	1.49

Systematic Improvement Type	Crash Type Prevented	Location Criteria	Crash Reduction Factor	Section Length	Suggested Five-Year Threshold Crash Level	Average Crash Costs ($)	Fatalities Per 100 Crashes
Pedestrian mid-block safety-signing and marking	Pedestrian crashes	Local rural	10-25 pedestrian crashes	Entire road	4 pedestrian crashes	260,445.28	2.83
Pedestrian intersection countdown signals	Pedestrian crashes	State urban	25 pedestrian crashes	Intersection	2 pedestrian crashes	247,448.41	3.30
Pedestrian intersection countdown signals	Pedestrian crashes	Local urban	25 pedestrian crashes	Intersection	2 pedestrian crashes	105,214.48	0.88

Each of the rows in the above table that lists crashes by segment or intersection will generate four tables of information – a statewide summary table, a more specific listing of segments/intersections by targeted crashes, a detailed listing of targeted crashes on segments/ intersections above a defined crash threshold, and a tabulation of other crash types that exceed threshold levels for other crash types within the limits of the segment. Samples of these four tables are shown below.

The statewide segment/intersection summary table provides information on the distribution of targeted crashes among segments/ intersections throughout the State.

Table 5-2: Statewide Segment/Intersection Summary Table

Number of Targeted Crashes Per Segment	Number of Segments	Cumulative Segments	Cumulative % of Segments	Cumulative Targeted Crashes	Cumulative % of Targeted Crashes
Highest	*1*	*1*	*1x100/all segments*	*X crashes*	*X(100)/all targeted crashes*
1		*Sum of all segments*	*100%*	*All targeted crashes*	*100%*

Segment summary tables are prepared for every crash type in the preceding tables that have information provided in the "Cluster Length" column. As an example, for the utility pole targeted crashes, eight segment summary tables would be prepared as follows: urban state, rural state, urban local, rural local, night state urban, night state rural, night urban local, and night rural local.

- For any given table, the segment which had the highest number of targeted crashes statewide would be listed in the first row of Column 1, progressing downward to the segment that had the lowest number of crashes (usually 1).

- The second column indicates the number of segments that had "crashes per segment numbers" equivalent to those indicated in column 1. As an example, if the first row had the highest crash segment of 50 targeted crashes and there was only one segment that had 50 crashes, then the number of segments for this row is one. If there were 75 segments that had 1 crash then the corresponding number of segments in the row that had one crash would be 75.
- If there were 1000 total segments in the listing, then the first row in the cumulative segment column (column 3) would start with 1 and the last row would be 1000.

- The cumulative percentage of segments (column 4) would take the cumulative segment row, multiply by 100 and divide by the total number of segments.
- The cumulative number of crashes (column 5) starts with the number of crashes in the top (highest) row and adds each row to it. As an example, if there were a total of 5000 crashes in all 1000 segments, the first row would be 50 and the last row would be 5000.
- The cumulative percentage of all targeted crashes (column 6) would take the cumulative targeted crash row, multiply by 100 and divide by the total number of targeted crashes.

An example of the value of the statewide summary table is that it can indicate that 60 percent of the targeted crash problem occurs on 4 percent of the segments that had targeted crashes; this amounts to 200 segments. Therefore, if the 200 segments can be treated with low-cost improvements, they can impact 60 percent of the statewide targeted crash problem.

Once the statewide segment/intersection summary table is completed, a threshold level of crashes per segment/intersection can be established and low-cost improvements pursued for locations at or above the threshold level. Further information beyond that provided in the summary table is needed to consider improvements at these segments/intersections.

A tabulation of each of the segments/intersections that exceed the threshold level of crashes is displayed in the following table.

Table 5-3: Candidate Targeted Segment/Intersection Table

Number Of Targeted Crashes	District	County	Municipality	State Route	Beginning Segment	Beginning Offset	Ending Segment	Ending Offset	Functional Class	AADT	% Alcohol-Related	% Unbuckled	% Aggressive Driving

Note that street name rather than State Route would list local roads if the targeted crashes are on local roads. Information on segment and offset would not be included.

Each segment listed in the segment summary table that was above the defined threshold level of targeted crashes per segment/intersection would appear as a row in the candidate targeted segment/intersection table. As an example, if there were 200 segments in the statewide segment/intersection summary table that were at or above a defined threshold level of crashes per segment, there would be 200 segments or rows of information in the candidate target segment/intersection table. Each row would provide information on the number of crashes, the location, and percentage of crashes that involve aggressive driving, alcohol, or unbelted drivers or occupants. This latter piece of information may be useful in determining the type of improvement to deploy. As an example, if rural state trees are the targeted crash type and one of the segments identified had 15 tree crashes, of which 80 percent involved alcohol, a targeted DUI enforcement strategy may be appropriate to consider in addition to tree removal.

For each of the segments displayed in the candidate detailed segment/intersection table, additional information pertaining to each targeted crash that occurred within the segment/intersection may be beneficial in determining if the low-cost improvement is appropriate to implement. A detailed segment/intersection table is prepared for each of the segments/intersections above the threshold level. As an example, if rural state trees are the targeted crashes and one of the segments above the threshold had 15 tree crashes, then a table listing the 15 tree crashes would be provided for the segment using the "Detailed Segment/Intersection Targeted Crash Table" format.

Table 5-4: Detailed Segment/Intersection Targeted Crash Table

District	County	Municipality	SR	Segment Number	Offset	Crash Report No.	Crash Type	Light	Weather	FHE	Alcohol-Related	Unbelted	Aggressive Driving	Causation Factor

Segments that appear on the Candidate Targeted Segment/Intersection Table for a given crash type may also appear in other types of crash types where other low-cost improvements are appropriate to consider. As an example, the segment on the rural state tree listing with 15 tree crashes may also appear on the curve listing and on the narrow shoulder listing. It is beneficial that the Highway Safety Engineer has knowledge of these collective safety problems at the time a determination is made to implement a series of low-cost

improvements. As such, for each candidate targeted segment/intersection table generated for the various crash type/improvements, a matrix will also be developed listing each segment/intersection that is above the established threshold crash level on the vertical scale and the remaining crash improvement types on the horizontal scale. Other crash types that have segments with sufficient crashes to equal or exceed threshold levels for other crash types will be highlighted in the matrix. As an example, if a segment in the rural state tree category had 15 tree crashes and exceeded the threshold, it would be listed as a row line item. If that same segment was within the limits of the curve, and narrow shoulder crash types and exceeded those respective thresholds, it would receive a check mark in the curve and narrow shoulder cells.

Table 5-5: Candidate Segment/Intersections Above Established Crash Threshold with Other Crash Types in Their Limits

Designated High Crash Category County	Route	Segment	Begin Offset	Aggressive Driving – Segments	Aggressive Driving – Intersections	Signalized Intersections	Stop Controlled Intersections.	Curves	Trees	Utility Poles	Guide Rails	Head-On And Opposing Sideswipe – 2 Lane	Head-On And Opposing Sideswipe – 4 Lane	Rear End	Wet Pavement	Run-Off-Road – Narrow Pavements	Run-Off-Road – Narrow Shoulders	Run-Off-Road – Paved Shoulders Available	Unbelted Crashes	Alcohol-Related Crashes	Pedestrians

Systematic deployment of low-cost improvements for the highway safety improvement program are based upon selecting, studying, and identifying appropriate improvements that will assist the District with meeting its crash reduction goal. The District Safety Engineer is the focal point within the District for conducting the low-cost systematic safety program. The model process for selecting, studying, and defining appropriate improvements to reduce the potential for future fatalities using the systematic process is as follows:

1. Review the cluster reports for all crash types within the District and select those cluster crash types that have the highest potential to save lives. Clusters that have combinations of high fatalities per 100 crashes, higher crash reduction factors for improvement types, crash types which have substantial numbers of high crash clusters, and improvement types which are relatively low in cost and easy to implement are the better sets of clusters to pursue.
2. Once an initial set of cluster crash types is established, the District Safety Engineer should meet with Maintenance personnel to determine if the improvement type associated with each crash type selected is better implemented by maintenance forces or contract. If by contract, consider a county-wide or District-wide contract for the improvement at numerous locations on the cluster lists.
3. Evaluate each candidate location on the cluster list to determine if the improvement type is appropriate to implement. At a minimum, this should include a review of the site using the photo log system and, desirably, a field review of the site. For many improvement types, input from other PennDOT personnel (e.g., District utility personnel for pole relocations, District right of way and maintenance personnel for tree removal, and District Traffic Engineer for sign, marking, and signal upgrades) will be needed before an improvement can be finalized.
4. In conjunction with the Planning and Program manager and Maintenance personnel, determine the best method or combination of methods (low-cost safety improvement program using maintenance funds and Highway Safety Improvement program funded through the 12-year program process) to fund and implement the improvements.
    a) Systematic deployment of proven low-cost safety improvements under Section 148 (HSIP) funding is permitted in the four safety focus areas as shown in Table 5-6. Section 148 HSIP funds may be used by county maintenance forces to deploy these low cost countermeasures. Regulation 23 CFR Part 635 Subpart B - Force Account Construction details the proper procedures to follow.

Table 5-6: Systematic Implementation of Proven Low Cost Countermeasures under Section 148 (HSIP)

Safety Focus Area	Countermeasures	Effectiveness	Guidance/Information
Head-On	Centerline Rumble Strips	Evaluation of Effectiveness of LCSIP Program: P:\bhste_shared\highway-safety\District_Safety_Planning\Highway Safety Improvement Tool Box\Evaluation of the Effectiveness of LCSIP (FINAL REPORT).pdf	Pub. 638 Chap. 5.4.12 (pg. 5-89)
Run-Off The Road	Edge-Line/Shoulder Rumble Strips	Desk Top Reference for Crash Reduction Factors: P:\bhste_shared\highway-safety\District_Safety_Planning\Highway Safety Improvement Tool Box\Desktop Reference for Crash Reduction Factors.pdf	Pub. 638 Chap. 5.4.15 (pg. 5-110)
Intersection	Sign and Marking Improvements at Stop-Controlled Intersections	District Guidance for Intersection Safety Implementation Plan (ISIP): Table 2 - Summary of ISIP's Most Effective Countermeasures by Category located at: P:\bhste_shared\highway-safety\District_Safety_Planning\Intersection Safety Implementation Plan (2010)\DISTRICT Intersection Safety Implementation Plan.docx	District Guidance for ISIP was developed from the PA ISIP located at: P:\bhste_shared\highway-safety\District_Safety_Planning\Intersection Safety Implementation Plan (2010)\PA Intersection Safety Implementation Plan (FHWA).pdf
	Signal and Sign Improvements at Signalized Intersections		
Curve-Related (It is encouraged to incorporate as many of the following countermeasures as possible to reduce curve related crashes/fatalities)	Delineate, chevron, RPM's (raised pavement markers)	Desk Top Reference for Crash Reduction Factors: P:\bhste_shared\highway-safety\District_Safety_Planning\Highway Safety Improvement Tool Box\Desktop Reference for Crash Reduction Factors.pdf	Low Cost Treatments for Horizontal Curve Safety: P:\bhste_shared\highway-safety\District_Safety_Planning\Highway Safety Improvement Tool Box\Curve Related Crashes\Research Documents\Low Cost Treatments for Horizontal Curves.pdf
	Advanced Curve Warning Signage		
	Pavement Curve Markings		
	Remove objects outside curve		
	Centerline/Shoulder rumble strips		
	Pave shoulders: outside & inside (in conjunction with edge-line and shoulder rumble strips)		
	Super elevation: add or correct		
	Any other low cost safety countermeasure that would mitigate the crash causation factor can be addressed		

5.3.6 Road Safety Assessments

To provide a comprehensive approach to identifying and mitigating safety concerns in existing transportation infrastructure, PennDOT has adopted the use of road safety assessments (RSA) into the project development process. Road safety assessments are different from the traditional safety review process in that they employ the use of independent, multi-disciplinary teams and consider not only motorized traffic, but all potential road users as well as road user capabilities and limitations (human factors) as they might relate to the built environment. Through this approach, assessment teams are able to identify safety concerns that would not otherwise been discovered as part of a standard safety review. More information on conducting Road Safety Assessments for PennDOT projects can be found in Publication10X, Appendix O, *Road Safety Assessment Procedures*.

Road SafetyAssessment training will be provided on an ongoing basis. Additional guidance on performing road safety assessments, including guidelines, may be found at the following website: http://safety.fhwa.dot.gov/rsa/. In addition the FHWA offers free peer to peer assistance in performing safety audits. That assistance may also be requested through the same FHWA website.

Each District should have staff experienced in conducting Road Safety Assessments in place. The team should be multidiscipline, consisting of members with design, traffic, safety, law enforcement, and emergency response backgrounds. Additional personnel or expertise may be added as needed on specific projects. The District Traffic Engineer should designate the team leader.

RSAs can be conducted at any stage(s) of a project, from the preliminary planning stage to operation of an existing facility. RSAs performed early in the planning and design stages of a project can be most effective in identifying road safety issues before they are “built into” the project, when fundamental changes to the design are still feasible.

The following criteria are suggested to conduct safety assessments:

- Typical project types for RSAs include 3R Safety and Mobility, bridge, and major construction projects. However, if there are safety concerns a project manager may request a RSA for any project.

- RSAs should be performed early enough in the preliminary design/construction process that changes resulting from the assessment may be incorporated into the project with minimal or no delay in project development.

- Written assessment findings should be prepared. They should define safety concerns that need to be addressed, and may suggest solutions.

- Audit findings should be presented to the following for review and response:

- ADE-Design for projects in the project development phase.
- ADE-Maintenance for betterment projects.
- ADE-Construction for projects in the construction phase.

The District ADE will determine an appropriate course of action to address the safety concerns identified.

The District should set goals for conducting RSAs on select projects.

Districts are encouraged to share the RSA checklists that are found on the FHWA safety audit website with Design and Construction Managers to use in their daily jobs to uncover and address safety concerns in the design and construction phases.

5.4 Methods to Identify Cost-Effective Improvements

All corridor, high-crash, and systematic deployments of low-cost improvement projects need to be evaluated in terms of their cost effectiveness

The following formula can be used to estimate the cost effectiveness of potential safety projects:

$$B/C = \frac{Ann\#Crashes \times AveCrashCost \times CRF}{AnnCost}$$

Where:

- B/C = Benefit to cost ratio used to determine if the project is cost effective. Usually a value above 1.0, and desirably above 2.0, is considered cost-effective.
- Ann#Crashes = Annual number of crashes = Number of targeted crashes at a given location over the past 5 years divided by five.
- AveCrashCost = Average cost of the crash type the countermeasure is targeted to reduce.
- CRF = Crash reduction factor or expected percentage of crashes reduced as a result of implementing a specific improvement type.
- AnnCost = Annual cost of the improvement. For construction improvements, annual cost is the construction cost annualized over the expected life of the improvement. For an education or enforcement improvement, annual cost is the annual cost of a full year of enforcement or education. Added maintenance costs for the countermeasure are also included if they are significant in relation to the annual construction costs.

In addition to determining if a countermeasure application is cost effective, the estimated impact of the countermeasure to reduce fatalities is also needed. The following formula can be used to estimate the annual number of fatalities that a project is expected to reduce:

$$EFR = Ann\#CrashesReduced \times \frac{Fatalities}{100Crashes}$$

Where:

- EFR = Estimated fatality reduction.
- Ann#CrashesReduced = Annual number of targeted crashes multiplied by CRF.
- Fatalities per 100 Targeted Crashes = Average number of fatalities per 100 similar crashes. This value can be found in Table 5-1 for each type of crash and location.
- CRF = Crash Reduction Factor = Expected percentage of crashes reduced as a result of implementing a specific improvement type.

It is also important to estimate the annual estimated fatality reduction of all safety improvements implemented over the previous calendar year within the District. As part of the District Safety Plan transmitted to HSTOD of each year, an estimate of the number of annual lives saved should be developed based upon the number of safety projects completed during the previous calendar year and the above formula.

5.5 Major Crash Types and Safety Countermeasures

The remainder of this chapter provides information on relationships among Strategic Highway Safety Plan safety focus area crash types and appropriate countermeasures as well as countermeasure application information for the following crash types:

Aggressive Driving

- Aggressive driving – segments.
- Aggressive driving – intersections.

Safety Infrastructure Improvements

- Signalized intersections.
- Stop controlled intersections.
- Curves.
- Trees.
- Utility poles.
- Guide rails.
- Head-on and opposing sideswipe.
- Rear end.
- Wet pavement.
- Run-off-road – narrow pavements, narrow shoulders, and paved shoulders available.

Increasing Seatbelt Usage

- Unbelted crashes.

Reducing Impaired (DUI) Driving

- Alcohol-related crashes.

Mature Driver Safety

Motorcycle Safety

Improving Pedestrian Safety

- Pedestrians.

Statewide data on these crash types can be found in Appendix E.

5.5.1 Aggressive Driving – Segments

Aggressive driving has been separated into two distinct categories – aggressive driving between intersections and aggressive driving at intersections. The separation has been made because the principal countermeasures, education and visible enforcement, require different methods of enforcement. The major driver causation factors associated with aggressive driver segment crashes are:

- Tailgating.
- Passing in a no passing zone.
- Driving on the wrong side of roadway.
- Careless passing or lane change.
- Speeding.
- Driving too fast for conditions.

Countermeasure #1 – Enforcement and Education on a Municipality-Wide Basis

Description
The strategy for this countermeasure is highly publicized and highly visible enforcement concentrating on:

- The more prevalent types of aggressive driving.
- The times when aggressive driving is more likely to occur.
- The locations which have the highest frequencies of aggressive driving crashes.

Highway sections within the municipality which also appear on the highway section aggressive driving segment list should be given priority enforcement attention.

Times and aggressive driving type emphasis areas need to be adjusted to reflect individual conditions within the municipality.

Candidate Municipalities
The recommended candidate municipality crash thresholds for enforcement and education on a municipality-wide basis are:

- Urban municipalities that have 150 or more aggressive driving segment crashes in 5 years.
- Rural municipalities that have 100 or more aggressive driving segment crashes in 5 years.

Municipalities that meet these thresholds and also have higher proportions of total crashes that are aggressive driving segment crashes, higher aggressive driver segment crashes per 1,000 residents, or higher aggressive driver segment crashes per one million VMT should be given consideration for area-wide enforcement and education.

Resources

Resources that can be used to develop effective enforcement and education programs can be found in the Model Work Plan for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths in Appendix D of this manual, the National Highway Traffic Safety Administration's (NHTSA) *Guide for Selective Traffic Enforcement Programs* (http://www.nhtsa.gov/people/injury/research/ACHIEVE.pdf), NCHRP Report 500, Volume 1: *A Guide for Addressing Aggressive-Driving Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v1.pdf), and *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices* (http://www.nhtsa.gov/people/injury/airbags/Countermeasures/images/Countermeasures.pdf).

Coordination with Other Enforcement and Education Initiatives

Often, municipalities have multiple crash concerns involving aggressive driving, unbelted driver and occupant injuries, and alcohol-related crashes. When more than one of these concerns occurs within a municipality, a coordinated approach is desirable so that the enforcement and education initiative targets all concerns. This requires reviewing the times and locations where individual crash concerns are concentrated and integrating them into an overall approach.

Effectiveness

A high-quality, coordinated enforcement and education initiative resulting in widespread knowledge among residents and drivers that aggressive driving will be detected and drivers will be penalized is expected to reduce aggressive driving segment crashes of all types by 25 percent during the time frame when the initiative is underway.

Countermeasure #2 – Enforcement and Education on a Highway Section Basis

Description

Highly publicized and highly visible enforcement should concentrate on the more prevalent types of aggressive driving and the times when they are more likely to occur. The municipal tables in the previous section may be used to identify statewide characteristics. Times and aggressive driving type emphasis areas need to be adjusted to reflect individual conditions within the section.

Targeted enforcement signs may also be considered if the criteria and requirements for these signs (found within Model Work Plan for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths in Appendix D of this manual) are met.

Candidate Highway Sections

The recommended candidate highway section crash thresholds for enforcement and education on a highway section basis are:

- Urban or rural State highway 3,000 feet sections that have eight or more aggressive driving segment crashes in 5 years.
- Urban or rural local highways that have eight or more aggressive driving segment crashes in 5 years.

In addition, since the length of local roads is not within the databases, the local road length needs to be identified and the aggressive driving segment crash density determined and should be at least three aggressive driving crashes per 1,000 feet.

Highway sections that have the highest numbers of aggressive driving crashes on the State system and those local roads that have combinations of the highest numbers of aggressive driving segment crashes and densities should be given high priority. In addition, those sections that have high numbers of aggressive driving crashes on the State system may be further prioritized based upon the AADT of the section.

Resources

Resources that can be used to develop effective enforcement and education programs can be found in the Model Work Plan for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths in Appendix D of this manual, the NHTSA *Guide for Selective Traffic Enforcement Programs* (http://www.nhtsa.gov/people/injury/research/ACHIEVE.pdf), NCHRP Report 500, Volume 1: *A Guide for Addressing Aggressive-Driving Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v1.pdf), and *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices* (http://www.nhtsa.gov/publications/HS810710/index.htm).

Coordination with Other Enforcement and Education Initiatives

Often, highway sections will have multiple crash concerns involving aggressive driving, unbelted driver and occupant injuries, and alcohol-related crashes. When more than one of these concerns occurs within a section, a coordinated approach is desirable so that the enforcement and education initiative targets all concerns. This requires reviewing the times and locations where individual crash concerns are concentrated and integrating them into an overall approach.

Effectiveness

A high-quality, coordinated enforcement and education initiative resulting in widespread knowledge among drivers that aggressive driving will be detected and drivers will be penalized is expected to reduce aggressive driving segment crashes of all types by 25 percent during the time frame when the initiative is underway.

Countermeasure #3 – Traffic Calming on Urban Collector and Local Roads

Description

PennDOT's Traffic Calming Handbook identifies traffic calming strategies that reduce speeding and other types of aggressive driving and guidance for their application. Potential traffic calming devices include:

- Bulb out/curb extension.
- Chicane.
- On street parking.
- Raised median island/pedestrian refuge.

- Traffic circle.
- Speed hump.
- Raised crosswalk.
- Raised intersection.
- Speed limit signing.
- Multi-way stop control.
- Commercial vehicle prohibition.
- Roadway narrowing through edge lines.
- Transverse pavement markings.

Candidate Highway Sections

The recommended candidate highway section crash thresholds for traffic calming on urban collector and local roads are:

- Urban State highway 3,000 feet collector or local road classified State road sections that have eight or more aggressive driving segment crashes in 5 years.
- Urban collector or local classified local road highways that have eight or more aggressive driving segment crashes in 5 years.

In addition, since the length of local roads is not within the databases, the local road length needs to be identified and the aggressive driving segment crash density determined and should be at least three crashes per 1,000 feet.

Highway sections that have the highest numbers of aggressive driving crashes on the State system and those local roads that have combinations of the highest numbers of aggressive driving segment crashes and densities should be given high priority. In addition, those sections that have high numbers of aggressive driving crashes on the State system may be further prioritized based upon the AADT of the section.

Resources
Guidance on each of the traffic calming devices can be found in the PennDOT Traffic Calming Handbook. Studies and the approval process for traffic calming devices must follow the provisions within the handbook.

Coordination with Other Enforcement and Education Initiatives
Traffic calming measures that use traffic control devices such as speed limit signing, multi-way stop traffic control, commercial vehicle prohibition, roadway narrowing through edge lines, and transverse pavement markings should be coordinated with local police for enforcement to ensure the effectiveness of the measure.

Effectiveness
The effectiveness of traffic calming devices to reduce aggressive driving crashes is not known. Information on effectiveness as it relates to reducing speed and other traffic flow factors may be found in the Traffic Calming Handbook.

5.5.2 Aggressive Driving – Intersections

Aggressive driving has been separated into two distinct categories – aggressive driving between intersections and aggressive driving at intersections. The separation has been made because the principal countermeasures, education and visible enforcement, require different methods to enforce. The major driver causation factors associated with aggressive driver intersection crashes are:

- Tailgating.
- Making an illegal U-turn.
- Making an improper or careless turn.
- Proceeding without clearance after a stop.
- Running a stop sign.
- Running a red light.
- Failure to respond to a traffic control device (TCD).
- Making an improper entrance to highway.
- Speeding.
- Driving too fast for conditions.

Countermeasure #1 – Enforcement and Education on a Municipality-Wide Basis

Description
The strategy for this countermeasure is highly publicized and highly visible enforcement concentrating on:

- The more prevalent types of aggressive driving.
- The times when they are more likely to occur.
- The locations which have the highest frequencies of aggressive driving crashes.

Highway sections within the municipality which also appear on the highway intersection aggressive driving intersection list should be given priority enforcement attention.

Times and aggressive driving type emphasis areas need to be adjusted to reflect individual conditions within the municipality.

Candidate Municipalities

The recommended candidate municipality crash threshold for enforcement and education on a municipality-wide basis is:

- Urban municipalities that have 150 or more aggressive driving intersection crashes in 5 years.
- Rural municipalities that have 100 or more aggressive driving intersection crashes in 5 years.

Municipalities that meet these thresholds and also have higher proportions of total crashes that are aggressive driving intersection crashes, higher aggressive driver intersection crashes per 1,000 residents, or higher aggressive driver intersection crashes per 1 million VMT should be given consideration for area-wide enforcement and education.

Resources

Resources that can be used to develop effective enforcement and education programs can be found in the Model Work Plan for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths in Appendix D of this manual, the NHTSA *Guide for Selective Traffic Enforcement Programs* (http://www.nhtsa.gov/people/injury/research/ACHIEVE.pdf), NCHRP Report 500, Volume 1: *A Guide for Addressing Aggressive-Driving Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v1.pdf), and *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices* (http://www.nhtsa.gov/publications/HS810710/index.htm).

Coordination with Other Enforcement and Education Initiatives

Often, municipalities have multiple crash concerns involving aggressive driving, unbelted driver and occupant injuries, and alcohol-related crashes. When more than one of these concerns occurs within a municipality, a coordinated approach is desirable so that the enforcement and education initiative targets all concerns. This requires reviewing the times and locations where individual crash concerns are concentrated and integrating them into an overall approach.

Effectiveness

A high-quality, coordinated enforcement and education initiative resulting in widespread knowledge among residents and drivers that aggressive driving will be detected and drivers will be penalized is expected to reduce aggressive driving intersection crashes of all types by 25 percent during the time frame when the initiative is underway.

Countermeasure #2 – Enforcement and Education on a Highway Intersection Basis

Description

Highly publicized and highly visible enforcement should concentrate on the more prevalent types of aggressive driving and the times when they are more likely to occur. The municipal tables in the previous section may be used to identify statewide characteristics. Times and aggressive driving type emphasis areas need to be adjusted to reflect individual conditions within the intersection.

Candidate Highway Intersections

The recommended candidate highway intersection crash thresholds for enforcement and education on a highway intersection basis are:

- Urban or rural State highway intersections that have eight or more aggressive driving intersection crashes in 5 years.
- Urban or rural local intersections that have eight or more aggressive driving intersection crashes in 5 years.

Highway intersections that have the highest numbers of aggressive driving crashes on the State system and those local roads that have the highest numbers of aggressive driving intersection crashes should be given high priority. In addition, those sections that have high numbers of aggressive driving crashes on the State system may be further prioritized based upon the through traffic-way AADT of the intersection.

Resources

Resources that can be used to develop effective enforcement and education programs can be found in the Model Work Plan for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths in Appendix D of this manual and the NHTSA *Guide for Selective Traffic Enforcement Programs* (http://www.nhtsa.gov/people/injury/research/ACHIEVE.pdf) and *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices* (http://www.nhtsa.gov/publications/HS810710/index.htm).

Coordination with Other Enforcement and Education Initiatives

Often, highway intersections will have multiple crash concerns involving aggressive driving, unbelted driver and occupant injuries, and alcohol-related crashes. When more than one of these concerns occurs within an intersection, a coordinated approach is desirable so that the enforcement and education initiative targets all concerns. This requires reviewing the times and locations where individual crash concerns are concentrated and integrating them into an overall approach.

Effectiveness

A high–quality, coordinated enforcement and education initiative resulting in widespread knowledge among drivers that aggressive driving will be detected and drivers will be penalized is expected to reduce aggressive driving intersection crashes of all types by 25 percent during the time frame when the initiative is underway.

Countermeasure #3 – Traffic Calming on Urban Collector and Local Roads

Description

PennDOT's Traffic Calming Handbook identifies traffic calming strategies that reduce speeding and other types of aggressive driving and guidance for their application. Potential traffic calming devices include:

- Bulb out/curb extension.
- Raised median island/pedestrian refuge.
- Traffic circle.
- Raised crosswalk.
- Raised intersection.
- Speed limit signing.
- Multi-way stop control.
- Commercial vehicle prohibition.

Candidate Highway Intersections

The recommended candidate highway intersections crash thresholds for traffic calming on urban collector and local roads are:

- Urban State highway 3,000 feet collector or local road classified State road intersections that have eight or more aggressive driving intersection crashes in 5 years.
- Urban collector or local classified local road highways that have eight or more aggressive driving intersection crashes in 5 years.

Highway intersections that have the highest numbers of aggressive driving crashes on the State and local system should be given high priority. In addition, those intersections that have high numbers of aggressive driving crashes on the State system may be further prioritized based upon the AADT of the intersection.

Resources
Guidance on each of the traffic calming devices can be found in PennDOT's Traffic Calming Handbook. Studies and the approval process for traffic calming devices must follow the provisions within the handbook.

Coordination with Other Enforcement and Education Initiatives
Traffic calming measures that use traffic control devices such as speed limit signing and multi-way stop traffic control should be coordinated with local police for enforcement to ensure the effectiveness of the measure.

Effectiveness
The effectiveness of traffic calming devices to reduce aggressive driving crashes is not known. Information on effectiveness as it relates to reducing speed and other traffic flow factors may be found in the Traffic Calming Handbook.

5.5.3 Signalized Intersection Crashes

Signalized intersection crashes, injuries, and fatalities have frequencies and characteristics associated with the type of area (urban/rural), and time (day or night) of occurrence. The primary countermeasures to reduce the level of signalized intersection crashes are infrastructure improvements. Two secondary education and enforcement countermeasures to reduce intersection crashes involve targeted aggressive driving behavior (primarily red light running) and automated red light enforcement.

Countermeasure #1 – Minor Traffic Signal Upgrades

Description
These improvements consist of the following minor traffic signal enhancements:

- Twelve-inch LED lenses on all signal heads.
- Back-plates on all signal heads.
- A minimum of one traffic signal head per approach lane.
- Traffic signal phase timing in accordance with the Institute of Transportation Engineers (ITE) timing standards, including an all red phase.
- Advanced left and right signal ahead warning signs similar to the advanced warning signs for stop control intersections for isolated traffic signals.
- Elimination of any late night flashing operations.
- Reflectorized Backplates where nighttime crashes are prevalent.

In the event that the mainline intersection entry speeds are excessive or that sight distance is inadequate and cannot be readily corrected, peripheral transverse strips may be considered on the mainline approaches to the intersection. The strips, appearing on both sides of the approach lane, are 8 inches in width and 12 inches deep. The design spacing for the strips can be determined using the following parameters:

- Initial approach speed.
- Desired intersection entrance speed.
- Targeted deceleration rate (3 to 6 ft/sec^2).
- Uniform bar spacing of four bars per second.

Candidate Signalized Intersections

The recommended candidate signalized intersection crash thresholds for minor signal enhancements are:

- Urban signalized intersections that have 25 or more angle crashes in 5 years.
- Rural signalized intersections that have 15 or more angle crashes in 5 years.

Intersections that meet these thresholds need to be field reviewed to determine the following:

- Existing traffic signal shortfalls compared to proposed improvements.
- Existence of sight distance limitations on any of the approaches and a determination of whether the limitation can be readily addressed. (If so, it should be considered as part of or about at the same time as the signal upgrades are implemented.)
- Existence of high intersection entry speeds on the mainline.

In addition, a review of the physical characteristics of the intersection and the crash data is needed to determine if other crash patterns exist and need to be addressed.

Signalized intersections that have an extraordinary frequency of severe crashes may be further improved with reduced crash potential by upgrading the appropriate physical characteristics of the intersections, with particular emphasis given to the conversion of the intersection to a roundabout.

Resources

Resources that can be used to identify appropriate countermeasures for signalized intersections can be found at the FHWA intersection safety website (http://safety.fhwa.dot.gov/intersection/) and NCHRP Report 500 Volume 12, *A Guide for Reducing Collisions at Signalized Intersections* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v12.pdf).

Coordination with Other Signalized Intersection Improvements

In addition to minor signal upgrades, oftentimes signalized intersections with high numbers of angle crashes also have multiple crash concerns involving running red lights, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns occurs at a signalized intersection, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur at the intersection, and integrating improvements into an overall approach.

Effectiveness

The research findings on effectiveness of signal upgrade enhancements are limited and confined to individual components such as increased lens size, retiming, and upgraded warning signs. No research has been found that collectively evaluates the overall impact of a set of signal upgrade improvements. However, based upon the research findings that are available, it is estimated that implementation of the overall set of signal upgrades at an "average" intersection can reduce angle crashes by 25 percent.

Countermeasure #2 – Left Turn Lanes and Left Turn Phases at Signalized Intersections

Description

This improvement consists of placement of left turn lanes and/or left turn signal phases on the approach to a high-speed intersection that has a high frequency and proportion of crashes involving left turn vehicles either with opposing through vehicles (angle or head-on crashes) or following through vehicles (rear-end crashes). It may also include modification to the traffic signal to add an exclusive left turn phase.

Candidate Signalized intersections

The recommended candidate signalized intersection crash threshold for left turn lanes is:

- Rural or urban signalized intersections that have speed limits greater than 35 MPH , and 30 or more crashes involving a mainline left turning vehicle (15 or more of which are angle or head on crashes with opposing through vehicles).

Intersections that meet this crash threshold need to be field reviewed to determine the following:

- Existence of left turn lanes or left turn signal phases at the intersection.
- Existence of sight distance limitations on any of the through approaches of the intersection that can increase the potential for through vehicle collisions.
- Existence of high intersection entry speeds on the mainline.
- An assessment of whether a roundabout is feasible to consider at the intersection in lieu of left turn lanes. Roundabouts have a superior CRF.

In addition, a review of the physical characteristics of the intersection and the crash data is needed to determine if other crash concerns, even with the upgraded left turn lanes, may be a concern. If so, these concerns should be considered in the overall development of safety improvements for the intersection.

Resources

Resources that can be used to identify crash mitigation techniques for left turn lanes and left turn phases at signalized intersections can be found at the FHWA intersection safety website (http://safety.fhwa.dot.gov/intersection/) and NCHRP Report 500 Volume 5, *A Guide for Addressing Unsignalized Intersection Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v5.pdf). Information on the design

requirements and process for developing design plans for left turn lanes and left turn phases may be found in the PennDOT Design Manual.

Coordination with Other Signalized Intersection Improvements

In addition to the installation of left turn lanes and/or exclusive left turn phases, oftentimes signalized intersections with high numbers of crashes also have multiple crash concerns involving aggressive driving, crashes at night, wet pavement crashes, or higher frequencies of angle crashes. When one or more of these additional concerns occurs at a signalized intersection, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur at the intersection, and integrating improvements into an overall approach.

Effectiveness

The evaluation of incorporating left turn lanes at intersections indicates a CRF between 40 and 50 percent for left turn crashes. The addition of an exclusive left turn phase to an added left turn lane is estimated to reduce left turn crashes by 58 percent based upon one research report. Roundabouts are projected to reduce all intersection crashes at average intersections by 90 percent.

Countermeasure #3 – Lighting at Unlit Signalized Intersections

Description

These improvements consist of lighting at unlit signalized intersections. Lighting should be designed in accordance with the procedures defined in the Design Manual Part 1A, Chapter 6, Section 6.4 M. Lighting improvements are eligible under the highway safety improvement program; however, the municipality in which the intersection resides must agree to operate, energize, and maintain the lighting once it is in place.

Candidate Signalized intersections

The recommended candidate signalized intersection crash threshold for lighting improvements is:

- Urban or rural signalized intersections that have 15 or more unlit night crashes in 5 years.

Intersections that that meet this threshold need to be field reviewed to determine the following:

- Existence of lighting at the intersections. If lighting exists, lighting improvements should not be considered.

Before moving beyond the programming stage of project development, PennDOT should obtain a commitment to operate, energize, and maintain proposed lighting for unlit candidate intersections from the municipality.

Resources

Resources that can be used to identify areas in need of improved lighting and information on improving lighting at signalized intersections can be found at the FHWA intersection safety website (http://safety.fhwa.dot.gov/intersection/) and NCHRP Report 500 Volume 5, *A Guide for Addressing Unsignalized Intersection Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v5.pdf). Information on the design requirements and process for developing design plans for intersection lighting systems may be found in the PennDOT Design Manual.

Coordination with Other Signalized Intersection Improvements

In addition to the installation of lighting enhancements, oftentimes signalized intersections with high numbers of crashes also have multiple crash concerns involving aggressive driving, slippery approaches, or higher frequencies of angle crashes. When one or more of these additional concerns occurs at a signalized intersection, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur at the intersection, and integrating improvements into an overall approach.

Effectiveness

The evaluation of lighting improvements at unlit intersections indicates a CRF of 40 percent for night crashes.

Countermeasure #4 – Skid-Resistant Overlay at Signalized Intersections

Description

This improvement consists of placement of a skid-resistant surface on the approach to a high-speed intersection that has a high frequency and proportion of wet pavement crashes. In addition, any severe rutting in the wheel paths is also addressed to reduce the potential for hydroplaning. The length of the improvement is dependent on the approach speeds and the probable locations for queue ends of stopped traffic. In general, the length should not be less than 800 feet.

Candidate Signalized Intersections

The recommended candidate signalized intersection crash threshold for skid-resistant surface improvements is:

- Rural or urban signalized intersections that have speed limits greater than 35 mph, eight or more wet pavement crashes in 5 years, and a wet/total crash ratio of at least 0.30.

Those intersections that meet this crash threshold and have mainline approach skid numbers of 30 (for rib tire tests) or 20 (for smooth tire tests) or less need to be field reviewed to determine the following:

- Existence of sight distance limitations on any of the approaches or significant downgrades into the intersection that can increase the need for a skid-resistant surface.
- Existence of high intersection entry speeds on the mainline.

- Existence of significant wheel path rutting that may increase the potential for hydroplaning and increased stopping distances.

In addition, a review of the physical characteristics of the intersection and the crash data is needed to determine if other crash concerns, even with the upgraded skid-resistant surface may be an issue. If so, these concerns should be considered in the overall development of safety improvements for the intersection.

If it is determined that a skid-resistant surface is needed but that it may not be possible to implement in the near future, the use of transverse peripheral pavement markings may be considered as an interim measure to reduce high end-approach speeds and lessen the need for a higher friction surface.

Resources

Resources useful for identifying candidate signalized intersections locations where surface friction improvements should be implemented can be found on the FHWA intersection safety website (http://safety.fhwa.dot.gov/intersection/) and NCHRP Report 500 Volume 5, *A Guide for Addressing Unsignalized Intersection Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v5.pdf).

Coordination with Other Signalized Intersection Improvements

In addition to the installation of skid-resistant surfaces, oftentimes signalized intersections with high numbers of crashes also have multiple crash concerns involving aggressive driving, crashes at night, or higher frequencies of angle crashes. When one or more of these additional concerns occurs at a signalized intersection, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur at the intersection, and integrating improvements into an overall approach.

Effectiveness

The evaluation of applying skid-resistant surfaces to intersection signalized approaches indicates a CRF of 50 percent for wet pavement crashes.

Countermeasure #5 – Dilemma Zone Detection Control Systems

Description

These systems utilize sets of detectors to predict when a vehicle will be in the dilemma zone. As the green phase approaches its end, the detection control sensors identify vehicles by their position, speed, and acceleration characteristics. Taking the signal's timing into account, the system performs automated calculations to determine if the vehicle will be in the dilemma zone as the signal would normally change to red. When such vehicles are identified, logic can be incorporated into the signal controller to extend the length of the green phase to accommodate those vehicles predicted to be in the dilemma zone, thereby avoiding a conflict with crossing traffic or following traffic (e.g., rear-end crash).

The system has been demonstrated at eight intersections in Texas. Evaluations have shown significant reductions in red light violation and crash frequencies. In addition, a lower cost alternative using advanced radar detection systems instead of pavement sensors has also been developed.

Candidate Signalized Intersections

The recommended candidate signalized intersection threshold for detection control systems is:

- Isolated rural signalized intersections with high-speed approaches (i.e., speed limits greater than 40 mph) that have 15 or more angle crashes in 5 years.

Intersections that meet these thresholds need to be field reviewed to determine the following:

- Existing traffic signal shortfalls compared to proposed improvements identified under minor traffic signal upgrades.
- Existence of sight distance limitations on any of the approaches and a determination if the limitation can be readily addressed. (If so, it should be considered as part of or about at the same time as the signal upgrades are implemented.)
- Existence of high intersection entry speeds on the mainline.
- Traffic volumes entering the intersection and intersection level of service. Intersections that are functioning close to capacity (Level of Service D) are not good candidates for detection control systems.

In addition, a review of the physical characteristics of the intersection and the crash data is needed to determine if other crash patterns exist and need to be addressed.

Resources

Resources that can be used to identify appropriate countermeasures for signalized intersections can be found at the FHWA intersection safety website (http://safety.fhwa.dot.gov/intersection/) and NCHRP Report 500 Volume 12, *A Guide for Reducing Collisions at Signalized Intersections* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v12.pdf).

Coordination with Other Signalized Intersection Improvements

In addition to detection control systems, oftentimes isolated rural, high-speed signalized intersections with high numbers of angle crashes also have multiple crash concerns involving running red lights, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns occurs at a signalized intersection, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur at the intersection, and integrating improvements into an overall approach.

Effectiveness

The research findings on the effectiveness of dilemma zone detection control systems applied at high-speed isolated rural intersection approaches is a reduction of 40 percent in angle crashes.

5.5.4 Stop Control Intersection Crashes

Stop control crashes, injuries, and fatalities have frequencies and characteristics associated with the type of area (urban/rural), and time of occurrence (day or night). The primary countermeasures to reduce the level of stop control intersection crashes are infrastructure improvements. Two secondary education and enforcement countermeasures to reduce intersection crashes involve targeted aggressive driving behavior (primarily red light running) and automated red light enforcement.

Countermeasure #1 – Stop Control Signing and Pavement Marking Improvements

Description
Signing and pavement marking improvements consist of the following enhancements, illustrated in Figure 5-3.

Mainline Signing

Important:

- Dual, left and right, advanced oversize warning signs with supplementary street name signs.

Beneficial:

- Florescent warning signs; flashing yellow solar powered LED beacons on signs.

Additional Potential Optional Improvements for Specific Concerns:

- Peripheral transverse pavement markings if approach speeds are high.
- Dynamic warning sign to advise through traffic that a stopped vehicle is at the intersection.
- Flashing overhead intersection beacon.
- Reflective stripes on post.

Stop Approach Signing and Marking

Important:

- Advanced stop ahead oversized intersection signs left and right.
- Left and right oversize stop signs.
- Removal of any foliage or parking that limits sight distance.
- Double arrow warning sign on stem of T intersections.

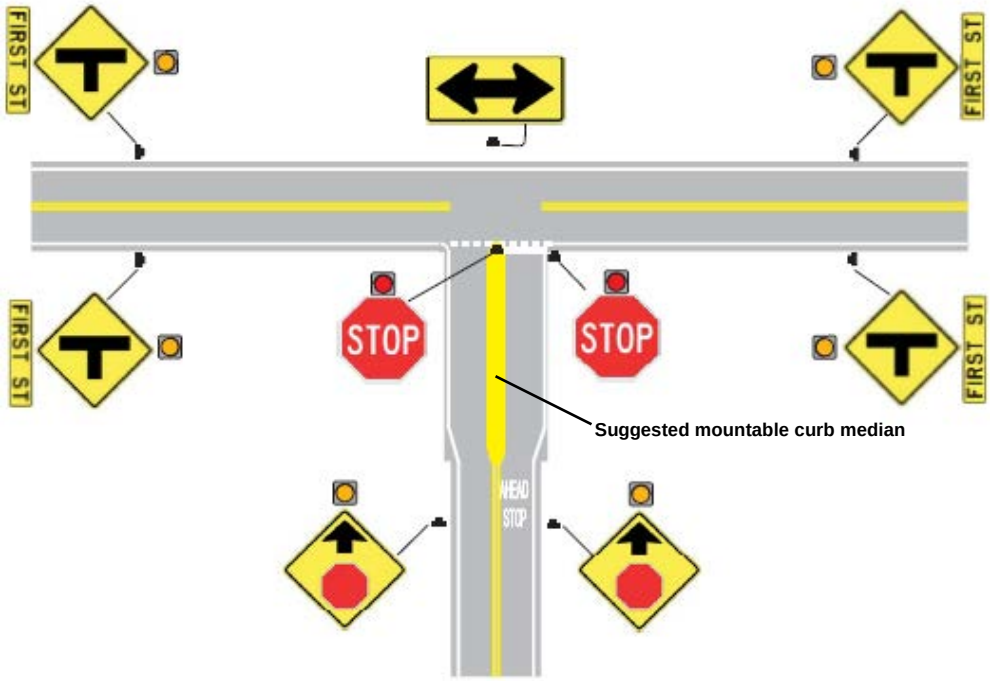
Beneficial:

- Advanced stop ahead warning signs-florescent yellow.

- Flashing yellow solar powered LED beacons on the advanced warning and stop signs.
- Extension of the through edge line using a short skip line.
- Properly placed stop bar if vehicles are not stopping at the proper location or turning trucks impinge over the centerline of the stop approach.
- Installation of a 6 foot or greater raised divisor on the stop approach.

Additional Potential Improvements for Specific Concerns:

- Transverse pavement markings if stop approach speeds are high.
- Transverse rumble strips in rural areas where noise is not a concern and running stop signs is a problem.
- Reflective stripes on sign posts.



Notes:

- Warning signs may be oversized and fluorescent for added visibility.
- Stop sign may be oversized for added visibility.
- Solid red beacons are used with intersection and stop ahead warning signs.
- Rumble strips or transverse markings may be placed on the stop approach if running stop sign crashes are a problem.
- Peripheral transverse markings may be placed in the through approach if intersection entry speeds are too high.

Figure 5-3: Sign and Pavement Marking Improvements

In the event that the mainline intersection entry speeds are excessive or that sight distance is inadequate and cannot be readily corrected, peripheral transverse strips may be considered on the mainline approaches to the intersection to reduce speeds. The strips, appearing on both sides of the approach lane, are 8 inches in width and 12 inches deep. The design spacing for the strips can be determined using the following suggested parameters:

- Initial approach speed.
- Desired intersection entrance speed.
- Targeted deceleration rate (3 to 6 ft/sec^2).
- Uniform bar spacing of four bars per second.

Figure 5-4: Peripheral Transverse Lines Treatment on an Approach to a Curve

An experimental option to the above enhancements using other sign and marking enhancements, particularly for consideration at intersections that do not have sight distance restrictions or high intersection entry speeds, is illustrated in Appendix D. Consult the Safety Division if this option is to be pursued.

Candidate Stop Control Intersections

The recommended candidate stop control intersection crash thresholds for sign and marking enhancements are:

- Urban stop control intersections that have 10 or more angle crashes in 5 years.
- Rural stop control intersections that have five or more angle crashes in 5 years.

Intersections that that meet these thresholds need to be field reviewed to determine the following:

- Existing sign and pavement markings and shortfalls compared to proposed signs and markings.
- Existence of sight distance limitations on any of the approaches and a determination if the limitation can be readily addressed. If so, it should be addressed as part of or about at the same time as the sign and marking improvements are implemented. If not, the peripheral transverse strips on the through approaches need to be considered to reduce speeds.
- Existence of high intersection entry speeds on the mainline.

- A review of the physical characteristics of the intersection and the crash data to determine if drivers running the stop sign, even with the upgraded signs and markings, may be a concern. If so, transverse rumble strips for rural areas where noise is not an issue, or transverse pavement markings for urban or rural areas and where noise is a concern need to be considered.

Stop control intersections that have an extraordinary frequency of severe crashes may be further improved by replacing passive warning signs with dynamic warning signs or by upgrading the appropriate physical characteristics of the intersections, with particular emphasis given to the conversion of the intersection to a roundabout.

Resources

Resources that can be used to identify appropriate countermeasures for stop control intersections can be found at the FHWA intersection safety website (http://safety.fhwa.dot.gov/intersection/) and NCHRP Report 500, Volume 5, *A Guide for Addressing Unsignalized Intersection Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v5.pdf).

Coordination with Other Stop Control Intersection Improvements

In addition to sign and marking enhancements, oftentimes stop control intersections with high numbers of angle crashes also have multiple crash concerns involving aggressive driving, slippery approaches, or higher frequencies under periods of darkness. When one or more of these additional concerns occurs at a stop control intersection, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur at the intersection, and integrating improvements into an overall approach.

Effectiveness

The research findings on the effectiveness of sign and marking enhancements are limited and confined to individual components such as increased warning size, use of beacons, and “Stop Ahead” markings. No research that collectively evaluates the overall impact of a set of sign and marking improvements has been found. However, based upon the research findings that are available, it is estimated that implementation of the overall set of sign and marking improvements at an “average” intersection can reduce angle crashes by 25 percent.

Countermeasure #2 – Lighting at Stop Control Intersections

Description

These improvements consist of lighting at unlit stop control intersections. Lighting should be designed in accordance with the procedures in the PennDOT Design Manual Part 1C, Chapter 3.3, Section B.17. Lighting improvements are eligible for funding under the highway safety improvement program; however, the municipality in which the intersection resides must agree to operate, energize, and maintain the lighting once it is in place.

Candidate Stop Control Intersections

The recommended candidate stop control intersection crash thresholds for lighting improvements are:

- Urban stop control intersections that have five or more unlit night crashes in 5 years.
- Rural stop control intersections that have five or more unlit night crashes in 5 years.

Intersections that meet these thresholds need to be field reviewed to determine if adequate lighting that meets approved design standards already exists. If it does, lighting improvements should not be considered.

Before moving beyond the programming stage of project development, PennDOT should obtain a commitment to operate, energize, and maintain proposed lighting for unlit candidate intersections from the municipality.

Resources

Resources that can be used to identify or consider lighting at stop control intersections can be found at the FHWA intersection safety website (http://safety.fhwa.dot.gov/intersection/) and NCHRP Report 500 Volume 5, *A Guide for Addressing Unsignalized Intersection Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v5.pdf). Information on the design requirements and process for developing design plans for intersection lighting systems may be found in the PennDOT Design Manual.

Coordination with Other Stop Control Intersection Improvements

In addition to the installation of lighting enhancements, oftentimes stop control intersections with high numbers of crashes also have multiple crash concerns involving aggressive driving, slippery approaches, or higher frequencies of angle crashes. When one or more of these additional concerns occurs at a stop control intersection, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur at the intersection, and integrating improvements into an overall approach.

Effectiveness

The evaluation of lighting improvements at unlit intersections indicates a CRF of 40 percent for night crashes.

Countermeasure #3 – Skid-Resistant Overlay at Stop Control Intersections

Description

This improvement consists of placing a skid-resistant surface on the approach to a high-speed intersection that has a high frequency and proportion of wet pavement crashes. In addition, any severe rutting in the wheel paths is also addressed to reduce the potential for hydroplaning. The length of the improvement is dependent on the approach speeds and the probable locations for queue ends of stopped traffic. In general, the length should not be less than 500 feet.

Candidate Stop Control Intersections

The recommended candidate stop control intersection crash threshold for skid-resistant surface improvements is:

- Rural or urban stop control intersections that have speed limits greater than 35 mph, eight or more wet pavement crashes in 5 years, and a wet/total crash ratio of at least 0.30.

Intersections that meet this crash threshold need to have the mainline approaches skid tested to determine if the coefficient of friction is at or below 0.30 (for rib tire tests) or 20 or below (for smooth tire tests). Those intersections that have skid numbers below either of these values should be field reviewed to determine the following:

- Existence of sight distance limitations on any of the approaches or significant downgrades into the intersection that can increase the need for a skid-resistant surface.
- Existence of high intersection entry speeds on the mainline.
- Existence of significant wheel path rutting that may increase the potential for hydroplaning and increased stopping distances.

In addition, a review of the physical characteristics of the intersection and the crash data is needed to determine if other crash concerns, even with the upgraded skid-resistant surface, may be an issue. If so, these concerns should be considered in the overall development of safety improvements for the intersection.

If it is determined that a skid-resistant surface is needed but that it may not be possible to implement in the near future, the use of transverse peripheral pavement markings may be considered as an interim measure to reduce high end-approach speeds and lessen the need for a higher friction surface.

Resources

Resources that can be used to identify stop control intersections where surface friction improvements should be considered can be found at the FHWA intersection safety website (http://safety.fhwa.dot.gov/intersection/) and NCHRP Report 500 Volume 5, *A Guide for Addressing Unsignalized Intersection Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v5.pdf).

Coordination with Other Stop Control Intersection Improvements

In addition to the installation of skid-resistant surfaces, oftentimes stop control intersections with high numbers of crashes also have multiple crash concerns involving aggressive driving, crashes at night, or higher frequencies of angle crashes. When one or more of these additional concerns occurs at a stop control intersection, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur at the intersection, and integrating improvements into an overall approach.

Effectiveness

The evaluation of applying skid-resistant surfaces to intersection stop approaches indicates a CRF of 50 percent for wet pavement crashes.

Countermeasure #4 –Mainline Left Turn Lanes at Stop Control Intersections

Description

This improvement consists of placing left turn lanes on the mainline approach to a high-speed intersection with a high frequency and proportion of crashes involving left turn vehicles, either with opposing through vehicles (angle or head-on crashes) or following through vehicles (rear-end crashes).

Candidate Stop Control Intersections

The recommended candidate stop control intersection crash threshold for left turn lanes is:

- Rural or urban stop control intersections that have speed limits greater than 35 mph, and 20 or more crashes involving a mainline left turning vehicle (15 or more of which are angle or head-on crashes with opposing through vehicles).

Intersections that meet this crash threshold need to be field reviewed to determine the following:

- Existence of left turn lanes at the intersection.
- Existence of sight distance limitations on any of the through approaches the intersection that can increase the potential for through vehicle collisions.
- Existence of high intersection entry speeds on the mainline.
- Traffic volumes at the intersection to determine if traffic signals are warranted.
- An assessment if a roundabout is feasible to consider at the intersection in lieu of left turn lanes. Roundabouts have a superior CRF.

In addition, a review of the physical characteristics of the intersection and the crash data is needed to determine if other crash concerns, even with the upgraded left turn lanes may be a concern. If so, these concerns should be considered in the overall development of safety improvements for the intersection.

Resources

Resources that can be used to identify crash mitigation techniques for left turn lanes at stop control intersections can be found at the FHWA intersection safety website (http://safety.fhwa.dot.gov/intersection/) and NCHRP Report 500 Volume 5, *A Guide for Addressing Unsignalized Intersection Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v5.pdf). Information on the design requirements and process for developing design plans for left turn lanes may be found in the PennDOT Design Manual.

Coordination with Other Stop Control Intersection Improvements
In addition to the installation of left turn lanes, oftentimes stop control intersections with high numbers of crashes also have multiple crash concerns involving aggressive driving, crashes at night, wet pavement crashes, or higher frequencies of angle crashes. When one or more of these additional concerns occurs at a stop control intersection, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur at the intersection, and integrating improvements into an overall approach.
Effectiveness

The evaluation of incorporating left turn lanes at intersections indicates a CRF between 40 and 50 percent for all left turn crashes. Roundabouts are projected to reduce all intersection crashes at average intersections by 90 percent.

5.5.5 Curve Crashes

Curve crashes, injuries, and fatalities have frequencies, severities, and characteristics associated with the entry speeds of vehicles coupled with the degree of curvature, the type of area (urban/rural), and time of occurrence (day or night). Unfortunately, there are no existing databases that contain information on degree of curvature, super-elevation, and continuous speed limits. The primary countermeasures to reduce the level of curve crashes are infrastructure improvements. Infrastructure improvements can be classified as either minor or major in terms of costs.

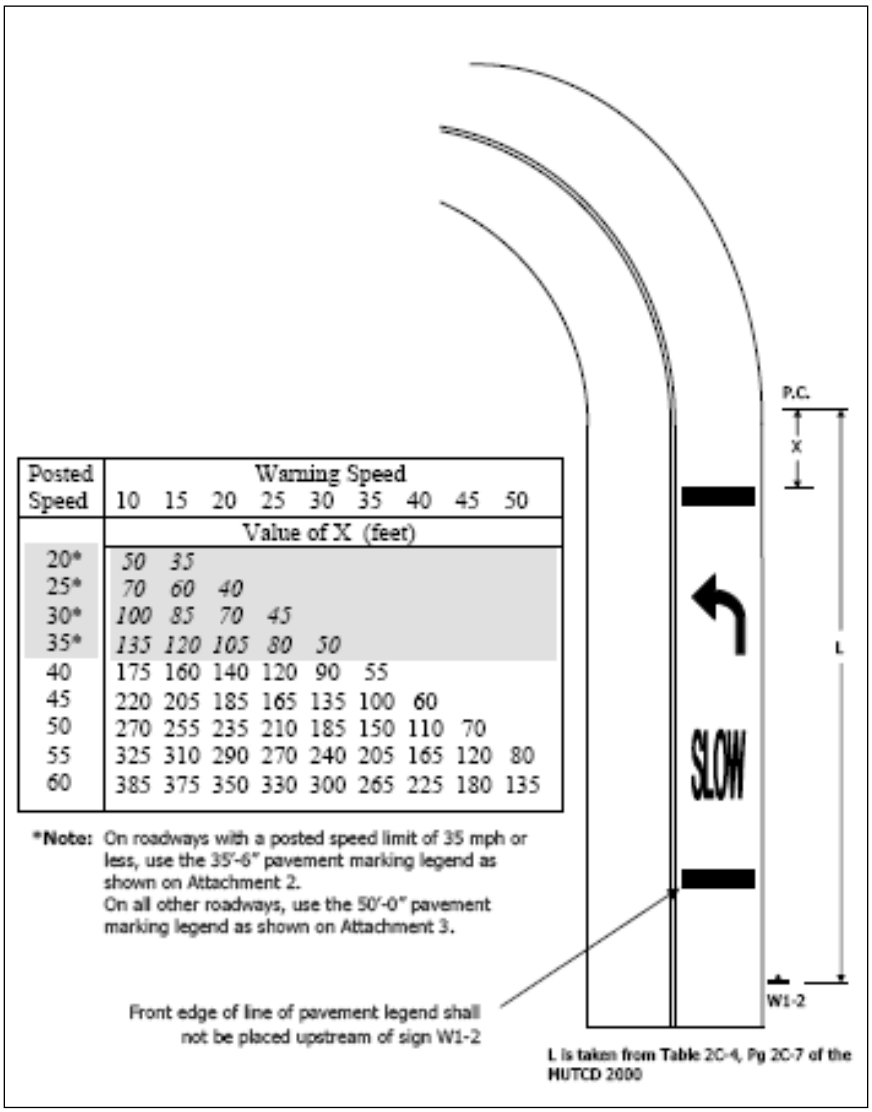
Secondary education and enforcement countermeasure to reduce curve crashes involving targeted aggressive driving, seat belts, or impaired driving may be considered, but are usually not feasible to be performed on a continuous basis for a given curve. However, performing secondary education and enforcement countermeasures on an area-wide basis where the area includes the curve may result in fewer curve crashes due to overall improvements in driver behavior. Curve crash data currently cannot be accessed in CDART. The HSTOD will provide Districts with data on high crash curves on a periodic basis.

Countermeasure #1 – Curve Upgrade Improvements – Minor and Major

Description
These improvements consist of the following potential curve sign and marking enhancements:

- Oversize advanced fluorescent yellow curve warning signs, doubled up (i.e., both sides of the roadway) with optional flashing yellow LED solar powered beacons.
- Advanced curve pavement markings including the SLOW legend as indicated in Figures 5-5 – 5-7. The XX MPH advisory speed marking shown in Figure 5-8 may be substituted for the SLOW legend as an alternate. Districts may modify the pavement marking layouts to suit practice.

- Correction of any shoulder drop offs within the curve.
- Chevron delineation around the curve.
- Curve widening. The 2001 AASHTO Green Book section "Traveled Way Widening on Horizontal Curves" (page 212) provides guidance for widening. Numerical design values are provided on Exhibit 3-51 of the same AASHTO section.



Posted Speed	Warning Speed 10	15	20	25	30	35	40	45	50
	Value of X (feet)								
20*	*50*	*35*							
25*	*70*	*60*	*40*						
30*	*100*	*85*	*70*	*45*					
35*	*135*	*120*	*105*	*80*	*50*				
40	175	160	140	120	90	55			
45	220	205	185	165	135	100	60		
50	270	255	235	210	185	150	110	70	
55	325	310	290	270	240	205	165	120	80
60	385	375	350	330	300	265	225	180	135

***Note:** On roadways with a posted speed limit of 35 mph or less, use the 35'-6" pavement marking legend as shown on Attachment 2.
On all other roadways, use the 50'-0" pavement marking legend as shown on Attachment 3.

Figure 5-5: Typical Layout and Placement of Supplemental Curve Pavement Marking

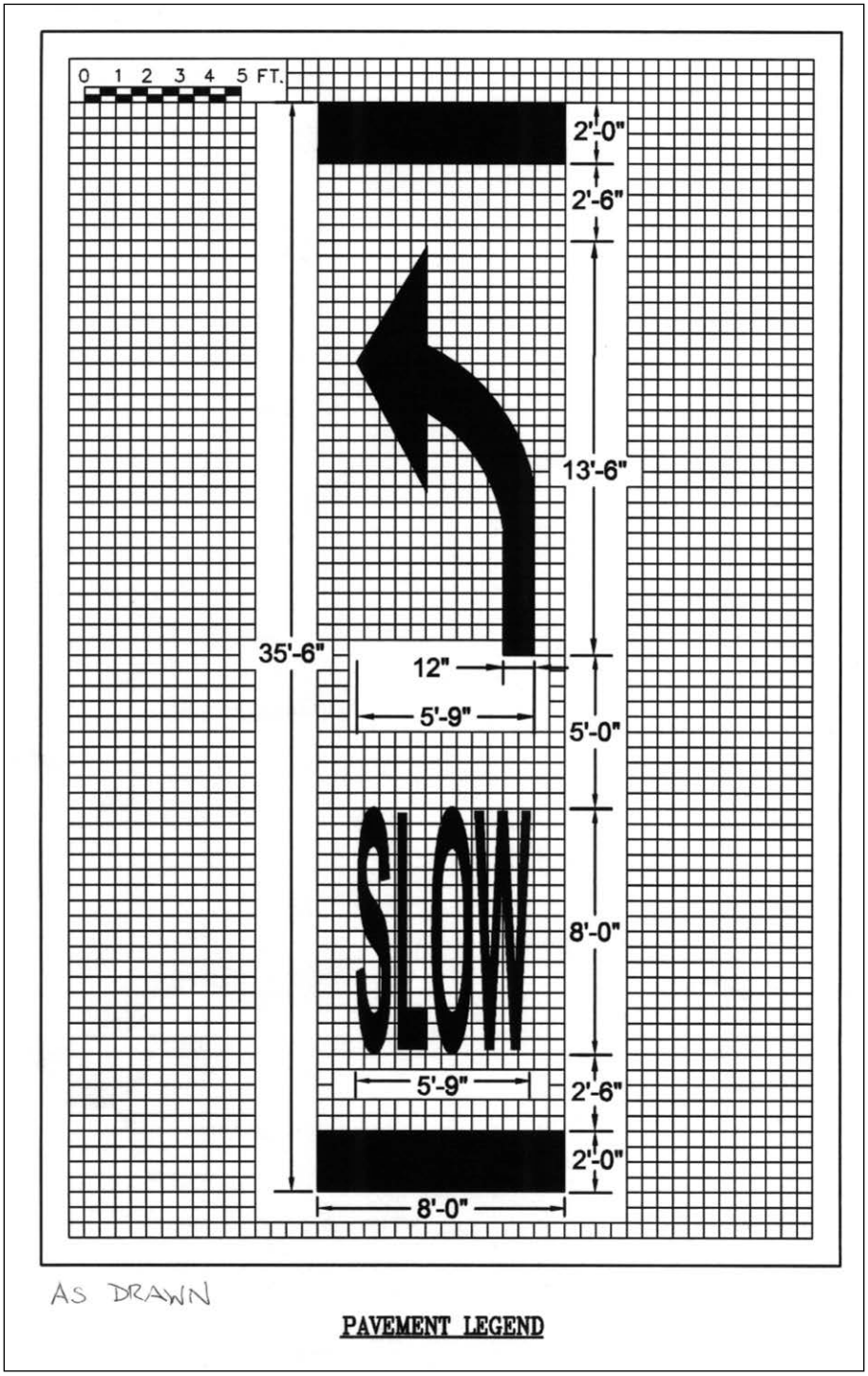


Figure 5-6: Low-Speed Standard Marking (Posted Speed Limit 35 MPH or Less)

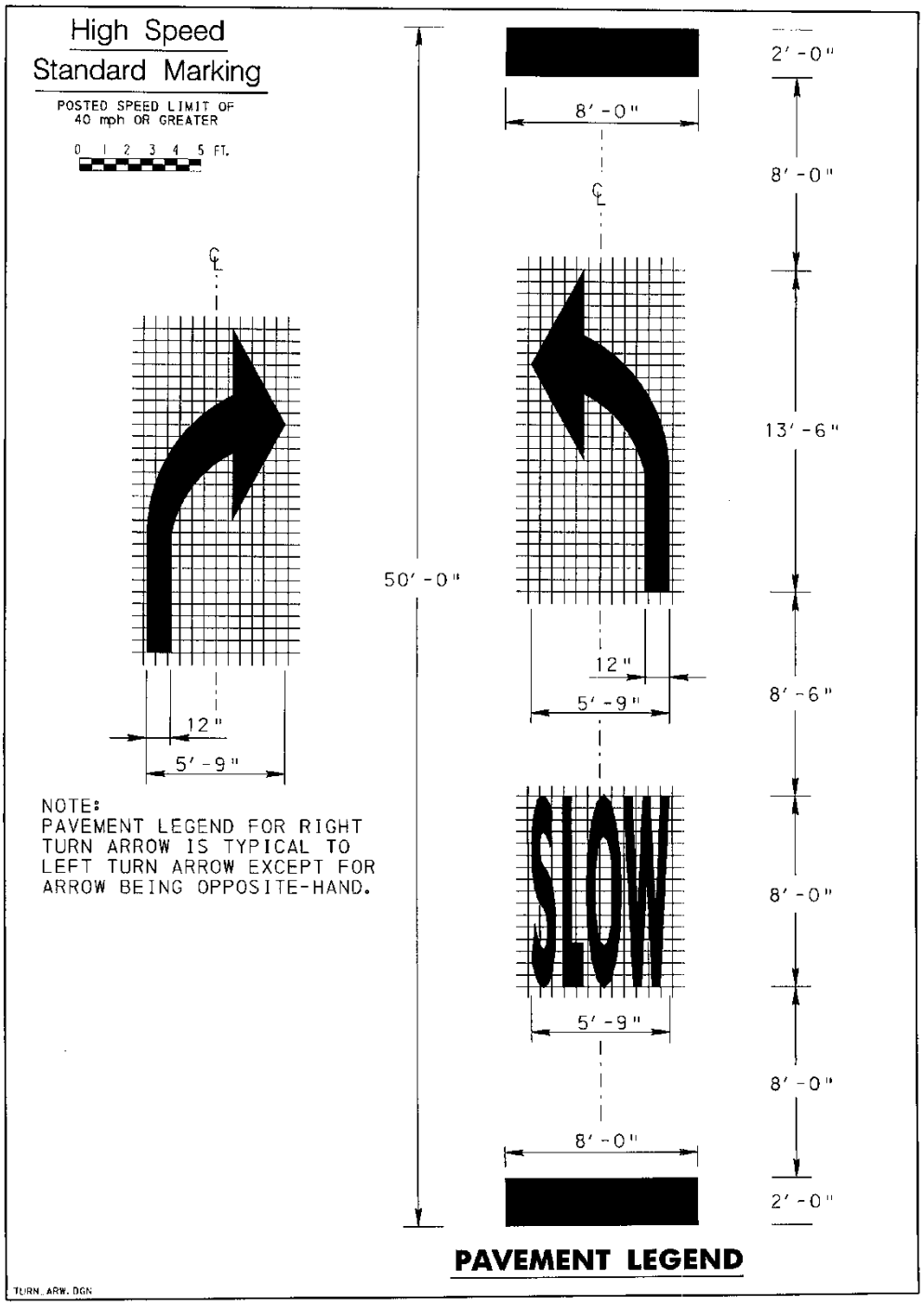


Figure 5-7: High-Speed Standard Marking (Posted Speed Limit 40 MPH or Greater)

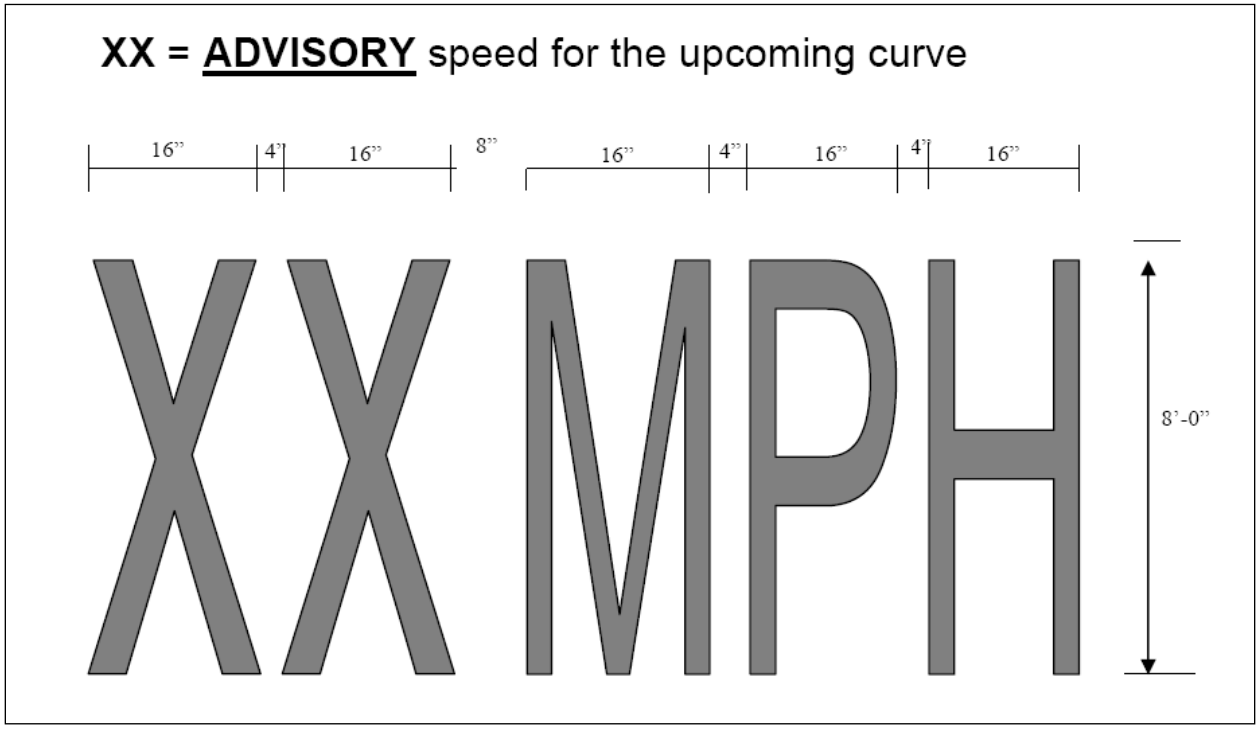


Figure 5-8: Legend Detail

In the event that the mainline curve entry speeds are excessive or that the differential between the 85th percentile approach speed and the design speed of the curve is greater than 15 MPH, peripheral transverse strips may also be considered on the approaches to the curve. The strips, appearing on both sides of the approach lane, are 8 inches in width and 12 inches deep. The design spacing for the strips can be determined using the following parameters:

- Initial approach speed.
- Desired intersection entrance speed.
- Targeted deceleration rate (3 to 6 ft/sec^2).
- Uniform bar spacing of four bars per second.

Candidate Curve Improvements

The recommended candidate curves crash thresholds for minor curve upgrades are:

- Urban curves that have 12 or more curve crashes in 5 years.
- Rural curves that have 8 or more curve crashes in 5 years.

Curves that meet these thresholds need to be field reviewed to determine the following:

- Existing sign and marking shortfalls compared to proposed improvements.
- Differentials between estimated 85th percentile approach speeds and curve design speeds.
- Existence of any sight distance limitations on any of the approaches to or within the curve.

- Existence of high curve entry speeds on the mainline.
- Potential to add centerline or edge rumble strips.
- Presence of shoulder drop offs at the edge of pavement.
- Wet pavement crash history on the curve and a determination if a skid test should be pursued (i.e., eight or more wet pavement crashes on the curve coupled with a wet/total crash ratio of at least 0.30).

In addition, a review of the physical characteristics of the curve and the crash data is needed to determine if other physical improvements need to be considered (e.g., major inadequacies in super-elevation; narrow or unpaved shoulders; compound curvature or significant drop in design speed).

Curves that have an extraordinary frequency of severe crashes may be further improved by using dynamic rather than passive warning signs. Dynamic curve warning signs are activated by sensors on the approach to the curve. These sensors detect vehicle speeds above a threshold level and flash warning messages to the driver to slow down. Other physical improvements such as super-elevation corrections, reshaping the cross-section, and skid resistant surfaces also may be considered if appropriate deficiencies exist.

Major curve alignment improvements need to be considered on curves where the above appropriate treatments have been installed and a severe crash problem continues to exist. Examples of curves that may fall into this category include:

- Compound curves with substantial differences in degree of curvature where drivers cannot judge where the point of compound curvature occurs and must make mid-course steering adjustments once drifting in the lane is recognized. Impaired or inattentive drivers will take longer to adjust and potentially will not be able to recover.
- Approaches to and within curves that have inadequate sight distance hiding the alignment of the curve.
- Curves that have intersections within the curve where a major crash problem involves the intersection.
- Curves with very significant differentials in design speed compared to approach speeds in which sign and pavement marking enhancements have not adequately addressed the problem.

Resources

Resources that can be used to identify appropriate countermeasures for curves can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/) and NCHRP Report 500 Volume 7: *A Guide for Reducing Collisions on Horizontal Curves* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v7.pdf). Of particular importance is a document on the FHWA road departure safety website, *Low-Cost Treatments for Horizontal Curve Safety* (http://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa07002/).

Coordination with Other Improvements

In addition to minor sign and marking upgrades, oftentimes curves with high numbers of crashes also have multiple crash concerns involving running off the road, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns occurs on a curve, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur on the curve, and integrating improvements into an overall approach.

Effectiveness

The research findings on effectiveness of curve sign and marking upgrade enhancements are limited and confined to individual components such as increased sign size and doubling up. No research has been found that collectively evaluates the overall impact of a set of minor sign and marking improvements as suggested above. However, based upon the research findings that are available, it is estimated that implementation of the overall set of sign and marking improvements for an average curve can reduce curve crashes by 25 percent. Skid resistant overlays on slippery pavements are estimated to reduce wet pavement crashes by 50 percent. Dynamic curve warning signs, while not evaluated, are expected to be more effective than the recommended passive sign and marking improvements, with a conservative CRF of 0.30 for all curve crashes. Re-alignment of curves to correct an identified major deficiency should eliminate almost all future curve crashes.

5.5.6 Tree Crashes

Tree crashes, injuries, and fatalities have frequencies and characteristics associated with the impact speed of vehicles; the frequency, size, and offset of trees; the type of area (urban/rural); and time of occurrence (day or night). Unfortunately, there are no existing databases that contain information on the frequency and offset of trees on the highway system. The primary countermeasures to reduce the level of tree crashes are infrastructure improvements that usually range from delineation to tree removal.

Secondary education and enforcement countermeasures to reduce tree crashes involving targeted aggressive driving, seat belts, or impaired driving may be considered, but are usually not feasible to be performed on a continuous basis for a given cluster of tree crashes. However, performing secondary education and enforcement countermeasures on an area-wide basis that includes the tree cluster section may result in fewer tree crashes due to overall improvements in driver behavior.

Countermeasures to Reduce the Frequency and/or Severity of Tree Crashes

Description

Crashes with trees account for the highest number of fatalities involving crashes with fixed objects. There are three general countermeasures: removal, protection, or delineation. Removal is normally only feasible in rural areas where the severity of tree crashes is high. Protection involving the installation of guide rails is usually not an appropriate safety solution since the increased length of guide rail increases crash exposure and results in higher crash frequencies even though crash severity decreases. Other passive improvements such as the installation of paved shoulders, edge rumble strips, traffic calming measures, or peripheral transverse bar markings to slow traffic can reduce the frequency and severity of tree crashes. Delineation is beneficial if a number of tree crashes occur at night.

Candidate Trees

The recommended candidate tree location crash threshold for tree safety countermeasures is:

- Urban or rural sections that have five or more tree crashes in 1,000 feet in 5 years. This requires a review of 5 year tree crashes on geo-spatial county maps to identify routes and longer highway sections that have concentrations of tree crashes.

For those tree clusters where tree removal or protection is not feasible, tree delineation is possible at cluster locations that meet the following recommended threshold level:

- Urban or rural sections that have four or more night tree crashes in 1,000 feet in 5 years. This requires a review of 5 year night tree crashes on geo-spatial county maps to identify routes and longer highway sections that have concentrations of night tree crashes.

Countermeasure Decision Process

Figure 5-7 shows the decision process for tree clusters. A detailed explanation of each step follows.

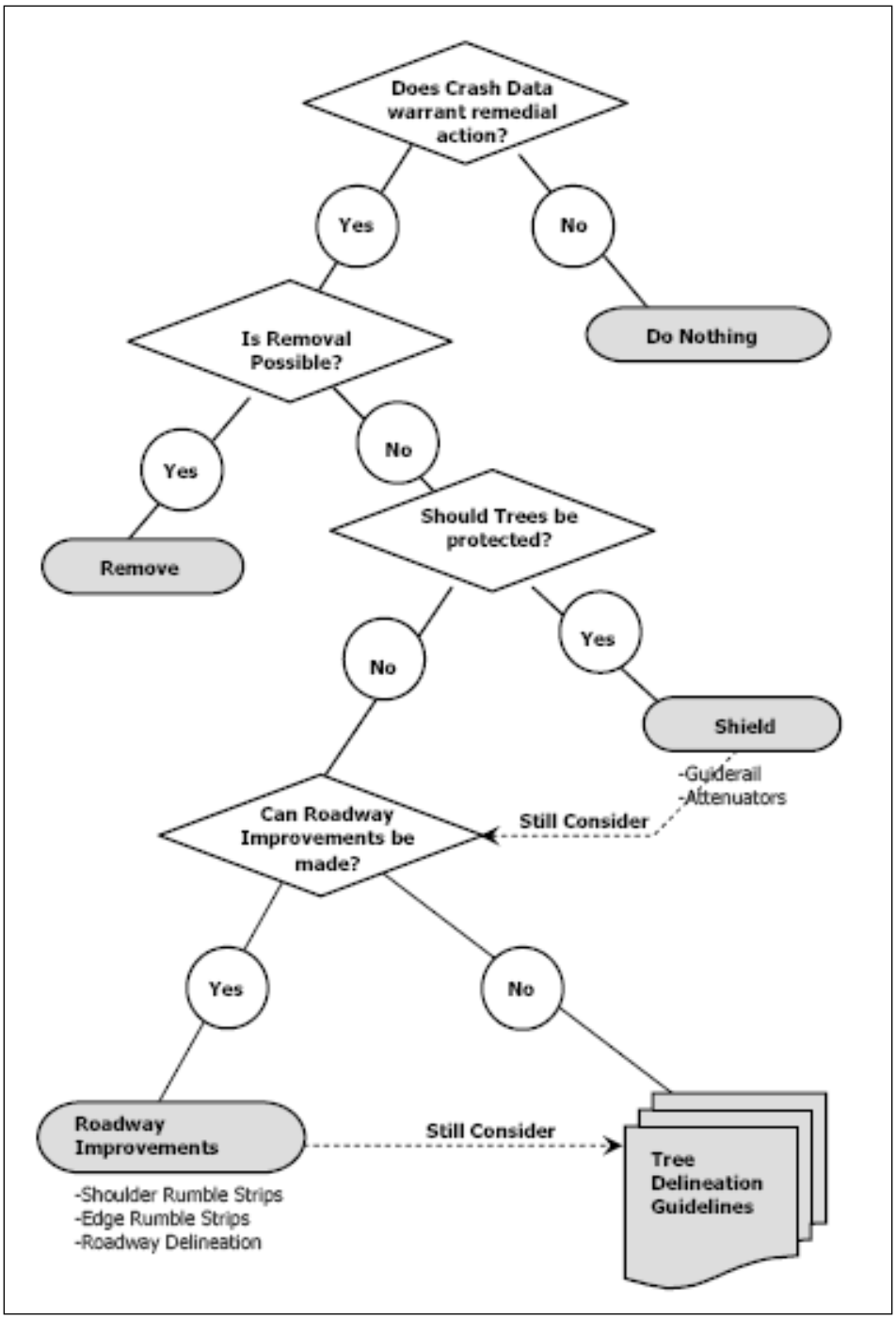


Figure 5-9: Tree Crash Cluster Decision Tree

Step 1: Does Crash Data Warrant Remedial Action?

Consider a location if it is listed in the hit tree cluster list. Locations are listed as a cluster if there are five or more crashes in 1,000 feet. Sites that have a high potential for future crashes should also be given consideration (review GIS tree crash maps to identify routes and longer sections of highway that have concentrations of tree crashes).

The Highway Safety Engineer, Roadside Manager, Assistant District Engineer or designee, County Maintenance Manager, and Environmental Manager should collectively review the list of tree cluster locations and GIS county tree crash maps to identify potential sites and mechanisms to remove vulnerable trees. Candidate sections should have concentrations of tree crashes and not be adjacent to homes or buildings, primarily in rural areas. A list of potential locations should be established. The District Right-Of-Way Unit should review the list and assist in determining if right-of-way involvement or issues are present on any of the identified sections.

The Environmental Manager and Roadside Manager should review sites on the list to determine if there are any significant environmentally sensitive issues associated with tree removal at any of the sections on the list. Those sections that have sensitive issues should be considered for protection or delineation unless the removal issues can be easily addressed.

Trees that are off the right-of-way, but are highly vulnerable should also be considered. The Office of Chief Counsel has advised that removal of vulnerable trees off of the right-of-way is possible based upon execution of a release without payment of compensation. Form RW-397-1, Authorization to Enter (Waiver of Claim) should be used. It may be useful to involve the Right-of-Way Unit staff experienced with the form.

Step 2: Is Removal Possible?

Consider trees for removal where:

- The roadside is such that removing the trees will increase recovery area significantly, such as the outside of a curve, or when removal coincides with an initiative to clear the roadside of all other significant hazards.
- There are isolated trees well within the clear zone.
- Trees show bark damage from repeated involvement in crashes.

And which are not in any of the following categories:

- Outside of PennDOT right-of-way and no additional right-of-way can be purchased.
- Member of an endangered species.
- Habitat for endangered species (i.e., Indiana Bats).
- Of any historic or cultural significance.

Vulnerable trees located beyond the right-of-way should be considered for removal through the purchase of right-of-way to increase the clear zone or the attainment of a release from the property owner, which can include replacement by planting less vulnerable trees or shrubbery.

The AASHTO Roadside Design Guide or the Roadside Safety Analysis Program (RSAP) may be used to determine the effectiveness of tree removal in increasing recovery areas and reducing future tree and run off the road crashes.

Tree removal should be at ground level with no stump heights remaining greater than four inches above the ground. Minor re-grading of the area, particularly if stump removal is performed, is desirable to improve the recovery zone.

Once a determination is made to remove a given set of trees, PennDOT or contract forces (dependent on which method is preferable to the County and District Office) may perform removal.

Step 3: Should the Trees be Shielded?

In rare instances, guide rail may be appropriate if a significant net safety benefit can be realized. Perform analysis using the RSAP or equivalent method to determine if a continuous guide rail in front of multiple trees located in close proximity will result in a substantial net safety benefit (i.e., the expected increase in less severe guide rail crashes produces a substantial overall reduction in crash costs compared to the projected costs of the fewer more severe tree crashes). If a substantial net benefit can be realized, installation of guide rail may be appropriate to consider.

Consider an attenuating system for isolated trees with multiple hits and conditions in which removal of the tree is not a viable option.

If trees are to be shielded, improvements to the existing roadway should still be considered.

Step 4: Can Improvements be Made to the Existing Roadway?

Consider additional delineation on the existing roadway such as edge lines, raised pavement markers (RPM), post delineators, or chevrons. Also, consider widened and paved shoulders.

In addition to delineation, consider alternative methods to keep the vehicle from leaving the roadway. Shoulder rumble strips may be effective if a paved shoulder 6 feet or wider exists. Edge rumble strips may be effective where paved shoulders are 4 feet or wider.

Other low-cost improvements to be considered are as follows:

- Advanced warning signs.
- Skid resistant pavement overlays.

- Increased highway lighting.[2]
- Peripheral transverse bar markings to slow speeds and reduce severity.

In urban areas, consider traffic calming measures to decrease speeds and reduce crash severity.

If additional improvements are possible, tree delineation should still be considered.

Step 5: Can Trees be Effectively Delineated?

The following guidelines for vulnerable tree delineation should be used to place delineation in night tree cluster areas.

Marking Height

Attach markings to the tree at a height four feet above the nearest roadway surface.

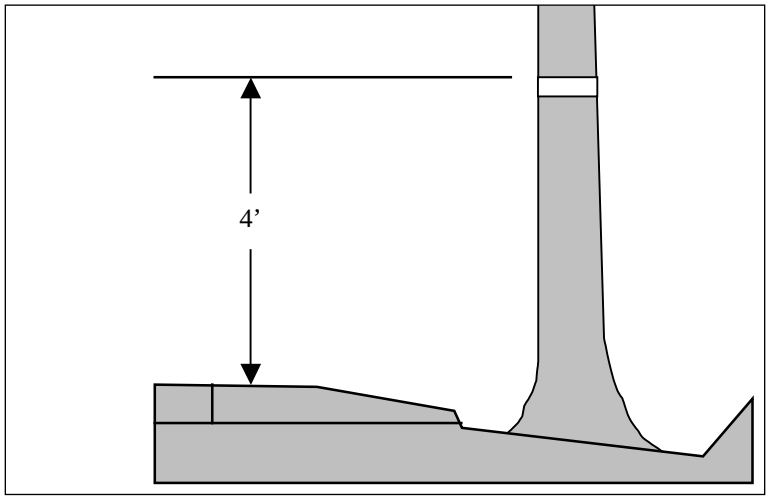


Figure 5-10: Marking Height for Vulnerable Tree Delineation

Material and Installation

The following sheeting type is acceptable for the strip of reflective material around tree:

- 3M #3811, 4 inch yellow flexible, high-intensity grade.

Install markings on every tree that meets the criteria set forth in these guidelines. Attach markings by wrapping sheeting around tree. Overlap the ends a minimum of four inches. No tacks, nails or staples should be used to apply tape to trees.

[2] Lighting improvements are eligible under the highway safety improvement program; however, the municipality in which the intersection resides must agree to operate, energize, and maintain the lighting once it is in place.

Guidelines for Use

- Horizontal Location – Place delineation on trees[3] located within required clear distance as indicated in Table 5-6. The required clear distance is measured perpendicularly from the edge of the travel lane to the tree.

Table 5-6: Clear Distances for Vulnerable Tree Delineation

Posted Speed Limit	Required Clear Distance
≥50 MPH	30 feet
45 MPH	22 feet
≤ 40 MPH	15 feet

- Trees Behind Curbs or Existing Guide Rails – It is not necessary to delineate trees located behind existing guide rail. Additionally, delineation is not required for trees that are both 18 inches behind curbs and along roadways with a posted speed limit below 40 MPH.

- Trees on Upward Slopes – It is not necessary to delineate trees located on upward slopes that are tall enough to eliminate the possibility of impact in the event of a crash.

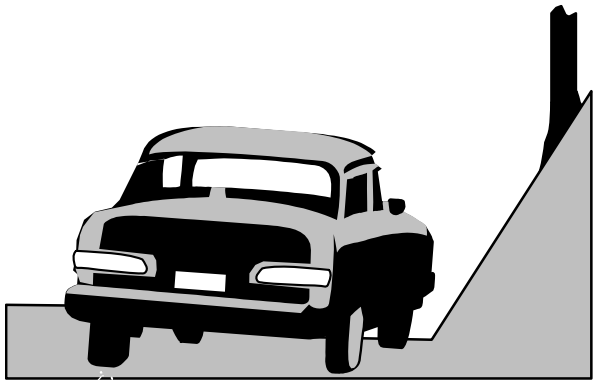


Figure 5-11: Upward Slope Where Delineation is not Needed

- Areas Where Tree Line and Roadway Alignment Differ – The existing roadway delineation should be evaluated to determine if it is to standard. If it is not to standard, bring it up to standard. Never use tree delineation as a substitute for roadway delineation.

  In locations where the tree alignment differs from the horizontal roadway alignment, delineation should not be placed without coordination with the District Highway Safety Engineer. Sound engineering judgment should be used to ensure that any proposed tree delineation will not lead the driver away from the roadway.

[3] In areas where tree density is high, it is not necessary to delineate every tree. Trees on the outer facing edge of the tree line should be delineated at a spacing of approximately 15 meters (50 feet).

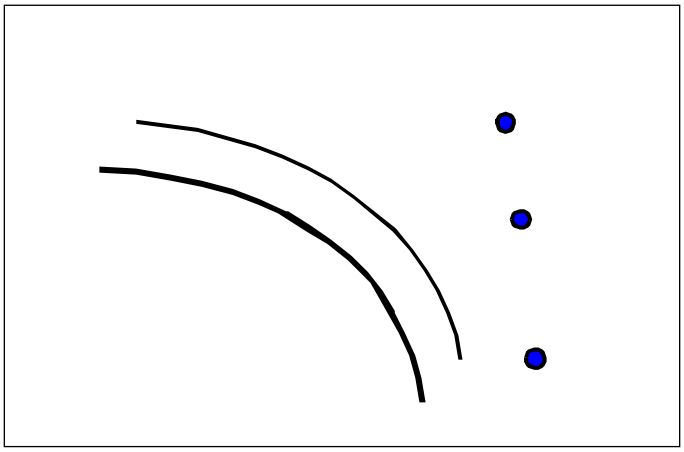


Figure 5-12: Example of Highway Section Where Tree Delineation Should be Avoided

Resources

Resources that can be used to identify appropriate countermeasures for locations with vulnerable trees can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/), NCHRP Report 500 Volume 3: *A Guide for Addressing Collisions with Trees in Hazardous Locations* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v3.pdf), and the AASHTO Roadside Design Guide.

Coordination with Other Run Off the Road Improvements

In addition to removal, shielding, or delineation of trees, oftentimes sections of highway with high numbers of tree crashes also have multiple crash concerns involving running off the road into other fixed objects, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns occurs in one of these sections, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur in the section, and integrating improvements into an overall approach.

Effectiveness

The research findings on effectiveness of tree removal need to be assessed in light of the roadside remaining after the trees are removed. As an example, if a wooded tree line is six feet off the edge of pavement and trees are to be cleared to provide a 15 foot clear roadside, the proportional difference in roadway incursions estimated through the AASHTO Roadside Design Guide may be used to estimate the impact of the tree removal.

If trees are to be shielded by guide rail, the RSAP program can estimate the net impact of the improvement considering that a less severe but more frequent crash with guide rail will occur.

Delineation of trees is estimated to reduce night crashes with trees by 10 percent.

5.5.7 Utility Pole Crashes

Utility pole crashes, injuries, and fatalities have frequencies and characteristics associated with impact speed of vehicles; the frequency, size, and offset of poles; the type of area (urban/rural); and time (day or night) of occurrence. Unfortunately, there are no existing databases that contain information on the frequency and offset of utility poles on the highway system. The primary countermeasures to reduce the level of utility pole crashes are infrastructure improvements that range from delineation to pole relocation.

Secondary education and enforcement countermeasure to reduce utility pole crashes involving targeted aggressive driving, seat belts, or impaired driving may be considered, but are usually not feasible to be performed on a continuous basis for a given cluster of pole crashes. However, performing secondary education and enforcement countermeasures on an area-wide basis that includes the utility pole cluster section may result in fewer pole crashes due to overall improvements in driver behavior.

Countermeasures to Reduce the Frequency and/or Severity of Utility Pole Crashes

Description
Crashes with utility poles account for the second highest number of fatalities involving crashes with fixed objects. There are three general countermeasures: relocation, shielding, or delineation. Relocation is normally only feasible in rural areas where the severity of utility pole crashes is high. Shielding involving the installation of guide rails is usually not an appropriate safety solution since the increased length of guide rail increases crash exposure and results in higher crash frequencies even though crash severity decreases. Other passive improvements such as the installation of paved shoulders, edge rumble strips, traffic calming measures, or peripheral transverse bar markings to slow traffic can reduce the frequency and severity of tree crashes. Delineation is beneficial if a number of pole crashes occur at night.

Candidate Utility Poles
The recommended candidate utility pole location crash threshold for utility pole safety countermeasures is:

- Urban or rural sections that have 5 or more utility pole crashes in 1,000 feet in 5 years. This requires a review of 5 year utility pole crashes on geo-spatial county maps to identify routes and longer highway sections that have concentrations of utility pole crashes.

For those utility pole clusters where pole relocation or protection is not feasible, pole delineation is possible at cluster locations that meet the following criteria:

- Urban or rural sections that have four or more utility pole crashes at night in 1,000 feet in 5 years. This requires a review of 5 year night utility pole crashes on geo-spatial county maps to identify routes and longer highway sections that have concentrations of night utility pole crashes.

Countermeasure Decision Process

Figure 5-11 shows the decision process for pole crash clusters. A detailed explanation of each step follows.

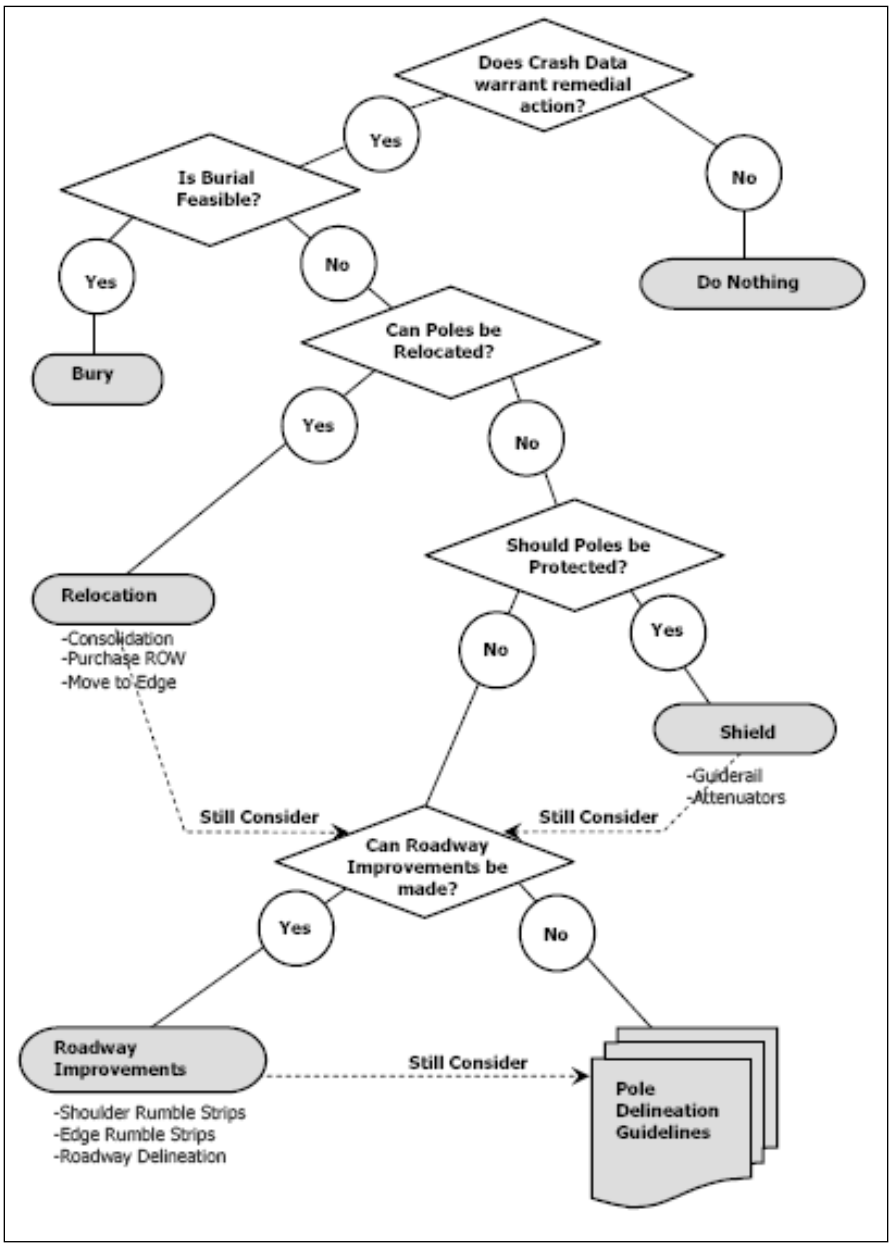


Figure 5-13: Pole Crash Cluster Decision Tree

1) The safety enhancement process is depicted as a decision tree, shown above. This process is based upon the AASHTO Roadside Design Guide. PennDOT Publication 13M, Design Manual Part 2, Chapter 12 establishes PennDOT's design guidelines for roadside safety, including guiderail and median barrier applications. These design guidelines contain tables for determining clear zone widths, as well as other criteria for determining a safe clear zone, and shall be used for determining clear zone widths in pole replacement locations.

2) The term feasible in the safety enhancement decision tree shown above is defined as the result of a benefit/cost analysis. The benefits are calculated based upon the number and severity of crashes mitigated by the proposed safety risk countermeasure (i.e., safer location, guiderail, delineation, etc.). The costs of a countermeasure include its design, construction, operations and maintenance, with consideration for its topography, right-of-way and clear zone widths, other obstructions, and pole line engineering.

3) The safety enhancement process requires collaboration between the PennDOT District offices and the utility companies working within the Districts. As much as practicable, this collaboration should be completed proactively as noted in Section 1.a.3., above. Collaboration around specific projects should take place as part of the HOP Permit Application process as articulated in PennDOT Publication 282, Highway Occupancy Permit Guidelines.

   a) PennDOT information must be shared with utility companies if the utility companies are to execute an effective design process. Useful information includes:

      - Right-of-way dimensions;
      - Department-specified clear zone dimensions;
      - Crash history, in the form of the latest HUPCC and RORCC;
      - Approximate costs of safety risk countermeasures. For example; the approximate cost per linear foot of the appropriate type of guiderail for a particular location.

   b) Utility companies must share information with the PennDOT Districts within which they work if PennDOT is to assist with determining feasible safety risk countermeasures. Such information includes approximate costs of above ground facility relocations.

   c) Both PennDOT and the utility companies working in its Districts shall document their collaboration toward assuring that the understanding of engineering and cost limitations, as well as mitigation decisions, are mutually understood. If available, use the appropriate PennDOT form for documentation.

4) The safety enhancement process, as depicted by the decision tree above, begins by determining if the removal or relocation of a pole or other above ground appurtenance from the clear zone is feasible.

a) If yes, then relocation should be planned with these considerations:

- Removal of the above-ground facility
- Purchasing right-of-way to place the pole or other appurtenance outside the clear zone (as described in Section 1.a. (2))
- Consolidating several utility services to fewer poles
- Moving the pole or other appurtenance as close as practicable to the right-of-way line
- Consider the feasibility of roadway improvements that may mitigate the potential for drivers to run off the road

b) If no, consider shielding.

5) Determine the feasibility of shielding a pole or other above ground utility appurtenance according to the guidelines in PennDOT Publication 13M, Design Manual Part 2, Chapter 12, Section 12.3.

a) If yes, then shielding should be planned with consideration for:

- Lateral offset
- Terrain effects
- Flare rate
- Length of need
- End treatments
- Consider the feasibility of roadway improvements that may mitigate the potential for drivers to run off the road

b) If no, consider roadway improvements.

6) Determine the feasibility of roadway improvements that may mitigate the potential for drivers to run off the road according to the guidelines in PennDOT Publication 46.

a) If yes, then roadway improvements should be planned. The kinds of improvements to consider include:

- Pavement markings
- Warning signs – W1 Series (Turn/Curve warning signs)

- Chevron alignment signs
- Delineators
- Raised pavement markers
- Post-mounted delineators
- Object markers
- Shoulder rumble strips
- Skid-resistant wearing courses
- Lighting

b) If no, consider delineation.

7) Determine the feasibility of delineating the pole or other above ground utility appurtenance. Delineate in accordance with guidelines provided in PennDOT Publication 638.

Step 1: Does Crash Data Warrant Remedial Action?

Consider a location if it is listed in the hit pole cluster list of five or more utility pole crashes in 1,000 feet within 5 years. In addition, review of geo-spatial county maps of 5 year utility pole crashes to identify routes and longer highway sections that have concentrations of utility pole crashes.

The Highway Safety Engineer, representative of the Permit Unit, and the Utility Relocation Unit Administrator should collectively review the list of utility pole cluster locations and GIS county utility pole crash maps to identify potential sites and mechanisms to reduce utility pole crashes within the list. Candidate sections should have concentrations of utility pole crashes on higher speed highways (i.e., posted speed limits of greater than 40 MPH) where pole crashes are more severe, primarily in rural areas. A list of potential locations should be established. The District Right-Of-Way Unit should review the list and assist in determining if right-of-way involvement or issues are present on any of the identified sections.

The Highway Safety Engineer should analyze the utility pole crash data within the high-crash section, right-of-way conditions, other highway deficiencies, and types of potential solutions and advise the Permit Unit of the outcome. The Permit Unit should notify the utility owner(s) to arrange a field view to discuss the problems relating to the existing utility pole locations and potential solutions. The District Highway Safety Engineer or representative should attend the field view. Four possible outcomes are possible: burial, relocation, protection, and delineation.

Step 2: Is Burial Possible?

Consider lines for burial where:

- The roadside is such that removing the utility poles will increase recovery area significantly or when burial coincides with an initiative to clear the roadside of all other significant hazards.
- Poles are repeatedly damaged in crashes.
- It is technically feasible and not unreasonably expensive to bury the pole.

Step 3: If Poles Should not be Removed, Should They be Relocated?

The common objective in relocation of utility poles is to move the poles as far as possible from the traveled way. Several options are available for the relocation of utility poles in high-crash areas. The recommended options include:

- Consolidation of utilities to poles on one side of the roadway.
- Combining utilities onto fewer poles to increase pole spacing.
- Relocation of poles in the segment for the purpose of obtaining a better clear zone. Poles should be relocated a minimum of 5 feet, with relocation to the edge of the clear zone being the preference. The following methods apply:
  - Purchase of strip right-of-way.
  - Utility pole company moves to private right-of-way.

Combination of the above options should also be considered.

If poles are to be relocated, improvements to the existing roadway should still be considered. Consideration should also be given to the removal of all other roadside hazards in the clear zone.

Step 4: Should the Poles be Shielded?

In rare instances, guide rail may be considered if a significant net safety benefit is realized. Perform analysis using the RSAP or equivalent method to determine if a continuous guide rail in front of multiple poles in close proximity will result in a substantial net safety benefit (i.e., the expected increase in less severe guide rail crashes produces a substantial overall reduction in crash costs compared to the projected costs of the fewer, more severe pole crashes). If a substantial net benefit can be realized, installation of guide rails may be appropriate to consider.

Consider attenuating system for isolated poles with multiple hits and conditions in which relocation of the pole is not a viable option.

If poles are to be shielded, improvements to the existing roadway should still be considered.

Step 5: Can Improvements be Made to the Existing Roadway?

Consider additional delineation on the existing roadway such as edge lines, RPMs, post delineators, or chevrons.

In addition to delineation, consider alternative methods to keep the vehicle from leaving the roadway. Shoulder rumble strips may be effective if a paved shoulder 6 feet or wider exists. Edge rumble strips may be effective where paved shoulders are 4 feet or wider.

Other low-cost improvements to be considered are as follows:

- Advanced warning signs.
- Skid resistant pavement overlays.
- Increased highway lighting.[4]
- Peripheral transverse bar markings to slow speeds and reduce severity.

In urban areas, consider traffic calming measures to decrease speeds and reduce crash severity.

If additional improvements are possible, utility pole delineation should still be considered.

Step 6: Can Poles be Effectively Delineated?

The following guidelines for utility pole delineation should be used to apply pole delineation in cluster areas.

Marking Height

Attach markings to the utility pole at a height 4 feet above the nearest roadway surface.

[4] Lighting improvements are eligible under the highway safety improvement program; however, the municipality in which the intersection resides must agree to operate, energize, and maintain the lighting once it is in place.

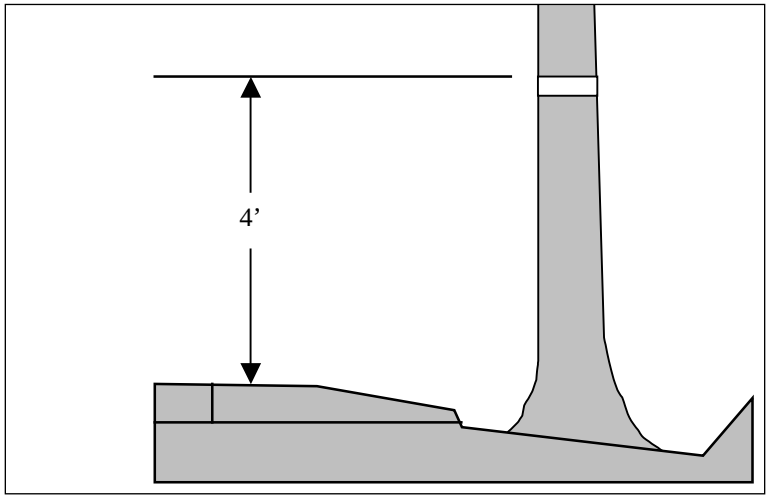


Figure 5-14: Marking Height for Utility Pole Delineation

Material and Installation

The following sheeting type is acceptable for the strip of reflective material around the utility pole:

- 3M #3811, 4 inch yellow flexible, high-intensity grade.

Install markings on every utility pole that meets the criteria set forth in these guidelines. Attach markings by wrapping sheeting around utility pole. Overlap the ends a minimum of 4 inches. No tacks, nails or staples should be used to apply tape to utility poles.

Guidelines for Use

- Horizontal Location – Place delineation on utility poles located within required clear distance as indicated in Table 5-7. The required clear distance is measured perpendicularly from the edge of the travel lane to the utility pole.

Table 5-7: Clear Distances for Utility Pole Delineation

Posted Speed Limit	Required Clear Distance
≥50 MPH	30 feet
45 MPH	22 feet
≤ 40 MPH	15 feet

- Utility Poles Behind Curbs or Existing Guide Rails – It is not necessary to delineate utility poles located behind existing guide rails. Additionally, delineation is not required for utility poles that are both 18 inches behind curbs and along roadways with a posted speed limit below 40 MPH.

- Utility Poles on Upward Slopes – It is not necessary to delineate utility poles located on upward slopes that are tall enough to eliminate the possibility of impact in the event of a crash.

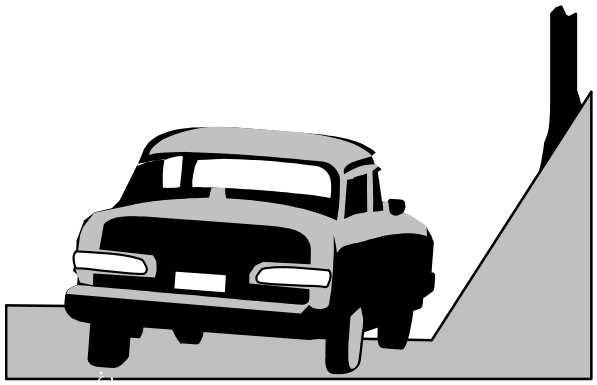


Figure 5-15: Upward Slope Where Delineation is not Needed

- Areas Where Utility Pole Line and Roadway Alignment Differ – The existing roadway delineation should be evaluated to determine if it is to standard. If it is not to standard, bring it up to standard. Never use utility pole delineation as a substitute for roadway delineation.

  In locations where the utility pole alignment differs from the horizontal roadway alignment, delineation should not be placed without coordination with the District Highway Safety Engineer. Sound engineering judgment should be used to ensure that any proposed utility pole delineation will not lead the driver away from the roadway.

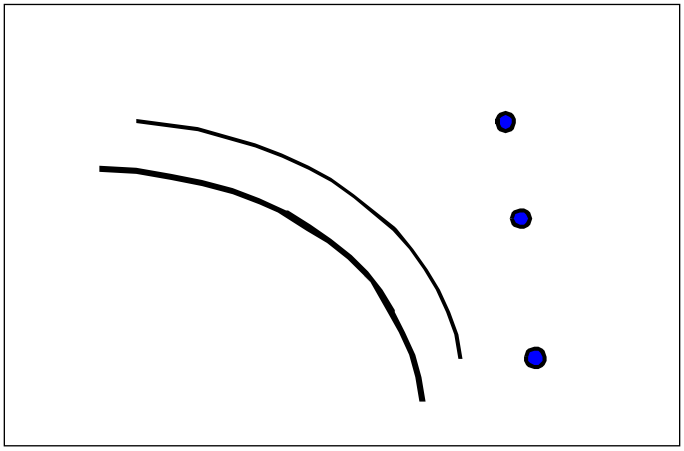


Figure 5-16: Example of Highway Section Where Utility Pole Delineation Should be Avoided

Resources

Resources that can be used to identify appropriate countermeasures for locations with at-risk utility poles can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/), NCHRP Report 500 Volume 6: *A Guide for Addressing Run-Off-Road Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v6.pdf), and the AASHTO Roadside Design Guide.

Coordination with Other Run Off the Road Improvements

In addition to burial, relocation, protection, or delineation of utility poles, oftentimes sections of highway with high numbers of utility pole crashes also have multiple crash concerns involving running off the road into other fixed objects, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns occurs in one of these sections, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, determining if additional concerns occur in the section, and integrating improvements into an overall approach.

Effectiveness

The research findings on effectiveness of utility pole treatments are listed in Table 5-8.

Table 5-8: Effectiveness of Utility Pole Treatments

Treatment	General Comment	Crash Reduction Factor
Burial of Utility	This is the most costly of solutions and should be restricted to those sections which have a very high number of pole crashes and burial will result in a significant improvement in a clear roadside. As an example, if a building line is five feet behind a pole, a certain percentage of crashes will still occur but the building will be hit with a different severity than the pole.	Dependent on the extent of clear roadside available after pole burial. The RSAP program may be used to determine the CRF for a given site. For after clear roadsides of 30 feet, burial yields a CRF of 1.0
Relocation	This usually requires right-of-way or easements. The company and PennDOT must jointly agree on the best method to acquire the land/easement.	Dependent on the before and after lateral offsets of the poles. Table 5-9 may be used to estimate the CRF based upon the difference in pole offsets from existing location to relocated location.
Delineation	Use PennDOT standards for four inch reflective tape.	0.10
Consolidation of Pole Lines to One Side	This can be combined with a relocation improvement for the remaining line to improve effectiveness.	1.0 times the proportion of poles hit on the side that the poles are to be removed.
Shoulder Rumble Strips	Can only be used when six-foot or wider paved shoulders are available in non-residential areas.	0.20 of all run-off-road crashes, including pole crashes.
Impact Attenuators	Only acceptable for highly vulnerable sign poles in low speed, less than 40 MPH areas where poles cannot be relocated and sufficient space is available for attenuator.	1.0 in terms of preventing deaths.

Table 5-9: Crash Reduction Factors for Pole Line Relocations

	Pole line After Relocation (ft)								
Pole Line Before Relocation (ft)	**6**	**8**	**10**	**12**	**15**	**17**	**20**	**25**	**30**
2	0.50	0.58	0.64	0.68	0.72	0.74	0.77	0.80	0.82
3	0.35	0.46	0.53	0.58	0.64	0.67	0.70	0.74	0.77
4	0.22	0.35	0.44	0,50	0.57	0.60	0.65	0.69	0.73
5	0.11	0.26	0.36	0.43	0.51	0.55	0.59	0.65	0.69
6	-	0.17	0.28	0.36	0.45	0.49	0.54	0.61	0.65
7	-	0.08	0.20	0.29	0.39	0.44	0.50	0.57	0.62
8	-	-	0.13	0.23	0.33	0.39	0.45	0.53	0.58
10	-	-	-	0.11	0.23	0.29	0.37	0.45	0.52
11	-	-	-	0.05	0.18	0.25	0.33	0.42	0.49
12	-	-	-	-	0.14	0.20	0.29	0.39	0.46
13	-	-	-	-	0.09	0.16	0.25	0.35	0.43
14	-	-	-	-	0.04	0.12	0.21	0.32	0.40
15	-	-	-	-	-	0.08	0.17	0.29	0.37

5.5.8 Guide Rail Crashes

Guide rail crashes, injuries, and fatalities have frequencies, severities, and characteristics associated with the impact speed of vehicles coupled with the type and condition of guide rail, the type of area (urban/rural), and time of occurrence (day or night). The primary countermeasures to reduce the level or severity of crashes associated with guide rail are:

- Eliminating or upgrading of non-350 compliant or low guide rail.
- Installation of guide rail to shield fixed objects or reduce severity.
- Delineation of guide rail to reduce the potential for night crashes.

As a first step, before enhancements to existing guide rail systems are considered, the feasibility of removing deficient guide rail should be considered. In doing so, it is important that the exposed cross slopes be modified if necessary to conform to design requirements that do not require guide rail. In addition, exposed fixed objects within the recovery zone need to be addressed.

Countermeasure #1 –Eliminating or Upgrading Non-350 Compliant Guide Rail

Description

The two major types of guide rails to consider for upgrading are:

- Strong post cable guide rail.
- Type 2S guide rail that is 27¾ inches or less in height.

The Roadway Management System (RMS) identifies guide rail by type and height differences compared to the standard height. This data can be merged with crash data for instances when crashes with guide rail is identified as the first harmful event. For comparison purposes, and to ensure better uniformity of crashes between different guide rail systems, only those crashes in rural areas on 55 MPH highways involving passenger cars where the first harmful event was hit guide rail were used.

When evaluating non-compliant 350 guard rail systems, first consideration should be given to eliminating the need for a guide rail. Eliminating guide rail can be considered if two conditions are met:

- The exposed final back slopes do not require guide rail using DM-2 criteria for guide rail installations.
- Fixed objects are removed from the recovery zone.

Strong post cable and Type 2S strong post that is less than 27¾ inches in height are the predominant types of guide rail to consider for removal or upgrading. Due to the reduced potential for a fatality, the desirable replacement is Type 2W, weak post W-beam, if an adequate clear zone exists behind the guide rail for deflection. Type 2S of deficient height may be modified to a Type 2S of standard height if the modification can be accomplished with minimal adjustments to the existing guide rail system.

Candidate Guide Rail Upgrade Systems

The recommended candidate guide rail section crash threshold for upgrades is:

- Urban or rural strong post cable or Type 2S less than 27¾ inches in height systems that have five or more crashes in 1,000 feet in 5 years.

Guide rail systems that meet this threshold need to be field reviewed to determine the type of guide rail upgrade or replacement that should be provided. In addition, a review of the physical characteristics of the section and the crash data also is needed to determine if other physical improvements need to be considered (e.g., curve improvements as described in the curve section, shoulder improvements, edge rumble strips).

Resources

Resources that can be used to identify appropriate countermeasures for sections with high frequencies of guide rail crashes can be found at the FHWA road departure safety website

(http://safety.fhwa.dot.gov/roadway_dept/), NCHRP Report 500 Volume 6: *A Guide for Addressing Run-Off-Road Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v6.pdf). The PennDOT Roadway Construction Standards RC-52M and RC-53M provide details regarding Type 2S and 2W requirements.

Coordination with Other Roadway Improvements

In addition to guide rail system upgrades, oftentimes sections with high numbers of crashes also have multiple crash concerns involving running off the road, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

Upgrading guide rails will not reduce crashes; it will increase the potential for reducing the severity of crashes. The reduction in severity and the reduced potential for a fatality may be estimated by taking the number of guide rail crashes that have occurred within the section over the past 5 years and multiplying it by the difference between the average crash costs of the deficient system and a standard system. The fatality reduction may be estimated using the same method, except using the differences in fatalities per 1,000 crashes in lieu of average crash costs.

Countermeasure #2 – Installation of New Guide Rail Sections or End Treatments to Reduce Severity

Description

Sites where the installation of guide rails to reduce severity may be beneficial include:

- Unprotected bridge ends.
- High or very steep embankment slopes where the severity of traversing the slope is more significant than striking a guide rail.
- Unprotected deep bodies of water in close proximity to the roadway.
- In rare instances, sections with numerous trees and/or poles where the frequency and severity of crashes with the trees or poles are collectively substantially greater than the increased frequency and severity of guide rail crashes.

The RSAP program should be run to compare the existing condition to the proposed guide rail condition to determine if a substantial net benefit will occur should the guide rail be installed.

Candidate Sites

Those unprotected bridge ends that are located on higher classification routes, which tend to have higher speeds and higher traffic volumes, have a higher exposure to being struck.

The recommended candidate bridge ends for guide rail end treatments from the crash data system use 10 years rather than 5 years of data since these crashes are rare events. They have the following recommended crash threshold:

- Urban or rural unprotected bridge ends that have two or more crashes in 1,000 feet in 10 years.

Candidate sections of highway with high or steep slopes and unprotected bodies of water need to be identified through visual observations of the roadway.

Guide rail systems that meet this threshold need to be field reviewed to determine the type of guide rail upgrade that should be provided. In addition, a review of the physical characteristics of the section and the crash data also is needed to determine if other physical improvements need to be considered (e.g., curve improvements as described in the curve section, shoulder improvements, edge rumble strips).

Resources

Resources that can be used to identify appropriate countermeasures for sections with high frequencies of guide rail crashes can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/), NCHRP Report 500 Volume 6: *A Guide for Addressing Run-Off-Road Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v6.pdf). The PennDOT Roadway Construction Standards RC-50M, RC-52M, and RC-53M provide details regarding transitions to bridge ends and Type 2S and 2B requirements.

Coordination with Other Roadway Improvements

In addition to guide rail system upgrades, oftentimes sections with high numbers of crashes also have multiple crash concerns involving running off the road, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

Installing guide rail end or full sections will not reduce crashes; it may increase the potential for reducing the severity of crashes. The reduction in severity and the reduced potential for a fatality may be estimated by taking the number and type of crashes that have occurred within the section over the past 10 years and multiplying it by the difference between the average crash costs of the existing condition and a proposed guide rail system. The fatality reduction may be estimated using the same method except using the differences in fatalities per 1,000 crashes in lieu of average crash costs. An alternate method is to use the RSAP program to estimate net benefits.

Countermeasure #3 – Installation of Delineation on W-Beam Guide Rail Sections

Description

Delineators positioned within the web of a W-beam or 16 inches above the guide rail section.

Candidate Sites

Candidate sites for placement of delineation within or directly above existing guide rail systems have the following recommended crash threshold:

- Urban or rural sections with four or more night guide rail crashes in 1,000 feet in 5 years.

Guide rail systems that meet this threshold need to be field reviewed to determine the type of guide rail and ability to place delineation within the web of the W-Beam. In addition, a review of the physical characteristics of the section and the crash data also is needed to determine if other physical improvements need to be considered (e.g., curve improvements as described in the curve section, shoulder improvements, edge rumble strips).

Resources

Resources that can be used to identify appropriate countermeasures for sections with high frequencies of guide rail crashes can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/), NCHRP Report 500 Volume 6: *A Guide for Addressing Run-Off-Road Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v6.pdf). PennDOT Publication 72M, *Standards for Roadway Construction*, RC-50M, RC-52M, and RC-53M provide details regarding transitions to bridge ends, Type 2S and 2B requirements. PennDOT Traffic Control Standards, TC-8604, provide details on the reflectors.

Coordination with Other Roadway Improvements

In addition to guide rail system delineation, oftentimes sections with high numbers of night crashes also have multiple crash concerns involving running off the road, slippery approaches, or higher frequencies of other crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

Installing of delineation within the web of W-Beam or directly above the guide rail is estimated to reduce night guide rail crashes by 10 percent.

5.5.9 Head-On Crashes

Head-on and opposing flow sideswipe crashes, injuries, and fatalities have frequencies, severities, and characteristics associated with the impact speed of vehicles coupled with the type of highway and AADT, and the type of area (urban/rural), and time (day or night) of occurrence. The primary countermeasures to reduce the frequency and level or severity of crashes associated with head-on crashes are as follows:

- Install centerline rumble strips (CLRS) on higher volume, two-lane highways.
- Install either wider centerlines or peripheral transverse markings in vulnerable areas where CLRS are not appropriate.
- Install weak post cable barrier systems in medians of divided highways with head-on crash frequencies or probabilities.

Countermeasure #1 – Install Centerline Rumble Strips (CLRS)

Description

CLRS may be installed on two-lane roads with pavement widths of 20 feet or greater. They can also be applied on undivided multi-lane roads.

Candidate CLRS Sections

The recommended candidate centerline rumble strip crash thresholds are:

- 20-foot or greater width two-lane and undivided four-lane highways with AADT greater than 1,500.
- Highways with less than 1,500 AADT and three or more head-on or opposing flow sideswipe crashes in 15,000 feet in 5 years.
- New pavement less than one-year-old, minimum 1½ inch depth.
- HSTOD should be consulted before CLRS are installed on highways with travel lane widths less than 10 feet.

Highway sections that meet these thresholds need to be field reviewed to confirm the following:

- The type of pavement is a bituminous wearing course and a BCBC base or better.
- Pavement is in sufficiently good condition, as determined by the District Pavement Engineer, to effectively accept the milling process without raveling or deteriorating. Otherwise the pavement needs upgraded prior to milling.
- Existing concrete pavements do not have overlays less than 2.5 inches in depth.

Retrofitting CLRS

If it is desired to retrofit CLRS on existing pavement, the pavement should be in sufficiently good condition, as determined by the District Pavement Engineer, to effectively accept the milling process without raveling or deteriorating the pavement. Otherwise the pavement needs to be upgraded prior to milling CLRS.

Utilize the following table when accounting for pavement age. In all cases, sound engineering judgment should be used when determining if the condition of the pavement is acceptable for the installation of CLRS.

Pavement Age	Conditions
< 1 year old	Ideal for placement of rumble strips
1-3 years old	Applicable for placement of rumble strips
3-5 years old	Prior to placing rumble strips: • Crack seal and/or place a seal coat treatment
> 5 years old	Prior to placing rumble strips: • Look for distress and cracking • Verify OPI is in good range (>85) • Consult with HSS/BOMO, Dist. Pavement Engineer, Publication 242 • Crack seal and/or place a seal coat treatment

Note that it is expected that in instances where rumble strips are to be filled-in and re-milled, there will be an added expense to the project. To cover these extra costs, Highway Safety Improvement Program (HSIP) funds can be applied to the projects, as rumble strips are an approved use of these funds.

In instances where the mainline will be overlaid, a series of treatments and guidance is currently under development and will be included in subsequent editions of this manual.

Design details for centerline rumble strips are provided in Publication 72M, *Standards for Roadway Construction*, RC-22M.

In addition, the following guidelines should be followed:

- CLRS should not be installed on bridge decks.
- CLRS may be installed in passing zones. The depth of rumble strips may be decreased from ½ inch to ⅜ inch in the passing zone area. If CLRS are discontinued through a passing zone area, engineering judgment is to be used to establish the end points and beginning points of the CLRS.
- CLRS are to be broken at intersections. CLRS may also be broken for driveways based upon engineering judgment. If broken, CLRS should be discontinued 25 feet from the point of curvature of any such highway or driveway.
- Milling of CLRS should be coordinated with the traffic line painting program to avoid milling newly applied traffic lines and installing new yellow lines within approximately 2 weeks of CLRS completion.
- Potential noise impacts need to be considered when contemplating the installation of CLRS in residential or built up areas.

Centerline Rumble Strips (CLRS) in Conjunction with Edgeline Rumble Strips (ERS)

While the crash reduction potential of CLRS and ERS separately significant at this time, we have insufficient knowledge and experience with the combined impact of both centerline and edgelines on the same project to warrant full deployment. Of primary concern is the tight travel

lane restrictions and the more frequent departures to one of the rumble strips. However, to gain that knowledge and experience, you are encouraged to incorporate centerline rumble strips on roadways with existing edgeline rumble strips utilizing engineering judgment on a pilot basis.

Consider using CLRS in conjunction with ERS on two-to-four lane highways (except Interstate & Expressways) with 11 feet or greater lane width and 4-6 feet of paved shoulder.

Deviation from the above specifications and guidelines may be considered by the District: however, they must be approved by HSTOD prior to being implemented.

Resources

Additional resources that can be used to identify appropriate countermeasures on sections with high frequencies of head-on and opposing flow sideswipe crashes can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/) and NCHRP Report 500 Volume 4: *A Guide for Addressing Head-On Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v4.pdf).

Coordination with Other Roadway Improvements

An ideal time to place CLRS is in conjunction with an overlay project.
In addition to CLRS, oftentimes sections with high numbers of head-on crashes also have multiple crash concerns involving running off the road, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

Installing centerline rumble strips is estimated to reduce head on and opposing flow crashes by 25 percent.

Countermeasure #2 – Countermeasures for Head-On Collisions in Urban Areas

Description

There are three potential countermeasures to consider for head-on collisions in urban areas:

- CLRS if noise issue can be addressed.
- Separation of opposing lanes by pavement markings if sufficient lateral clearance is available.
- Wider double yellow centerlines (6 or 8 inch) or dual RPMs at an approximate 50 foot spacing 6-12 inches beyond standard double yellow centerlines (experimental, not proven).

Candidate Sites for Urban Head-On Collision Countermeasures

The recommended candidate threshold for urban head-on countermeasures is:

- Urban highway sections with five or more head-on or opposing flow sideswipe crashes in 15,000 feet.

Sections that meet this threshold need to be field reviewed to determine the type of countermeasure best able to reduce head-on crash potential. In addition, a review of the physical characteristics of the section and the crash data is needed to determine if other physical improvements need to be considered.

Resources

Resources that can be used to identify appropriate countermeasures on sections with high frequencies of head-on crashes can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/), the AASHTO Roadside Design Guide, and NCHRP Report 500 Volume 4: *A Guide for Addressing Head-On Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v4.pdf).

Coordination with Other Roadway Improvements

In addition to improvements to reduce the potential for head-on crashes, oftentimes sections with high numbers of crashes also have multiple crash concerns involving running off the road, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

Installing CLRS will reduce head-on and opposing flow sideswipe crashes by an estimated 25 percent. Increasing the space and creating a buffer between opposing lanes will also decrease the potential for head-on crashes. Reductions of up to 50 percent for four-foot buffers have been found, but there are insufficient evaluations to validate these levels. Increases in centerline pavement markings from 4 inches to 6 or 8 inches have been widely accepted by drivers. However, there are no data that indicate that wider markings reduce crashes.

Countermeasure #3 – Installation of Weak Post Cable Guide Rail Systems to Reduce Cross-Over Crashes.

Description

Cross-over crashes resulting in high-speed head-on crashes are rare, but usually very severe, events. The width of the median, AADT, speed limit, and location along the highway section can increase or decrease the probability that a cross-over crash will occur.

Candidate Sites for Cable Guide Rail Placement

The recommended candidate crash threshold level for the placement of cable guide rail to prevent crossover crashes is:

- Urban or rural sections with medians and three or more cross-over crashes in 15,000 feet in 5 years.

Highway sections that meet this threshold need to be field reviewed to determine the type and width of median and potential median barrier to place within the median. In addition, a review of the physical characteristics of the section and the crash data is needed to determine if other physical improvements need to be considered (e.g., curve improvements as described in the curve section, shoulder improvements, edge rumble strips). Please refer to Publication 13M, *Design Manual 2*, Chapter 12.5.D and Table 12.9 for specific placement and cable median barrier system selection.

Resources

Resources that can be used to identify appropriate countermeasures on sections with high frequencies of guide rail crashes can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/), the AASHTO Roadside Design Guide, NCHRP Report 500 Volume 6: *A Guide for Addressing Run-Off-Road Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v6.pdf), and the PennDOT Publication 72M, *Standards for Roadway Construction*, RC-50M and RC-52M.

Coordination with Other Roadway Improvements

In addition to guide rail system installation, oftentimes sections with cross-over crashes may also have multiple crash concerns involving running off the road, slippery approaches, or higher frequencies of other crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

Installing a weak post cable system may prevent cross-over crashes, but increase the number of crashes with a guide rail. RSAP may be run to determine the net benefit of placing a guide rail in the median.

5.5.10 Rear-End Crashes

Rear end segment crashes, injuries, and fatalities have frequencies, severities, and characteristics associated with the impact speeds of vehicles coupled with the type of highway and AADT, and the type of area (urban/rural), and time of occurrence (day or night). The primary countermeasures to reduce the frequency and level or severity of crashes associated segment-based rear end crashes are:

- Install DOT markers on highways which have a number of rear-end crashes involving tailgating.
- Convert two-lane highways with high numbers of rear-end crashes to three lanes, or convert undivided lower volume four-lane highways to three lanes.

Countermeasure #1 – Install DOT Markers

Description

- DOT markers are considered an experimental countermeasure. It is strongly recommended that Districts consult with HSTOD when considering the application of DOT markers at a specified location. Districts may consider deviation from the provisions, specifications, and guidelines below. However, these deviations require approval by HSTOD prior to implementation.

- The DOT markings have mixed results in terms of assisting the motorist in establishing a safe following distance. Use this treatment in areas where there is a high concentration of aggressive driving or tailgating-related crashes. Markings are spaced such that safe distance is kept between vehicles when a minimum of two markings separates them. Safe distance is defined based on a 2 second following rule. Figure 5-17 provides graphical explanation of the 2-second rule when applied to the spacing and layout of the DOT markings. Areas with significant grade differences should generally be avoided.

- Marking – The marking consists of a series of ellipses ("DOTs") marked in all lanes at equal spacing according to the posted roadway speed (see Marking Spacing (S) in the table in Figure 5-18). The marking is to be centered in the travel lane. The ratio of width to height for the elliptical mark is 1:3 based on standard oblong pavement markings referenced in the MUTCD. Markings should be applied according to Figure 5-19.

- Marking Spacing (S) – The pavement markings should be placed such that the spacing is according to the table in Figure 5-18. Spacing is based on posted speed for any given roadway.

- Pattern Spacing (X) – The distance between successive series of DOTs is also based on posted speed and can be found in the table in Figure 5-18. This distance should be adjusted as appropriate to meet field conditions.

- Signing – A minimum of three signs should be placed in accordance with PennDOT Publication 108, *Sign Foreman's Manual*:

  1. "DON'T TAILGATE" – 1,000 feet before the first pattern.
  2. "KEEP MIN 2 DOTS APART" – at the second marking in each set of "DOTs."[5]
  3. "MAINTAIN SAFE FOLLOWING DISTANCE" – 1,000 feet after the last pattern.

  For signing layout, see Figure 5-20.

- Total Number of Patterns – At a minimum, two patterns should be used in the application of the DOT treatment. If this treatment needs to be applied over an extended area, additional patterns can be included provided the pattern spacing (X) follows Figure 5-20.

[5] Optional sign legend can read "KEEP MIN ONE SPACE APART"

- Highway Capacity (Traffic Volume) – Driver adherence to the DOT treatment may reduce or limit the highway capacity at locations where it is applied. On higher volume roadways, this can cause congestion during peak volume periods. For this reason, capacity analysis is recommended. If the peak hour volume of a roadway is expected to exceed the maximum capacity (c) calculated in the table in Figure 5-21, the DOT treatment should not be installed. The calculation of maximum capacity is described in Figure 5-21 and 5-22.

- The DOT treatment is most effective when it is accompanied by visible law enforcement. It is recommended that enforcement agencies provide at least 10 hours per week of visible enforcement for maximum effectiveness.

- DOT pavement markings can be installed via projects initiated exclusively for this purpose.

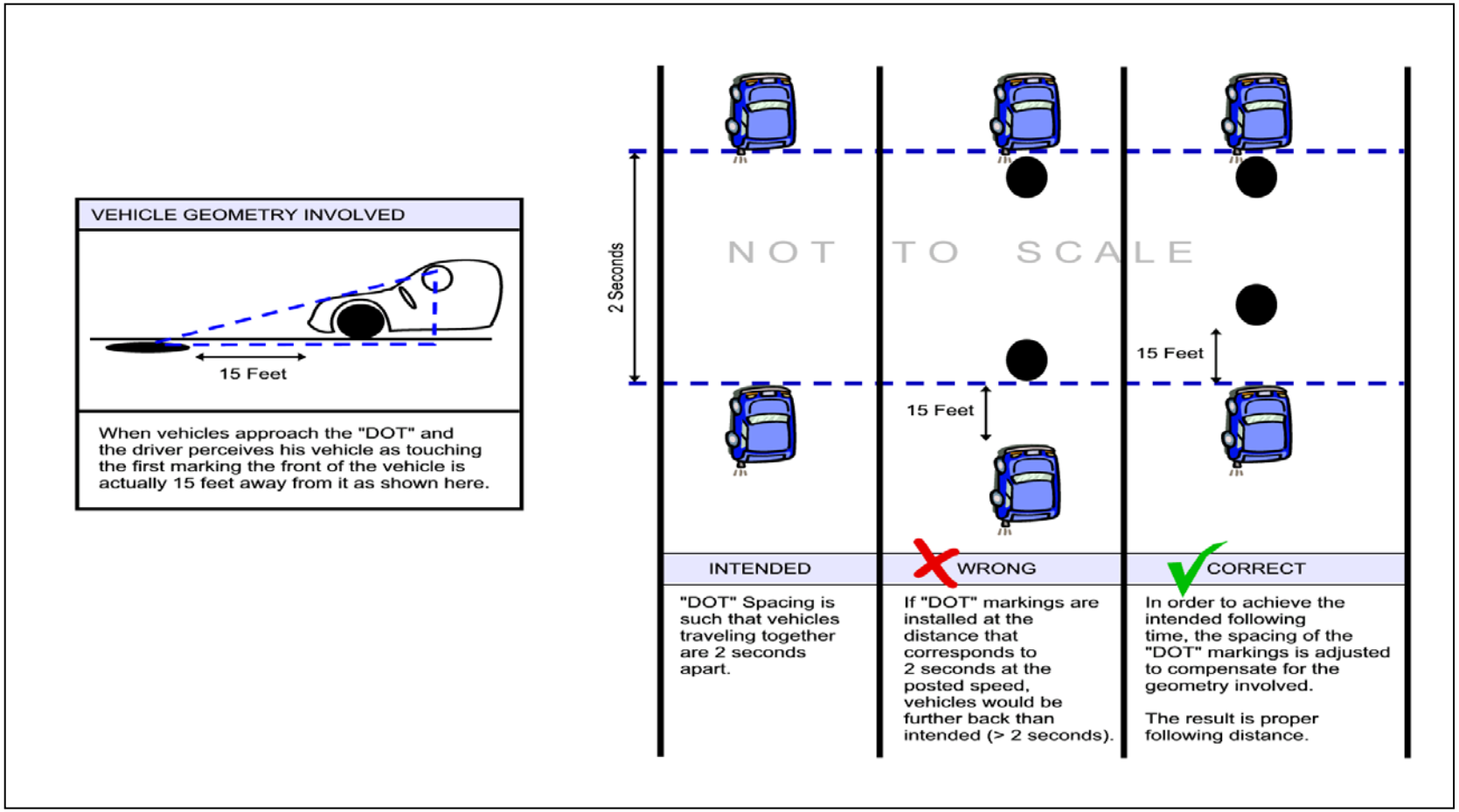


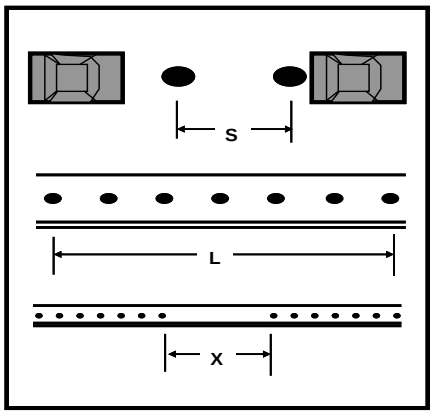
Figure 5-17: Understanding DOT Spacing

Pennsylvania "DOT" Tailgating Treatment

Comprehension Time :	5 sec
P/R Time :	2.5 sec
Adjustment Time :	20 sec
Following Time :	2 sec
Effective Time :	60 sec
Vehicle Correction :	15 ft

Table 1 - Spacing and Length

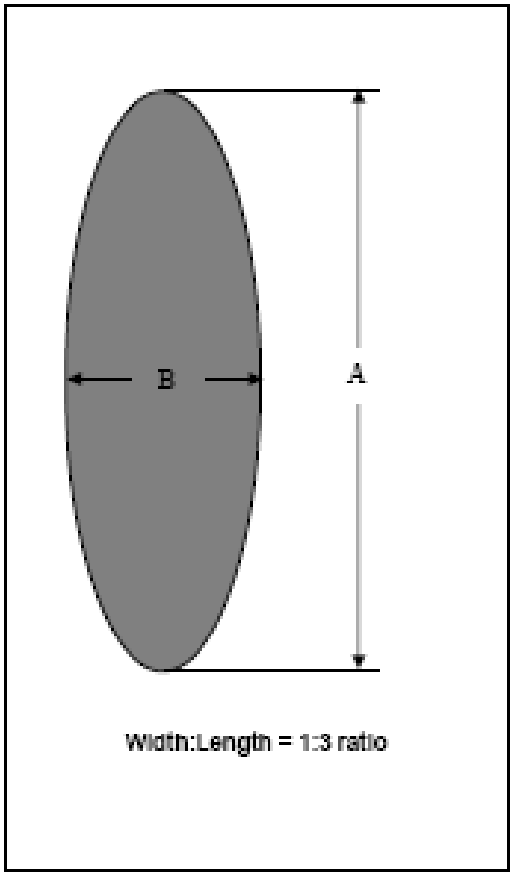
Posted Speed (mph)	Posted Speed (fps)	Distance Travelled (ft)	S Marking Spacing (ft)	Minimum # Markings in Pattern	L Min Pattern Length (ft)	X Pattern Spacing (ft)
25	37	73	60	18	1020	2200
30	44	88	75	18	1275	2640
35	51	103	90	17	1440	3080
40	59	117	105	17	1680	3520
45	66	132	115	17	1840	3960
50	73	147	130	17	2080	4400
55	81	161	145	17	2320	4840
60	88	176	160	17	2560	5280
65	95	191	175	16	2625	5720



Definitions

Comprehension Time *(sec)*	Amount of Time required for driver to comprehend the meaning of the markings.
P/R Time *(sec)*	Indicates Time required for an average driver on target roadway to percieve that an action is required and to begin that action. Typical Value is 2.5 seconds.
Adjustment Time *(sec)*	Amount of Time provided for the following driver to gauge and adjust the Distance between their vehicle and the lead vehicle.
Following Time *(sec)*	The enforcable following time for target roadway. Vehicles should travel a Distance apart from each other such that this Time has passed for a following vehicle to reach the location of the lead vehicle at Time t_0.
Effective Time *(sec)*	Length of Time for which the pattern maintains an effect on the driver. Relates to how long the driver can maintain the Distance corresponding to the *Following Time* after leaving the pattern.
Posted Speed *(fps)*	Relates to the Posted Speed Limit on the target roadway.
Distance Traveled *(ft)*	At the given *Posted Speed*, this indicates the Distance the vehicle will travel in the *Following Time*. Value is *Posted Speed (fps)* times *Following Time (sec)*.
Marking Spacing, S *(ft)*	This Distance reflects the spacing between two pavement markings within the pattern such that vehicle will traverse two markings in the *Following Time*. Value is equal to *Distance Traveled (ft)* rounded to the next 5 foot length less the *Vehicle Correction*
Vehicle Correction *(ft)*	Distance vehicle must be away from the nearest DOT to allow the DOT to be visible from the drivers eye position. Value assumed to be 15 ft measured from bumper to edge of DOT marking.
# Markings in Pattern	The number of markings at the *Marking Spacing* that can be placed in the length of roadway required to travel at the Posted Speed for the total required Comprehension, P/R, and Adjustment Times. Value is that length (ft) divided by *Marking Spacing (ft)* rou
Pattern Length, L *(ft)*	Distance from the center of the first marking in the pattern to the center of the last marking in the pattern. Value is the *Number of Markings*, less one, times *Marking Spacing*.
Pattern Spacing, X *(ft)*	Distance a vehicle will travel between Marking Patterns. Relates to *Effective Time* such that the effect of the previous set of markings will just begin to fade as driver encounters the next set. Value is *Posted Speed (fps)* times *Effective Time (sec)*.

Figure 5-18: DOT Spacing and Length



	A (ft)	B (ft)	Area (sq ft)
Two Lane Highway	7.5	2.5	14.71
Interstate	12	4	37.68

Figure 5-19: DOT Typical Marking

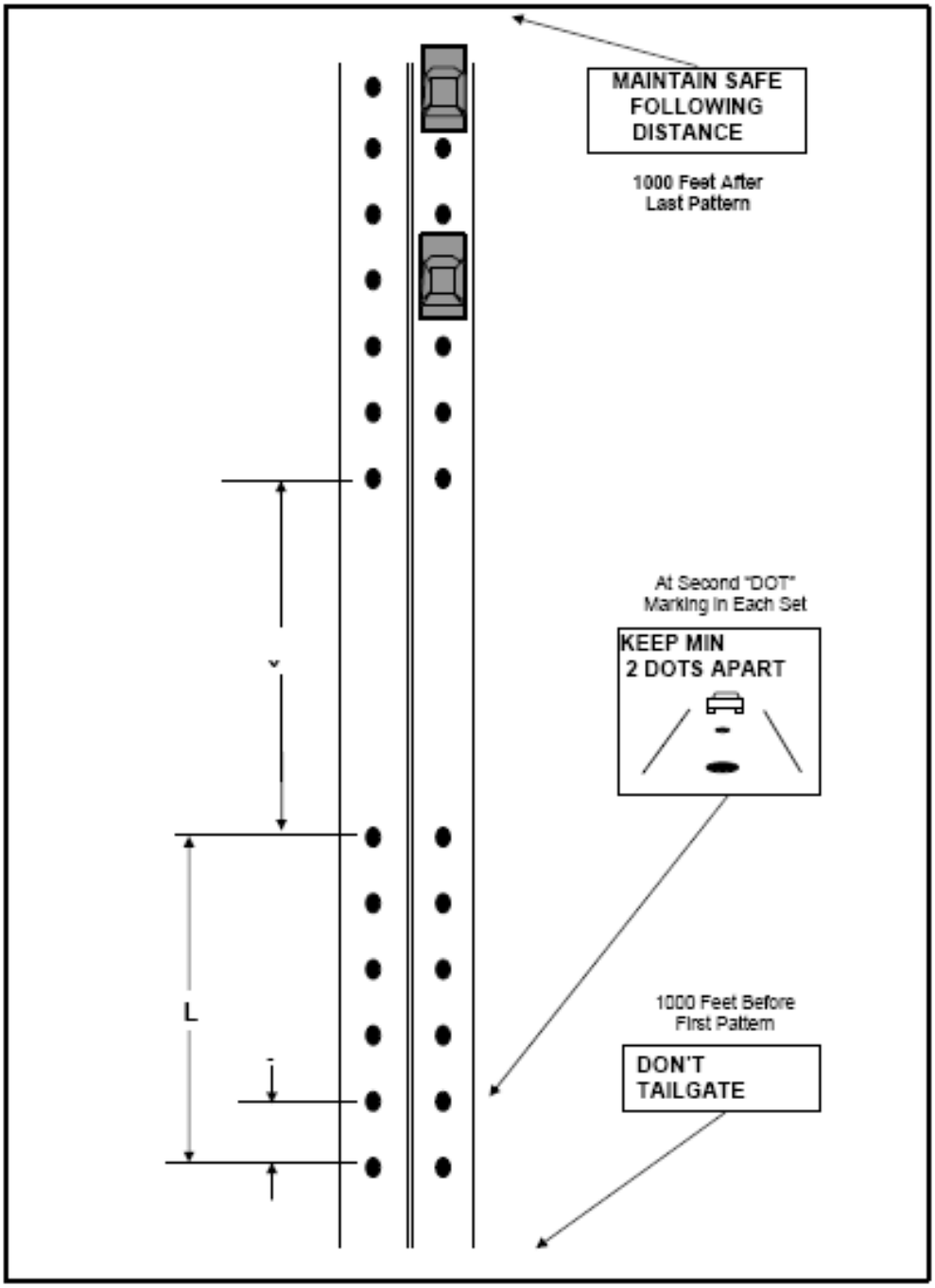


Figure 5-20: DOT Sign and Pattern Layout

Pennsylvania "DOT" Tailgating Treatment

Capacity Calculations

Flow Rate (veh/hr) = Density (veh/mi) * Average Travel Speed (miles / hr)

Capacity adjustment factor = **0.xx** given ___% trucks and ____ terrain
(from capacity adjustment table, page 7)

Max Capacity = **0.xx** of Flow Rate (capacity adjustment factor)

Vehicle Correction : 15 ft

Maximum Capacity (C) = (Flow Rate) * (Capacity adjustment factor)

Assumption: Vehicle spacing will equal the spacing of the markings + 15 feet (see figure 1, page 2)

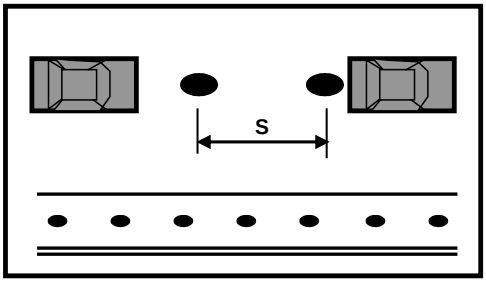


Table 2 - Spacing and Maxmimum Capacity [1]

Posted Speed (mph)	S Marking Spacing (ft)	VS Vehicle Spacing (ft)	D Density (veh/mi/ln)	V Flow Rate (Veh/hr)	C Maximum Capacity (Veh/hr/ln)
25	60	75	70.4	1,760	see formula
30	75	90	58.7	1,761	
35	90	105	50.3	1,761	
40	105	120	44.0	1,760	
45	115	130	40.6	1,827	
50	130	145	36.4	1,820	
55	145	160	33.0	1,815	
60	160	175	30.2	1,812	
65	175	190	27.8	1,807	

[1] - Capacity given is reduced to account for less than ideal geometric conditions, variations in travel speed, and the presence of heavy trucks

Definitions

Posted Speed *(mph)*	Relates to the Posted Speed Limit on the target roadway.
Density, D *(veh/mile)*	The average vehicle spacing in the traffic stream, which is given in terms of vehicles per mile, is known as the density. It is calculated by dividing 5,280 by the *vehicle spacing (ft)* between each vehicle in the traffic stream.
Marking Spacing, S *(ft)*	This Distance reflects the spacing between two pavement markings within the pattern such that vehicle will traverse two markings in the *Following Time*. Value is equal to *Distance Traveled (ft)* rounded to the next 5 foot length less the *Vehicle Correction.* For the purposes of the calculation of the maximum capacity, it was assumed that the marking spacing plus the vehicle correction (15 feet) is equal to the vehicle spacing.
Vehicle Correction *(ft)*	Distance vehicle must be away from the nearest DOT to allow the DOT to be visible from the drivers eye position. Value assumed to be 15 ft measured from bumper to edge of DOT marking. (see Figure 1, page 2 for a graphical explanation)
Flow Rate, V *(veh/hr)*	The flow rate (veh/hr) is equal to the *Density (veh/mile)* multiplied by the *Average Travel Speed (mph)*. For the purposes of the calculation of the maximum capacity, it was assumed that *Average Travel Speed (mph)* is equal to the posted speed limit.
Maximum Capacity, C *(veh/hr/lane) and the capacity adjustment factor*	The maximum capacity is equal to the *Flow Rate (veh/hr)* mulitiplied by the *capacity adjustment factor* and is in terms of vehicles per hour **per lane**. The minimum 10% reduction in capacity (0.90 capacity adjustment factor) is needed to account for the less than ideal geometric conditions that are often encountered in the field. The reduction will also account for variations in travel speed that are likely to occur because of motorists' unfamiliarity with the "dot" tailgating treatment. Any additional reduction in capacity will account for the presence of a significant number of heavy trucks in the traffic stream. Please see the capacity adjustment table (page 7) for the calculation of the capacity adjustment factor.

Figure 5-21: DOT Spacing and Maximum Capacity

Pennsylvania "DOT" Tailgating Treatment

Capacity Adjustment Table

Capacity = (Flow Rate) * (Capacity adjustment factor)

Flow Rate should be multiplied by the appropriate factor in the table below to account for the presence of trucks in the traffic stream

Assume minimum reduction of 10% (90% capacity adjustment factor) to account for less than ideal geometric conditions and variations in travel speed

When selecting the appropriate capacity reduction factor, it is very important to correctly choose the terrain. As defined in the Highway Capacity Manual, **level terrain** causes *heavy trucks to operate at nearly the same speeds as passenger cars*. **Rolling terrain** causes heavy trucks to *reduce their speeds substantially lower than those of passenger cars.* **Mountainous terrain** causes heavy trucks to *operate at crawl speeds for extended periods of time.*

Given the above definitions, level terrain should be selected for the majority of the roadways, rolling terrain should only be selected for hilly areas where heavy trucks travel at significantly lower speeds than passenger cars, and mountainous terrain should be used infrequently and only at those locations with the most severe terrain.

Capacity adjustment factor:

	Percent Trucks									
Terrain	**5%**	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**	**45%**	**≥ 50%**
Level	0.90	0.90	0.90	0.90	0.89	0.87	0.85	0.83	0.82	0.80
Rolling	0.90	0.87	0.82	0.77	0.73	0.69	0.66	0.63	0.60	0.57
Mountainous	0.85	0.74	0.66	0.59	0.53	0.49	0.45	0.42	0.39	0.36

Capacity adjustment factor is equal to the HV factor in the Highway Capacity Manual (HCM) 2000.
HV Calculation from the HCM 2000 pg 21-7 (equation 21-4) and pg 23-8 (equation 23-3).
E_T factor is taken from Exhibits 21-8 and 23-8 on pages 21-8 and 23-9 of HCM 2000.

HV Factor calculation is shown in this table:

		Percent Trucks									
Terrain	**E_T**	**5%**	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**	**45%**	**≥ 50%**
Level	1.5	0.97561	0.952381	0.930233	0.909091	0.888889	0.869565	0.851064	0.833333	0.816327	0.8
Rolling	2.5	0.930233	0.869565	0.816327	0.769231	0.727273	0.689655	0.655738	0.625	0.597015	0.571429
Mountainous	4.5	0.851064	0.740741	0.655738	0.588235	0.533333	0.487805	0.449438	0.416667	0.38835	0.363636

Note: This is the same as the capacity adjustment factor for values less than 0.9.

Figure 5-22: DOT Capacity Adjustment Table

Candidate DOT Treatment Sections

The recommended candidate DOT treatment crash thresholds are:

- Rural 2-lane highways with AADT less than 8,000 and 50 or more segment-based rear-end crashes in 6,000 feet in 5 years.
- Rural 2-lane highways with AADT less than 18,000 and 75 or more segment-based rear-end crashes in 6,000 feet in 5 years.

Highway sections that meet these thresholds need to be field reviewed to determine the following:

- The type and condition of the pavement surface and ability to place a marker on it.
- The frequency and spacing of any traffic signals in the section. If traffic signals are present, the placement of DOT markings encompassing traffic signals is not advisable due to the variable speeds within the vicinity of the signal.
- The amount of change in average speed within the section. If there are significant changes, HSTOD should be consulted regarding the advisability of using DOT markers.

In addition, the District should obtain input from police organizations that patrol the section of highway, particularly regarding their viewpoints on patrolling the section and using the markings to reduce tailgating crashes. A capacity analysis of the section also should be done to determine if congestion may occur if the markers are installed.

Resources

There are no other resources available regarding use of DOT markers.

Coordination with Other Roadway Improvements

In addition to DOT markers, oftentimes sections with high numbers of rear-end crashes also have multiple crash concerns involving turning vehicles, running off the road, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Countermeasure #2 – Conversion of Two-Lane Highway to Three Lanes and Conversion of Low Volume Four-Lane Highways to Three Lanes

Description

This countermeasure involves converting wide two-lane sections of highway with space to add a center lane and a substantial number of crashes involving rear-end and turning crashes into a

three-lane highway with the center lane being a turning lane. A similar conversion on low volume, four-lane, undivided highways involves conversion to two through lanes and a center left turn lane.

Over the past decades, PennDOT has extensively implemented these types of improvements and candidate sections of highway that meet these conditions are rare. The data systems do not accurately identify the number of through travel lanes, so the identification of potential sections to consider converting must be accomplished by observation.

Candidate Lane Conversion Treatment Sections

The recommended candidate lane conversion treatment crash thresholds are:

- Wide (minimum 30 feet) 2-lane highways with 50 or more segment-based rear-end or other crashes involving a turning vehicle in 6,000 feet in 5 years.
- Four-lane undivided highways (35 to 48 feet in total width) with AADT less than 18,000 and 75 or more segment-based rear-end crashes or other crashes involving a turning vehicle in 6,000 feet in 5 years.

Highway sections that meet these thresholds need to be field reviewed to determine:

- The type, width, and condition of the pavement surface and ability to modify lane configurations.
- The frequency and spacing of any traffic signals in the section. If traffic signals are present, particularly on four-lane sections, a thorough capacity analysis is needed to determine if conversion will create an unsatisfactory level of service.

In addition, the District should obtain input from police organizations that patrol the section of highway, particularly regarding their viewpoints on patrolling the section and modifying the lane configuration in terms of reducing turning and rear-end crashes. A capacity analysis of the section should also be done to determine if congestion may occur if the conversion is made.

Coordination with Other Roadway Improvements

In addition to converting lane configurations, oftentimes sections with high numbers of rear-end crashes and crashes involving turning vehicles also may have concerns regarding running off the road, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

The effectiveness of converting wide two-lane highways to three lanes and converting low volume four-lane highways to three lanes is a 30 percent reduction in all section crashes.

5.5.11 Wet Pavement Crashes

Wet pavement crashes, injuries, and fatalities have frequencies, severities, and characteristics associated with the speed of vehicles coupled with the type of highway, friction characteristics of the pavement surface, portion of time that the pavement is wet, rutting depths that can further reduce available friction and increase potential for hydroplaning, AADT, the type of area (urban/rural), and friction requirements in the section. The primary countermeasures to reduce the frequency and level or severity of crashes associated with wet pavement are:

- Application of a skid resistant surface on highways that have a high number and proportion of wet pavement crashes and a low friction surface.
- Speed reductions on highways that have a high number and proportion of wet pavement crashes and a low friction surface, which lessen the need for available friction.

Countermeasure #1 Install Skid Resistant Surface

Description
Drivers need a varying level of pavement surface friction to safely remain within travel lanes under a variety of operating circumstances. Pavement surface friction varies based on a variety of factors including type of aggregate, surface macro-texture, pavement age, extent of surface polishing, rutting, time since last rainfall, and depth of water in wheel tracks. Drivers can also influence the amount of surface friction generated based upon tire friction characteristics, tread depth, and vehicle operating speed.

The amount of surface friction needed to maintain safe control of a vehicle is a function of the specific circumstances of the driving situation, which includes the types of vehicle and tires, operating characteristics, and highway environment.

Fundamental Principles

- As operating speeds increase, wet pavement friction decreases. The rate of decrease differs by pavement type, but often drops 20 – 25 percent when speeds increase from 30 MPH to 50 MPH.
- In general, higher friction surfaces are needed on higher speed facilities.
- As water depth increases in the wheel path, pavement surface friction decreases and the potential for hydroplaning increases.
- Pavement surfaces with minimal macro-texture (minimal voids) coupled with bald tires or tires with minimal tread depths are more likely to produce hydroplaning conditions given sufficient water depths and operating speeds.
- Pavement surface friction characteristics vary significantly throughout the year. Lower values are found during summer months under light rain conditions, immediately after long dry intervals.

Pavement friction characteristics vary depending on the surface's coarse aggregate type and size and the amount of aggregate exposed. "Flushed" surfaces comprised primarily of asphalt with little coarse aggregate exposure have lower friction characteristics. As aggregates wear, they normally polish from tire contact, resulting in generally lower friction values. The rate of decrease in friction values is dependent on a variety of factors, but primarily the rate at which the coarse aggregate polishes. PennDOT has adopted skid resistance level (SRL) ratings for a variety of aggregates that are applied to different AADT volume groups such that the surface should provide acceptable pavement friction over the life of the pavement.

Higher Friction Need Areas

If all traffic moved at relatively constant speed on a tangent level section of highway, friction requirements would be minimal. However, when abrupt speed changes involving hard braking or traversing sharp curves at high speeds occur; additional friction is needed to minimize the potential for loss of control.

Examples of conditions which have a higher potential for increased friction demand are:

- Curves with a design speed substantially less (i.e., less than 16 KPH difference) than the legal speed limit or 85th percentile operating speed. Note that curves that meet this condition and are on a steep downward gradient, have intersection or driveways within the curve, or have significant rutting increase the need for friction.
- Compound, reverse, or broken back curves on highways with speed limits of 50 MPH or greater.
- Tangent sections with speed limits of 50 MPH or greater or 85th percentile speeds above 50 MPH and a high frequency of access points (i.e., 10 or more driveways or intersections per segment).
- Section of crest vertical curve with significant shortfalls in stopping sight distance (i.e., 200 feet or greater shortfall) and one or more intersections or driveways within sight distance limitations.
- Area of mainlines and ramp junctions in interchange areas where deceleration and acceleration lanes are 500 feet or less in length.
- Sections with observable frequent skid markings.
- Intersection approaches on the through highway with high operating speeds (i.e., in excess of 40 MPH) through the intersection and high turning volumes (i.e., 10 percent or greater turning left or right) or 1,000 or more AADT on the cross street.
- Surfaces that are almost entirely devoid of aggregate (e.g., flushed or polished) with operating speeds greater than 40 MPH.
- Surfaces that have substantially different skid qualities in each wheel path and frequent hard stopping is anticipated.

Potential Improvements

A hierarchy of suggested improvements is as follows:

1. Eliminate or substantially reduce the need for friction. This is often non-attainable, especially on non-programmed sections where it may require significant physical improvements such as curve flattening and/or addition of turning lanes at intersections.
2. Install a new pavement surface that has micro- and macro-texture skid resistant qualities.
3. Attempt to lower operating speeds in the section and thus lessen the friction needs of vehicles.

Candidate Surface Improvement Sections

The recommended candidate wet pavement surface friction treatment crash threshold is:

- Urban or rural sections that have speed limits greater than 40 MPH and eight or more wet pavement crashes and a wet/total crash ratio of 0.30 or greater.

Highway sections that meet these thresholds need to be field reviewed by the District Safety Engineer to determine if a high friction demand may exist within the section. If so, the District Safety Engineer should initiate a skid test request to determine the friction characteristics of the section.

Actions should be recommended for those sections that meet all of the following provisions:

- Sections that meet the wet pavement surface friction treatment crash thresholds identified above.
- Sections that have at least one high friction demand need to be identified from the field review.
- Ribbed tire test results that yield skid numbers of 35 or less or smooth tire test results that yield skid numbers of 20 or less.

The Highway Safety Engineer should coordinate with the Pavement Engineer for the determination of an appropriate course of action.

At those sections where a more skid resistant surface is recommended, it is appropriate to consider interim improvements that may reduce the potential for a wet pavement crash until the new surface is applied. The installation of a “Slippery When Wet” warning sign with a word placard underneath may be considered. However, the effectiveness of these signs to reduce wet pavement crashes has not been determined. Another alternative that may be considered is sign

and marking initiatives, such as the use of peripheral transverse markings to lower speeds and thus reduce the level of friction levels needed.

The Highway Safety Engineer and Pavement Engineer should present their recommendations and cost estimates for all sections that meet the above criteria to the Maintenance Programming Engineer by the end of each calendar year. The Assistant District Engineer (ADE) -Maintenance and the Maintenance Programming Engineer will determine the funding effort that can be made available to address surface friction needs based upon annual funds available and other priorities and defined needs. The ADE-Maintenance will program that amount in the annual work plan and the 213 Program each year. The ADE-Maintenance will also consider unfunded locations as candidates for future betterment programs. Contracts should be let in the spring of each year such that all work can be accomplished by October 1. All four engineers will determine the priority sections to advance with the funds available.

Coordination with Other Roadway Improvements

In addition to skid resistant surfaces, oftentimes sections with high numbers of wet pavement crashes also have multiple crash concerns involving turning vehicles, curve crashes, running off the road, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

The application of skid resistant surfaces on skid deficient pavement surfaces is expected to reduce wet pavement crashes by 50 percent.

5.5.12 Run-Off-Road Crashes

Run-off-road (ROR) crashes involve single vehicle hit fixed object and rollover crashes as first harmful event crashes, injuries, and fatalities. They have frequencies, severities, and characteristics associated with the impact speed of vehicles coupled with the type of highway and AADT, and the type of area (urban/rural), and time of occurrence (day or night). Countermeasures associated with striking the three major fixed objects – trees, utility poles, and guide rails – have been addressed previously. Other driver countermeasures involving aggressive driving, impaired driving, and unbelted drivers and occupants also are important in reducing the frequency and severity of run off the road crashes. The remaining infrastructure countermeasures to reduce the frequency and level or severity of crashes associated with road departures are as follows:

- Widen narrow lanes on rural two-lane highways.
- Widen shoulders on rural two- and multi-lane highways (include rumble strips any time that the paved shoulder is widened more than four feet).Consider applications of edge rumble

strips (ERS) any time the paved shoulder is widened to between four and six feet. Consider applications of shoulder rumble strips when the paved shoulder is widened six feet or greater.
- Install edge line pavement markings or transverse peripheral markings on narrow pavements.

These countermeasures are most applicable in rural areas where widths for cross-section improvements are more easily implemented.

Countermeasure #1 – Widen Narrow Lanes on Rural Highways

Description
Pavement widening may be considered on rural two-lane roads with pavement widths less than 22 feet. Oftentimes shoulders are either minimal in width or non-existent and should be considered for widening concurrent with the lane widening.
Candidate Pavement Widening Sections

The recommended candidate pavement widening crash threshold is:

- Rural, less than 22 feet wide 2-lane highways with 20 or more ROR crashes in 3,000 feet in 5 years.

Highway sections that have the highest numbers of ROR crashes on the State system and those local roads that have combinations of the highest numbers of ROR driving route crashes and densities should be given high priority. In addition, those sections that have high numbers of ROR crashes on the State system may be further prioritized based upon the AADT of the section.

Highway sections that meet this threshold and are of priority consideration for widening need to be field reviewed to determine the following:

- The scope of the improvements that should be considered for the section, including potential need for shoulder and alignment enhancements along with pavement structure and guide rail improvements.
- The limits of the proposed improvement that should be considered.
- Any other crash concerns within the limits.

Resources
Additional resources that can be used to identify appropriate countermeasures on sections with high frequencies of ROR crashes can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/) and NCHRP Report 500 Volume 6: *A Guide for Addressing Run-Off-Road Collisions*.

Coordination with Other Roadway Improvements
This initiative should be coordinated with the Bureau of Maintenance and Operations' systematic approach in the 213 Program to widen narrow lanes. In addition to pavement widening,

oftentimes sections with high numbers of ROR crashes also have multiple crash concerns involving slippery approaches, curves, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

Widening lane widths is estimated to reduce all crashes (primarily ROR) as follows:

Table 5-10: Effectiveness of Widening Lane Width

Lane Width or Shoulder Widening	Lane Widening CRF
1 foot	12 percent
2 feet	23 percent
3 feet	32 percent
4 feet	40 percent

Widening shoulders in conjunction with the lane widening will increase the overall crash reduction on the section.

Countermeasure #2 – Widen Shoulders on Rural Two-Lane and Four-Lane Highways

Description

Shoulder widening may be considered on rural two- and four-lane roads with shoulder widths less than 6 feet. In limited cases, additional sections that have a very high incidence of ROR crashes and have 6 to eight feet wide shoulders may also be considered for widening with a maximum width of 10 feet.

Candidate Shoulder Widening Sections

The recommended candidate shoulder widening crash threshold is:

- Rural, 2-lane (pavement width 22 feet or greater)[6] and 4-lane highways with shoulders less than 6 feet in width and 20 or more ROR crashes in 3,000 feet in 5 years.

Highway sections that have the highest numbers of ROR crashes should be given high priority. In addition, those sections that have high numbers of ROR crashes may be further prioritized based upon the AADT of the section.

[6] Two-lane highway sections with pavements less than 22 feet have the same crash criteria as Countermeasure #1 (lane widening) and any shoulder widening enhancements on these sections should be considered in conjunction with the lane widening.

Highway sections that meet this threshold need to be field reviewed to determine the following:

- The type and width of existing shoulders and potential to widen, pave, and add edge rumble strips.
- The probable width increases and shoulder upgrades that should be pursued.

In addition, a review of the physical characteristics of the section and the crash data is needed to determine if other physical improvements need to be considered (e.g., curve improvements as described in the curve section, fixed object removal, edge rumble strips).

Resources

Resources that can be used to identify appropriate countermeasures on sections with high frequencies of head-on crashes can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/), NCHRP Report 500 Volume 6: *A Guide for Addressing Run-Off-Road Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v6.pdf), and the AASHTO Roadside Design Guide.

Coordination with Other Roadway Improvements

In addition to improvements to reduce the potential for ROR crashes, oftentimes sections with high numbers of crashes also have multiple crash concerns involving curves, slippery approaches, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

Upgrading shoulder widths and upgrading stabilized shoulders to paved shoulders will reduce ROR crashes dependent upon the existing and proposed widths of shoulders as indicated in the crash modification factor (CMF) tables below.

Table 5-11: Crash Modification Factors for Various Shoulder Widths and AADT Ranges

	ADT		
Shoulder Width	**< 400**	**400 – 2,000**	**> 2,000**
0 feet	1.10	$1.1+2.5\times10^{-4}$(ADT-400)	1.50
2 feet	1.07	$1.07+1.43\times10^{-4}$(ADT-400)	1.30
4 feet	1.02	$1.02+8.125\times10^{-5}$(ADT-400)	1.15
6 feet	1.00	1.00	1.00
8 feet	0.98	$0.98+6.875\times10^{-5}$(ADT-400)	0.87

Table 5-12: Accident Modification Factors for Various Shoulder Types and Widths

Shoulder Type	Shoulder Width (feet)							
	0	**1**	**2**	**3**	**4**	**6**	**8**	**10**
Paved	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Gravel	1.00	1.00	1.01	1.01	1.01	1.02	1.02	1.03
Composite	1.00	1.01	1.02	1.02	1.03	1.04	1.06	1.07
Turf	1.00	1.01	1.03	1.04	1.05	1.08	1.11	1.14

A crash reduction factor may be calculated from the above accident modification factors by subtracting the quotient of the before-improvement CMF by the after-improvement CMF from 1.0. As an example, if a roadway section with 2,500 AADT went from 0 to 6 feet in shoulder width, the CRF for shoulder improvements would result in a 33 percent reduction in crashes (CRF), calculated as follows:

$$CRF = 1 - \frac{AMFafter}{AMFbefore}$$

$$CRF = 1 - \frac{1.0}{1.5} = 0.33$$

In addition, the application of edge rumble strips on proposed paved shoulders 4 feet or greater in width should be considered as an additional 20 percent reduction in ROR crashes with this improvement.

Countermeasure #3 –Rumble Strip Applications (Edge or Shoulder) in Conjunction with Paved Shoulders Four to Six Feet or Greater in Width

Description
Bicycle tolerable shoulder rumble strips (BTSRS) and edgeline rumble strips (ERS) may be considered for installation on rural highways with pavement shoulders 4 to 6 feet or greater in width.

Responsibilities

- District Safety Engineer is the process owner.
- District Pedestrian/Bicycle Coordinator shall jointly review the areas to be targeted.

Guidelines for Use – BTSRS

Description

- The purpose of BTSRS is to reduce ROR crashes on highways (except interstates and expressways).

Candidate BTSRS Sections

- Consider BTSRS for the following types of two- or multi-lane highways (except interstates and expressways):

  a. Where the roadway lane width is 11 feet or greater, 6 feet or greater of paved shoulder, and the posted speed is 55 MPH or greater, the BTSRS shall be installed on the shoulder. Gap spacing of 12 feet in every 60 feet may be provided for bicyclists' (refer to PennDOT Publication 72M, *Standards for Roadway Construction*, RC-22M).

  b. Where the roadway lane width is 11 feet or greater, 6 feet or greater paved shoulder and the posted speed is less than 55 MPH, the BTSRS shall be installed on the shoulder. Gap spacing of 12 feet in every 60 feet may be provided for bicyclists' (refer to PennDOT Publication 72M, *Standards for Roadway Construction*, RC-22M).

  c. If the shoulder width is four feet or more but less than 6 feet in any case, consider the edgeline rumble strips (ERS), outlined below.

  d. If the paved shoulder width is less than 4 feet, do not consider ERS or BTSRS.

Highway sections that meet these thresholds need to be field reviewed to confirm the following:

- Installing BTSRS on bituminous pavement requires a bituminous wearing course surface with BCBC base or better.
- Existing concrete pavements do not have overlays less than 2.5 inches in depth.

Retrofitting BTSRS

If it is desired to retrofit BTSRS on existing pavement, the pavement and shoulder should be in sufficiently good condition, as determined by the District Pavement Engineer, to effectively accept the milling process without raveling or deteriorating the pavement. Otherwise both the pavement and shoulders need to be upgraded prior to milling BTSRS.

If shoulders are not to be overlaid on interstates and expressways, it is not necessary to overlay the shoulders and re-cut the rumble strips. In instances where the shoulders will be overlaid, a series of treatments and guidance is currently under development and will be included in subsequent editions of this manual.

Note that it is expected that in instances where rumble strips are to be filled-in and re-milled, there will be an added expense to the project. To cover these extra costs, Highway Safety Improvement Program (HSIP) funds can be applied to the projects, as rumble strips are an approved use of these funds.

In addition, the following guidelines should be followed:

- The paved shoulder must be equal in smoothness to that of the adjacent travel lane.
- Do not install BTSRS on bridge decks.
- BTSRS are to be broken for intersections. Also consider breaking for driveways according to engineering judgment. When breaking BTSRS pattern, discontinue BTSRS 25 feet from the point of curvature of any such highway or driveway (refer to PennDOT Publication 72M, *Standards for Roadway Construction*, RC-22M).
- Coordinate the milling of BTSRS with all necessary project phases. Do not mill the BTSRS until all appropriate construction phases are completed.
- Take into consideration potential noise impacts when contemplating the installation of BTSRS in residential or urban areas.
- As part of multi-modal transportation system planning, consult the District Pedestrian/Bicycle Coordinator where BTSRS are being planned for installation and determine if the District Coordinator has any concerns. These concerns may include Bicycle PA routes, other local bike routes, national bike routes in Pennsylvania, proposed bike routes from Metropolitan Planning Organization (MPO)/Local Development Districts (LDD), regional plans, and potential Americans with Disabilities (ADA) violations.
- Gap spacing should only be installed as part of new BTSRS installations or as part of resurfacing projects.

Deviation from the above specifications and guidelines may be considered by the District; however, they must be approved by the HSTOD prior to being implemented.

The practice of installing both center and edge-line rumble strips along the same segments of road is becoming more common. When applying edge and center line rumble strips in combination, consideration should be given to total pavement width to determine how to best accommodate and serve all road users. Edge-line rumble strips should only be considered on roadways with 11 feet or greater travel lane width and 4-6 feet paved shoulder. HSTOD should be consulted before CLRS and ELRS are installed in combination on highways with travel lane widths less than 11 feet.

Guidelines for Use – ERS

Description

- The purpose of ERS is to reduce ROR crashes on two-to four-lane highways (except interstates and expressways).

Candidate ERS Sections

- Consider ERS for the following types of two- to four-lane highways (except interstate and expressways):
    a. On highways with 11 feet or greater lane width and 4 to 6 feet of paved shoulder, ERS shall be installed on the edge of the roadway. Gap spacing of 12 feet in every 60 feet for bicyclists', as shown in figure 5-29.
    b. If the shoulder width is greater than or equal to 6 feet, consider the BTSRS as described above.
- If there is concern with the pavement joint between the roadway and the shoulder, the District may consider the following options:
    a. Where shoulder width is between 5 and 6 feet, offset ERS 2 to 4 inches from the joint into the shoulder surface.
    b. Where shoulder width is less than 5 feet, the District may offset ERS 2 to 4 inches from the joint into the travel lane surface.

Highway sections that meet these thresholds need to be field reviewed to confirm the following:

- Installing ERS on bituminous pavement requires bituminous wearing course surface with BCBC base or better.
- Existing concrete pavements do not have overlays less than 2.5 inches in depth.

Retrofitting ERS

If it is desired to retrofit ERS on existing pavement, the pavement and shoulder should be in sufficiently good condition, as determined by the District Pavement Engineer, to effectively accept the milling process without raveling or deteriorating the pavement. Otherwise both the pavement and shoulders need to be upgraded prior to milling any desired ERS.

If shoulders are not to be overlaid on interstates and expressways, it is not necessary to overlay the shoulders and re-cut the rumble strips. In instances where the shoulders will be overlaid, a series of treatments and guidance is currently under development and will be included in subsequent editions of this manual.

Note that it is expected that in instances where rumble strips are to be filled-in and re-milled, there will be an added expense to the project. To cover these extra costs, Highway Safety Improvement Program (HSIP) funds can be applied to the projects, as rumble strips are an approved use of these funds.

In addition, the following guidelines should be followed:

- The ERS shall be discontinued 50 feet before and after adjacent guide rail, where the face of the guide rail is located less than four feet from the edge line of the roadway.
- The paved shoulder and the adjacent travel lane should be of equal smoothness.
- Do not install ERS on bridge decks.
- ERS are to be broken for intersections. Also consider breaking for driveways according to engineering judgment. When breaking ERS pattern, discontinue ERS 25 feet from the point of curvature of any such highway or driveway (refer to PennDOT Publication 72M, *Standards for Roadway Construction*, RC-22M)
- Coordinate the milling of ERS with all necessary project phases. Do not mill the ERS until all appropriate construction phases are completed.
- Coordinate the milling of ERS with traffic line painting operations.
    a. To avoid milling newly applied traffic lines.
    b. To install new white edge lines within two weeks of ERS completion.
- Take into consideration potential noise impacts when contemplating the installation of ERS in residential or urban areas. Do not install ERS on the inside of moderate to sharp curves which are in the immediate vicinity of any residence.
- As part of multi-modal transportation system planning, consult the District Pedestrian/Bicycle Coordinator where ERS are being planned for installation, and determine if the District Coordinator has any concerns. These concerns may include Bicycle PA routes, other local bike routes, national bike route segments in Pennsylvania, proposed bike routes from MPO/LDD regional plans, and potential ADA violations.
- Gap spacing should only be installed as part of new ERS installations or as part of resurfacing projects.

Edgeline Rumble Strips (ERS) in Conjunction with Centerline Rumble Strips (CLRS)

While the crash reduction potential of ERS and CLRS separately is significant at this time, we have insufficient knowledge and experience with the combined impact of both centerline and edgelines on the same project to warrant full deployment. Of primary concern is the tight travel lane restrictions and the more frequent departures to one of the rumble strips. However, to gain that knowledge and experience, you are encouraged to incorporate edgeline rumble strips on roadways with existing centerline rumble strips utilizing engineering judgement on a pilot basis. Edgelines should be omitted on the inside of moderate to sharp curves, which encompass dwellings. Drivers tend to use the shoulder area more in these situations increasing the noise level.

Consider using ERS in conjunction with CLRS on two-to-four lane highways (except Interstate & Expressways) with 11 feet or greater lane width and 4-6 feet of paved shoulder.

Deviation from the above specifications and guidelines may be considered by the District; however, they must be approved by HSTOD prior to being implemented.

Candidate Highway Sections for Shoulder or Edge Rumble Strip Applications

The recommended candidate shoulder rumble strip crash threshold for the application of either edge or shoulder rumble strips is:

- Rural highways with paved shoulders 4 feet or greater in width and five or more ROR crashes in 3,000 feet in 5 years.

Highway sections that meet this threshold need to be field reviewed to determine the following:

- The scope of the improvements that should be considered for the section including potential need for shoulder enhancements along with pavement structure and guide rail improvements.
- The limits of the proposed improvement that should be considered.
- Any issues that may relate to the installation of edge rumble strips at the site.
- Any other crash concerns within the limits.

Resources

Additional resources that can be used to identify appropriate countermeasures on sections with high frequencies of ROR crashes can be found the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/) and NCHRP Report 500 Volume 6: *A Guide for Addressing Run-Off-Road Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v6.pdf).

Coordination with Other Roadway Improvements

In addition to installing edge rumble strips on paved shoulders, oftentimes sections with high numbers of ROR crashes also have multiple crash concerns involving slippery approaches, curves, or higher frequencies of crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

The installation of edge rumble strips on paved shoulders is projected to reduce all ROR crashes by 20 percent.

Countermeasure #4 – Edge Lines or Peripheral Transverse Markings on Narrow Rural Highways

Description

There are a significant number of miles of narrow (i.e., 18 feet or less) rural highways that have a high number of ROR crashes. However, widening the pavements and shoulders of a substantial number of miles of these highways is unrealistic from both a financial and cost effectiveness basis. There are few low-cost solutions to address ROR crashes on these highways that are experimental and no proven. Some States and countries have applied low-cost pavement markings to reduce ROR crashes. The results are either generally inconclusive or show crash reductions in the 5 to 10 percent range. The two most promising pavement markings to consider are as follows:

- Edge lines, either standard 4 inch width or wider (e.g., 6 to 8 inches).
- Peripheral transverse pavement markings.

While not a conventional application, after careful evaluations, edge lines may be placed on narrow rural highways with a high number of ROR crashes that have not been previously marked and without centerlines.

Candidate Highway Sections for Enhanced Pavement Markings

The recommended candidate highway section crash thresholds for enhanced pavement markings are:

- Rural, two-lane highway sections with pavement width 18 feet or less and eight or more ROR crashes in 3,000 feet in 5 years.
- Rural, two-lane highway sections with pavement width between 18 and 20 feet and shoulder width 2 feet or less and eight or more ROR crashes in 5 years.

Highway sections that have the highest numbers of ROR crashes should be given high priority. In addition, those sections that have high numbers of ROR crashes may be further prioritized based upon the AADT of the section.

Highway sections that meet this threshold need to be field reviewed to determine the type, width, and condition of the existing pavement and ability to place pavement markings on it. In addition, the field review should include:

- A review of all crashes within the section, including an assessment of the number of run off the road, head on, and opposing flow sideswipe crashes.
- An assessment of areas within the section that have limited sight distance or intersections where it is appropriate to consider center line markings to supplement the edge markings.

- A review of the physical characteristics of the section and the crash data to determine if other physical improvements need to be considered (e.g., curve improvements as described in the curve section, fixed object removal).

Since these are not conventional applications, Districts pursuing pavement markings on these routes require approval of the installation by HSTOD prior to being implemented.

Resources

Resources that can be used to identify appropriate countermeasures on sections with high frequencies of ROR crashes can be found at the FHWA road departure safety website (http://safety.fhwa.dot.gov/roadway_dept/) and NCHRP Report 500 Volume 6: *A Guide for Addressing Run-Off-Road Collisions* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v6.pdf).

Coordination with Other Roadway Improvements

In addition to pavement marking enhancements, oftentimes sections with ROR crashes may also have multiple crash concerns involving slippery approaches or higher frequencies of other crashes under periods of darkness. When one or more of these additional concerns exists, a coordinated approach may be desirable so that the overall improvement targets all concerns. This requires reviewing the crash data for these additional concerns, assessing the physical conditions in the section to determine if additional concerns should be addressed, and integrating these improvements into an overall approach.

Effectiveness

Placing edge lines of standard or wider dimensions (i.e., 6 to 8 inches), particularly on narrow roads of insufficient width to add centerlines, or the installation of peripheral transverse markings on these same sections, has not been thoroughly evaluated. However, based upon limited data from other States and countries, a 5 to 10 percent reduction in crashes may be estimated for these types of improvements.

5.5.13 Unbelted Injury and Fatal Crashes

Unbelted crashes, injuries, and fatalities have frequencies and characteristics associated with the type and age of vehicle, time (day or night) of occurrence, type of area (urban/rural) that the crash occurred, and age/sex of the unbuckled driver. The primary countermeasures to reduce the level of unbuckled drivers and occupants are repetitive and concentrated education and enforcement initiatives using NHTSA's Click It or Ticket (CIOT) concept, applied either on a municipal-wide or highway section basis.

Countermeasure #1 – Enforcement and Education on a Municipality-Wide Basis

Description

The strategy for this countermeasure is highly publicized and highly visible enforcement utilizing NHTSA's CIOT campaign concentrating on:

- The times when they are more likely to occur.
- The locations which have the highest frequencies of unbuckled driving crashes.

Statewide information on unbuckled driving crash times of occurrence are shown in the following tables.

Highway sections within the municipality which also appear on the unbuckled crash segment list should be given priority enforcement attention.

Times need to be adjusted to reflect individual conditions within the municipality.

Candidate Municipalities

The recommended candidate municipality crash thresholds for enforcement and education on a municipality-wide basis are:

- Urban municipalities that have 200 or more unbuckled injury or fatal crashes in 5 years.
- Rural municipalities that have 150 or more unbuckled injury or fatal crashes in 5 years.

Municipalities that meet these thresholds and also have higher proportions of total crashes that involve unbuckled injuries and fatalities, higher unbuckled crashes per 1,000 residents, or higher unbuckled crashes per one million VMT, and higher unbuckled fatalities per 100 unbuckled crashes should be given consideration for area-wide enforcement and education.

Resources

Resources that can be used to develop effective enforcement and education programs can be found in the Model Work Plan for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths in Appendix D of this manual and the NHTSA *Guide for Selective Traffic Enforcement Programs* (http://www.nhtsa.gov/people/injury/research/ACHIEVE.pdf) and *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices* (http://www.nhtsa.gov/publications/HS810710/index.htm). In addition, the NHTSA CIOT website has a large amount of relevant information on guidelines for conducting and evaluating effective safety belt education and enforcement campaigns, including other States' best practices (http://www.nhtsa.gov/CIOT).

Coordination with Other Enforcement and Education Initiatives

Often, municipalities have multiple crash concerns involving aggressive driving, unbelted driver and occupant injuries, and alcohol-related crashes. When more than one of these concerns occurs

within a municipality, a coordinated approach is desirable so that the enforcement and education initiative targets all concerns. This requires reviewing the times and locations where individual crash concerns are concentrated and integrating them into an overall approach.

Effectiveness

A high-quality, coordinated enforcement and education initiative resulting in widespread knowledge among residents and drivers that unbelted driving will be detected and drivers will be penalized is expected to reduce unbelted driving. However, there are no validated studies that define the level of reduction that may be expected from such an initiative. Obviously, the intensity and frequency of stoppages coupled with the level and quality of messages that reach the public through the media will influence the results.

Countermeasure #2 – Enforcement and Education on a Highway Section Basis

Description

Highly publicized and highly visible enforcement should concentrate on the times when unbelted fatalities and injuries are more likely to occur. The municipal tables in the previous section may be used to identify statewide characteristics for enforcement purposes. Times need to be adjusted to reflect individual conditions within a segment.

Candidate Highway Segments

The recommended candidate highway segment crash thresholds for enforcement and education on a highway segment basis are:

- Urban or rural State highway 3,000 foot segments that have 12 or more unbelted fatal or injury crashes in 5 years.
- Urban or rural local entire roads that have 12 or more unbelted fatal or injury crashes in 5 years.

Highway segments that have the highest numbers of unbelted crashes, particularly on rural highways on the State system, and those local roads that have the highest numbers of unbelted crashes again emphasizing those on rural roads, should be given high priority. In addition, those segments that have high numbers of unbelted fatal and injury crashes on the State system may be further prioritized based upon the AADT. In addition, the data should be displayed on geographic information system (GIS) maps so that routes that have a number of segments with high numbers of unbelted crashes can be identified and visually linked together for enforcement purposes.

Resources

Resources that can be used to develop effective enforcement and education programs can be found in the Model Work Plan for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths in Appendix D of this manual and the NHTSA *Guide for Selective Traffic Enforcement Programs* (http://www.nhtsa.gov/people/injury/research/ACHIEVE.pdf), *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway*

Safety Offices (http://www.nhtsa.gov/publications/HS810710/index.htm), and NCHRP Report 500, Volume 11, *A Guide for Increasing Seat Belt Use* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v11.pdf).

In addition, the NHTSA CIOT website has a large amount of relevant information on guidelines for conducting and evaluating effective safety belt education and enforcement campaigns, including other States' best practices (http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.ce4a601cdfe97fc239d17110cba046a0).

Coordination with Other Enforcement and Education Initiatives

Often, municipalities have multiple crash concerns involving aggressive driving, unbelted driver and occupant injuries, and alcohol-related crashes. When more than one of these concerns occurs within a municipality, a coordinated approach is desirable so that the enforcement and education initiative targets all concerns. This requires reviewing the times and locations where individual crash concerns are concentrated and integrating them into an overall approach.

Effectiveness

A high-quality, coordinated enforcement and education initiative resulting in widespread knowledge among residents and drivers that unbelted driving will be detected and drivers will be penalized is expected to reduce unbelted driving. However, there are no validated studies that define the level of reduction that may be expected from such an initiative. Obviously, the intensity and frequency of stoppages coupled with the level and quality of messages that reach the public through the media will influence the results.

5.5.14 Alcohol-Related Crashes

Alcohol-related crashes, injuries, and fatalities have frequencies and characteristics associated with the type and age of vehicle, time (day or night) of occurrence, and type of area (urban/rural) that the crash occurred, and age/sex of the impaired driver. The primary countermeasures to reduce the level of alcohol-related crashes are repetitive and frequent education and enforcement initiatives, primarily sobriety checkpoints, and roving (saturation) patrols. To be effective, the threat of being stopped and tested has to be considered great enough by potential drivers who may drink and drive, that a substantial portion of that driving population will modify driving behavior to avoid or minimize the level of drinking and driving. The NHTSA *Saturation Patrols & Sobriety Checkpoints Guide* has been adapted by PennDOT for use on either a municipal-wide or highway section basis (http://www.nhtsa.dot.gov/people/injury/alcohol/saturation_patrols/index.html).

Countermeasure #1 – Sobriety Checkpoints and Roving (Saturation) Patrols on a Municipality-Wide Basis

Description

The strategy for this countermeasure is highly publicized and highly visible enforcement utilizing sobriety checkpoints and roving (saturation) patrols. The NHTSA *Saturation Patrols &*

Sobriety Checkpoints Guide provides guidance on effective deployment of these strategies (http://www.nhtsa.dot.gov/people/injury/alcohol/saturation_patrols/index.html).

Checkpoints and roving (saturation) patrols must be publicized extensively to be effective. Paid media may be necessary to complement news stories and other earned media, especially in a continuing checkpoint program. In addition, checkpoints must be conducted frequently enough so that a substantial portion of the drinking and driving population within the municipality will be aware of the potential for being stopped and either stop or reduce their level of drinking and driving.

Sobriety checkpoints or roving (saturation) patrols are most appropriately performed at times and locations as follows:

- The times when impaired driving is more likely to occur.
- The locations which have the highest frequencies of impaired driving crashes.

Highway sections within the municipality, which also appear on the impaired driving crash segment list, should be given priority enforcement attention.

Times need to be adjusted to reflect individual conditions within a given municipality.

Candidate Municipalities

The recommended candidate municipality crash thresholds for enforcement and education on a municipality-wide basis are:

- Urban municipalities that have 75 or more impaired driving crashes in 5 years.
- Rural municipalities that have 50 or more impaired driving crashes in 5 years.

Municipalities that meet these thresholds, that have higher impaired driving fatalities per 100 impaired driving crashes and have either higher proportions of total crashes that involve impaired driving, higher impaired driving crashes per 1,000 residents, or have higher impaired driving crashes per 1 million VMT should be given consideration for area-wide sobriety checkpoints and/or roving patrols.

Resources

Resources that can be used to develop effective enforcement and education programs can be found in the Model Work Plan for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths in Appendix D of this manual and the NHTSA *Guide for Selective Traffic Enforcement Programs* (http://www.nhtsa.gov/people/injury/research/ACHIEVE.pdf) and *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices* (http://www.nhtsa.gov/publications/HS810710/index.htm). In addition, the NHTSA impaired driving website has a large amount of relevant information on guidelines for

conducting and evaluating effective sobriety checkpoint programs and roving (saturation) patrols, including other States' best practices (http://www.nhtsa.gov/Impaired).

Coordination with Other Enforcement and Education Initiatives

Oftentimes municipalities have multiple crash concerns involving aggressive driving, unbelted driver and occupant injuries, and alcohol-related crashes. When more than one of these concerns occurs within a municipality, a coordinated approach is desirable so that the enforcement and education initiative targets all concerns. This requires reviewing the times and locations where individual crash concerns are concentrated and integrating them into an overall approach.

Effectiveness

A high-quality, well publicized, municipality-wide sobriety checkpoint program with frequent checkpoints is expected to reduce impaired driving crashes, injuries, and fatalities by 20 percent. This estimate is based upon a systematic review of 11 high-quality studies. Obviously, if checkpoints are performed infrequently or are not well publicized, these reductions will probably not occur.

Roving (saturation) patrols are very effective in arresting impaired drivers. However, the effects of well publicized roving (saturation) patrols on impaired driving crashes, injuries, or fatalities have not yet been determined.

Countermeasure #2 – Enforcement and Education on a Highway Section Basis

Description

Highly publicized and highly visible enforcement should concentrate on the times when impaired driving crashes are more likely to occur. The municipal tables in the previous section may be used to identify statewide characteristics for enforcement purposes. Times need to be adjusted to reflect individual conditions within a segment.

Candidate Highway Segments

The recommended candidate highway segment crash thresholds for impaired driving enforcement and education on a highway segment basis are:

- Urban or rural State highway 3,000 foot segments that have five or more impaired driving crashes in 5 years.
- Urban or rural local entire roads that have five or more impaired driving crashes in 5 years.

Highway segments that have the highest numbers of impaired driving crashes, particularly on rural highways on the State system and those local roads that have the highest numbers of impaired driving crashes again emphasizing those on rural roads, should be given high priority. In addition, those segments that have high numbers of impaired driving crashes on the State system may be further prioritized based upon the AADT. In addition, the data should be

displayed on GIS maps so that routes that have a number of segments with high numbers of impaired driving crashes can be identified and visually linked together for enforcement purposes.

Resources

Resources that can be used to develop effective enforcement and education programs can be found in the Model Work Plan for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths in Appendix D of this manual and the NHTSA *Guide for Selective Traffic Enforcement Programs* (http://www.nhtsa.gov/people/injury/research/ACHIEVE.pdf) and *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices* (http://www.nhtsa.gov/publications/HS810710/index.htm). In addition, the NHTSA impaired driving website has a large amount of relevant information on guidelines for conducting and evaluating effective sobriety checkpoint programs and roving (saturation) patrols, including other States' best practices (http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.18e416bf1b09b6bbbf30811060008a0c/).

Coordination with Other Enforcement and Education Initiatives

Often, municipalities have multiple crash concerns involving aggressive driving, unbelted driver and occupant injuries, and alcohol-related crashes. When more than one of these concerns occurs within a municipality, a coordinated approach is desirable so that the enforcement and education initiative targets all concerns. This requires reviewing the times and locations where individual crash concerns are concentrated and integrating them into an overall approach.

Effectiveness

A high-quality, well publicized, sobriety checkpoint program on a highway section with frequent checkpoints is expected to reduce impaired driving crashes, injuries, and fatalities by 20 percent. This estimate is based upon a systematic review of 11 high-quality studies. Obviously, if checkpoints are performed infrequently or are not well publicized, these reductions will probably not occur.

Roving (saturation) patrols are very effective in arresting impaired drivers. However, the effects of well publicized roving (saturation) patrols on impaired driving crashes, injuries, or fatalities have not yet been determined.

5.5.15 Mature Driver Safety

Promote Mature Driver Education Classes through AAA, AARP, and Seniors' groups for Safe Driving. Approve an online course to facilitate this training.

Identify ways to make intersections, signing and other roadway facilities more accommodating for older drivers – potential engineering changes, which may include roundabouts.

A comprehensive education plan to address planning, assessment, referrals, program alternatives, legal and law enforcement issues (JNET information)

A continuing medical education (CME) credit course for physicians on medical reporting requirements.

Develop and update assessment/decision-making tools for older drivers, their families and caregivers, the medical community, pharmacists, human service agencies and other stakeholders

Educate city planners, developers, students, engineers and community groups how to prepare and manage senior mobility issues in their communities.

5.5.16 Motorcycle Safety

Public Information programs to educate all roadway users on the presence of motorcycles and to publicize training opportunities and the Live Free Ride Alive web site, which includes information about rider safety and the dangers of drinking and riding:

Training for law enforcement in motorcycle DUI detection and motorcycle crash investigation

Enhanced law enforcement tied to events where alcohol is served

Conduct a "Share the Road with Motorcycles" program through paid and earned media

Encourage use of protective equipment

Focused education for motorcycle safety during motorcycle events

5.5.17 Pedestrian Crashes

Pedestrian crashes, injuries, and fatalities have frequencies and characteristics associated with the location (intersection or mid-block), time of occurrence (day or night), type of area (urban/rural) that the crash occurred, and age/sex of the pedestrian. The primary countermeasures to reduce the level of pedestrian crashes are combinations of education, enforcement, and engineering initiatives applied on an area-wide, corridor or location-specific site.

Countermeasure #1 – Development of Municipality-Wide Pedestrian Safety Action Plans

Description
FHWA has developed a comprehensive guide, *How to Develop a Pedestrian Safety Action Plan* (http://www.walkinginfo.org/training/pdps/). The development of pedestrian safety action plans may be considered for those municipalities that a) exhibit a significant pedestrian safety problem, particularly in comparison to other municipalities of similar size, and b) have municipal officials

who commit to actively participating in and supporting the development of a pedestrian safety action plan.

FHWA also has developed the *Pedestrian Safety Guide and Countermeasure Selection System* (http://www.walkinginfo.org/pedsafe/index.cfm) to provide practitioners with the latest information available for improving the safety and mobility of those who walk. The online tools provide the user with a list of possible engineering, education, or enforcement treatments to improve pedestrian safety and/or mobility based on user input about a specific location. This may be helpful in identifying pedestrian safety concerns.

Education and enforcement strategies that are generated from the pedestrian safety action plan may be considered for 402 programming consideration as described in Chapter 2 of this manual. Infrastructure safety improvements generated from a pedestrian safety action plan may be considered for safety programming as part of the annual safety improvement programming process described in Chapter 2 of this manual.

Candidate Municipalities

The recommended candidate municipality crash thresholds for the development of pedestrian safety action plans are:

- Urban municipalities that have 75 or more pedestrian crashes in 5 years.
- Rural municipalities that have 50 or more pedestrian crashes in 5 years.

Municipalities that meet these thresholds and have higher pedestrian fatalities per 100 impaired driving crashes, and either higher proportions of total crashes that involve pedestrians, higher pedestrian crashes per 1,000 residents, or higher pedestrian crashes per 1 million VMT should be given consideration for area-wide pedestrian safety action plan development.

Resources

Resources that can be used to develop a pedestrian safety action plan can be found in the FHWA *How to Develop a Pedestrian Safety Action Plan* (http://www.walkinginfo.org/training/pdps/). Information on countermeasures compiled by FHWA may be found at the *Pedestrian Safety Guide and Countermeasure Selection System* (http://www.walkinginfo.org/pedsafe/index.cfm). Additional information and documents pertaining to pedestrian safety may be found on the FHWA pedestrian safety website (http://safety.fhwa.dot.gov/ped_bike/) and the NHTSA pedestrian safety website (http://www.nhtsa.gov/Pedestrians) and NCHRP Report 500, Volume 10, *Guidance for Reducing Collisions Involving Pedestrians* (http://trb.org/publications/nchrp/nchrp_rpt_500v10.pdf).

Coordination with Other Enforcement and Education Initiatives

In addition to pedestrian safety, oftentimes municipalities have multiple crash concerns involving aggressive driving and alcohol-related crashes which may heighten pedestrian safety concerns. When one of these additional concerns occurs within a municipality on the same highway section

or intersection that involves a pedestrian safety problem, a coordinated approach may be desirable so that the enforcement and education initiative targets all concerns. This requires reviewing the times and locations where individual crash concerns are concentrated and integrating them into an overall approach.

Effectiveness

The research findings on the effectiveness of pedestrian safety countermeasures are limited, probably since pedestrian crashes are infrequent occurrences. Two overall documents on the effectiveness of pedestrian safety countermeasures are as follows:

- Transportation Research Board – NCHRP Report 500, Volume 10, *Guidance for Reducing Collisions Involving Pedestrians* (http://trb.org/publications/nchrp/nchrp_rpt_500v10.pdf).
- NHTSA – *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices* (http://www.nhtsa.gov/publications/HS810710/index.htm).

District Highway Safety Guidance Manual

Chapter 6 — Other Safety Topics

December, 2014

District Highway Safety Guidance Manual

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6.1 Overview of Other District Safety Topics

There are several other safety topics that do not fit into the material in Chapters 1 – 5. They include:

- Provisions for detours for bicyclists and pedestrians during construction projects.
- Pedestrian safety and mobility related to sidewalks.
- Car-bicycle Share the Road signs.
- Bicycle PA sign inspection schedule.
- Bicycles on freeways.
- Traffic counting.
- Roadside memorials.
- Dare to care bystander care program.
- Retention of mountable curbs during resurfacing.

Information on each of these subjects follows.

6.2 Provisions for Detours for Bicyclists and Pedestrians During Construction Projects

For several years, the Commonwealth's transportation goals have emphasized multi-modal balance and inter-modal connectivity to provide more effective transportation. Part of this effort includes renewed concentration on provisions for other modes, including bicycle and pedestrian transportation. The Pennsylvania Department of Transportation (PennDOT) has endorsed this effort and has adopted the Federal Highway Administration's (FHWA) twin goals of doubling the percentage of all trips made by bicycling and walking, while simultaneously reducing bicycle and pedestrian crashes by 10 percent. The PennDOT Statewide Bicycle and Pedestrian Master Plan provides actions to achieve these goals.

Statewide, The Bicycle/Pedestrian Plan expresses two broad goals:

a) Double the percentage of trips by foot and bicycle by the year 2015. The exact percentages will be developed with the implementation of this plan.
b) Reduce the number of fatalities among bicyclists and pedestrians to a level corresponding to the goals established in the most current version of the Pennsylvania Strategic Highway Safety Plan.

Simultaneous with this shift, PennDOT embarked upon a "Maintenance First" policy aimed at rehabilitating existing roadways and bridges. The result has been an increase in the amount of roadway work done within existing right-of-way versus work done on new right-of-way. One

side effect of construction within existing right-of-way has been an increased impact on bicycle and pedestrian transportation. In some cases, motorized traffic has been maintained or rerouted in a reasonable manner, while bicycle/pedestrian traffic has not been maintained. A significant number of complaints received in the PennDOT Bicycle/Pedestrian Program Office pertain to PennDOT or PennDOT-sponsored construction projects that curtail or sever existing bicycle/pedestrian routes.

The U.S. Congress addressed this concern in language included in the 1998 Transportation Equity Act for the 21st Century (TEA-21). Section 1202 of that act amended Section 217 of Title 23, United States Code to:

> Direct the Secretary of Transportation to not approve any project or take any regulatory action that will result in the severance of an existing major route or have a significant adverse impact on the safety of non-motorized transportation traffic, unless such project or regulatory action provides for a reasonable alternative route or such route exists.

In addition, Chapter 6 of the 2009 edition of the Manual on Uniform Traffic Control Devices (MUTCD) requires the needs of pedestrians and bicyclists are met in all areas of temporary traffic control.

For the purposes of this manual, the definition of "route" includes the following:

- Pedestrian – Sidewalks, trails, marked and unmarked crosswalks, pedestrian overpasses, pedestrian signing and marking, and other pedestrian provisions.
- Bicyclists – In the 1999 American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Development of Bicycle Facilities*, bikeway is defined as "a generic term for any road, street, path, or way which in some manner is specifically designated for bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes."

Provisions for accommodating bicyclists and pedestrians should be included in the detour routing for all construction projects. The provisions should include signing and marking to convey the following information:

1. Bikeway/walkway closed.
2. Detour direction signing, including turns.
3. Distance measurements if detour is longer than 0.5 miles for pedestrians and 2 miles for bicyclists. These measurements may be placed at either end of the detour route. The measurements should be given in blocks for pedestrians and miles/kilometers for bicyclists.

6.3 Provisions for Sidewalk Installations

PennDOT is permitted by Pennsylvania law to install sidewalks as a part of State funded projects under certain circumstances (e.g., to address the safety of pedestrian traffic). Generally, sidewalk installation is at the discretion of the Secretary and requires formal agreement with affected municipalities. The installation is considered a "construction improvement," with repairs and maintenance being a municipality responsibility. The Federal requirement for consideration of pedestrian needs is provided in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Based on SAFETEA-LU, Federal funds may be used to construct sidewalks.

PennDOT plans and policies, including PennPlanMoves, the Statewide Bicycle/Pedestrian Master Plan, and Context Sensitive Design Practices, strongly advocate enhanced pedestrian access and mobility. In support of these published plans, PennDOT Design Manuals state that "Pedestrians are a part of every roadway environment and attention must be paid to their presence in urban as well as rural areas." As a result of its legal authority and advocacy to improve pedestrian mobility, PennDOT is moving from the "replace only disturbed existing sidewalks" position to "construct sidewalks when pedestrian needs exist on a project."

Financing the cost of a new sidewalk to meet a pedestrian need is not a clear issue. Municipalities have various ordinances regarding sidewalks and responsibilities of adjacent property owners. Sidewalks and incidental curbing to facilitate a sidewalk are eligible for Federal funding on Federal-aid projects. Each District may establish a cost-sharing agreement among the parties on a case-by-case basis with the following three conditions:

1. The municipality or property owner contributes a fair portion of the total sidewalk and incidental curbing construction costs or required match on Federal-aid projects. Services provided to PennDOT through the Agility Program are also allowable as a form of cost-sharing.
2. Any right-of-way costs and needs to facilitate the sidewalk would be the responsibility of the municipality.
3. The municipality agrees to operate and maintain the sidewalk.

An agreement between the municipality and the Department specifying these conditions also needs to be established.

6.4 Car-Bicycle Share the Road Signs

Requests for installation of car-bicycle share the road signs may come from any legitimate source, including the following internal and external sources:

- Internal – PennDOT designers or their consultants may independently include installation of the signs as part of the project development process. In addition, PennDOT personnel or their consultants may suggest locations for the signs as a stand-alone project.
- External – Non-PennDOT personnel may suggest locations for installation with or without solicitation by PennDOT. These suggestions may be included as part of a larger project or as a stand-alone project. Forums for this input may be District Bicycle/Pedestrian Advisory Committee, Metropolitan Planning Organization (MPO)/Local Development District (LDD) Bicycle/Pedestrian Advisory Committee, dialogs open with the public, or other sources. However, PennDOT will not provide signs to local municipalities for installation on local roads.

Any request should include the following steps:

1. Submit the sign request to the District Bicycle/Pedestrian Coordinator for review. The criteria for road selection should include roads which possess any or all of the following:
   a. A road that is being promoted as a cycling route by a local or State agency.
   b. A demonstrated need based upon the travel patterns of local bicyclists.
   c. A car-bicycle crash history.
   d. Bottlenecks – Bridges or short stretches of roads that lack paved shoulders.
   e. Driveways – Sections of road with numerous commercial driveways, as a cluster of suburban strip malls.
   f. Sections where lanes are too wide (i.e., greater than 14 feet) and motorists are tempted to travel two abreast and crowd cyclists off of the road.
   g. Narrow roads where cyclists can only proceed safely by using the full lane width.
2. If the District Bicycle/Pedestrian Coordinator determines the signs are justified, the signs may be ordered by contacting the HSTOD Bicycle/Pedestrian Coordinator. PennDOT is responsible for maintaining the signs.
3. The District Traffic Engineer or his designee and the District Bicycle/Pedestrian Coordinator should jointly determine placement of signs along identified routes.

6.5 Bicycle PA Route Sign Inspection Schedule

The Bicycle PA touring route system was initiated by PennDOT and the Pennsylvania Pedal Cycle and Pedestrian Advisory Committee (PPAC) in 1999 and now totals over 2,200 miles of signed bicycle routes and rail-trails. These routes showcase the cultural and physical highlights of the Commonwealth and have received high marks from users.

To maintain this system's high standards, an annual Bicycle PA sign inspection program is to be conducted by the Bicycle/Pedestrian Coordinator or designee. The goal of the program is to have

all signs inspected by Memorial Day of each year. This target date will ensure that maintenance will be completed prior to the beginning of the peak bicycle tour season. Any necessary replacement signs may be ordered directly from the sign shop using commodity code 0721-5030-3636. Note that this covers the limited number of miles of bicycle routes on local roads since the installation and maintenance of the signs is financed entirely by a Federal enhancement grant.

6.6 Bicycle on Freeway Application Process

In June 1992, the Pennsylvania Legislature passed Senate Bill 559 (later known as Act 47), amending Title 75 Pennsylvania Consolidated Statutes to include Section 3511. The general rule of Section 3511 established a statutory ban of pedal cycles on State-designated freeways within the Commonwealth. The Section also stipulates that pedal cycles may be authorized on freeways provided that PennDOT established an application review process to administer requests for exceptions.

6.6.1 Application and Response Process

In compliance with the above referenced statutes, PennDOT has established the following process:

1. The applicant prepares a form containing the following information:
   a. A description of the proposed route, referenced by interchange names, numbers, or both. State route and section numbers (obtainable from the District Office) may also be used.
   b. A justification of the route request and a statement as to why an alternate route is not practical or possible. Plans, contour maps, photographs, and other documents may be included.
2. The form is submitted to the Central Office, Bicycle/Pedestrian Coordinator.
3. The form is sent to the District Office for review and a recommendation.
4. The District Office determines that the road in question is a freeway as per the definition provided in Title 75.
5. The District Bicycle/Pedestrian Coordinator and representatives from the District Traffic and Maintenance Units (Plans Unit optional) conduct a field view of the roads in question. At a minimum, the field view should determine:
   a. Alternates – length, condition, geometrics.
   b. Freeway section – condition, shoulder type, width, shoulder condition (i.e., pavement integrity).
6. The District considers the evaluation factors listed in the next section.

7. As a result of the field view, the District provides conditions and recommendations to the Central Office Bicycle/Pedestrian Coordinator. The District will make one of the following recommendations within 45 days of receipt of the original application:
    a. Approve.
        i. No other reasonable route available based on length or safety.
        ii. Safe access available (e.g., shoulder can be used as a designated bikeway).
    b. Approve in part.
        i. Section of requested route may meet criteria; alternate routes may satisfy the remainder.
    c. Disapprove.
        i. Requested route cannot safety accommodate bicycles (e.g., shoulder may be too narrow or its condition may be of such poor quality that it cannot accommodate bicycles).
        ii. Reasonable, safe alternate available.
    d. Insufficient information.
        i. Additional information must be provided before a decision can be rendered.
8. The Central Office Bicycle/Pedestrian Coordinator makes the final decision.
9. The signature of the Secretary of Transportation or Deputy Secretary for Highway Administration is obtained.
10. The applicant is notified in writing after a decision is rendered. If the application is approved, the applicant is informed that riding may be permitted sunrise to sunset only.
11. If the application is approved, notification is placed in the Pennsylvania Bulletin.

Figure 6-1 shows the application form for bicycles on freeways.

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION

REQUEST FOR PERMISSION TO OPERATE A
PEDALCYCLE ON A PENNSYLVANIA FREEWAY
UNDER SECTION 3511 OF THE VEHICLE CODE

Name _____

Organization _____

Address _____

_____

Daytime Phone Number ( )_____

Section of Freeway Requested For Use (Reference by interchange name or number on freeway or intersecting route number):

From _____

_____

To _____

_____

Reasons Why Any Alternate Route is Not Suitable (Consider length and safety considerations of alternate route. Use continuation sheets, if necessary. Attach maps, photographs, and other documentation, if appropriate):

_____

_____

_____

_____

_____

_____

_____

_____

_____

Figure 6-1: Bicycles of Freeways Application Form

6.6.2 Application Evaluation Criteria

The following factors should be considered in evaluating an alternate route:

1. Length of the detour.
2. Average daily traffic (less than 500 is favorable).
3. Speed limit (lower than 35 MPH is favorable).
4. The presence/absence of potentially hazardous conditions, including but not limited to:
    a. Pavement condition.
    b. Driveways.
    c. Narrow shoulders, paved or unpaved.
    d. No paved shoulders.
    e. Narrow motor vehicle lanes.
    f. Pedestrian traffic.
    g. Railroad tracks, especially skewed crossings.
    h. Narrow bridges.
    i. Poor sight distance.
    j. Rough road surfaces.
    k. Parked vehicles.
    l. Turning trucks.
    m. Percent of truck, bus, and recreational vehicle traffic.

The following factors should be considered in evaluating the freeway for acceptability for bicycles:

1. Paved shoulder of sufficient width and acceptable riding surface to accommodate a designated bicycle route.
2. Presence of milled rumble strips.

6.6.3 Other Considerations

- PennDOT will make every reasonable attempt to work with an applicant to solicit all pertinent information so that PennDOT can make a well-informed decision. Each application will be judged on merit on a case-by-case basis. However, an applicant may appeal a final decision. The applicant must submit a request in writing within 20 days to:

Administrative Docket Clerk
9th Floor
Commonwealth Keystone Building
Harrisburg, PA 17120

A minimum fee of $100.00 will be charged to the applicant.

- The applicant will be notified that in the future, should conditions change, a re-application may be permitted.

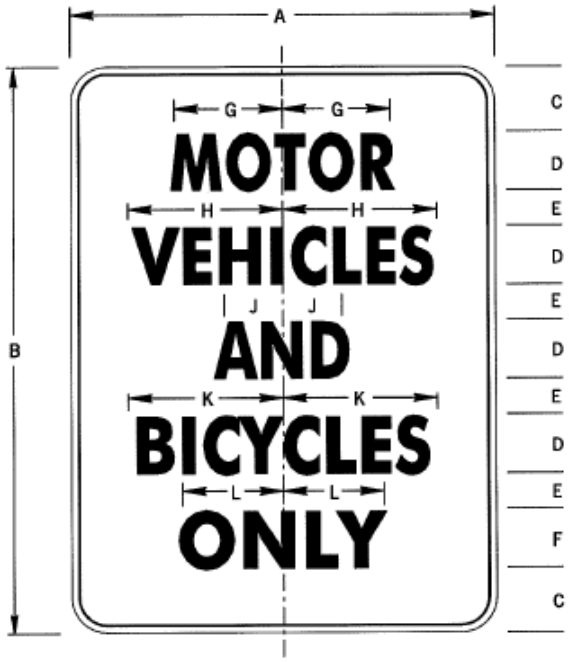
- Central Office and District Bicycle/Pedestrian Coordinators will each keep a map showing those sections of freeways which are opened and make the map available upon request.

- Signs must be erected at both the ramp entrance and exit points to grant bicyclists permission to use the route and to notify motorists of the presence of bicycles.

6.6.4 Bicycle Signs – Justifications

R5-3-1A – Motor Vehicles and Bicycles Only

The motor vehicles and bicycles only sign (R5-3-1A) shall be used at all freeway entrance ramps for those sections of freeway where bicycles as well as motor vehicles are permitted. It should be placed at the beginning of the ramp where bicyclists can see it and before motorists are involved with the actual merge movement onto the freeway proper.



DIMENSIONS – IN												
SIGN SIZE A x B	C	D	E	F	G	H	J	K	L	MAR–GIN	BOR–DER	BLANK STD.
36" x 48"	5.5	5C	3	5D	9.1	12.9	5.3	12.9	8.4	0.6	0.8	B5–4836

Figure 6-2: Motor Vehicles and Bicycles Only Sign (R5-3-1A)

R5-3-1B – Bicycles Must Use Shoulder

The bicycles must use shoulder sign (R5-3-1B) shall be used only on freeway segments where bicyclists are permitted. They shall be placed along the roadway so they can be viewed by both bicyclists and motorists. The purpose of the sign is to direct the bicyclists to the proper position of the highway and to alert motorists of the presence of bicyclists in the freeway.

DIMENSIONS – IN										
SIGN SIZE A x A	B	C	D	E	F	G	H	MAR–GIN	BOR–DER	BLANK STD.
48" x 48"	6	6C	4	15.5	8.5	6	17	0.6	0.8	B3–48

Figure 6-3: Bicycles Must Use Shoulder Sign (R5-3-1B)

R5-3-1C – All Bicycles Must Exit

The all bicycles must exit sign (R5-3-1C) shall be used at a freeway interchange exit ramp beyond which bicycles are not permitted.

DIMENSIONS – IN										
SIGN SIZE A x A	B	C	D	E	F	G	H	MAR–GIN	BOR–DER	BLANK STD.
48" x 48"	6	6C	4	5.9	15.5	8.5	6.7	0.6	0.8	B3–48

Figure 6-4: All Bicycles Must Exit Sign (R5-3-1C)

R5-3-1D –Bicycle Restrictions

The bicycle restrictions sign (R5-3-1D) shall indicate the age restrictions for bicyclists on freeways. The R5-3-1D shall be mounted below the motor vehicles and bicycles only sign (R5-3-1A).

DIMENSIONS – IN												
SIGN SIZE A x B	C	D	E	F	G	H	J	K	L	MAR–GIN	BOR–DER	BLANK STD.
36" x 24"	3	2C	1.6	12.5	12	12.7	10	14.3	0.6	0.4	0.6	B5–3624

Figure 6-5: Bicycle Restrictions Sign (R5-3-1D)

6.7 Safety and Work Zone Traffic Control Policy for Traffic Counting Operations

The safety and work zone traffic control policy pertains to the installation, maintenance, repair, or removal of traffic counting equipment for the purpose of recording traffic volumes, classification, and weight. While this policy encompasses most situations encountered during the installation, maintenance, repair, or removal of traffic counting equipment and is intended to highlight and clarify key safety and work zone issues, it is ultimately the responsibility of those engaged in this activity to comply with the policy set forth in the referenced regulations and publications.

6.7.1 General

This policy applies to all PennDOT personnel, MPOs, Regional Planning Organizations (RPO), contracted vendors, and others engaged in the installation, maintenance, repair, or removal of traffic counting equipment on highways within Pennsylvania.

6.7.2 Vehicle

The vehicle(s) used during the installation, maintenance, repair or removal of traffic counting equipment shall be equipped with either a fixed or portable flashing or revolving yellow strobe light or a bar of lights. The single light or bar of lights shall be placed on the vehicle at a location that is visible by approaching traffic from all directions. Please refer to Department of Transportation Regulations, 67 PA Code, Chapter 173, “Flashing or Revolving Lights on Emergency and Authorized Vehicles.”

6.7.3 Personal Protection Equipment and Attire

The following are regulations regarding equipment and attire for personal protection as specified in PennDOT’s *Safety Policy Manual*, Publication 445.

High Visibility Outerwear

All personnel involved in the installation, maintenance, repair, or removal of traffic counting equipment shall wear protection in accordance with Publication 213, General Note number 9. For nighttime conditions the outerwear must meet requirements for worker visibility as specified in Publication 46.

Head Protection

During the installation, maintenance, repair, or removal of traffic counting equipment, all personnel shall wear a hard hat. The hard hat may only be removed at the point of and during any task that makes it difficult to keep the hard hat on the head, at which time the hard hat may be removed and placed next to the worker to complete the task. The hard hat must be replaced immediately after completing the task. These tasks may include but are not limited to: kneeling to install portable counters and/or road tubes, in-pavement sensor installations and routing of sensor lead wires.

Eye Protection

Safety goggles/glasses with side-impact protection shall be worn during any installation, maintenance, repair, or removal of traffic counting equipment operation that may cause an object or material to become airborne. Eyewear must meet ANSI/ISEA Z87.1 standards.

Hand Protection

Gloves shall be worn during any installation, maintenance, repair, or removal of traffic counting equipment operation that may cause abrasions, laceration, blisters, or punctures to the hand(s).

6.7.4 Work Zone Safety and Signing

The basic principles and guidelines for work zone traffic control are officially contained in Department of Transportation Regulation, 67 PA Code, Chapter 212, 2006 Official Traffic Control Devices and Publication 213 Temporary Traffic Control Guidelines. These documents are available at www.dot.state.pa.us. Most activities performed during the installation and removal of portable traffic counters and the installation, maintenance, or repair of permanent traffic counting facilities can be considered short-term operations, adjacent to any roadway, and therefore shall comply with Publication 213, Figure 5.

6.7.5 Additional Safety Precautions

The work performed by personnel during the installation, maintenance, repair, or removal of traffic counting equipment affords a sense of independence but also demands quickness and a heightened sense of alertness due to exposure to passing motorists. It is for these reasons that PennDOT personnel are required to adhere to this policy and observe all possible safety precautions to prevent injury to PennDOT personnel and to prevent hazardous conditions for the motoring public.

- Carefully plan the location of traffic counts by following routes that restrict numerous directional changes or excessive mileage. A tangent section of highway is best for setting

traffic counts. This allows for additional sight distance and helps to ensure that the road tube is not torn up due to hard steering or braking traffic.

- Pull the vehicle(s) onto the shoulder and turn on the four-way flashers, flashing or revolving yellow strobe light or a bar of lights, and headlights. This will give additional warning to approaching motorists. Resist the temptation to avoid these precautions; they are the only notification an approaching motorist has of your location.
- Wear personal protective equipment; this includes a hardhat, safety goggles/glasses, gloves, and a high visibility safety vest as required.
- Allow enough time to travel between count locations. Look for a stable (but not too hard) surface to strike nails or spikes into and be careful to strike the center of the nail head or spike to avoid ricochet. Carefully secure the "dead end" of the road tube far enough away from the path of travel to avoid being struck by passing traffic.
- Wait until all cars in a row have passed and there is no sound of approaching traffic.
- Allow enough time to set counts safely and be sure to have enough "slack" in hand before starting across the highway. Tie off and secure road tube connection points carefully to avoid having the road tube and nails pulled up by traffic.
- Avoid setting traffic counters in areas of tall grass that may harbor ticks and other flying insects. Wear a good pair of hiking shoes, long sleeve shirt, and durable jeans that protect the legs.
- Drive defensively! Other drivers are often impatient as you turn or slow down to set up traffic counts. Use turn signals and mirrors; avoid backing up whenever possible. The long wheelbase of a typical van creates a blind spot to the rear and to the side. Report crashes or injuries to your supervisor immediately.
- Although you are encouraged to set as many traffic counts as time permits, do not attempt to set a count in an area that is obviously dangerous; look for another location that is safer. If this is not possible, do not attempt to set that count, and notify your supervisor.

6.7.6 PennDOT Traffic Counter Training

All personnel who will be engaged in installing and removing portable traffic counters shall view PennDOT's traffic counter training video, which includes safety and installation/removal best practices. This video is available on the Bureau of Planning and Research "Traffic Partners Page," http://www.dot.state.pa.us/Internet/bureaus/pdPlanRes.nsf/infoBPRvideochoice.

6.8 Roadside Memorials

Penn DOT does not have an official policy related to the erection of roadside memorials. The only memorial markers officially authorized are signs for legislatively designated portions of highway. Historically, PennDOT has not approved official requests for memorial markers and signs. However, when roadside markers are erected, PennDOT typically does not remove them unless they pose a safety concern. If the memorial is in a state of disrepair after a period of time, PennDOT may remove it.

6.9 Bystander Care

As part of the strategic safety focus area, PennDOT personnel have the opportunity in rare instances to save someone's life. PennDOT employees, particularly maintenance forces, are frequently on the highways, and on an infrequent basis, are the first people at a crash scene. When people are injured severely, they sometimes die because of excess loss of blood or suffocation before emergency medical personnel can reach them. The Department of Health and PennDOT have a joint effort underway to train volunteers to react to this rare situation in a positive manner and possibly save someone's life. Penn DOT volunteers participate in a two-hour training session, Dare to Care, conducted by Department of Health.

The goal of the training course is to reduce deaths that result from severe crashes on highways, particularly in rural areas. While not a traditional first aid course, the course is related to first aid. It focuses on five simple steps to maintain life until medical assistance arrives:

- Recognize an emergency.
- Stop to help.
- Call for help.
- Start the breathing.
- Stop the bleeding.

Participants who complete the course are provided a glove box containing a face shield, gloves, and a small safety reminder card.

PennDOT normally offers the two-hour course at County maintenance facilities in the Winter/Spring. District or County personnel attending the course do so on a strictly voluntary basis. The Department of Health provides the instructors and may be willing to provide instruction to accommodate winter shifts (i.e., late evening/early morning). The District Training Coordinator is often the District contact point with the Department of Health for this training.

6.10 Mountable Curb Median Retention During Resurfacing Improvements

A few of PennDOT's older arterials have mountable curb medians separating traffic. These mountable curbs have a minimal effect on averting head-on collisions resulting from out of control vehicles. However, they have a significant safety benefit in restricting left turning movements from the mainline or from adjacent driveways. As these arterials age and require overlays, the mountable curb medians' safety benefits may be severely compromised if the resultant overlay opens access of the facility and allows drivers to begin making left turns.

One of the prime principles of highway design is not to compromise highway safety. As such, the following guideline is provided for the assessment of overlay improvements on arterials with mountable curb:

- Would the removal or partial covering of the mountable curb result in a substantive number of left turn movements?

If the answer is no and there is minimal or no potential for developing turning movements in the future, the mountable curb may be eliminated. The potential for placing a positive standard median barrier (i.e., F-shape) to prevent head on collisions needs to be reviewed. If not possible or appropriate, the mountable curb may be replaced with standard pavement markings.

If the answer is yes, first priority is given to replacing the mountable curb with a positive standard median barrier (i.e., F-shape) to prevent head-on collisions and restrict left turn movements. This is particularly important if the operating speeds are in excess of 40 MPH. Special attention must be given to address sight distance concerns at existing breaks in the median. If these sight distance concerns cannot be adequately addressed, the mountable curb should be replaced in kind, as per the Roadway Construction Standards (RC-65M).

Documentation of the above assessment should be made part of the project file.

6.11 Full Width Pavement Markings on High-Speed Highways

Pavement markings may have a lower coefficient of friction, particularly when the surfaces are wet, than that of adjacent pavements. Normally this does not constitute a problem for vehicles. However, full width markings, which encompass the entire travel lane width and are more than four feet in length, such as those that depict route markings, should be avoided on highways with higher operating speeds (i.e., operating speeds in excess of 40 MPH) where the markings cannot be avoided by vehicles traversing the section.

District Highway Safety Guidance Manual

Appendix A — **District Safety Plan Guidelines**

December, 2014

District Highway Safety Guidance Manual

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A.1 Purpose

The Commonwealth of Pennsylvania has adopted the AASHTO highway safety goal of halving the current five-year average of traffic-related fatalities in two decades. The ultimate goal is a five-year average of 706 fatalities per year for the 2026-2030 period.

To guide our overall efforts in achieving this goal, the Department has developed a Strategic Highway Safety Plan (SHSP) which includes specific action items, goals, and metrics.

A portion of the effort required to achieve our goal is performed at the District level. To promote forward planning and support of the overall efforts, each District shall develop a District Safety Plan that will support the statewide SHSP as part of their annual District Business Planning cycle. The annual District Safety Plan shall be completed each year by March 31 of the preceding state fiscal year.

A.2 District Safety Planning Process and Timeline

A projected timeline for the District highway safety planning process is presented in Figure 1.

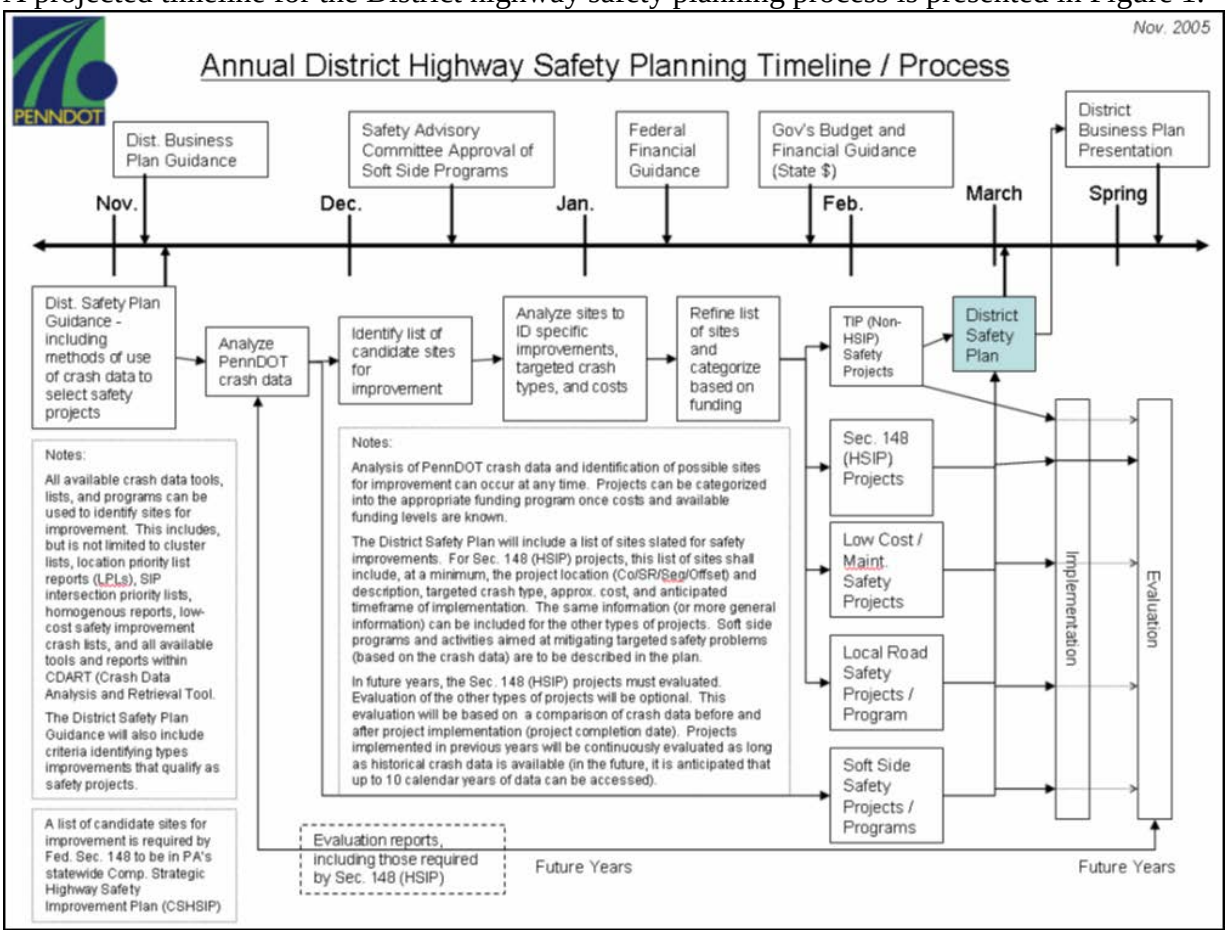

Figure 1. District Safety Planning Timeline/Process

A.3 District Highway Safety Champion

Each District has designated a "highway safety champion," who will be a point of contact for all highway safety related matters at the District level. Each highway safety champion will effectively implement, manage, report, and coordinate the planning of all highway safety initiatives and programs.

Table A-1: District Highway Safety Champions

1-0	2-0	3-0	4-0	5-0	6-0	8-0	9-0	10-0	11-0	12-0
Brian Smith	Jim Roman	Bill Houpt	Bob Wasilchak	Charles Richards	Ashwin Patel	Jason Hershock	John Fraundorfer	Adam Marshall	Kathryn Power	Cory Craft

A.4 District Safety Plan Project Guidance

The introduction to the safety portion of the District Safety Plan will include historic fatality information and the District safety goal in terms of five year average fatalities. The District Safety Champion should also be identified in this section of the plan. Total fatality goals for each District are located in the respective Highway Safety Summary Report versions.

At its core, the District Safety Plan will include lists of planned safety projects and initiatives chosen by analyzing crash data and working with the planning partners to mitigate safety problems at targeted locations in the District. The projects and initiatives will be divided into separate sections in the District Safety Plan based on the following categories:

1. Safety Projects
    - A. TIP (Non-HSIP, Section 148) Safety Projects
    - B. Section 148 Funding
    - C. Low-Cost Improvement Projects
        - I. Low-Cost Safety Improvement Projects (LCSIP)
        - II. Low-Cost Risk Management Projects (LCRMP)
        - III. Other Maintenance Safety Projects
    - D. Local Road Safety Projects and Initiatives
2. Safety Press Officer Planned Activities
3. Non-Compliant Shoulder Rumble Strip Tracking
4. District Strategic Highway Safety Plan (SHSP)

A.4.1 Safety Projects

4.1.A TIP (Non-HSIP, Section 148) Safety Projects

These long-term safety projects are generally too costly to be programmed using Section 148 – HSIP funds or do not meet the requirements of SOL 470-11-02. However, they can be programmed on the Transportation Improvement Program (TIP) as safety projects using other federal-aid funds such as Surface Transportation Program and National Highway System funds.

Other long-term projects already programmed on the TIP that may have substantial safety benefit should also be listed in this section of the safety plan.

4.1.B Section 148 HSIP Funding

The Highway Safety Improvement Program (HSIP) is a federally-funded program which serves to reduce fatalities and major injuries on the nation's highways through implementation of infrastructural countermeasures. The program was established in 2005 and has proved critical in helping Pennsylvania reduce highway fatalities by approximately 15% since its inception.

The recent federal Moving Ahead for Progress in the 21st Century (MAP-21) legislation has increased Pennsylvania's HSIP funding from $45 million to approximately $92 million per year. This surge in funding will greatly assist efforts to reach our aggressive highway safety goals, which include reducing highway fatalities by 50% within 20 years.

FUNDING ALLOCATION

The $92 million in funding will be allocated as follows:

I. Implementation of Infrastructural Safety Countermeasures: Approximately $57 million (62%) of the safety funding will be allocated towards this effort. Project sites and studies shall be selected and prioritized solely on the injury and fatality reduction potential of the proposed project, as supported by the crash data history. In order to ensure the strategic, data driven investment of our safety dollars, the following selection process should be used in programming Section 148 – HSIP projects:

1. First, select projects that contain locations listed on the Statewide High Crash Locations priority ranking, starting with most recent year. Low cost improvements, that will directly address the main crash history causations at these locations, can be considered. Statewide High Crash Locations are published in the annual District Highway Safety Summary Reports, which are located at:
   P:\bhste_shared\highway-safety\State of Highway Safety Summary Report\District Reports

2. Next, consider deploying systematic implementation of proven low cost countermeasures by addressing the recommendations mentioned in the Intersection Safety Implementation Plan (ISIP), the Roadway Departure Implementation Plan (RDIP), as well as the four safety focus areas identified in Table 1.

Table 1. Systematic, Proven, Low Cost Countermeasures

Safety Focus Area	Suggested Countermeasures	Guidance / Information
Head-On	Centerline Rumble Strips	Pub. 638 Chap. 5.4.12
	Cable Median Barrier	Next Edition of Pub. 638
	Wrong Way Entry Ramp	Next Edition of Pub. 638
Run-Off-Road	Edge-line/Shoulder Rumble Strips	Pub. 638 Chap. 5.4.15 & RDIP
	Elimination of Substandard Cable Guide Rail	Next Edition of Pub. 638
Intersections	Sign, Pavement Marking, and Signal Improvements	Pennsylvania Intersection Safety Implementation Plan
Curve-Related	Delineation, Advance Signage, Obstruction Clearing, Rumble Strips, High Friction Surface Treatment, Shoulder Pavement, Super-elevation Modification, etc.	*Low Cost Treatments for Horizontal Curve Safety*, FHWA, 2006

Note that FHWA has assisted PennDOT with the two previously-mentioned safety plans:

- The Intersection Safety Implementation Plan (ISIP) identifies a large number of low-cost countermeasures at specific intersections with crashes above a defined crash threshold. Plan information is located at: P:\bhste_shared\highway-safety\District_Safety_Planning\Intersection Safety Implementation Plan

- The Roadway Departure Implementation Plan (RDIP) identifies a large number of relatively low-cost, cost-effective countermeasures at many targeted roadway departure sites with moderate crash levels. Plan information is located at: P:\bhste_shared\highway-safety\District_Safety_Planning\Roadway Departure Implementation Plan (Est 2012)

3. Section 148 – HSIP funds may be used by county maintenance forces to deploy these low cost countermeasures. Regulation 23.CFR.635 Subpart B – Force Account Construction details the proper procedures to follow. This includes the widening of shoulders so that projects may qualify for the placement of edge line rumble strips. Maintaining existing safety features/maintenance activities (such as tree trimming, line painting, maintaining traffic control devices/signs, etc.) are not the intent of Section 148 funding and will not be approved. These types of systematic safety improvements may be addressed with Section 715, Low Cost Safety Improvement Program Funding and/or Maintenance Funds.

– OR –

A District may program locations identified on Planning Organization High Crash Lists or District High Crash Corridor Lists. Both types of lists are published in the annual District Highway Safety Summary Reports.

4. Projects not meeting the above criteria may be programmed, but first must be approved by the Program Management Committee. Such approval requests must include the following information to be considered for approval:
    - General Project Information, including scope, costs and estimated completion dates.
    - District strategy for exceeding its fatality goal, with the consideration of this project.
    - Justification and safety benefit of programming a non-Statewide High Crash Location/Systematic project, related to fatality goals.

I. Implementation of Systemic Low Cost Safety Countermeasures: This portion of the HSIP MAP-21 funding has specifically been set aside to cover the Special Rules regarding Rural Roads and Older Drivers and Pedestrians. The remaining $35 million (38%) will be divided as follows:
    a) $16 million (17%) for Roadway Departure Implementation Plan (RDIP) projects
    b) $10 million (11%) for Intersection Safety Implementation Plan (ISIP) projects
    c) $9 million (10%) set-a-side for systematic improvements. These can include:
        - Rumble strips
        - Cable Median Barrier
        - High Friction Surface Treatment
        - Wrong Way Entry Ramp Countermeasures
        - Elimination of substandard cable guide rail
        - Etc.

The Highway Safety and Traffic Operations Division (HSTOD) will continue to work in conjunction with the Center for Program Development and Management to review and verify the eligibility of projects for HSIP funding. The Assistant

District Executive for Design in each District should maintain a program overview so each District meets the metrics for the HSIP funds.

4.2.C Low Cost Improvement Projects

4.2.C.i Low Cost Safety Improvement Projects (LCSIP)

The following guidelines are to be used when developing your District's systematic safety improvement program:

1.) At a minimum, 50 percent of the District LCSIP budget (Governor's $10 Million Safety Fund – App. 583, Program 715) will be utilized for systematic safety improvements.
   a.) It is understood that the systematic implementation of an improvement can take many years to complete because of limited safety funding.
   b.) The remaining District LCSIP budget will be used to implement safety improvements that address high crash locations for specific types of crashes.
      i.) Use CDART and the specific crash flags to generate lists and maps of potential improvement locations.
      ii.) LCSIP funds will still be distributed by county and they cannot be transferred between counties.
2.) From the menu of safety improvements shown below, the Districts will decide which improvement(s) will be systematically implemented in their region.
   a.) The improvement categories shown below are in priority order based upon their potential to reduce fatalities. The priority order may vary from District to District depending upon local conditions.
   b.) When planning the systematic implementation of improvements start with higher volume roadways first and then work toward the lower volume roadways.
3.) All safety improvements aren't applicable to all locations – implementation will depend on the facility type, roadside environment, urban/rural surroundings, pavement type, pavement age, lane/shoulder width, etc.
4.) All systematic safety improvements will be implemented at all viable locations in accordance with applicable design and construction criteria, regardless of crash history.
5.) Begin thinking about future years and a long-range plan for systematic implementation of safety improvements.
   a.) HSTOD will discuss each District's plans during periodic District safety conference calls.
   b.) Provide an estimate of the total quantity of systematic improvements that will be implemented each year.
6.) HSTOD will consider other systematic improvements not shown in the menu below on a case-by-case basis as they are submitted by the Districts.
7.) The Districts will not use these funds to perform activities or install improvements that are normally completed as part of routine maintenance

work and with normal maintenance funding (such as crack sealing, routine shoulder and drainage work, routine paving work, etc.).

8.) HSTOD will review the completed District Safety Plans to determine if the above conditions are met.

Menu of Systematic Safety Improvement Countermeasures (In Priority Order)

1. Centerline rumble strips
2. Shoulder rumble strips (with 6 feet minimum shoulder – can widen shoulder and include necessary backup)
3. Edgeline rumble strips (with 4 feet minimum shoulder – can widen shoulder and include necessary backup)
4. Provide 4 feet of paved shoulder and edgeline rumble strips on all non-expressway traffic routes above 5,000 ADT
5. Fix shoulder drop-offs (should be addressed as a regular maintenance activity)
6. Install left turn lane
7. Clear brush and embankments for visibility at intersections (should be addressed as a regular maintenance activity)
8. Remove frequently hit trees within clear zone or existing right-of-way
9. Advance curve warning pavement markings
10. Move frequently hit utility poles outside clear zone or existing right-of-way
11. Install add crashworthy transitions at bridge ends
12. Replace non-standard cable guide rail

Additionally, to expand on the systematic approach, FHWA has assisted PennDOT with the development of the following plans:

1) The Intersection Safety Implementation Plan (ISIP) identifies a large number of low-cost countermeasures at specific intersections with crashes above a defined crash threshold.
2) The Roadway Departure Implementation Plan (RDIP) identifies a large number of relatively low-cost, cost-effective countermeasures at many targeted roadway departure sites with moderate crash levels.

Note that the recommendations from both of the plans are eligible for safety (LCSIP and HSIP) funding.

Implementation of Safety Improvements Using LCSIP Funds at High Crash Locations

For the remaining 50 percent (or less) of the District's LCSIP budget, projects are to be selected based on the guidance provided by the August 7, 2014 Memo, which can be found at:

LCSIP Fiscal Guidance Memos

NOTE: Quarterly reports on the implementation of LCSIP countermeasures must be provided by the District on the 15th after each quarter because low-cost safety improvements are installed using funds from the Governor's Budget Initiative.

4.2.C.ii Low Cost Risk Management Projects (LCRMP)

Most of PennDOT's tort liability issues result from traffic incidents where a hazardous condition or roadway deficiency is present and is the alleged cause. As part of the development of an overall highway safety program, Low Cost Risk Management Projects (LCRMP) should be part of the mix of projects that are identified and implemented.

LCRMP serve to complement the Department's overall highway safety program by addressing smaller maintenance and operational improvements that tend to be the focus of many of these tort claims. Locations that are selected for these improvements may or may not have a past crash history, but by their nature have the potential to result in serious injuries, damages or unnecessary tort exposure.

Each district has a designated Risk /Tort Manager who should be consulted and will be instrumental in helping to develop and prioritize the list of LCRMP to be included as part of the District's overall highway safety program.

Table A-4: District Risk Management/Tort Coordinators

1-0	2-0	3-0	4-0	5-0	6-0	8-0	9-0	10-0	11-0	12-0
Doug Schofield	Dennis Prestash (Acting)	Jeff Stepanik	Joe Cassaro	Chade Sankari	Ron Notar	Jason Hershock (Acting)	Jim Osborn	Daryl Messinger	Jonathan Geisinski	Robb Dean

The following approaches should be emphasized when developing and implementing LCRMP:

- Improvements at tort litigation and claim sites, past and present
- Systematic elimination of select deficiencies (cable guide rail, shoulder drop-offs, etc.)
- Improvements at isolated sites with any of the deficient roadway conditions that follow in this section.

High Tort Potential Deficiency Areas:

- **Signing & Pavement Markings**
  Signing – missing, obscured and/or poor retro-reflective signs - most notably stop signs and other important regulatory and warning signs
  Pavement Markings – missing, incorrect, confusing, and/or poor retro-reflective markings

- **Pavement Conditions**
  Slippery Pavement – pavements with low skid resistance due to normal polishing of aggregate or bleeding/flushing
  Potholes – deformities in the pavement, which are not corrected in a timely manner after the department receives notice of their existence
  Rutting – this deformity often results in standing water in the roadway's wheel paths causing vehicle hydroplaning -- additionally, even when dry, rutting can be of concern to motorcycle traffic

- **Traffic Barrier**
  Guide Rail – non-functional, inadequate, and/or poorly maintained guide rail
  Median Barrier – lack of positive separation on high speed, multi-lane facilities that meet the warrants for median barrier and have a crash history
  Obsolete Features – system features that are outdated due to significant changes in traffic, access, vehicle mix, Department standards, etc., since the original design/construction of the facility (example: old obsolete cable systems)

- **Fixed Objects**
  Trees, rocks, embankments, unauthorized objects, etc. that are within the right of way and/or "clear zone" that pose a higher risk for being struck by an errant vehicle

- **Sight Distance**
  Inadequate corner and/or stopping sight distance often caused by vegetation and/or roadway geometry (embankments, curves, over-verticals, etc.)

- **Drainage / Icy Spots**
  Isolated Icy Spots – icy patches when the remainder of the roadway is dry
  Inadequate Drainage – flooding or ponded water caused by blocked, missing or incorrectly installed drainage facilities

- **Pavement / Shoulder Edge Drop-offs**
  A differential in elevation at the pavement/shoulder edge in excess of two inches is a potential risk concern for errant vehicles.

- **Roadway Geometry / Design**
  Substandard/incorrect design – usually alleged that state/federal standards in place at the time were not followed. Often these issues show themselves in the form of one of the previously mentioned deficiencies.

- **Problem Intersection Traffic Control**
  Identifying select problematic intersections in need of new, revised, and/or updated traffic control often involves partnerships with local municipalities, especially with respect to traffic signal installations and upkeep. Although Regulation (Title 67 Transportation, Chapter 212, Section 212.5) places primary responsibility for traffic signal installation, maintenance, and operation with the local municipality, this does not release the department from tort liability exposure, especially if a serious crash occurs at an intersection with a history of known or previous safety concerns that could have been corrected by the installation of a traffic signal or other upgraded traffic control.

  A good risk management approach involves proactive, continued dialogue with local municipalities and others to resolve the problem. If agreement cannot be reached between the district and respective municipality, then the district needs to consider improvement options--as the ultimate

responsibility for intersection safety on state roads resides with the department.

In a limited number of cases, the installation of a new traffic signal or roundabout by the department may be the only solution to improved safety at an identified known problematic intersection, especially where the municipality is otherwise unwilling to assume their maintenance and operation ownership responsibilities. This improvement option may include the programming of a new Transportation Improvement Program (TIP) project or the expansion of an existing TIP project to include signal installation or a roundabout, with the municipality assuming ownership responsibilities.

- **Problem Slope Stability Areas**
  Identify critical slopes adjacent to the roadway that exhibit potential for failing or have a history of failures and safety concerns that can be corrected by stabilizing the slope. These areas will need to be examined by the District Geotechnical Engineer to determine the appropriate course of action. Generally, the remediation of such areas requires work beyond the budget and capabilities of our maintenance program and may require a separate funded project to be programmed.

4.2.C.iii Other Maintenance Safety Projects

These are the projects done under the Maintenance Program from routine maintenance activities that may improve safety. The Maintenance Unit will coordinate sites to be improved with the District Safety Engineer.

Typical types of safety improvement projects that can be implemented as a part of the routine Maintenance Program include:

- Tree removal
- Fixing shoulder drop-offs or shoulder upgrades
- Slope and curve flattening
- Guide rail improvement or replacement
- Drainage improvements
- Protecting bridge ends – transition guide rail
- Addressing slippery pavement
- Sight distance improvements

These activities can be done by maintenance work force or contract.

4.2.D Local Road Safety Projects and Initiatives

Improving highway safety on local roadways is an important part achieving our highway safety goals and is therefore included as an objective of the District Safety Plan.

Districts can improve the safety of local roads by implementing the following activities:

- Identify municipalities with high crash areas
- Determine types of crashes occurring

- Work with local municipalities on highway safety concerns
- Work with the Local Technical Assistance Program (LTAP) staff to assist local municipalities
- Work with municipalities on low-cost highway safety improvement project recommendations
- Refer high-benefit, low-cost projects to HSTOD for funding (limited dollars will be set aside from the National Highway Traffic Safety Administration funds for pilot projects)
- Coordinate agreement between PennDOT and local municipalities for projects identified for implementation
- Coordinate agreement activities with District Municipal Services staff and the Bureau of Municipal Services

A.5 Safety Press Officer Guidance

Districts can develop a systematic approach to supporting driver behavior related issues through the activities of the District Safety Press Officer (SPO). By working with safety grantees local agencies, District SPOs can help support statewide and local efforts of increasing the seat belt and child passenger restraint rates, reducing alcohol-related crashes and fatalities, reducing aggressive driving, enhancing younger and older driver safety, increasing heavy truck safety, improving work zone safety, and enhancing safety for other users of the transportation system such as pedestrians, bicyclists, and motorcyclists.

Examples of action items for a typical District Safety Press Officer can be found at:
P:\bhste_shared\highway-safety\District_Safety_Planning\Safety Press Officers

The SPOs' areas of focus should be data-driven; safety data for the District can be found in the annual District Highway Safety Summary Report.

The District SPOs should also continue to visit local police departments to stress the importance of improving the quality of crash reporting by utilizing the correct methods (i.e., electronically or with the most current forms). The current rate of electronic crash report submissions is 94%.

A.6 Non-Compliant Rumble Strips

PennDOT has been installing edgeline rumble strips on non-freeway highways since 2002. Since that time, construction standards have evolved and now reflect the safe accommodation of all road users, including bicyclists. Where shoulders are available and clear, bicyclists will often choose to use them to avoid conflicts with faster moving vehicles. However, as legal road users, they may also be in the travel lane.

Some of rumble strip installations were not placed in accordance with the guidelines in Publication 638 and may pose a safety hazard to roadway users when bicyclists are forced into

the travel lane. This in turn forces motorists attempting to overtake the bicyclist to pass unsafely. There are two options to deal with this issue: 1) fill the non-compliant rumble strips during the normal pavement life cycle, or 2) widen the roadway shoulder to permit existing rumble strips to come into compliance.

When a District proposes to correct a non-compliant rumble strip installation, the project should be included in the appropriate section of the District Safety Plan. Additionally, HSTOD should be notified when the project is complete.

A.7 District Strategic Highway Safety Plans

PennDOT has developed a Strategic Highway Safety Plan (SHSP) for Pennsylvania for 2012. The SHSP was developed by working with stakeholders and partners to target priority Safety Focus Areas and to develop strategies and action items to achieve our highway safety goals. It is recommended that each District also work with their stakeholders and partners to develop a District-specific SHSP based on the new goals established in the Statewide SHSP. The District Safety Summary Reports, distributed annually in the summer, will be based on the statewide goals from the statewide SHSP. It is recommended that Districts utilize this report for the development of their District SHSP.

Districts have the option of including their SHSP as part of this section of the District Safety Plan or submitting it as a separate document. Districts should now have a SHSP developed. This should align with the State's SHSP, per MAP-21.

A.8 District Safety Plan Template

An Excel template for the District Safety Plan has been created and placed at:
P:\bhste_shared\highway-safety\District_Safety_Planning\Completed_Dist_Safety_Plans

The template document has tabs set up for the information required in Sections 4.0 through 7.0 of this guidance document. Please utilize this template for District Safety Plan submissions.

> Completed District Safety Plans shall be placed in the appropriate Date and District subfolders.

A.9 Evaluation of Projects and Annual Federal Reporting

Utilizing available project and crash data, HSTOD performs safety evaluations of projects in compliance with federal regulations. These evaluations determine the effectiveness of implemented safety projects and countermeasures. Therefore, it is critical that the Districts accurately report project location information (County/Route/Segmet/Offset) on the safety plan

and within MPMS. Accurate project completion dates are also required to prepare the annual reports and effectiveness studies required by FHWA.

A.10 Network Resource Links

Resources and Data Root Folder
P:\bhste_shared\highway-safety\District_Safety_Planning

District Safety Plans
P:\bhste_shared\highway-safety\District_Safety_Planning\Completed_Dist_Safety_Plans

District Safety Plan Template
P:\bhste_shared\highway-safety\District_Safety_Planning\Completed_Dist_Safety_Plans

The State of Highway Safety Summary Reports
P:\bhste_shared\highway-safety\State of Highway Safety Summary Report

District Highway Safety Summary Reports
P:\bhste_shared\highway-safety\State of Highway Safety Summary Report\District Reports

Pennsylvania Intersection Safety Implementation Plan (ISIP)
P:\bhste_shared\highway-safety\District_Safety_Planning\Intersection Safety Implementation Plan

Pennsylvania Roadway Departure Implementation Plan (RDIP)
P:\bhste_shared\highway-safety\District_Safety_Planning\Roadway Departure Implementation Plan (Est 2012)

LCSIP Project Guidance and Memo
P:\bhste_shared\highway-safety\District_Safety_Planning\backup guidance\project selection guidance

Fiscal Coding Guidance:
P:\bhste_shared\highway-safety\District_Safety_Planning\Fiscal Coding Guidance

Examples of Action Items for a Typical District Safety Press Officer
P:\bhste_shared\highway-safety\District_Safety_Planning\Safety Press Officers

Highway Safety Improvement Toolbox
P:\bhste_shared\highway-safety\District_Safety_Planning\Highway Safety Improvement Tool Box

District Action Plans
P:\bhste_shared\highway-safety\District_Safety_Planning\Safety Action Plan

District Highway Safety Guidance Manual

Appendix B — **Yield to Pedestrian Channelizing Devices Pedestrian Safety Program**

December, 2014

District Highway Safety Guidance Manual

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B.1 Overview

Every year, approximately 150 pedestrians die on Pennsylvania's roads. This represents approximately 11 percent of all highway deaths. Older pedestrians (65+) are the most vulnerable and are highly over-represented in the total. This is due to their generally decreased faculties (slower gait, poorer eyesight or hearing, reduced agility) and increased frailty. Each year, just that group alone (pedestrians 65 and over) accounts for nearly 4 percent of all highway deaths in the Commonwealth. Other over-represented groups are adults in there 40s or early 50s and children aged 5-9. The latter group accounts for the highest number of injuries among pedestrians.

As part of its ongoing efforts to reduce pedestrian crashes on the Commonwealth's highways, PennDOT is purchasing and will provide to municipalities Yield to Pedestrian Channelizing Devices that meet all Federal and State criteria for traffic signs and crashworthiness. They are placed on roadway centerlines within 50 feet of crosswalks to remind motorists that they are to obey State law and yield to pedestrians in those crosswalks.

The PennDOT Highway Safety and Traffic Operation Division (HSTOD) has established a vendor contract to secure Yield to Pedestrian Channelizing Devices for eligible municipalities that have crosswalks that meet established criteria. The devices are being stored at the PennDOT Sign Shop in Harrisburg.

The District Pedestrian/Bicycle Coordinator is the principal coordinator in the approval and distribution of these devices to eligible municipalities.

B.2 Program Conditions

The following eligibility criteria have been placed on this program:

1. The units are intended for mid-block crossings or intersections. However, if used at intersections, they must be placed slightly in advance of and as close to the crosswalk as feasible without interfering with turning vehicle traffic.
2. All crosswalks must be marked (no unpainted crosswalks). Continental crosswalks are recommended and preferred. The root shared drive folder for all District Safety Planning resources and data is located here: P:\bhste_shared\highway-safety\District_Safety_Planning.

B.3 Determining Potential Locations

Potential locations for usage are determined by two methods.

B.3.1 Method #1 – Pedestrian Crash Locations

Pedestrian crash locations for municipalities with significant numbers of pedestrian crashes qualify for consideration of this program. Current municipalities and high pedestrian crash locations within the municipalities may be found on the P-drive.

B.3.2 Method #2 –Special Requests

District Bicycle/Pedestrian Coordinators may also accept requests for the devices from municipalities, police departments, safety program managers, Safety CRCs, advocacy groups (through a government entity), school districts, District Safety Engineers, and other interested parties, based upon safety need. If the request is not based upon a crash history, it should be based upon a community safety problem need where motorists do not yield to pedestrians in crosswalks. Those interested parties also must complete the attached Yield to Pedestrian Channelizing Devices Application Form.

In addition to completing the application form, the requesting municipality must also complete the Crosswalk Compliance Survey Form documenting the need for the device through a survey ("before" counts) for each crosswalk location. The purpose of the "before" studies are to demonstrate motorists' non-compliance with crosswalk laws at any candidate intersection in their jurisdiction. Non-compliance is defined as the percentage of motorists who fail to yield to pedestrians who have indicated their intent to cross by stepping off the curb, standing in the crosswalk at the curb (just outside the travel path of motor vehicles), or a similar signal of intent, and their is sufficient time for the passing motorist to react and safely yield to the pedestrian.

The "before" study should consist of manual or other counts to demonstrate that there is a need for better motorist education regarding pedestrian laws. A recommended procedure for the preliminary count would be for a representative of the requesting agency or municipality to conduct two 1-hour counts at similar times on any 2 days of 1 week (for example, 7:30 – 8:30 AM on a Monday and a Wednesday) and record the degree of compliance. Post-installation studies will also be required at 7-day, 30-day, and 180-day intervals following installation.

B.4 Completing the Application Process

The following steps should be done to complete the application process. See the attached Application form:

1. After meeting with PennDOT, the municipality completes the Yield to Pedestrian Channelizing Devices Application Form and the Crosswalk Compliance Survey Form and submits them to the appropriate District Bicycle/Pedestrian Coordinator. The District Bicycle/Pedestrian Coordinator shall review the municipalities' application and ensure that the request is appropriate and complete.
2. The District Bicycle/Pedestrian Coordinator will ensure that the "before" counts are done before the units are released to the municipalities. At periods of 7 days, 30 days, and 180 days after installation of the devices, the municipality is required to conduct "after" studies to measure motorist compliance. The District Bicycle/Pedestrian Coordinator shall collect the completed count forms from the municipality and send them to the Highway Safety and Traffic Operations Division for analysis.
3. Upon approval of the Yield to Pedestrian Channelizing Device Application Form and the initial crosswalk counts on the Crosswalk Compliance Survey Form, the District Bicycle/Pedestrian Coordinator authorizes shipment of the requested number of devices to the appropriate County Maintenance Office. Upon approval of the Yield to Pedestrian Channelizing Device Application Form and the initial crosswalk counts on the Crosswalk Compliance Survey Form, the District Bicycle/Pedestrian Coordinator authorizes transfer of the requested number of devices from the designated district repository to the to the municipality. A representative of the municipality then picks up the units from the district repository. The District Bicycle/Pedestrian Coordinator will create an order list by count date, and municipality.
4. The municipality places the devices at the appropriate locations and conducts the "after" crosswalk compliance survey forms at intervals of 7 days, 30 days, and 180 days after the placement and transmits the after surveys on the Crosswalk Compliance Survey Form to the District Bicycle/Pedestrian Coordinator.
5. Upon completion and receipt of the after surveys on the Crosswalk Compliance Survey Form from the municipality, the District Bicycle/Pedestrian Coordinator records the distribution of the devices on the "Yield to Pedestrian Channelizing Device Distribution Form" and forwards a copy of the before and after Crosswalk Compliance Survey Forms and the Yield to Pedestrian Channelizing Device Form from the municipality to the Highway Safety and Traffic Operations Division.
6. The Highway Safety and Traffic Operations Division analyzes the before and after information and uses this information to establish future policy and use of the Yield to Pedestrian Channelizing Device.

B.5 Forms

The following forms are included in this appendix:

1. Yield to Pedestrian Channelizing Device Application Form
2. Crosswalk Compliance Survey Form
3. Yield to Pedestrian Channelizing Device Distribution Form

YIELD TO PEDESTRIAN CHANNELIZING DEVICE APPLICATION FORM

Date_____
PennDOT Engineering District _____
Requesting Municipality/Agency_____
County_____
Address_____
Contact Person_____
Contact Person's Phone No. (____)_____
Contact Person's Fax No. (____)_____
Contact Person's e-mail address _____
Local Agency, Office, Department, etc. responsible for maintaining the devices
_____
_____

Crosswalk Locations (Intersection or Mid-block) Where Devices Requested	No.
1._____	___
Description of Problem_____	
2._____	___
Description of Problem_____	
3._____	___
Description of Problem_____	
4._____	___
Description of Problem_____	
5._____	___
Description of Problem_____	
6._____	___
Description of Problem_____	
7._____	___
Description of Problem_____	
8._____	___
Description of Problem_____	
9._____	___
Description of Problem_____	
10._____	___
Description of Problem_____	
Total Number of Devices Requested	___

PENNDOT CROSSWALK COMPLIANCE SURVEY FORM

This survey is designed as a simple measure of motorists' and pedestrians' compliance at marked crosswalks. The following steps are recommended.

1. Select a marked crosswalk where there is a pedestrian crash history or where motorist noncompliance is demonstrated or reputed to be very poor.
2. Choose two 1-hour observation periods within a 1-week time period that have identical times and identical conditions. Example: same crosswalk, same times of the week (12 noon - 1:00 PM on a Monday and a Tuesday) with similar weather patterns. Weather conditions that are conducive to walking (e.g., a dry, sunny day) are preferable. The observer may find that some or most of the crossings made by pedestrians will occur outside the crosswalk. The number of people who actually walk within the crosswalk lines may be minimal for the "before" studies, even though the total number of pedestrian uses at the subject crosswalk is substantial.
3. Conduct two sampling periods for each of the three post-installation ("after") periods.

Record the following information for each location and observation period:
(Photocopy this form before using).

Municipality _____
County_____
Date_____ Day of Week _____Hour of Day_____
Crosswalk Location (intersection, or if mid-block, direction to nearest intersection)_____
_____
Observer's Name _____
Weather Conditions _____
Check One: "Before" Study ____ "One Week After Installation" Study _____
"One Month After Installation" Study _____
"Six Months After Installation" Study _____

Condition	No. of pedestrians
Pedestrians who cross within the marked crosswalk and have no conflicts with motorists (there are no motorists present at the time).	
Pedestrians who cross not within the crosswalk, but within 50 feet of either side of it, and have no conflicts with motorists (there are no motorists present at the time).	
Motorists who yield to pedestrians within the marked crosswalk.	
Motorists who yield to pedestrians crossing within 50 feet of the marked crosswalk.	
Pedestrians who yield to motorists within the marked crosswalk (motorist failure to yield).	
Pedestrians who yield to motorists within 50 feet of the marked crosswalk.	

YIELD TO PEDESTRIAN CHANNELIZING DEVICE DISTRIBUTION AND SURVEY TRACKING FORM

District ___ -0

Total Devices Received _____

Municipality _____

Location No.	Pre-Survey Date	Date of Distribution of Device(s)	Date of 7-Day Post Survey	Date of 30-Day Post Survey	Date of 180-Day Post Survey
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					

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Appendix C — **Crash Data Resources**

December, 2014

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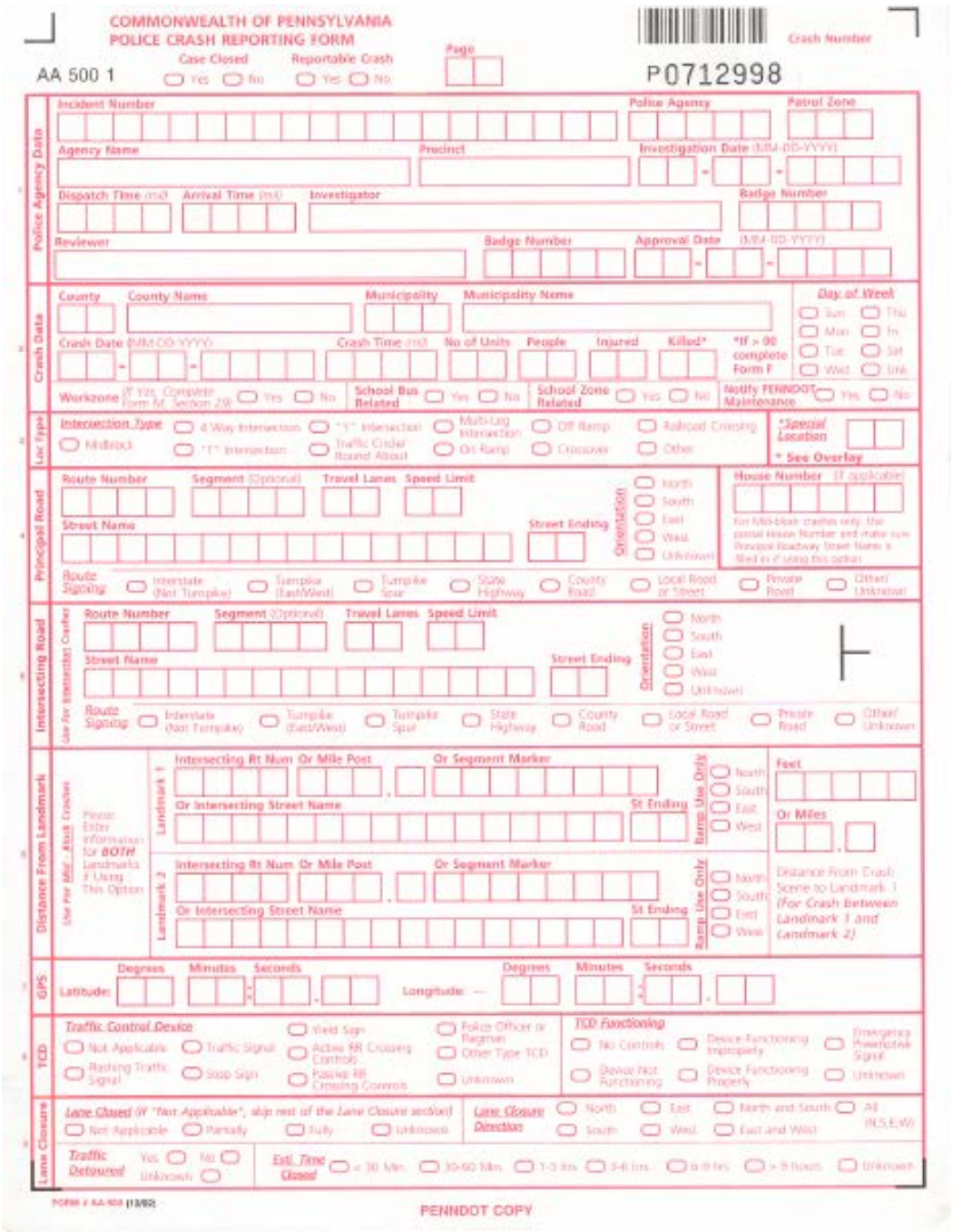
C.1 Standard Police Crash Report



COMMONWEALTH OF PENNSYLVANIA
POLICE CRASH REPORTING FORM

AA 500 1

Case Closed ☐ Yes ☐ No
Reportable Crash ☐ Yes ☐ No
Page
Crash Number P0712998

Police Agency Data
Incident Number
Police Agency
Patrol Zone
Agency Name
Precinct
Investigation Date (MM-DD-YYYY)
Dispatch Time (mil)
Arrival Time (mil)
Investigator
Badge Number
Reviewer
Badge Number
Approval Date (MM-DD-YYYY)

Crash Data
County
County Name
Municipality
Municipality Name
Day of Week: ☐ Sun ☐ Mon ☐ Tue ☐ Wed ☐ Thu ☐ Fri ☐ Sat ☐ Unk
Crash Date (MM-DD-YYYY)
Crash Time (mil)
No of Units
People
Injured
Killed*
*If > 00 complete Form F
Workzone (If Yes, Complete Form M, Section 29) ☐ Yes ☐ No
School Bus Related ☐ Yes ☐ No
School Zone Related ☐ Yes ☐ No
Notify PENNDOT Maintenance ☐ Yes ☐ No

Loc Type
Intersection Type: ☐ 4 Way Intersection ☐ "Y" Intersection ☐ Multi-Leg Intersection ☐ Off Ramp ☐ Railroad Crossing ☐ Midblock ☐ "T" Intersection ☐ Traffic Circle/ Round About ☐ On Ramp ☐ Crossover ☐ Other
*Special Location
* See Overlay

Principal Road
Route Number
Segment (Optional)
Travel Lanes
Speed Limit
Street Name
Street Ending
Orientation: ☐ North ☐ South ☐ East ☐ West ☐ Unknown
House Number (If applicable)
For Mid-block crashes only. Use postal House Number and make sure Principal Roadway Street Name is filled in if using this option
Route Signing: ☐ Interstate (Not Turnpike) ☐ Turnpike (East/West) ☐ Turnpike Spur ☐ State Highway ☐ County Road ☐ Local Road or Street ☐ Private Road ☐ Other/ Unknown

Intersecting Road (Use for Intersection Crashes)
Route Number
Segment (Optional)
Travel Lanes
Speed Limit
Street Name
Street Ending
Orientation: ☐ North ☐ South ☐ East ☐ West ☐ Unknown
Route Signing: ☐ Interstate (Not Turnpike) ☐ Turnpike (East/West) ☐ Turnpike Spur ☐ State Highway ☐ County Road ☐ Local Road or Street ☐ Private Road ☐ Other/ Unknown

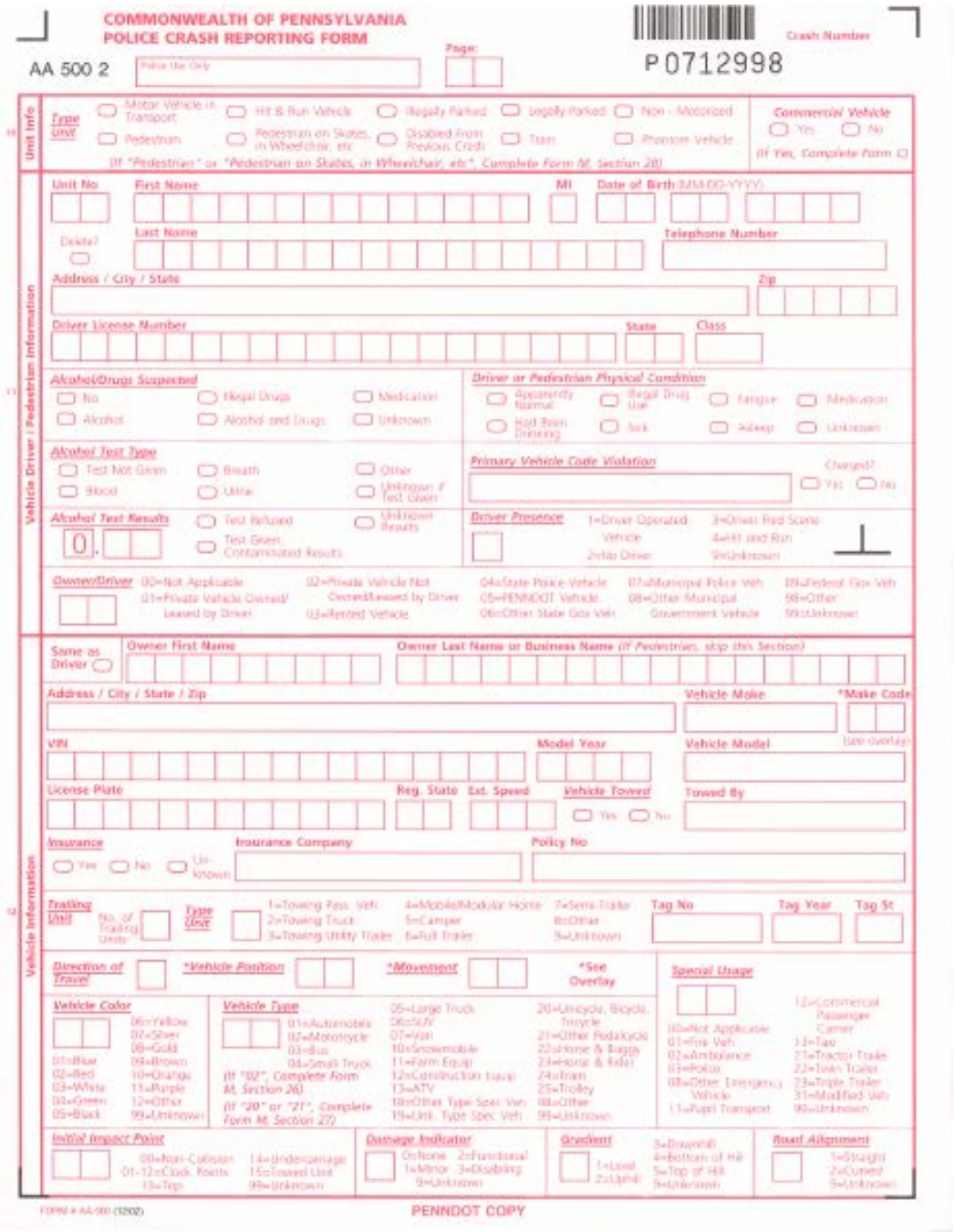
Distance From Landmark (Use For Mid - Block Crashes)
Please Enter Information for BOTH Landmarks if Using This Option
Landmark 1
Intersecting Rt Num
Or Mile Post
Or Segment Marker
Or Intersecting Street Name
St Ending
Ramp Use Only: ☐ North ☐ South ☐ East ☐ West
Landmark 2
Intersecting Rt Num
Or Mile Post
Or Segment Marker
Or Intersecting Street Name
St Ending
Ramp Use Only: ☐ North ☐ South ☐ East ☐ West
Feet
Or Miles
Distance From Crash Scene to Landmark 1 (For Crash Between Landmark 1 and Landmark 2)

GPS
Latitude: Degrees Minutes Seconds
Longitude: — Degrees Minutes Seconds

TCD
Traffic Control Device: ☐ Not Applicable ☐ Traffic Signal ☐ Yield Sign ☐ Police Officer or Flagman ☐ Flashing Traffic Signal ☐ Stop Sign ☐ Active RR Crossing Controls ☐ Other Type TCD ☐ Passive RR Crossing Controls ☐ Unknown
TCD Functioning: ☐ No Controls ☐ Device Functioning Improperly ☐ Emergency Preemptive Signal ☐ Device Not Functioning ☐ Device Functioning Properly ☐ Unknown

Lane Closure
Lane Closed (If "Not Applicable", skip rest of the Lane Closure section): ☐ Not Applicable ☐ Partially ☐ Fully ☐ Unknown
Lane Closure Direction: ☐ North ☐ East ☐ North and South ☐ All (N,S,E,W) ☐ South ☐ West ☐ East and West
Traffic Detoured: Yes ☐ No ☐ Unknown ☐
Est. Time Closed: ☐ < 30 Min. ☐ 30-60 Min. ☐ 1-3 hrs ☐ 3-6 hrs ☐ 6-9 hrs ☐ > 9 hours ☐ Unknown

FORM # AA-500 (13/02)
PENNDOT COPY



COMMONWEALTH OF PENNSYLVANIA
POLICE CRASH REPORTING FORM

AA 500 2

Police Use Only

Page:

Crash Number
P0712998

Unit Info

Type Unit: Motor Vehicle in Transport; Hit & Run Vehicle; Illegally Parked; Legally Parked; Non - Motorized; Pedestrian; Pedestrian on Skates, in Wheelchair, etc; Disabled From Previous Crash; Train; Phantom Vehicle

If "Pedestrian" or "Pedestrian on Skates, in Wheelchair, etc", Complete Form M, Section 28)

Commercial Vehicle: Yes / No
If Yes, Complete Form

Vehicle Driver / Pedestrian Information

Unit No | First Name | MI | Date of Birth (MM-DD-YYYY)

Delete?

Last Name | Telephone Number

Address / City / State | Zip

Driver License Number | State | Class

Alcohol/Drugs Suspected: No; Alcohol; Illegal Drugs; Alcohol and Drugs; Medication; Unknown

Driver or Pedestrian Physical Condition: Apparently Normal; Illegal Drug Use; Fatigue; Medication; Had Been Drinking; Sick; Asleep; Unknown

Alcohol Test Type: Test Not Given; Breath; Other; Blood; Urine; Unknown if Test Given

Primary Vehicle Code Violation | Charged? Yes / No

Alcohol Test Results: 0.

Test Refused; Test Given Contaminated Results; Unknown Results

Driver Presence: 1=Driver Operated Vehicle; 2=No Driver; 3=Driver Fled Scene; 4=Hit and Run; 9=Unknown

Owner/Driver: 00=Not Applicable; 01=Private Vehicle Owned/Leased by Driver; 02=Private Vehicle Not Owned/Leased by Driver; 03=Rented Vehicle; 04=State Police Vehicle; 05=PENNDOT Vehicle; 06=Other State Gov Veh; 07=Municipal Police Veh; 08=Other Municipal Government Vehicle; 09=Federal Gov Veh; 98=Other; 99=Unknown

Vehicle Information

Same as Driver | Owner First Name | Owner Last Name or Business Name (If Pedestrian, skip this Section)

Address / City / State / Zip | Vehicle Make | *Make Code

VIN | Model Year | Vehicle Model (see overlay)

License Plate | Reg. State | Est. Speed | Vehicle Towed: Yes / No | Towed By

Insurance: Yes / No / Unknown | Insurance Company | Policy No

Trailing Unit: No. of Trailing Units | Type Unit: 1=Towing Pass. Veh; 2=Towing Truck; 3=Towing Utility Trailer; 4=Mobile/Modular Home; 5=Camper; 6=Full Trailer; 7=Semi-Trailer; 8=Other; 9=Unknown | Tag No | Tag Year | Tag St

Direction of Travel | *Vehicle Position | *Movement | *See Overlay

Vehicle Color: 01=Blue; 02=Red; 03=White; 04=Green; 05=Black; 06=Yellow; 07=Silver; 08=Gold; 09=Brown; 10=Orange; 11=Purple; 12=Other; 99=Unknown

Vehicle Type: 01=Automobile; 02=Motorcycle; 03=Bus; 04=Small Truck (If "02", Complete Form M, Section 26); 05=Large Truck; 06=SUV; 07=Van; 10=Snowmobile; 11=Farm Equip; 12=Construction Equip; 13=ATV; 18=Other Type Spec Veh; 19=Unk. Type Spec Veh; (If "20" or "21", Complete Form M, Section 27); 20=Unicycle, Bicycle, Tricycle; 21=Other Pedalcycle; 22=Horse & Buggy; 23=Horse & Rider; 24=Train; 25=Trolley; 08=Other; 99=Unknown

Special Usage: 00=Not Applicable; 01=Fire Veh; 02=Ambulance; 03=Police; 08=Other Emergency Vehicle; 11=Pupil Transport; 12=Commercial Passenger Carrier; 13=Taxi; 21=Tractor Trailer; 22=Twin Trailer; 23=Triple Trailer; 31=Modified Veh; 99=Unknown

Initial Impact Point: 00=Non-Collision; 01-12=Clock Points; 13=Trip; 14=Undercarriage; 15=Towed Unit; 99=Unknown

Damage Indicator: 0=None; 1=Minor; 2=Functional; 3=Disabling; 9=Unknown

Gradient: 1=Level; 2=Uphill; 3=Downhill; 4=Bottom of Hill; 5=Top of Hill; 9=Unknown

Road Alignment: 1=Straight; 2=Curved; 9=Unknown

FORM # AA-500 (12/02)

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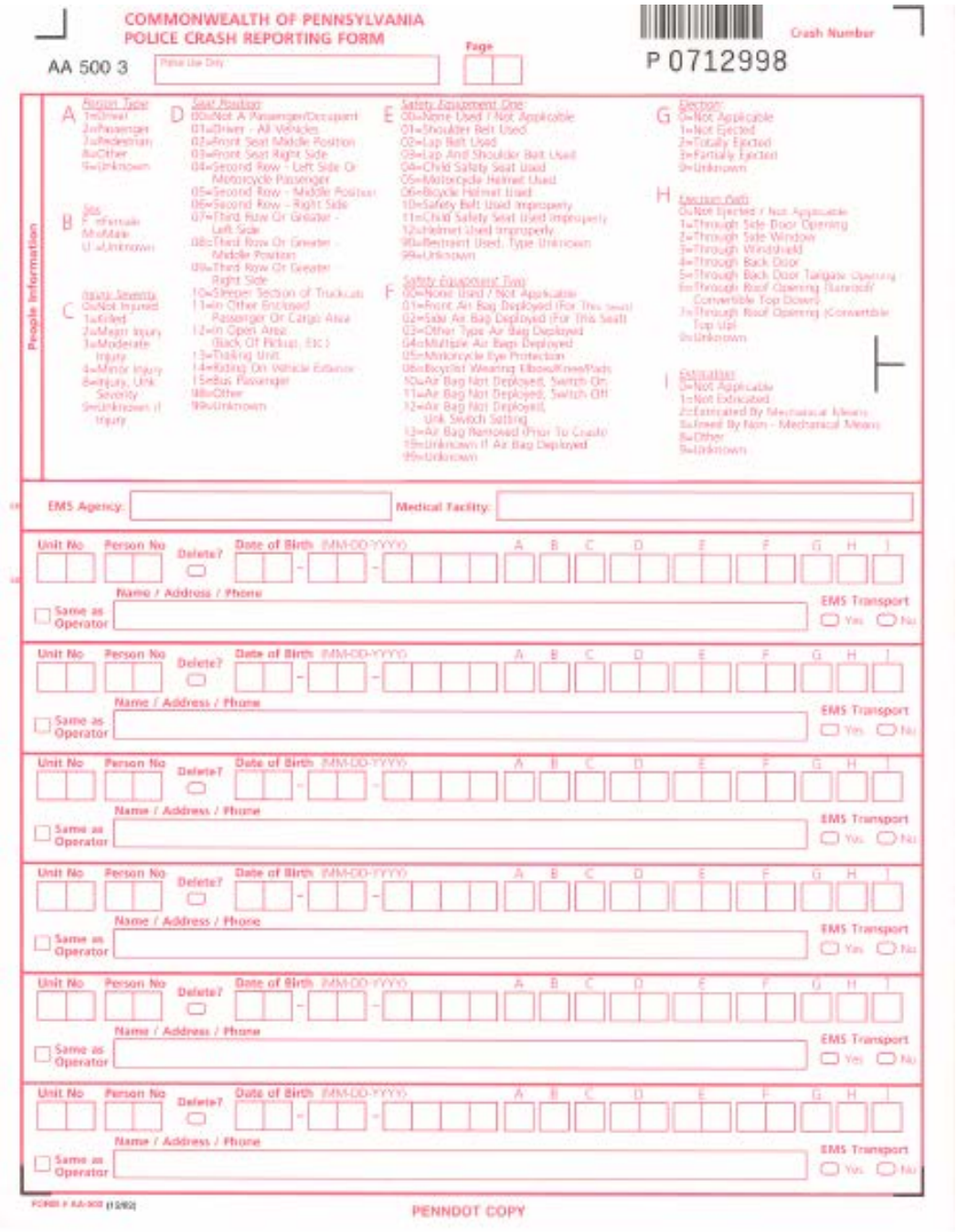

COMMONWEALTH OF PENNSYLVANIA
POLICE CRASH REPORTING FORM

AA 500 3

Police Use Only

Page

Crash Number

P 0712998

People Information

A Person Type
1=Driver
2=Passenger
3=Pedestrian
4=Other
5=Unknown

B Sex
F=Female
M=Male
U=Unknown

C Injury Severity
0=Not Injured
1=Killed
2=Major Injury
3=Moderate Injury
4=Minor Injury
8=Injury, Unk Severity
9=Unknown if Injury

D Seat Position
00=Not A Passenger/Occupant
01=Driver - All Vehicles
02=Front Seat Middle Position
03=Front Seat Right Side
04=Second Row - Left Side Or Motorcycle Passenger
05=Second Row - Middle Position
06=Second Row - Right Side
07=Third Row Or Greater - Left Side
08=Third Row Or Greater - Middle Position
09=Third Row Or Greater Right Side
10=Sleeper Section of Truck/cab
11=In Other Enclosed Passenger Or Cargo Area
12=In Open Area (Back Of Pickup, Etc.)
13=Towing Unit
14=Riding On Vehicle Exterior
15=Bus Passenger
98=Other
99=Unknown

E Safety Equipment One
00=None Used / Not Applicable
01=Shoulder Belt Used
02=Lap Belt Used
03=Lap And Shoulder Belt Used
04=Child Safety Seat Used
05=Motorcycle Helmet Used
06=Bicycle Helmet Used
10=Safety Belt Used Improperly
11=Child Safety Seat Used Improperly
12=Helmet Used Improperly
98=Restraint Used, Type Unknown
99=Unknown

F Safety Equipment Two
00=None Used / Not Applicable
01=Front Air Bag Deployed (For This Seat)
02=Side Air Bag Deployed (For This Seat)
03=Other Type Air Bag Deployed
04=Multiple Air Bags Deployed
05=Motorcycle Eye Protection
06=Bicyclist Wearing Elbow/Knee/Pads
10=Air Bag Not Deployed, Switch On
11=Air Bag Not Deployed, Switch Off
12=Air Bag Not Deployed, Unk Switch Setting
13=Air Bag Removed Prior To Crash
19=Unknown If Air Bag Deployed
99=Unknown

G Ejection
0=Not Applicable
1=Not Ejected
2=Totally Ejected
3=Partially Ejected
9=Unknown

H Ejection Path
0=Not Ejected / Not Applicable
1=Through Side Door Opening
2=Through Side Window
3=Through Windshield
4=Through Back Door
5=Through Back Door Tailgate Opening
6=Through Roof Opening (Sunroof/ Convertible Top Down)
7=Through Roof Opening (Convertible Top Up)
9=Unknown

I Extrication
0=Not Applicable
1=Not Extricated
2=Extricated By Mechanical Means
3=Freed By Non - Mechanical Means
4=Other
9=Unknown

EMS Agency: Medical Facility:

Unit No | Person No | Delete? | Date of Birth (MM-DD-YYYY) | A | B | C | D | E | F | G | H | I
Name / Address / Phone | Same as Operator | EMS Transport Yes No

Unit No | Person No | Delete? | Date of Birth (MM-DD-YYYY) | A | B | C | D | E | F | G | H | I
Name / Address / Phone | Same as Operator | EMS Transport Yes No

Unit No | Person No | Delete? | Date of Birth (MM-DD-YYYY) | A | B | C | D | E | F | G | H | I
Name / Address / Phone | Same as Operator | EMS Transport Yes No

Unit No | Person No | Delete? | Date of Birth (MM-DD-YYYY) | A | B | C | D | E | F | G | H | I
Name / Address / Phone | Same as Operator | EMS Transport Yes No

Unit No | Person No | Delete? | Date of Birth (MM-DD-YYYY) | A | B | C | D | E | F | G | H | I
Name / Address / Phone | Same as Operator | EMS Transport Yes No

Unit No | Person No | Delete? | Date of Birth (MM-DD-YYYY) | A | B | C | D | E | F | G | H | I
Name / Address / Phone | Same as Operator | EMS Transport Yes No

FORM # AA-500 (12/02)

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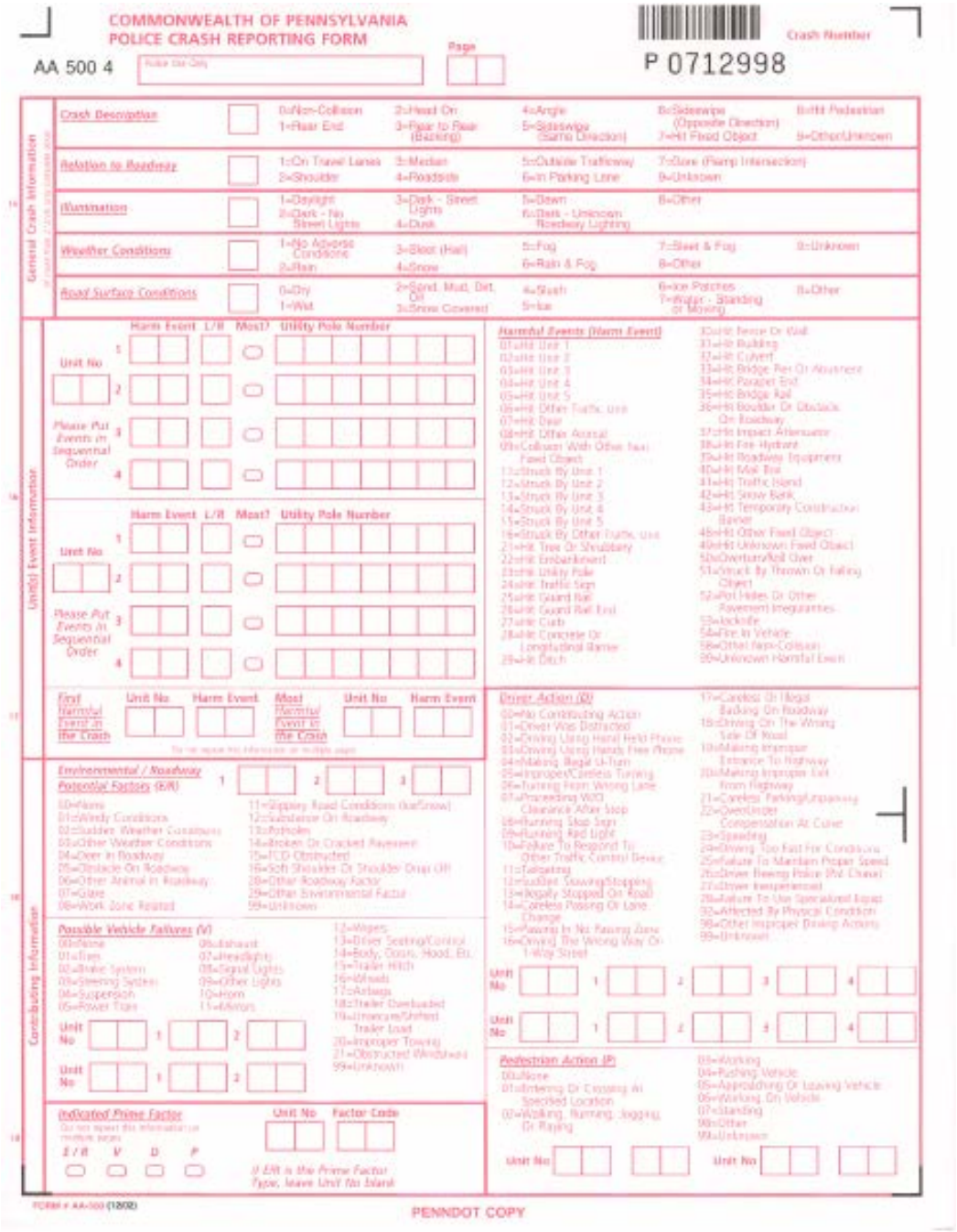

COMMONWEALTH OF PENNSYLVANIA
POLICE CRASH REPORTING FORM

AA 500 4

Police Use Only

Page

Crash Number

P 0712998

General Crash Information

Crash Description: 0=Non-Collision; 1=Rear End; 2=Head On; 3=Rear to Rear (Backing); 4=Angle; 5=Sideswipe (Same Direction); 6=Sideswipe (Opposite Direction); 7=Hit Fixed Object; 8=Hit Pedestrian; 9=Other/Unknown

Relation to Roadway: 1=On Travel Lanes; 2=Shoulder; 3=Median; 4=Roadside; 5=Outside Trafficway; 6=In Parking Lane; 7=Gore (Ramp Intersection); 9=Unknown

Illumination: 1=Daylight; 2=Dark - No Street Lights; 3=Dark - Street Lights; 4=Dusk; 5=Dawn; 6=Dark - Unknown Roadway Lighting; 8=Other

Weather Conditions: 1=No Adverse Conditions; 2=Rain; 3=Sleet (Hail); 4=Snow; 5=Fog; 6=Rain & Fog; 7=Sleet & Fog; 8=Other; 9=Unknown

Road Surface Conditions: 0=Dry; 1=Wet; 2=Sand, Mud, Dirt, Oil; 3=Snow Covered; 4=Slush; 5=Ice; 6=Ice Patches; 7=Water - Standing or Moving; 8=Other

Unit(s) Event Information

Unit No | Harm Event | L/R | Most? | Utility Pole Number

Please Put Events in Sequential Order

Harmful Events (Harm Event)

First Harmful Event in the Crash | Unit No | Harm Event

Most Harmful Event in the Crash | Unit No | Harm Event

Contributing Information

Environmental / Roadway Potential Factors (E/R)

Possible Vehicle Failures (V)

Indicated Prime Factor | Unit No | Factor Code

E / R | V | D | P

If E/R is the Prime Factor Type, leave Unit No blank

Driver Action (D)

Pedestrian Action (P)

FORM # AA-500 (12/02)

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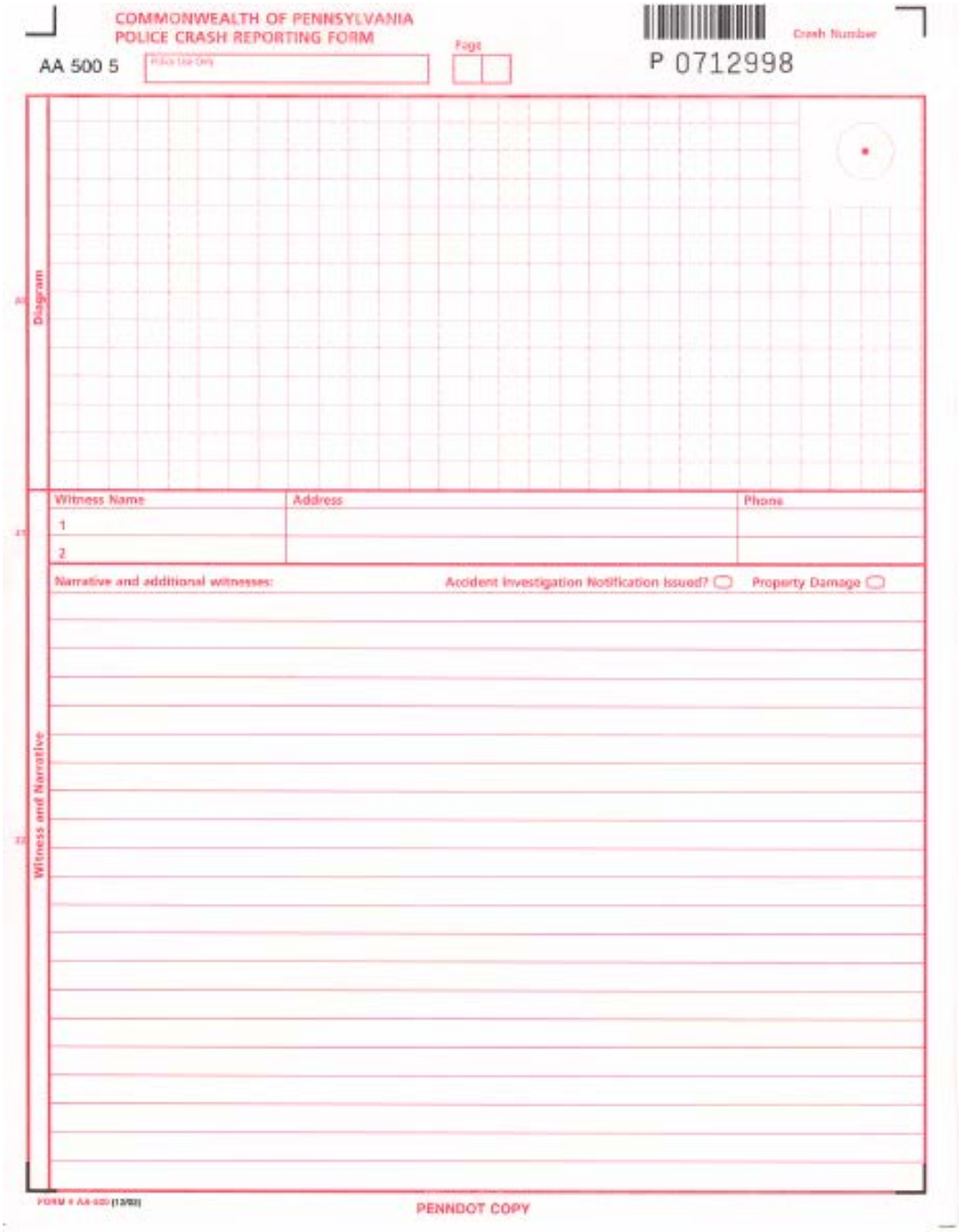

COMMONWEALTH OF PENNSYLVANIA
POLICE CRASH REPORTING FORM

AA 500 5

Page

Crash Number
P 0712998

Diagram

Witness Name	Address	Phone
1		
2		

Narrative and additional witnesses:

Accident Investigation Notification Issued? ☐ Property Damage ☐

Witness and Narrative

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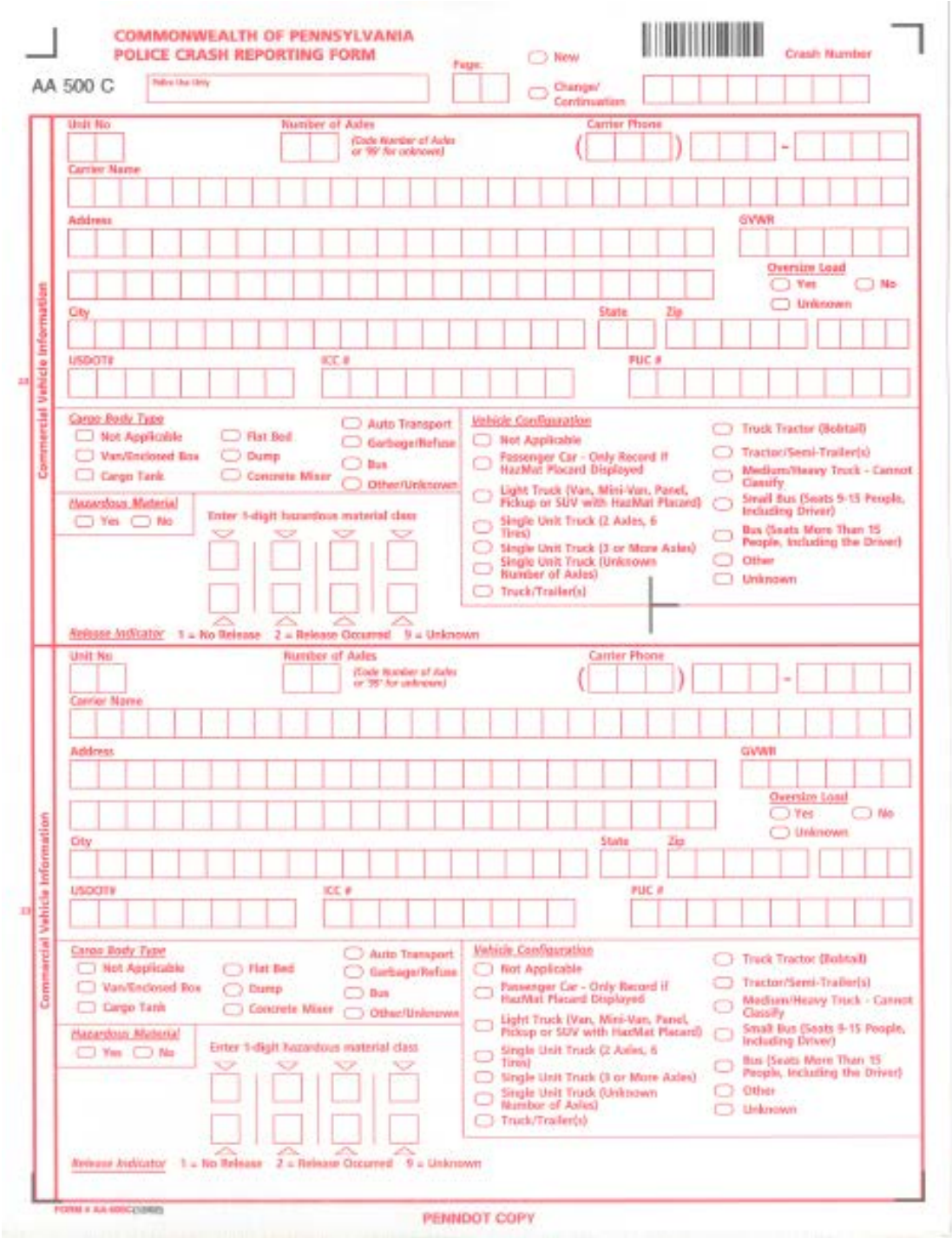

COMMONWEALTH OF PENNSYLVANIA
POLICE CRASH REPORTING FORM

AA 500 C

Police Use Only

Page:

New

Change/ Continuation

Crash Number

Commercial Vehicle Information

Unit No

Number of Axles (Code Number of Axles or '99' for unknown)

Carrier Phone ( ) -

Carrier Name

Address

GVWR

Oversize Load: Yes No Unknown

City

State

Zip

USDOT#

ICC #

PUC #

Cargo Body Type: Not Applicable; Van/Enclosed Box; Cargo Tank; Flat Bed; Dump; Concrete Mixer; Auto Transport; Garbage/Refuse; Bus; Other/Unknown

Hazardous Material: Yes No

Enter 1-digit hazardous material class

Vehicle Configuration: Not Applicable; Passenger Car - Only Record if HazMat Placard Displayed; Light Truck (Van, Mini-Van, Panel, Pickup or SUV with HazMat Placard); Single Unit Truck (2 Axles, 6 Tires); Single Unit Truck (3 or More Axles); Single Unit Truck (Unknown Number of Axles); Truck/Trailer(s); Truck Tractor (Bobtail); Tractor/Semi-Trailer(s); Medium/Heavy Truck - Cannot Classify; Small Bus (Seats 9-15 People, Including Driver); Bus (Seats More Than 15 People, Including the Driver); Other; Unknown

Release Indicator: 1 = No Release 2 = Release Occurred 9 = Unknown

Commercial Vehicle Information

Unit No

Number of Axles (Code Number of Axles or '99' for unknown)

Carrier Phone ( ) -

Carrier Name

Address

GVWR

Oversize Load: Yes No Unknown

City

State

Zip

USDOT#

ICC #

PUC #

Cargo Body Type: Not Applicable; Van/Enclosed Box; Cargo Tank; Flat Bed; Dump; Concrete Mixer; Auto Transport; Garbage/Refuse; Bus; Other/Unknown

Hazardous Material: Yes No

Enter 1-digit hazardous material class

Vehicle Configuration: Not Applicable; Passenger Car - Only Record if HazMat Placard Displayed; Light Truck (Van, Mini-Van, Panel, Pickup or SUV with HazMat Placard); Single Unit Truck (2 Axles, 6 Tires); Single Unit Truck (3 or More Axles); Single Unit Truck (Unknown Number of Axles); Truck/Trailer(s); Truck Tractor (Bobtail); Tractor/Semi-Trailer(s); Medium/Heavy Truck - Cannot Classify; Small Bus (Seats 9-15 People, Including Driver); Bus (Seats More Than 15 People, Including the Driver); Other; Unknown

Release Indicator: 1 = No Release 2 = Release Occurred 9 = Unknown

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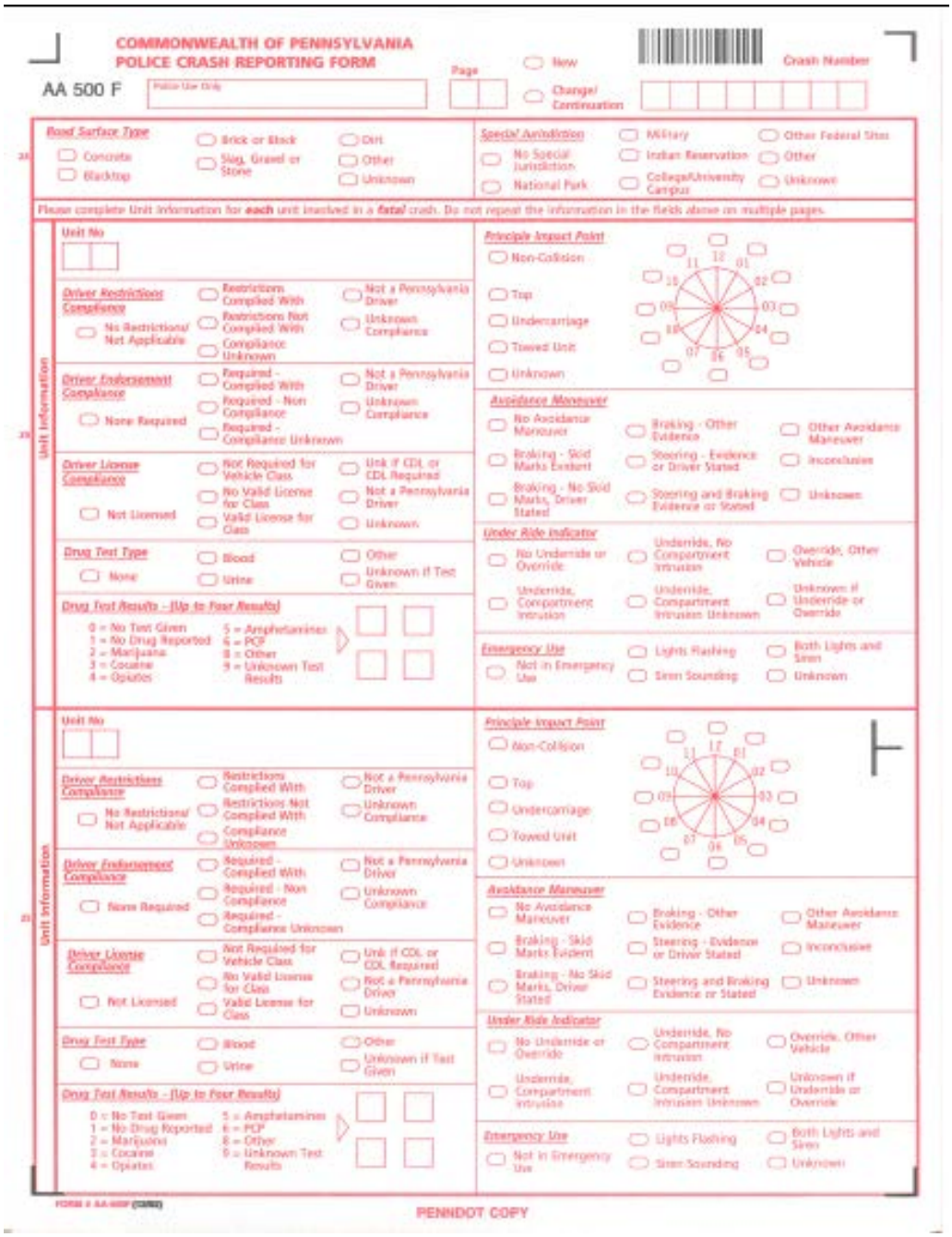

COMMONWEALTH OF PENNSYLVANIA
POLICE CRASH REPORTING FORM

AA 500 F

Police Use Only

Page

New

Crash Number

Change/ Continuation

Road Surface Type
- Concrete
- Blacktop
- Brick or Block
- Slag, Gravel or Stone
- Dirt
- Other
- Unknown

Special Jurisdiction
- No Special Jurisdiction
- National Park
- Military
- Indian Reservation
- College/University Campus
- Other Federal Site
- Other
- Unknown

Please complete Unit Information for **each** unit involved in a **fatal** crash. Do not repeat the information in the fields above on multiple pages.

Unit Information

Unit No

Driver Restrictions Compliance
- No Restrictions/ Not Applicable
- Restrictions Complied With
- Restrictions Not Complied With
- Compliance Unknown
- Not a Pennsylvania Driver
- Unknown Compliance

Driver Endorsement Compliance
- None Required
- Required - Complied With
- Required - Non Compliance
- Required - Compliance Unknown
- Not a Pennsylvania Driver
- Unknown Compliance

Driver License Compliance
- Not Licensed
- Not Required for Vehicle Class
- No Valid License for Class
- Valid License for Class
- Unk if CDL or CDL Required
- Not a Pennsylvania Driver
- Unknown

Drug Test Type
- None
- Blood
- Urine
- Other
- Unknown if Test Given

Drug Test Results - (Up to Four Results)
0 = No Test Given
1 = No Drug Reported
2 = Marijuana
3 = Cocaine
4 = Opiates
5 = Amphetamines
6 = PCP
8 = Other
9 = Unknown Test Results

Principle Impact Point
- Non-Collision
- Top
- Undercarriage
- Towed Unit
- Unknown

Avoidance Maneuver
- No Avoidance Maneuver
- Braking - Skid Marks Evident
- Braking - No Skid Marks, Driver Stated
- Braking - Other Evidence
- Steering - Evidence or Driver Stated
- Steering and Braking Evidence or Stated
- Other Avoidance Maneuver
- Inconclusive
- Unknown

Under Ride Indicator
- No Underride or Override
- Underride, Compartment Intrusion
- Underride, No Compartment Intrusion
- Underride, Compartment Intrusion Unknown
- Override, Other Vehicle
- Unknown if Underride or Override

Emergency Use
- Not in Emergency Use
- Lights Flashing
- Siren Sounding
- Both Lights and Siren
- Unknown

Unit Information

Unit No

Driver Restrictions Compliance
- No Restrictions/ Not Applicable
- Restrictions Complied With
- Restrictions Not Complied With
- Compliance Unknown
- Not a Pennsylvania Driver
- Unknown Compliance

Driver Endorsement Compliance
- None Required
- Required - Complied With
- Required - Non Compliance
- Required - Compliance Unknown
- Not a Pennsylvania Driver
- Unknown Compliance

Driver License Compliance
- Not Licensed
- Not Required for Vehicle Class
- No Valid License for Class
- Valid License for Class
- Unk if CDL or CDL Required
- Not a Pennsylvania Driver
- Unknown

Drug Test Type
- None
- Blood
- Urine
- Other
- Unknown if Test Given

Drug Test Results - (Up to Four Results)
0 = No Test Given
1 = No Drug Reported
2 = Marijuana
3 = Cocaine
4 = Opiates
5 = Amphetamines
6 = PCP
8 = Other
9 = Unknown Test Results

Principle Impact Point
- Non-Collision
- Top
- Undercarriage
- Towed Unit
- Unknown

Avoidance Maneuver
- No Avoidance Maneuver
- Braking - Skid Marks Evident
- Braking - No Skid Marks, Driver Stated
- Braking - Other Evidence
- Steering - Evidence or Driver Stated
- Steering and Braking Evidence or Stated
- Other Avoidance Maneuver
- Inconclusive
- Unknown

Under Ride Indicator
- No Underride or Override
- Underride, Compartment Intrusion
- Underride, No Compartment Intrusion
- Underride, Compartment Intrusion Unknown
- Override, Other Vehicle
- Unknown if Underride or Override

Emergency Use
- Not in Emergency Use
- Lights Flashing
- Siren Sounding
- Both Lights and Siren
- Unknown

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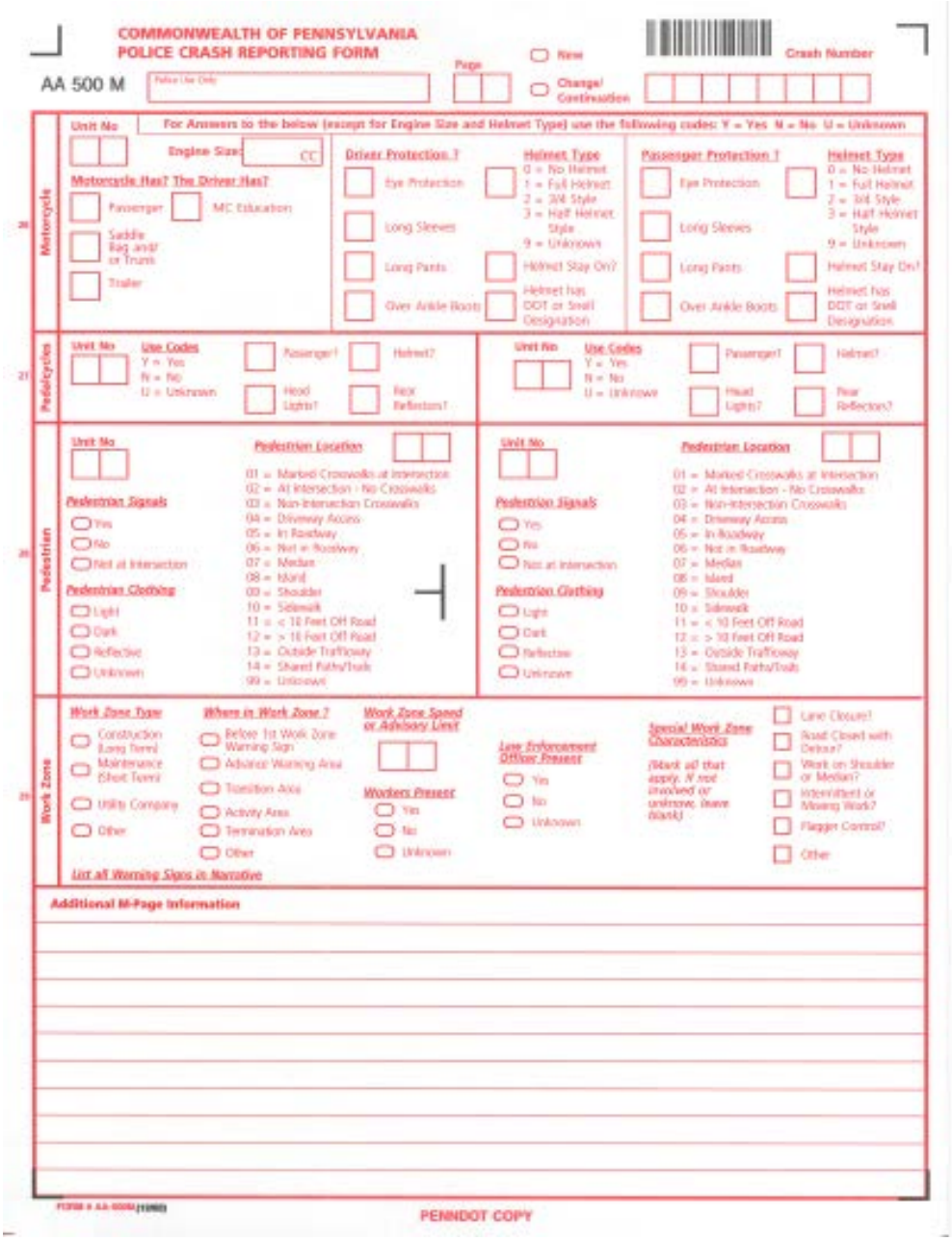

COMMONWEALTH OF PENNSYLVANIA
POLICE CRASH REPORTING FORM

AA 500 M

Police Use Only

Page

New

Change/ Continuation

Crash Number

Motorcycle

Unit No

For Answers to the below (except for Engine Size and Helmet Type) use the following codes: Y = Yes N = No U = Unknown

Engine Size: CC

Motorcycle Has? The Driver Has?

Passenger

MC Education

Saddle Bag and/ or Trunk

Trailer

Driver Protection ?

Eye Protection

Long Sleeves

Long Pants

Over Ankle Boots

Helmet Type
0 = No Helmet
1 = Full Helmet
2 = 3/4 Style
3 = Half Helmet Style
9 = Unknown

Helmet Stay On?

Helmet has DOT or Snell Designation

Passenger Protection ?

Eye Protection

Long Sleeves

Long Pants

Over Ankle Boots

Helmet Type
0 = No Helmet
1 = Full Helmet
2 = 3/4 Style
3 = Half Helmet Style
9 = Unknown

Helmet Stay On?

Helmet has DOT or Snell Designation

Pedalcycles

Unit No

Use Codes
Y = Yes
N = No
U = Unknown

Passenger?

Helmet?

Head Lights?

Rear Reflectors?

Unit No

Use Codes
Y = Yes
N = No
U = Unknown

Passenger?

Helmet?

Head Lights?

Rear Reflectors?

Pedestrian

Unit No

Pedestrian Location

01 = Marked Crosswalks at Intersection
02 = At Intersection - No Crosswalks
03 = Non-Intersection Crosswalks
04 = Driveway Access
05 = In Roadway
06 = Not in Roadway
07 = Median
08 = Island
09 = Shoulder
10 = Sidewalk
11 = < 10 Feet Off Road
12 = > 10 Feet Off Road
13 = Outside Trafficway
14 = Shared Paths/Trails
99 = Unknown

Pedestrian Signals

Yes

No

Not at Intersection

Pedestrian Clothing

Light

Dark

Reflective

Unknown

Unit No

Pedestrian Location

01 = Marked Crosswalks at Intersection
02 = At Intersection - No Crosswalks
03 = Non-Intersection Crosswalks
04 = Driveway Access
05 = In Roadway
06 = Not in Roadway
07 = Median
08 = Island
09 = Shoulder
10 = Sidewalk
11 = < 10 Feet Off Road
12 = > 10 Feet Off Road
13 = Outside Trafficway
14 = Shared Paths/Trails
99 = Unknown

Pedestrian Signals

Yes

No

Not at Intersection

Pedestrian Clothing

Light

Dark

Reflective

Unknown

Work Zone

Work Zone Type

Construction (Long Term)

Maintenance (Short Term)

Utility Company

Other

Where in Work Zone ?

Before 1st Work Zone Warning Sign

Advance Warning Area

Transition Area

Activity Area

Termination Area

Other

Work Zone Speed or Advisory Limit

Workers Present

Yes

No

Unknown

Law Enforcement Officer Present

Yes

No

Unknown

Special Work Zone Characteristics

(Mark all that apply. If not involved or unknown, leave blank)

Lane Closure?

Road Closed with Detour?

Work on Shoulder or Median?

Intermittent or Moving Work?

Flagger Control?

Other

List all Warning Signs in Narrative

Additional M-Page Information

PENNDOT COPY

C.2 Crash Record System (CRS) Data Elements

COLLISION TYPE

0 – Non collision
1 – Rear-end
2 – Head-on
3 – Rear-to-rear (Backing)
4 – Angle
5 – Sideswipe (same dir.)
6 – Sideswipe (Opposite dir.)
7 – Hit fixed object
8 – Hit pedestrian
9 – Other or Unknown

ENV_ROAD_FACTOR

00 – None
01 – Windy conditions
02 – Sudden weather conditions
03 – Other weather conditions
04 – Deer in roadway
05 – Obstacle on roadway
06 – Other animal in roadway
07 – Glare
08 – Work Zone Related
11 – Slippery road conditions (Ice/Snow)
12 – Substances on roadway
13 – Potholes
14 – Broken or cracked pavement
15 – TCD Obstructed
16 – Soft shoulder or shoulder drop off
28 – Other roadway factor
29 – Other environmental factor
99 – Unknown

ILLUMINATION

1 – Daylight
2 – Dark – no street lights
3 – Dark – street lights
4 – Dusk
5 – Dawn
6 – Dark – unknown roadway lighting
8 – Other
9 – Unknown (expired)

INTERSECT_TYPE

00 – Mid-block
01 – Four way intersection
02 – “T” intersection
03 – “Y” intersection
04 – Traffic circle or Round About
05 – Multi-leg intersection
06 – On ramp
07 – Off ramp
08 – Crossover
09 – Railroad crossing
10 – Other
99 – Unknown (expired)

PRIME_FACTOR_TYPE

D – Driver
E – Environmental / Roadway
P – Pedestrian
V – Vehicle

COUNTY

01 – ADAMS
02 – ALLEGHENY
03 – ARMSTRONG
04 – BEAVER
05 – BEDFORD
06 – BERKS
07 – BLAIR
08 – BRADFORD
09 – BUCKS
10 – BUTLER
11 – CAMBRIA
12 – CAMERON
13 – CARBON
14 – CENTRE
15 – CHESTER
16 – CLARION
17 – CLEARFIELD
18 – CLINTON
19 – COLUMBIA
20 – CRAWFORD

COUNTY (continued)

21 – CUMBERLAND
22 – DAUPHIN
23 – DELAWARE
24 – ELK
25 – ERIE
26 – FAYETTE
27 – FOREST
28 – FRANKLIN
29 – FULTON
30 – GREENE
31 – HUNTINGDON
32 – INDIANA
33 – JEFFERSON
34 – JUNIATA
35 – LACKAWANNA
36 – LANCASTER
37 – LAWRENCE
38 – LEBANON
39 – LEHIGH
40 – LUZERNE
41 – LYCOMING
42 – MCKEAN
43 – MERCER
44 – MIFFLIN
45 – MONROE
46 – MONTGOMERY
47 – MONTOUR
48 – NORTHAMPTON
49 – NORTHUMBERLAND
50 – PERRY
51 – PIKE
52 – POTTER
53 – SCHUYLKILL
54 – SNYDER
55 – SOMERSET
56 – SULLIVAN
57 – SUSQUEHANNA
58 – TIOGA
59 – UNION
60 – VENANGO

COUNTY (continued)

61 – WARREN

HARM_EVENT (continued)

37 – Hit impact attenuator or crash cushion

RELATION_TO_ROAD

1 – On roadway

62 – WASHINGTON
63 – WAYNE
64 – WESTMORELAND
65 – WYOMING
66 – YORK
67 – PHILADELPHIA

HARM_EVENT

01 – Hit unit 01
02 – Hit unit 02
03 – Hit unit 03
04 – Hit unit 04
05 – Hit unit 05
06 – Hit other traffic unit
07 – Hit deer
08 – Hit other animal
09 – Collision with other non-fixed object
11 – Struck by unit 01
12 – Struck by unit 02
13 – Struck by unit 03
14 – Struck by unit 04
15 – Struck by unit 05
16 – Struck by Other Traffic Unit
21 – Hit tree or shrubbery
22 – Hit embankment
23 – Hit utility pole
24 – Hit traffic sign
25 – Hit guard or guide rail
26 – Hit guard or guide rail end
27 – Hit curb
28 – Hit concrete or longitudinal barrier
29 – Hit ditch
30 – Hit fence or wall
31 – Hit building
32 – Hit culvert
33 – Hit bridge pier or abutment
34 – Hit parapet end
35 – Hit bridge rail
36 – Hit boulder or obstacle in roadway
38 – Hit fire hydrant
39 – Hit roadway equipment
40 – Hit mail box
41 – Hit traffic island or channelization
42 – Hit snow bank
43 – Hit temporary construction barrier
48 – Hit other fixed object
49 – Hit unknown fixed object
50 – Overturn or Roll over
51 – Struck by thrown or falling object
52 – Pothole or other pavement irregularities
53 – Jackknife
54 – Fire in vehicle
58 – Other non-collision
99 – Unknown what was hit

SPECIAL LOCATION

0 – Not applicable
1 – Underpass
2 – Ramp
3 – Bridge
4 – Tunnel
5 – Toll Booth
6 – Cross over related
7 – Driveway or Parking Lot
8 – Ramp and bridge
9 – Unknown

WORK_ZONE_TYPE

1 – Construction
2 – Maintenance
3 – Utility company
8 – Other
2 – Shoulder
3 – Median
4 – Roadside (off trafficway; on vehicle area)
5 – Outside trafficway (in area not meant for vehicles)
6 – In parking lane
7 – Gore (intersection of ramp and highway)
9 – Unknown

ROAD_CONDITION

0 – Dry
1 – Wet
2 – Sand/ mud/ dirt/ oil/ or gravel
3 – Snow covered
4 – Slush
5 – Ice
6 – Ice Patches
7 – Water – standing or moving
8 – Other
9 – Unknown (expired)

TCD_TYPE

0 – Not applicable
1 – Flashing traffic signal
2 – Traffic signal
3 – Stop sign
4 – Yield sign
5 – Active RR crossing controls
6 – Passive RR crossing controls
7 – Police officer or flagman
8 – Other Type TCD
9 – Unknown

SAFETY EQUIPMENT 1

00 = None Used / Not Applicable
01 = Shoulder Belt Used
02 = Lap Belt Used
03 = Lap and Shoulder Belt Used
04 = Child Safety Seat
05 = Motorcycle Helmet Used
06 = Bicycle Helmet Used
10 = Safety Belt Used Improperly
11 = Child Safety Seat Used Improperly
12 = Helmet Used Improperly
90 = Restraint Used, Type Unknown
99 = Unknown

SAFETY EQUIPMENT 2

00 - None used or not applicable
01 - Front air bag deployed (for this seat)
02 - Side air bag deployed (for this seat)
03 - Other type air bag deployed
04 - Multiple airbags deployed
05 - Motorcycle eye protection
06 - Bicyclist wearing elbow, knee or other pads
10 - Air bag not deployed/ switch on
11 - Air bag not deployed/ switch off
12 - Air bag not deployed/ unknown switch setting
13 - Air bag removed (prior to crash)
19 - Unknown if air bag deployed
99 - Unknown

URBAN_RURAL

1 – RURAL
2 – SMALL URBAN AREA (pop. To 49,999)
3 – URBANIZED AREA (pop. 50,000 to 199,999)
4 – URBANIZED AREA (pop. 200,000 or more)

WEATHER

1 – No adverse conditions
2 – Rain
3 – Sleet (hail)
4 – Snow
5 – Fog
6 – Rain and fog

WEATHER (continued)

7 – Sleet and fog
8 – Other
9 – Unknown

DVR_ACTION

00 – No contributing action
01 – Driver was distracted
02 – Driving using hand-held phone
03 – Driving using hands-free phone
04 – Making illegal U-turn
05 – Making improper or careless turn
06 – Turning from wrong lane
07 – Proceeding w/o clearance after stop
08 – Running stop sign
09 – Running red light
10 – Failure to respond to TCD
11 – Tailgating
12 – Sudden slowing or stopping
13 – Illegally stopped on road
14 – Careless passing or lane change
15 – Passing in no passing zone
16 – Driving the wrong way on 1-way street
17 – Careless or illegal backing on roadway
18 – Driving on the wrong side of roadway
19 – Making improper entrance to highway
20 – Making improper exit from highway
21 – Careless parking or unparking
22 – Over or under compensation at curve
23 – Speeding
24 – Driving too fast for conditions
25 – Failure to maintain proper speed
26 – Driver fleeing police (police chase)
27 – Driver inexperienced
28 – Failure to use specialized equipment
92 – Affected by Physical Condition
98 – Other improper driving actions
99 – Unknown

AVOIDANCE MANEUVER

0 - No avoidance maneuver
1 - Braking - skid marks evident
2 - Braking - no skid marks, driver stated
3 - Braking - other evidence
4 - Steering - evidence or driver stated
5 - Steering and braking - evidence or stated
6 - Other avoidance maneuver
7 - Inconclusive
9 - Unknown

TCD_FUNCTIONING

0 – No Controls
1 – Device not Functioning
2 – Device Functioning improperly
3 – Device Functioning properly
4 – Emergency Preemptive Signal
9 – Unknown

CARGO BODY TYPE

0 – Not Applicable
1 – Van/Enclosed Box
2 – Cargo Tank
3 – Flat Bed
4 – Dump
5 – Concrete Mixer
6 – Auto Transport
7 – Garbage/Refuse
8 – Bus
9 – Unknown

SURFACE_TYPE

1 - Concrete
2 - Blacktop
3 - Brick or Block
4 - Slag, Gravel, or Stone
5 - Dirt
8 - Other
9 - Unknown

SPECIAL_JURISDICTION_CODE

0 – No Special Jurisdiction
1 – National Park
2 – Military
3 – Indian Reservation
4 – College/University Campus
5 – Other Federal Sites
8 - Other
9 - Unknown

LT_RT_CD

L - Left
O - Other
R - Right
U - Unknown

RDWY_ORIENT

E - East
N - North
S - South
U - Unknown
W - West

ENDORSEMENT COMPLIANCE CODE

0 - None required
1 - Required - complied with
2 - Required - non compliance
3 - Required - compliance unknown

VEHICLE CONFIGURATION

00 – Not Applicable
01 - Passenger Car Record if Hazmat Placard displayed
02 – Light Truck (Van, Minivan, Panel, PU, SUV w/Hazmat
03 – Single Unit Truck (2 Axles, 6 Tires)
04 – Single Unit Truck (3 or more Axles)
05 – Single Unit Truck (Unknown Number of Axles)
06 – Truck/Trailer
07 - Truck Tractor (Bobtail)
08 – Tractor/Semi-Trailer
09 – Medium Heavy Truck- Cannot Classify
10 – Small Bus (Seats 9- 15 People, Inc. driver)

VEHICLE CONFIGURATION (continued)

11 – Bus (Seats more than 15 People, Including the Driver
98 – Other
99 - Unknown

LICENSE STATUS

0 - Driver not present
1 - Not licensed
2 - Suspended
3 - Revoked
4 - Expired
5 - Canceled or denied
6 - Valid
7 - Learner's permit
8 - Temporary
9 - Unknown
{blank} - Not a Pennsylvania Driver

LICENSE COMPLIANCE CODE

0 - Not licensed
1 - Not required for vehicle class
2 - No valid license for this class
3 - Valid license for class
7 - Not a Pennsylvania driver
8 - Unknown if has CDL or CDL required
9 - Unknown

TRAILING VEHICLE TYPE

1 - Passenger vehicle
2 - Truck
3 - Utility trailer
4 - Mobile or modular home
5 - Camper
6 - Trailer
7 - Semi-trailer
8 - Other
9 - Unknown

WORK_ZONE_LOC

1 – Before the 1st work zone warning sign
2 – Advance warning area
3 – Transition area
4 – Activity area

ALC_TEST_RESULT

00 - Result = 0.00
01 - Result = 0.01
02 - Result = 0.02
03 - Result = 0.03
04 - Result = 0.04
05 - Result = 0.05
06 - Result = 0.06
07 - Result = 0.07
08 - Result = 0.08
09 - Result = 0.09
10 - Result = 0.10
11 - Result = 0.11
12 - Result = 0.12
13 - Result = 0.13
14 - Result = 0.14
15 - Result = 0.15
16 - Result = 0.16
17 - Result = 0.17
18 - Result = 0.18
19 - Result = 0.19
20 - Result = 0.20
21 - Result = 0.21
22 - Result = 0.22
23 - Result = 0.23
24 - Result = 0.24
25 - Result = 0.25
26 - Result = 0.26
27 - Result = 0.27
28 - Result = 0.28
29 - Result = 0.29
30 - Result = 0.30
31 - Result = 0.31
32 - Result = 0.32
33 - Result = 0.33

ALC_TEST_RESULT (continued)

34 - Result = 0.34
35 - Result = 0.35
36 - Result = 0.36
37 - Result = 0.37
38 - Result = 0.38
39 - Result = 0.39
40 - Result = 0.40
41 - Result = 0.41
42 - Result = 0.42
43 - Result = 0.43
44 - Result = 0.44
45 - Result = 0.45
46 - Result = 0.46
47 - Result = 0.47
48 - Result = 0.48
49 - Result = 0.49
50 - Result = 0.50
51 - Result = 0.51
52 - Result = 0.52
53 - Result = 0.53
54 - Result = 0.54
55 - Result = 0.55
56 - Result = 0.56
57 - Result = 0.57
58 - Result = 0.58
59 - Result = 0.59
60 - Result = 0.60
61 - Result = 0.61
62 - Result = 0.62
63 - Result = 0.63
64 - Result = 0.64
65 - Result = 0.65
66 - Result = 0.66
67 - Result = 0.67
68 - Result = 0.68
69 - Result = 0.69
70 - Result = 0.70
71 - Result = 0.71
72 - Result = 0.72
73 - Result = 0.73

ALC_TEST_RESULT (continued)

74 - Result = 0.74
75 - Result = 0.75
76 - Result = 0.76
77 - Result = 0.77
78 - Result = 0.78
79 - Result = 0.79
80 - Result = 0.80
81 - Result = 0.81
82 - Result = 0.82
83 - Result = 0.83
84 - Result = 0.84
85 - Result = 0.85
86 - Result = 0.86
87 - Result = 0.87
88 - Result = 0.88
89 - Result = 0.89
90 - Result = 0.90
91 - Result = 0.91
92 - Result = 0.92
93 - Result = 0.93
94 - Result = 0.94 or greater
95 - Test refused
97 - Test given and contaminated results
99 - Unknown results

ALC_DRUG_SUSPECTED

1 - No
2 - Alcohol
3 - Illegal drugs
4 - Alcohol and drugs
5 - Medication
9 - Unknown

ALC_TEST_TYPE

0 - Test not given
1 - Blood
2 - Breath
3 - Urine
8 - Other
9 - Unknown if test given

LANE CLOSURE DIECTION

1 – North
2 – South
3 – East
4 – West
5 – North And South
6 – East and West
7 – All (N,S,E,W)

VEH_MOVEMENT

01 - Going straight
02 - Slowing or stopping in lane
03 - Stopped in traffic lane
04 - Passing or overtaking vehicle
05 - Leaving a parked position
06 - Parked
07 - Entering a parked position
08 - Trying to avoid animal, ped, object, veh, etc
09 - Turning right on red
10 - Turning right
11 - Turning left on red
12 - Turning left
13 - Making a U-turn
14 - Backing up
15 - Changing lanes or merging
16 - Negotiating curve - right
17 - Negotiating curve - left
98 - Other
99 - Unknown

RDWY_ALIGNMENT

1 - Straight
2 - Curved
9 - Unknown

TRAVEL_DIRECTION

E - East
N - North
S - South
U - Unknown
W - West

DVR_PED_CONDITION

0 - Apparently normal
1 - Had been drinking
2 - Illegal drug use
3 - Sick
4 - Fatigue
5 - Asleep
6 - Medication
9 - Unknown

EJECTION_IND

0 - Not applicable
1 - Not ejected
2 - Totally ejected
3 - Partially ejected
9 - Unknown

RESTRICTIONS COMPLIANCE

0 - No restrictions or not applicable
1 - Restrictions complied with
2 - Restrictions not complied with
3 - Restrictions compliance unknown
7 - Not a Pennsylvania Driver
9 - Unknown if Restricted

EJECTION PATH

0 - Not Ejected / Not Applicable
1 - Through side door opening
2 - Through side window
3 - Through windshield
4 - Through back door
5 - Through back door tailgate opening
6 - Through roof opening sunroof or conv. top down
7 - Through roof opening (Convertible Top Up)
9 - Unknown

INJ_SEVERITY

0 - Not injured
1 - Killed
2 - Major injury
3 - Moderate injury

INJ_SEVERITY (continued)

4 - Minor injury
8 - Injury/ Unknown Severity
9 - Unknown

PED_ACTION

00 - None
01 - Entering or crossing at specified location
02 - Walking, running, jogging, playing or cycling
03 - Working
04 - Pushing vehicle
05 - Approaching or leaving vehicle
06 - Playing or working on vehicle
07 - Standing
98 - Other
99 - Unknown

PED_LOCATION

01 - Marked crosswalks at intersection
02 - At intersection: no crosswalks
03 - Non-intersection - crosswalks
04 - Driveway access
05 - In Roadway
06 - Not in Roadway
07 - Median
08 - Island
09 - Shoulder
10 - Sidewalk
11 - Less than 10 feet off road
12 - Greater than 10 feet off road
13 - Outside Trafficway
14 - Shared Paths or Trails
99 - Unknown

PED_SIGNAL

1 - Pedestrian signal
2 - No pedestrian signal
3 - Not at intersection
9 - Unknown (expired)

DVR_LIC_STATE

AB - Alberta/ Can
AG - Aguascalientes/ Mex
AK - Alaska/ US
AL - Alabama/ US
AR - Arkansas/ US
AZ - Arizona/ US
BC - British Columbia/ Can
BN - Baja Calif. N./ Mex
BS - Baja Calif. S./ Mex
CA - California/ US
CH - Chihuahua/ Mex
CI - Coahuila/ Mex
CL - Colima/ Mex
CM - Campeche/ Mex
CO - Colorado/ US
CS - Chiapas/ Mex
CT - Connecticut/ US
DC - District of Columbia/ US
DE - Delaware/ US
DF - Federal District/ Mex
DU - Durango/ Mex
FL - Florida/ US
GA - Georgia/ US
GR - Guerrero/ Mex
GT - Guanajuato/ Mex
HG - Hidalgo/ Mex
HI - Hawaii/ US
IA - Iowa/ US
ID - Idaho/ US
IL - Illinois/ US
IN - Indiana/ US
JA - Jalisco/ Mex
KS - Kansas/ US
KY - Kentucky/ US
LA - Louisiana/ US
MA - Massachusetts/ US
MB - Manitoba/ Can
MC - Michoacan/ Mex
MD - Maryland/ US
ME - Maine/ US

DVR_LIC_STATE (continued)

MI - Michigan/ US
ML - Morelos/ Mex
MN - Minnesota/ US
MO - Missouri/ US
MS - Mississippi/ US
MT - Montana/ US
MX - Mexico/ Mex
NA - Nayarit/ Mex
NB - New Brunswick/ Can
NC - North Carolina/ US
ND - North Dakota/ US
NE - Nebraska/ US
NF - Newfoundland/ Can
NH - New Hampshire/ US
NJ - New Jersey/ US
NL - Nuevo Leon/ Mex
NM - New Mexico/ US
NS - Nova Scotia/ Can
NT - Nunavut/ Can
NV - Nevada/ US
NY - New York/ US
OA - Oaxaca/ Mex
OH - Ohio/ US
OK - Oklahoma/ US
ON - Ontario/ Can
OR - Oregon/ US
PA - Pennsylvania/ US
PE - Prince Edward Is./ Can
PR - Puerto Rico/ US
PU - Puebla/ Mex
QC - Quebec/ Can
QE - Queretaro/ Mex
QR - Quintana Roo/ Mex
RI - Rhode Island/ US
SC - South Carolina/ US
SD - South Dakota/ US
SI - Sinaloa/ Mex
SK - Saskatchewan/ Can
SL - San Luis Potosi/ Mex
SO - Sonora/ Mex

DVR_LIC_STATE (continued)

TA - Tamaulipas/ Mex
TB - Tabasco/ Mex
TL - Tlaxcala/ Mex
TN - Tennessee/ US
TX - Texas/ US
UT - Utah/ US
VA - Virginia/ US
VC - Vera Cruz/ Mex
VT - Vermont/ US
WA - Washington/ US
WI - Wisconsin/ US
WV - West Virginia/ US
WY - Wyoming/ US
YC - Yucatan/ Mex
YT - Yukon Territory/ Can
ZA - Zacatecas/ Mex
ZF - Unknown State (Can/Mex)
ZG - US Government/ US
ZI - International Agency
ZO - Other Foreign Country
ZZ - Unknown State/ US

PERSON_TYPE

1 - Driver
2 - Passenger
7 - Pedestrian
8 - Other
9 – Unknown

UNIT_TYPE

01 - Motor vehicle in transport
02 - Legally parked
03 - Illegally parked
05 - Hit and run vehicle
06 - Disabled from a previous crash
11 - Non-motorized
21 - Train
31 - Pedestrian
32 - Pedestrian on skates/ in wheelchair/ etc.
51 - Phantom vehicle

BODY_TYPE

01 - Convertible
02 - 2-Door sedan, hardtop or coupe
03 - 3-Door hatch back
04 - 4-Door sedan or hardtop
05 - 5-Door sedan or hatch back
06 - Station wagon. Excluding van and truck-based
08 - Other automobile type
09 - Unknown automobile type
10 - Automobile-based pickup
11 - Automobile-based panel truck
12 - Compact utility e.g. Tracker; Cherokee; etc
13 - Large limousine
14 - 3-wheel automobile or auto derivative
15 - Large utility; Tahoe; Range Rover; Etc.
16 - Utility station wagon
19 - Unknown utility style body type
20 - Motorcycle
21 - Moped
22 - Three-wheeled motorcycle or moped
23 - Off-road motorcycle
24 - ATV - all terrain vehicle
25 - Mini-bike or motor scooter
28 - Other motorcycle type
29 - Unknown motorcycle type
30 - School bus
31 - Cross country or inner city bus (i.e. Greyhound bus)
32 - Transit bus
38 - Other bus
39 - Unknown bus
40 - Mini-van
41 - Large van
42 - Step-in or walk-in van
43 - Van-based motor home
44 - Van-based school bus
45 - Van-based transit bus
48 - Other type van
49 - Unknown van type
50 - Compact pickup
51 - Standard pickup
52 - Pickup with slide in camper

BODY_TYPE (continued)

53 - Convertible pickup
58 - Other pickup type
59 - Unknown pickup type
60 - Cab chassis-based (includes light stake, dump, tow trucks)
61 - Truck-based panel
62 - Light truck-based motor home
68 - Other light conventional truck
69 - Unknown light truck
70 - Single unit straight truck (10000<="19500)
71 - Single unit straight truck (19500<="26000)
72 - Single unit straight truck (GVWR>26000)
73 - Single unit straight truck (GVWR unknown)
74 - Medium or heavy truck-based motor home
75 - Truck tractor with or without trailers
76 - Big step van
78 - Camper or motor home unknown truck type
79 - Unknown heavy truck
80 - Snowmobile
81 - Farm equipment other than trucks
82 - Construction equipment other than trucks
88 - Other type special vehicles
90 - Unicycle or bicycle or tricycle
91 - Other pedal cycle
92 - Horse and buggy
93 - Horse and rider
94 - Train
95 - Trolley
98 - Other body type
99 - Unknown body type

COLOR

01 - Blue
02 - Red
03 - White
04 - Green
05 - Black
06 - Yellow
07 - Silver
08 - Gold
09 - Brown

COLOR (continued)

10 - Orange
11 - Purple
12 - Other
99 - Unknown

SEAT_POSITION

00 - Not a passenger or occupant
01 - Driver - all vehicles
02 - Front seat middle position
03 - Front seat right side
04 - Second row - left side or motorcycle passenger
05 - Second row - middle position
06 - Second row - right side
07 - Third row or greater - left side
08 - Third row or greater - middle position
09 - Third row or greater - right side
10 - Sleeper section of truck cab
11 - In other enclosed passenger or cargo area
12 - In open area (back of pickup etc.)
13 - Trailing unit
14 - Riding on vehicle exterior
15 - Bus passenger
98 - Other
99 - Unknown

SPECIAL_USAGE

00 - Not applicable
01 - Fire vehicle
02 - Ambulance
03 - Police
08 - Other emergency vehicle
11 - Pupil transport
12 - Comm. passenger carrier
13 - Taxi
21 - Tractor trailer
22 - Twin trailer
23 - Triple trailer
31 - Modified vehicle
99 - Unknown

CLOTHING TYPE

1 - LIMITED ACCESS
2 - PARTIAL ACCESS
3 - NO ACCESS CONTROL

VEH_FAILURE 1-2

00 - None
01 - Tires
02 - Brake system
03 - Steering system
04 - Suspension
05 - Power train
06 - Exhaust
07 - Headlights
08 - Signal lights
09 - Other lights
10 - Horn
11 - Mirrors
12 - Wipers
13 - Driver seating/control
14 - Body/ doors/ hood/ etc
15 - Trailer hitch
16 - Wheels
17 - Airbags
18 - Trailer overloaded
19 - Unsecured or shifted trailer load
20 - Improper towing
21 - Obstructed windshield
99 - Unknown

VEH_TYPE

01 - Automobile
02 - Motorcycle
03 - Bus
04 - Small truck
05 - Large truck
06 - SUV
07 - Van
10 - Snowmobile
11 - Farm Equipment
12 - Construction Equipment

VEH_TYPE (continued)

13 - ATV
18 - Other type special veh
19 - Unknown type special veh
20 - Unicycle, bicycle or tricycle
21 - Other pedal cycle
22 - Horse and buggy
23 - Horse and rider
24 - Train
25 - Trolley
98 - Other vehicle
99 - Unknown vehicle

OWNER_DRIVER

00 - Not applicable
01 - Private vehicle owned or leased by driver
02 - Private vehicle not owned or leased by driver
03 - Rented vehicle
04 - State police vehicle
05 - PennDOT vehicle
06 - Other state government vehicle
07 - Municipal police vehicle
08 - Other municipal government vehicle
09 - Federal government vehicle
98 - Other
99 - Unknown

EMERGENCY VEHICLE USE

0 - Not in emergency use
1 - Lights flashing
2 - Siren sounding
3 - Both lights and siren
9 - Unknown

IMPACT POINT

00 - Non-collision
01 - 1 O-Clock Position
02 - 2 O-Clock Position
03 - 3 O-Clock Position
04 - 4 O-Clock Position
05 - 5 O-Clock Position
06 - 6 O-Clock Position
07 - 7 O-Clock Position
08 - 8 O-Clock Position

IMPACT POINT (continued)

09 - 9 O-Clock Position
10 - 10 O-Clock Position
11 - 11 O-Clock Position
12 - 12 O-Clock Position
13 - Top
14 - Undercarriage
15 - Towed unit
99 - Unknown

VEH_POSITION

00 - Not applicable (for peds.)
01 - Right lane (Curb)
02 - Right turn lane
03 - Left lane
04 - Left turn lane
05 - Two-direction center turn lane
06 - Other forward moving lane
07 - Oncoming traffic lane
08 - Left of trafficway
09 - Right of trafficway
10 - HOV lane
11 - Shoulder right
12 - Shoulder left
13 - One lane road
98 - Other
99 - Unknown

SEX

F - Female
M - Male
U - Unknown

HELMET TYPE

0 – No Helmet
1 – Full Helmet
2 – ¾ Style
3 – Half Helmet Style
9 – Unknown

VEHICLE MAKE

01 - American Motors
02 - Jeep/Willys/Kaiser
03 - AM General

VEHICLE MAKE (continued)

06 - Chrysler
07 - Dodge
08 - Imperial
09 - Plymouth
10 - Eagle
12 - Ford
13 - Lincoln
14 - Mercury
18 - Buick/Opel
19 - Cadillac
20 - Chevrolet
21 - Oldsmobile
22 - Pontiac
23 - GMC
24 - Saturn
25 - Grumman
29 - Other Domestic
30 - Volkswagen
31 - Alfa Romero
32 - Audi
33 - Austin; Healey
34 - BMW
35 - Nissan; Datsun
36 - Fiat
37 - Honda
38 - Isuzu
39 - Jaguar
40 - Lancia
41 - Mazda
42 - Mercedes-Benz
43 - MG
44 - Peugeot
45 - Porsche
46 - Renault
47 - Saab
48 - Subaru
49 - Toyota
50 - Triumph
51 - Volvo
52 - Mitsubishi
53 - Suzuki
54 - Acura
55 - Hyundai

VEHICLE MAKE (continued)

56 - Merkur
57 - Yugo
58 - Infiniti
59 - Lexus
60 - Daihatsu
61 - Sterling
62 - Land Rover
63 - KIA
64 - Daewoo
69 - Other imports
70 - BSA
71 - Ducati
72 - Harley-Davidson
73 - Kawasaki
74 - Moto-Guzzi
75 - Norton
76 - Yamaha
80 – Brockway
81 - Reo; Diamond Reo
82 - Freightliner
83 - FWD
84 - Navistar; Intl. Harvest
85 - Kenworth
86 - Mack
87 - Peterbilt
88 - Iveco/Magirus
89 - White/GMC/Autocar
90 - Bluebird
91 - Eagle Coach
92 - Gillig
93 - MCI
94 - Thomas Built
98 - Other
99 - Unknown

ROUTE SIGN

1 - Interstate - non turnpike
2 - State highway
3 - County road
4 - Local road or street
5 - East-West portion of turnpike
6 - Turnpike spur (extension)
7 - Private Road
9 - Other / Unknown

UNDER RIDE IND

0 - No under ride or override
1 - Under ride, compartment intrusion
2 - Under ride, no compartment intrusion
3 - Under ride, compartment intrusion unknown
4 - Override, other vehicle
9 - Unknown if under ride or override

HAZMAT CODE

0 - Not Applicable - No Hazardous Material
1 - Explosives
2 - Gases - Compressed or Dissolved or Refrigerated
3 - Flammable Liquid
4 - Flammable Solids - Combustible or Water Reactive
5 - Oxidizing Substances - Organic Peroxides
6 - Poisonous (toxic) and Infectious Substances
7 - Radioactive Material
8 - Corrosives
9 - Miscellaneous Dangerous Goods
U - Unknown if any Hazardous Material Present

CDL_LIC_RESTR

1 - CORRECTIVE LENSES
2 - DUAL MIRRORS
3 - AUTOMATIC
4 - SPECIAL EQUIPMENT
5 - DAYLIGHT DRIVING ONLY
6 - CLASSIFIED DRIVER

CDL_LIC_RESTR (continued)

7 - RESTRICTED LICENSE
8 - MOTORCYCLE MOTOR NOT > 5 BRAKE HP
A - DUAL CONTROL PERMIT
B - HAND EMERGENCY BRAKE
C - CLASSIFIED OPERATOR
D - HAND DIMMER AND/OR HAND THROTTLE
E - OUTSIDE MIRRORS
G - EXTENSION ON GAS AND/OR BRAKE
H - ALL HAND CONTROLS
I - EQUIP. WITH POWER BRAKE AND/OR STEER
J - SPECIAL FOOT CONTROLS EQUIPMENT
K - KNOB ON STEERING WHEEL
L - CORRECTIVE LENSES
N - GEAR SHIFT ON STEERING WHEEL
O - SPECIAL HAND CONTROLEQUIPMENT
P - LEFT OR RIGHT GAS PEDAL
Q - OTHER
R - RESTRICTED
S - EQUIP. WITH AUTOMATIC TYPE SHIFT
V - RESTRICTED MOTORCYCL
X - SEE ENDORSEMENT
Y - HEARING AIDE (SCHOOLBUS ONLY)
Top of Form
Z - DAYLIGHT DRIVING ONLY
Bottom of Form

DAMAGE IND

0 - None
1 - Minor (drivable)
2 - Functional (mod. - may be undrivable)
3 - Disabling (severe - not drivable)
9 - Unknown

EXTRICATION IND

0 - Not applicable
1 - Not extricated
2 - Extricated by mechanical means
3 - Freed by non-mechanical means
8 - Other
9 - Unknown

CRASH DAY

1 - Sunday
2 - Monday
3 - Tuesday
4 - Wednesday
5 - Thursday
6 - Friday
7 - Saturday
8 - Unknown
9 - Sunday

GRADIENT CODE

1 - Level roadway
2 - Uphill
3 - Downhill
4 - Sag/bottom of hill
5 - Crest/top of hill
9 - Unknown

VINA BODY TYPE

MAT - All Terrain
MEN - Enduro
MMK - Mini Bike
MMM - Mini Moto Cross
MMP - Moped
MMR - Mini Road / Trail
MMS - Motor Scooter
MMX - Moto Cross
MMY - Mini Cycle
MRC - Racer
MRS - Road / Street
MRT - Road / Trail
MT - Dirt
MTL - Trail / Dirt
MTR - Trail
P2D - Sedan 2 Dr.

VINA BODY TYPE (continued)

P2F - Formal Hardtop 2 Dr.
P2H - Hatchback 2 Dr.
P2L - Liftback 3 Dr.
P2P - Pillard Hardtop 2 Dr.
P2T - Hardtop 2 Dr.
P2W - Wagon 2 Dr.
P3D - Runabout 3 Dr.
P3P - Coupe 3 Dr.
P4D - Hatchback 4 Dr.
P4H - Hatchback 4 Dr.
P4L - Liftback 5 Dr.
P4P - Pillard Hardtop 4 Dr.
P4T - Hardtop 4 Dr.
P4W - Wagon 4 Dr.
P5D - Sedan 5 Dr.
PAM - Ambulance
PCB - Cab & Chassis (Luv)
PCP - Coupe
PCV - Convertible (Jeep)
PHB - Hatchback
PHR - Hearse
PHT - Hardtop
PIN - Incomplete Passenger
PLB - Liftback
PLM - Limousine
PNB - Notchback
PPK - Pickup
PPN - Panel
PRD - Roadster
PSB - Sport Hatchback
PSC - Sport Coupe
PSD - Sedan
PSV - Sport Van
PSW - Station Wagon
PUT - Utility
PWW - Wide Wheel Wagon
T2W - 2 Dr. Wagon / Sport Utility
T3B - 3 Dr. Extended Cab / Chassis
T3C - 3 Dr. Extended Cab Pickup
T4B - 4 Dr. Extended Cab / Chassis
T4C - 4 Dr. Extended Cab Pickup
T4W - 4 Dr. Wagon / Sport Utility
T8V - 8 Passenger Sport Van

VINA BODY TYPE (continued)

TAC - Auto Carrier
TAR - Armored Truck
TBU - Bus
TCB - Chassis and Cab
TCC - Conventional Cab
TCG - Cargo Van
TCH - Crew Chassis
TCL - Club Chassis
TCM - Concrete or Transit Mixer
TCR - Crane
TCS - Super Cab / Chassis Pickup
TCU - Custom Pickup
TCV - Convertible (Jeep Commando, Suzuki Samurai,
TCW - Crew Pickup
TCY - Cargo Cutaway
TDP - Dump
TDS - Truck, Tractor (diesel)
TEC - Extended Cargo Van
TES - Extended Sport Van
TEV - Ext Van
TEW - Extended Window Van
TFB - Flatbed or Platform
TFC - Forward Control (Land Rover)
TFT - Fire Truck
TGG - Garbage or Refuse
TGL - Gliders
TGN - Grain
THO - Hopper
TIC - Incomplete Chassis
TIE - Incomplete External Van
TLG - Logger
TLL - Suburban & Carry All
TMH - Motorized Home
TMP - Multi-purpose
TMV - Maxi Van
TMW - Maxi Wagon
TMY - Motorized Cutaway
TPC - Club Cab Pickup
TPD - Parcel Delivery
TPK - Pickup
TPM - Pickup with Camper mounted on bed
TPN - Panel
TPS - Super Cab Pickup

VINA BODY TYPE (continued)

TRD - Roadster (Jeep, Jeep Commando)

TS1 - One Seat

TS2 - Two Seat

TSN - Step Van

TSP - Sport Pickup

TST - Stake or Rack

TSV - Sports Van

TSW - Station Wagon (Jeep Wagoneer, Dodge Sportsman

TTB - Tilt Cab

TTL - Tilt Tandem

TTM - Tandem

TTN - Tank

TTR - Tractor Truck (Gasoline)

TUT - Utility (Blazer, Jimmy, Scout, etc.)

TVC - Van Camper

TVD - Display Van

TVN - Van

TVT - Vanette (including Metro and Handy Van)

TVW - Window Van

TWK - Tow Truck Wrecker

TWW - Wide Wheel Wagon

TXT - Travelall

TYY - Cutaway

C.3 Location Priority Listing (LPL)

C.3.1 Combined LPL List

Location Priority Listings (LPLs) are roadway listings generated by HSTOD that compare a roadway with similar types of roads across the Commonwealth. These are initially generated similarly to the regular cluster reports, but are refined by making the comparisons with a homogenous report. An accident rate is generated for the cluster and is approximately one standard deviation above the statewide average rate for the particular type of highway and type of cluster. The relative severity of the cluster is calculated to use for ranking the LPL clusters. Project selection based on these listings should be performed in conjunction with analysis based on principles of the Highway Safety Manual.

- CO = County code.
- SR = State Route number.
- DIR IND = Direction indicator.
- P = Primary direction, on divided roads this is north or east bound.
- S = Secondary, on divided roads this is south or west bound.
- BEGIN SEG/OFFSET = Point at which cluster starts on the SR.
- END SEG/OFFSET = Point at which cluster ends on the SR.
- RELATIVE SEVERITY = Sum of the relative severities of the individual accidents for all segments.
- TOTAL ACCIDENTS = Accidents of the type selected for the specific cluster within the area. The cluster starts and ends at a point where an accident of the type selected occurred.
- AVG RATE = Statewide average rate for this particular type of cluster and the characteristics of the cluster area.
- ACTUAL RATE = Actual rate for the cluster.
- CRITICAL RATE = Approximates one standard deviation above the average rate.
- ACTUAL/CRITICAL = Ratio of actual to critical rate.
- PRIORITY RANK = Descending order within the county and type of LPL cluster based on the relative accident severity.
- XREF = Indicator as to whether the area was listed on the previous five-year similar cluster run.

C.3.2 Intersection Location Priority Report

The Intersection LPL is a similar to a regular LPL in that comparisons are made to the average rates of similar intersections across the Commonwealth through the use of a homogeneous report. Unlike the regular LPLs, where routes are considered in a linear fashion, the Intersection LPL looks at all legs of a particular intersection, considering all incoming volumes and all intersection-related accidents on each leg. Volumes for local roads, which are not readily

available, are assumed based on the type of intersection. As in the regular LPL, relative severities are calculated and used for ranking purposes.

- INTERSEC KEY = Reference number generated by the program to identify each intersection. The key is composed of county, State Route, and a sequential number, is used for an individual run of this program, and is not permanent.
- URB RUR = Identifies whether the intersection is located in an urban or rural area.
- SIGNAL = Indicator of whether the intersection is Signalized (T), has a Stop/Yield sign (S), other controls (O), or is not controlled (N).
- TRAF RTE = Indicates whether the intersection contains at least one PA or US traffic route.
- CONTROL FLOW = Sum of the traffic on all legs.
- RELATIVE SEVERITY = Sum of the relative severities of the individual accidents at the intersection.
- TOTAL ACCIDENTS = Accidents for the 5-year period.
- AVG ACC. RATE = Statewide average rate, based on control flow, for this type of intersection.
- ACTUAL ACC. RATE = Actual rate for the intersection.
- ACTUAL/AVG ACC RATIO = Ratio of the actual rate to the average rate.
- AVG SEVERITY RATE = Indicator of the average relative severity of all intersections within the category (i.e., if all the accidents at intersections of this type were property damage only (PDO), the average relative severity rate for this type of intersection would be 1.000).
- AVG INTENS. RATE = Average number of accidents at intersections of this type statewide.
- PRIORITY = Rank within the county based on relative severity.

The second line of the entry contains various indicators, including road count (i.e., the number of different roads intersecting). The third line of the entry gives the reference for the roads making up the intersection. State routes are designated by County/State Route/Segment/Offset, while local roads are designated by street name.

C.3.3 Homogeneous Report

A homogeneous report gives the statewide accident experience for various broad categories of roadway. The report covers a 5-year period and includes the average accident rate and accident intensity for each broad category.

- RURAL/URBAN = Self explanatory.
- NFAC = Non-full access control.
- FAC = Full access control.
- UNDIV = Undivided highways.
- DIV = Divided highways.
- TOTAL WIDTH = Total pavement width ranges.
- ADT RANGE = Average daily traffic ranges.

- MILLION VEHICLE MI/5 YRS = Millions of vehicle miles traveled over the 5-year period for the category.
- LENGTH = Total statewide miles of highway for the category.
- ACC TOTAL = Total accidents within the category for the 5-year period.
- SEVERITY RATE = A relative rate for comparing accident severity among the various categories.
- ACCIDENT RATE = Statewide accident rate (accidents per million vehicle miles of travel) for the category over the 5 year period (ACC TOTAL/MILLION VEHICLE MI).
- ACCIDENT INTENSITY = Statewide intensity rate (accidents per mile) for the category over the 5-year period (ACC TOTAL/LENGTH).

C.4 Sample Data – Systematic Deployments

Systematic deployment of low-cost improvements cost effectively involve a wide variety of strategies and countermeasures deployed on an area-wide, segment or intersection basis. Each improvement impacts a specific type of crash. The major type of crash categories are as follows:

Aggressive Driving

- Aggressive driving – segments.
- Aggressive driving – intersections.

Increasing Seatbelt Usage

- Unbelted crashes.

Reducing Impaired (DUI) Driving

- Alcohol-related crashes.

Improving Pedestrian Safety

- Pedestrians.

Safety Infrastructure Improvements

- Signalized intersections.
- Stop controlled intersections.
- Curves.
- Trees.
- Utility poles.
- Guide rails.
- Head-on and opposing sideswipe.

- Rear end.
- Wet pavement.
- Run-off-road – narrow pavements, narrow shoulders, and paved shoulders available.

Each of these crash categories can be further broken down by the organization responsible for addressing the problem (e.g., State or local), by urban or rural area (which have significant differences in severity for the same crash types), by improvement type, and by limiting constraints that apply both to improvement types and to specific portions of the crash category (e.g., lighting an intersection to reduce night crashes).

There are a considerable number of combinations for each of the above crash categories. The following set of tables provides more detailed information for each of the categories on:

- Crash type.
- Fatalities per 100 crashes for that set of crashes, which is needed to estimate the impact of improvements in saving lives and achieving a fatality goal.
- Average crash cost for the specific crash type.
- Area-wide frequency traits for improvements that can be deployed on an area-wide basis (usually limited to education and enforcement initiatives).
- Cluster length.
- Threshold cluster level for cost-effective deployment.
- Specific improvement type.

Table C-1: Aggressive Driving – Segments

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Aggressive Driving – All Segments Urban	✓	✓	Number of 5-year aggressive driving crashes per urban municipality		150 aggressive driving segment crashes per municipality	Area-wide aggressive driving segment education and enforcement
Aggressive Driving – All Segments Rural	✓	✓	Number of 5-year aggressive driving crashes per rural municipality		75 aggressive driving segment crashes per municipality	Area-wide aggressive driving segment education and enforcement
Aggressive Driving – State Segments Urban	✓	✓	NA	3,000 ft.	8 or more aggressive driving urban crashes per 3,000 ft.	Segment aggressive driving education and enforcement
Aggressive Driving – State Segments Rural	✓	✓	NA	3,000 ft.	8 or more aggressive driving rural crashes per 3,000 ft.	Segment aggressive driving education and enforcement
Aggressive Driving – Local Segments Urban	✓	✓	NA	Entire road	8 or more aggressive driving crashes per urban route	Segment aggressive driving education and enforcement
Aggressive Driving – Local Segments Rural	✓	✓	NA	Entire road	8 or more aggressive driving crashes per rural route	Segment aggressive driving education and enforcement

Table C-2: Aggressive Driving – Intersections

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Aggressive Driving – Stop Intersection Urban	✓	✓	Number of 5-year aggressive driving crashes per urban municipality	NA	150 stop intersection aggressive driving crashes per municipality	Area-wide stop intersection aggressive driving education and enforcement
Aggressive Driving – Stop Intersection Rural	✓	✓	Number of 5-year aggressive driving crashes per rural municipality	NA	75 stop intersection aggressive driving crashes per municipality	Area-wide stop intersection aggressive driving education and enforcement
Aggressive Driving – Signal Intersection Urban	✓	✓	Number of five-year aggressive driving crashes per urban municipality	NA	150 signal intersection aggressive driving crashes per municipality	Area-wide signal intersection aggressive driving education and enforcement
Aggressive Driving – Signal Intersection Rural	✓	✓	Number of 5-year aggressive driving crashes per rural municipality	NA	75 signal intersection aggressive driving crashes per municipality	Area-wide signal intersection aggressive driving education and enforcement
Aggressive Driving – State Stop Urban	✓	✓	NA	Intersection	8 or more aggressive driving urban crashes per intersection	Intersection aggressive driving education and enforcement
Aggressive Driving – State Stop Rural	✓	✓	NA	Intersection	8 or more aggressive driving rural crashes per intersection	Intersection aggressive driving education and enforcement

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Aggressive Driving – Local Stop Urban	✓	✓	NA	Intersection	8 or more aggressive driving crashes per intersection	Intersection aggressive driving education and enforcement
Aggressive Driving – Local Stop Rural	✓	✓	NA	Intersection	8 or more aggressive driving crashes per intersection	Intersection aggressive driving education and enforcement
Aggressive Driving – State Signal Urban	✓	✓	NA	Intersection	8 or more aggressive driving urban crashes per intersection	Intersection aggressive driving education and enforcement
Aggressive Driving – State Signal Rural	✓	✓	NA	Intersection	8 or more aggressive driving rural crashes per intersection	Intersection aggressive driving education and enforcement
Aggressive Driving – Local Signal Urban	✓	✓	NA	Intersection	8 or more aggressive driving crashes per intersection	Intersection aggressive driving education and enforcement
Aggressive Driving – Local Signal Rural	✓	✓	NA	Intersection	8 or more aggressive driving crashes per intersection	Intersection aggressive driving education and enforcement

Table C-3: Unbelted Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Unbelted– All Segments Urban	✓	✓	Number of 5-year unbelted crashes per urban municipality	NA	200 unbelted crashes per municipality	Safety belt education and enforcement
Unbelted– All Segments Rural	✓	✓	Number of 5-year unbelted crashes per rural municipality	NA	150 unbelted crashes per municipality	Safety belt education and enforcement
Unbelted– State Segments Urban	✓	✓	NA	3,000 ft.	12 or more unbelted crashes urban crashes per 3,000 ft.	Safety belt education and enforcement
Unbelted– State Segments Rural	✓	✓	NA	3,000 ft.	12 or more unbelted rural crashes per 3,000 ft.	Safety belt education and enforcement
Unbelted– Local Segments Urban	✓	✓	NA	Entire road	12 or more unbelted crashes per urban route	Safety belt education and enforcement
Unbelted– Local Segments Rural	✓	✓	NA	Entire road	12 or more unbelted crashes per rural route	Safety belt education and enforcement

Table C-4: Alcohol-Related Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Alcohol-Related – All Segments Urban	✓	✓	Number of 5-year alcohol-related crashes per urban municipality		75 alcohol-related crasher per municipality	Sobriety checkpoints and selective DUI enforcement
Alcohol-Related – All Segments Rural	✓	✓	Number of 5-year alcohol-related crashes per rural municipality		50 alcohol-related crashes per municipality	Sobriety checkpoints and selective DUI enforcement
Alcohol-Related – State Segments Urban	✓	✓	NA	3,000 ft.	5 or more alcohol-related urban crashes per 3000 ft.	Sobriety checkpoints and selective DUI enforcement
Alcohol-Related – State Segments Rural	✓	✓	NA	3,000 ft.	5 or more alcohol-related rural crashes per 3000 ft.	Sobriety checkpoints and selective DUI enforcement
Alcohol-Related – Local Segments Urban	✓	✓	NA	Entire road	5 or more alcohol-related crashes per urban route	Sobriety checkpoints and selective DUI enforcement
Alcohol-Related – Local Segments Rural	✓	✓	NA	Entire road	5 or more alcohol-related crashes per rural route	Sobriety checkpoints and selective DUI enforcement

Table C-5: Pedestrian Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Pedestrian Crashes – All Segments Urban	✓	✓	Number of 5-year pedestrian crashes per urban municipality	NA	50 pedestrian crashes per municipality	Pedestrian education and enforcement
Pedestrian Crashes – All Segments Rural	✓	✓	Number of 5-year pedestrian crashes per rural municipality	NA	25 pedestrian crashes per municipality	Pedestrian education and enforcement
Pedestrian Crashes – State Segments Urban	✓	✓	NA	3,000 ft.	4 or more pedestrian crashes urban crashes per 3,000 ft.	Mid-block pedestrian safety improvements
Pedestrian Crashes – State Segments Rural	✓	✓	NA	3,000 ft.	4 or more pedestrian rural crashes per 3,000 ft.	Mid-block pedestrian safety improvements
Pedestrian – Local Segments Urban	✓	✓	NA	Entire road	4 or more pedestrian crashes per urban route	Mid-block pedestrian safety improvements
Pedestrian crashes – local segments rural	✓	✓	NA	Entire road	4 or more pedestrian crashes per rural route	Mid-block pedestrian safety improvements

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Pedestrian crashes – state intersections urban	✓	✓	NA	Single Intersection	2 or more pedestrian crashes urban crashes per intersection	Pedestrian countdown signals
Pedestrian crashes – local intersection urban	✓	✓	NA	Single Intersection	2 or more pedestrian crashes per urban intersection	Pedestrian countdown signals

Table C-6: Signalized Intersection Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Signalized Crashes – State Intersections Urban	✓	✓	NA	Intersection	25 or more signal crashes urban intersections	Minor safety signal upgrades
Signalized Crashes – State Intersections Rural	✓	✓	NA	Intersection	15 or more signal crashes rural intersections	Minor safety signal upgrades
Signalized Crashes – Local Intersection Urban	✓	✓	NA	Intersection	25 or more signal crashes urban intersections	Minor safety signal upgrades
Signalized Crashes – Local Intersection Rural	✓	✓	NA	Intersection	15 or more signal crashes rural intersections	Minor safety signal upgrades
Night Unlit Signalized Crashes – State Intersections Urban	✓	✓	NA	Intersection	15 or more night unlit signal crashes urban intersection	Lighting

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Night Unlit Signalized Crashes – State Intersections Rural	✓	✓	NA	Intersection	15 or more night unlit signal crashes rural intersections	Lighting
Night Unlit Signalized Crashes – Local Intersection Urban	✓	✓	NA	Intersection	15 or more night unlit signal crashes per urban intersection	Lighting
Night Unlit Signalized Crashes – Local Intersection Rural	✓	✓	NA	Intersection	15 or more night unlit signal crashes per rural intersection	Lighting
Wet Pavement Signalized Crashes – State Intersection Rural	✓	✓	NA	Intersection	8 or more wet pavement signal crashes rural intersections &wet/total>.30	Surface friction improvement

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Wet Pavement Signalized Crashes – State Intersection Urban	✓	✓	NA	Intersection	8 or more wet pavement signal crashes rural intersections & wet/total>.30	Surface friction improvement

Table C-7: Stop Controlled Intersection Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Stop Control Crashes – State Intersections Urban	✓	✓	NA	Intersections	5 or more stop control crashes urban intersections	Improved Sign and marking
Stop Control Crashes – State Intersections Rural	✓	✓	NA	Intersections	5 or more stop control crashes rural intersections	Improved Sign and marking
Stop Control Crashes – Local Intersection Urban	✓	✓	NA	Intersections	5 or more stop control crashes urban intersections	Improved Sign and marking
Stop Control Crashes – Local Intersection Rural	✓	✓	NA	Intersections	5 or more stop control crashes rural intersections	Improved Sign and marking
Night Unlit Stop Control Crashes – State Intersections Urban	✓	✓	NA	Intersections	5 or more night unlit stop control crashes urban intersection	Lighting

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Night Unlit Stop Control Crashes – State Intersections Rural	✓	✓	NA	Intersections	5 or more night unlit stop control crashes rural intersections	Lighting
Night Unlit Stop Control Crashes – Local Intersection Urban	✓	✓	NA	Intersections	5 or more night unlit stop control crashes per urban intersection	Lighting
Night Unlit Stop Control Crashes – Local Intersection Rural	✓	✓	NA	Intersections	5 or more night unlit stop control crashes per rural intersection	Lighting
Wet Pavement Stop Control Crashes – State Intersection Rural	✓	✓	NA	Intersections	8 or more wet pavement stop control crashes rural intersections &wet/total >.30	

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Wet Pavement Stop Control Crashes – Local Intersection Rural	✓	✓	NA	Intersections	8 or more wet pavement stop control crashes rural intersections & wet/total >.30	

Table C-8: Curve Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Curve Crashes – State Urban	✓	✓	NA	1,000 ft.	8 or more curve crashes per 1,000 ft.	Signing and marking improvements
Curve Crashes – State Rural	✓	✓	NA	1,000 ft.	8 or more curve crashes per 1,000 ft.	Signing and marking improvements
Curve Crashes – Local Urban	✓	✓	NA	Entire road	12 or more curve crashes per 1,000 ft.	Signing and marking improvements
Curve Crashes – Local Rural	✓	✓	NA	Entire road	12 or more curve crashes per 1,000 ft.	Signing and marking improvements

Table C-9: Tree Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Tree Crashes – State Segments Urban	✓	✓	NA	1,000 ft.	5 or more tree crashes urban crashes per 1,000 ft.	Tree removal or replacement
Tree Crashes – State Segments Rural	✓	✓	NA	1,000 ft.	5 or more tree rural crashes per 1,000 ft.	Tree removal or replacement
Tree Crashes – Local Segments Urban	✓	✓	NA	Entire road	5 or more tree crashes per urban route	Tree removal or replacement
Tree Crashes – Local Segments Rural	✓	✓	NA	Entire road	5 or more tree crashes per rural route	Tree removal or replacement
Night Tree Crashes – State Segments Urban	✓	✓	NA	1,000 ft.	4 or more night tree crashes urban crashes per 1,000 ft.	Tree delineation
Night Tree Crashes – State Segments Rural	✓	✓	NA	1,000 ft.	4 or more night tree crashes rural crashes per 1,000 ft.	Tree delineation

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Night Tree Crashes – Local Segments Urban	✓	✓	NA	Entire road	4 or more night tree crashes per urban route	Tree delineation
Night Tree Crashes – Local Segments Rural	✓	✓	NA	Entire road	4 or more night tree crashes per rural route	Tree delineation

Table C-10: Utility Pole Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Pole Crashes – State Segments Urban	✓	✓	NA	1,000 ft.	5 or more pole urban crashes per 1,000 ft.	Utility pole relocation
Pole Crashes – State Segments Rural	✓	✓	NA	1,000 ft.	5 or more pole rural crashes per 1,000 ft.	Utility pole relocation
Pole Crashes – Local Segments Urban	✓	✓	NA	Entire road	5 or more pole crashes per urban route	Utility pole relocation
Pole Crashes – Local Segments Rural	✓	✓	NA	Entire road	5 or more pole crashes per rural route	Utility pole relocation
Night Pole Crashes – State Segments-Urban	✓	✓	NA	1,000 ft.	4 or more night pole crashes urban crashes per 1,000 ft.	Utility pole delineation
Night Pole Crashes – State Segments-Rural	✓	✓	NA	1,000 ft.	4 or more night pole crashes rural crashes per 1,000 ft.	Utility pole delineation

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Night Pole Crashes – Local Segments Urban	✓	✓	NA	Entire road	4 or more night pole crashes per urban route	Utility pole delineation
Night Pole Crashes – Local Segments Rural	✓	✓	NA	Entire road	4 or more night pole crashes per rural route	Utility pole delineation

Table C-11: Guide Rail Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Old Guide Rail Crashes – State Segments Urban	✓	✓	NA	1,000 ft.	5 or more strong post cable or strong post W-beam less than 24" guide rail urban crashes per 1,000 ft.	Elimination (if feasible) or new guard rail
Old Guide Rail Crashes – State Segments Rural	✓	✓	NA	1,000 ft.	5 or more strong post cable or strong post W-beam less than 24" guide rail urban crashes per 1,000 ft.	Elimination (if feasible) or new guard rail
Night Guide Rail Crashes – State Segments-Urban	✓	✓	NA	1,000 ft.	4 or more night guide rail urban crashes per 1,000 ft.	Guard rail delineation
Night Guide Rail Crashes – State Segments-Rural	✓	✓	NA	1,000 ft.	4 or more night guide rail rural crashes per 1,000 ft.	Guard rail delineation
Night Guide Rail Crashes – Local Segments Urban	✓	✓	NA	Entire road	4 or more night guide rail crashes per urban route	Guard rail delineation

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Night Guide Rail Crashes – Local Segments Rural	✓	✓	NA	Entire road	4 or more night guide rail crashes per rural route	Guard rail delineation

Table C-12: Head-On and Opposing Sideswipe Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Two-Lane Crashes – State Segments Urban	✓	✓	NA	15,000 ft.	5 or more HO or opposing SS urban crashes per 15,000 ft.	Wider centerline pavement markings
Two-Lane Crashes – State Segments Rural –22 Ft. Or Greater	✓	✓	NA	15,000 ft.	3 or more HO or opposing SS rural crashes per 15,000 ft.	Centerline rumble strips
Two-Lane Crashes – State Segments Rural –18-20 Ft.	✓	✓	NA	15,000 ft.	3 or more HO or opposing SS rural crashes per 15,000 ft.	Wider centerline pavement markings
Four-Lane Crashes Undivided – State Segments-Urban	✓	✓	NA	15,000 ft.	5 or more HO or opposing SS urban crashes per 15,000 ft.	Wider centerline pavement markings
Four-Lane Crashes Undivided – State Segments-Rural	✓	✓	NA	15,000 ft.	3 or more HO or opposing SS rural crashes per 15,000 ft.	Centerline rumble strips

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Four-Lane Crashes Divided – State Segments-Rural	✓	✓	NA	15,000 ft.	3 or more HO or opposing SS rural crashes per 15,000 ft.	Centerline rumble strips
Four-Lane Crashes Freeway – State Segments-Urban	✓	✓	NA	15,000 ft.	3 or more HO or opposing SS urban crashes per 15,000 ft.	Median guard rail
Four-Lane Crashes Freeway – State Segments-Rural	✓	✓	NA	15,000 ft.	3 or more HO or opposing SS rural crashes per 15,000 ft.	Median guard rail

Table C-13: Rear End Crashes (DOT Markers)

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Two-Lane Rural – State Segments With AADT Between 3000-8000	✓	✓	NA	6,000 ft.	50 or more rear end crashes rural per 6,000 ft.	Install DOT markers (experimental)
Four-Lane Rural – State Segments With AADT Less Than 18000	✓	✓	NA	6,000 ft.	75 or more rear end crashes rural per 6,000 ft.	Install DOT markers (experimental)

Table C-14: Wet Pavement Crashes

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Rural – State Segments With Wet Pavement Crashes	✓	✓	NA	3,000 ft.	8 or more wet pavement crashes rural per 3,000 ft. and a wet/total crash ratio >.30	Higher friction surface

Table C-15: Run Off the Road Crashes – Narrow Pavements

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Two-Lane Rural – State Segments With Pavement Widths 18-20 Ft.	✓	✓	NA	3,000 ft.	20 or more SV crashes rural highways between 18-20 ft. wide per 3,000 ft.	Lane widening
Two-Lane Rural – State Segments With Pavement Widths < 18 Ft.	✓	✓	NA	3,000 ft.	20 or more SV crashes rural highways less than 18 ft. wide per 3,000 ft.	Lane widening or experimental edge pavement markings to provide motorists improved information of the pavement edge location

Table C-16: Run Off the Road Crashes – Narrow Shoulders

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Two-Lane Rural – State Segments With Shoulders <4 Ft.	✓	✓	NA	3,000 ft.	20 or more SV crashes rural highways with shoulders <4 ft. per 3,000 ft.	Shoulder widening
Four-Lane Rural – State Segments With Shoulders <4 Ft.	✓	✓	NA	3,000 ft.	20 or more SV crashes rural highways with shoulders < 4 ft. per 3,000 ft.	Shoulder widening

Table C-17: Run Off the Road Crashes – Paved Shoulders Available

Crash Type	Fatalities per 100 Crashes	Cost per Crash	Area-Wide Frequency	Cluster Length	Suggested 5-Year Threshold Cluster Level	Improvement Type
Two-Lane Rural – State Segments With 4 Ft. Or > Paved Shoulders And SV Crashes	X	X	NA	3,000 ft.	8 or more SV crashes rural highways with 4 ft. or greater paved shoulders per 3,000 ft.	Shoulder rumble strips
Four-Lane Rural – State Segments With 4 Ft. Or > Paved Shoulders And SV Crashes	X	X	NA	3,000 ft.	8 or more SV crashes rural highways with 4 ft. or greater paved shoulders per 3,000 ft.	Shoulder rumble strips

C.4.1 Output Formats – Area-Wide and Segment/Intersection-Based Deployments

Crash type and associated improvement type for the line items in each of the previous tables will generate data output that can assist users in identifying cost-effective levels of deployment for each improvement type. Five output tables are provided. The first table provides information on area-wide countermeasures. The second through fifth tables provide information for segment- or intersection-based deployments. A discussion for each table follows.

Table C-18: Education and Enforcement Countermeasures Factors (Aggressive Driving – Segments, Aggressive Driving – Intersections, Alcohol-Related, Unbelted, Pedestrian)

District (1)	County (2)	Municipality (3)	Total Targeted Crashes (4)	Cumulative % of Total Statewide Targeted Crashes (5)	Total Targeted Fatalities (6)	Cumulative % of Total Targeted Fatalities (7)	Targeted Crashes Per 1000 Residents (8)	Targeted Crashes Per Million VMT (9)	% of All Crashes That Are Targeted Crashes (10)	% of All Fatalities That Are Targeted Fatalities (11)	Fatalities/100 Crashes (12)	% of Targeted Crashes That Are Alcohol-Related (13)	% of Targeted Fatalities That Are Alcohol-Related (14)	% of Targeted Crashes That Are Unbelted (15)	% of Targeted Fatalities That Ate Unbelted (16)	% of Targeted Crashes That Are Alcohol-Related and Unbelted (17)	% of Targeted Fatalities That Are Alcohol-Related and Unbelted (18)

Twelve area-wide tables are generated, each with a targeted crash (e.g., aggressive driving – segment, aggressive driving – intersection, alcohol-related, unbelted, and pedestrians) for both urban and rural municipalities. The statewide output is arranged in an Excel spreadsheet format to allow easy sorting to identify District and County priorities.

- Municipalities (column 3) are listed in order of descending number of statewide targeted crashes (i.e., municipality with the highest number of statewide targeted crashes is listed first).
- Columns 1 and 2 provide information on the District and County in which the municipality is located.
- Column 4 provides information on the 5-year total targeted crashes.
- Column 5 provides information for each municipality on the cumulative percentage of total statewide targeted crashes that have occurred for municipalities at or above the targeted crash level for the municipality. This is important because it may show that the top 25 or so municipalities account for over 75 percent of the statewide targeted crash problem.
- Columns 6 and 7 are similar to columns 4 and 5, except they provide information on targeted fatalities rather than crashes.
- Columns 8 and 9 provide information on the rate of targeted crashes by population and VMT and can be used for comparison with other municipalities.
- Columns 10 and 11 provide information on the relative proportion of the targeted crash and fatalities within the municipality that are targeted crashes.
- Column 12 is an indicator of the relative severity of the targeted crashes within the municipality and can be used to predict the lives saved should an education and enforcement countermeasure be deployed.
- Columns 13 through 18 provide information on the proportion of targeted crashes that involve other crash factors. As an example, if Aggressive Driving – Segments is the targeted crash type and the data show that a high percentage of the fatalities involve alcohol, then the education and enforcement strategies may be altered to account for characteristics of alcohol-related crashes.

Each of the rows in the above tables that list crashes by segment or intersection (not area-wide) will generate four tables of information – a statewide summary table, a more specific listing of segments/intersections by targeted crashes, a detailed listing of targeted crashes on segments/intersections above a defined crash threshold, and a tabulation of other crash types that exceed threshold levels for other crash types within the limits of the segment. Samples for these four tables are shown below.

The statewide segment/intersection summary table provides information on the distribution of targeted crashes among segments/intersections throughout the State.

Table C-19: Statewide Segment/Intersection Summary Table

Number of Targeted Crashes Per Segment	Number of Segments	Cumulative Segments	Cumulative % of Segments	Cumulative Targeted Crashes	Cumulative % of Targeted Crashes
Highest	*1*	*1*	*1x100/all segments*	*X crashes*	*X(100)/all targeted crashes*
1		*Sum of all segments*	*100%*	*All targeted crashes*	*100%*

Segment summary tables are prepared for every crash type in the preceding tables that have information provided in the "Cluster Length" column. As an example, for the utility pole targeted crashes, eight segment summary tables would be prepared as follows: urban state, rural state, urban local, rural local, night state urban, night state rural, night urban local, and night rural local.

- For any given table, the segment which had the highest number of targeted crashes statewide would be listed in the first row of column 1, progressing downward to the segment that had the lowest number of crashes (usually 1).
- The second column indicates the number of segments that had "crashes per segment numbers" equivalent to those indicated in column 1. As an example, if the first row had the highest crash segment of 50 targeted crashes and there was only 1e segment that had 50 crashes, then the number of segments for this row is 1. If there were 75 segments that had 1 crash then the corresponding number of segments in the row that had 1 crash would be 75.
- If there were 1,000 total segments in the listing, then the first row in the cumulative segment column (column 3) would start with 1 and the last row would be 1,000.

- The cumulative percentage of segments (column 4) would take the cumulative segment row, multiply by 100 and divide by the total number of segments.
- The cumulative number of crashes (column 5) starts with the number of crashes in the top (highest) row and adds each row to it. As an example, if there were a total of 5,000 crashes in all 1,000 segments, the first row would be 50 and the last row would be 5,000.
- The cumulative percentage of all targeted crashes (column 6) would take the cumulative targeted crash row, multiply by 100 and divide by the total number of targeted crashes.

An example of the value of the statewide summary table is that it can indicate that 60 percent of the targeted crash problem occurs on 4 percent of the segments that had targeted crashes; this amounts to 200 segments. Therefore, if the 200 segments can be treated with low-cost improvements, the improvements have the potential to impact 60 percent of the statewide targeted crash problem.

Once the statewide segment/intersection summary table is completed, a threshold level of crashes per segment/intersection can be established and low-cost improvements pursued for locations at or above the threshold level. Further information beyond that provided in the summary table is needed to consider improvements at these segments/intersections.

A tabulation of each of the segments/intersections that exceed the threshold level of crashes is displayed in the following table.

Table C-20: Candidate Targeted Segment/Intersection Table

Number Of Targeted Crashes	District	County	Municipality	State Route	Beginning Segment	Beginning Offset	Ending Segment	Ending Offset	Functional Class	AADT	% Alcohol-Related	% Unbuckled	% Aggressive Driving

Note that street name rather than State Route would list local roads if the targeted crashes are on local roads. Information on segment and offset would not be included.

Each segment listed in the segment summary table that was above the defined threshold level of targeted crashes per segment/intersection would appear as a row in the candidate targeted segment/intersection table. As an example, if there were 200 segments in the statewide segment/intersection summary table that were at or above a defined threshold level of crashes per segment, there would be 200 segments or rows of information in the candidate target segment/intersection table. Each row would provide information on the number of crashes, the location, and percentage of crashes that involve aggressive driving, alcohol, or unbelted drivers or occupants. This latter piece of information may be useful in determining the type of improvement to deploy. As an example, if rural STATE trees are the targeted crash type and one of the segments identified had 15 tree crashes, of which 80 percent involved alcohol, a targeted DUI enforcement strategy may be appropriate to consider in addition to tree removal.

For each of the segments displayed in the candidate detailed segment/intersection table, additional information may be beneficial pertaining to each targeted crash that occurred within the segment/intersection in determining if the low-cost improvement is appropriate to implement. A detailed segment/intersection table is prepared for each of the segments/intersections above the threshold level. As an example, if rural state trees are the targeted crashes and one of the segments above the threshold had 15 tree crashes, then a table listing the 15 tree crashes would be provided for the segment using the “Detailed Segment/Intersection Targeted Crash Table” format.

Table C-21: Detailed Segment/Intersection Targeted Crash Table

District	County	Municipality	SR	Segment Number	Offset	Crash Report No.	Crash Type	Light	Weather	FHE	Alcohol-Related	Unbelted	Aggressive Driving	Causation Factor

Segments that appear on the Candidate Targeted Segment/Intersection Table for a given crash type may also appear in other types of crash types where other low-cost improvements are appropriate to consider. As an example, the segment on the rural state tree listing with 15 tree crashes may also appear on the curve listing and on the narrow shoulder listing. It is beneficial that the Highway Safety Engineer has knowledge of these collective safety problems at the time a determination is made to implement a series of low-cost improvements. As such, for each candidate targeted segment/intersection table generated for the various crash type/improvements, a matrix will also be developed listing each segment/intersection that is above the established threshold crash level on the vertical scale and the remaining crash improvement types on the horizontal scale. Other crash types that have segments with sufficient crashes to equal or exceed threshold levels for other crash types will be highlighted in the matrix. As an example, if a segment in the rural state tree category had 15 tree crashes and exceeded the threshold, it would be listed as a row line item. If that same segment was within the limits of the curve, and narrow shoulder crash types and exceeded those respective thresholds, it would receive a check mark in the curve and narrow shoulder cells.

Table C-22: Candidate Segment/Intersections Above Established Crash Threshold with Other Crash Types in Their Limits

Designated High Crash Category / County	Route	Segment	Begin Offset	Aggressive Driving – Segments	Aggressive Driving – Intersections	Unbelted Crashes	Alcohol-Related Crashes	Pedestrians	Signalized Intersections	Stop Controlled Intersections.	Curves	Trees	Utility Poles	Guide Rails	Head-On And Opposing Sideswipe – 2 Lane	Head-On And Opposing Sideswipe – 4 Lane	Rear End	Wet Pavement	Run-Off-Road – Narrow Pavements	Run-Off-Road – Narrow Shoulders	Run-Off-Road – Paved Shoulders Available

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Appendix D — **Studies and Countermeasures Resources**

December, 2014

District Highway Safety Guidance Manual

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D.1 Model Work Plan for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths

D.1.1 Background

Aggressive driving, impaired driving, and unbelted drivers and occupants collectively account for over 1,000 highway deaths each year in Pennsylvania. Each of these fatalities involves some violation of a traffic law. Research has found that highly visible, targeted enforcement can substantially reduce fatalities and injuries associated with these types of crashes. Unfortunately, police do not have the capacity to enforce all of the laws all of the time on all of the highways. However, these crashes tend not to be uniformly distributed throughout the highway system, but tend to be concentrated on certain sections of highway and at certain times of the day. Thus, if the sections of road where concentrations of certain crashes occur are known, highly visible enforcement may be applied at a potentially acceptable investment in police resources resulting in a substantive reduction in targeted crashes within the high crash section.

Existing programs such as the Buckle Up and Smooth Operator grants to select police departments and the Sobriety Checkpoint Program are a good foundation. However there are insufficient Federal 402 Funds to provide grants to all of the police departments with problems in these areas.

The vision of the model work program is to achieve measurable comprehensive program area and statewide reductions in aggressive driving, impaired driving, and unbelted travel fatalities through the effective application of highly visible enforcement in the vast majority of sections of highway with concentrations of these types of crashes.

D.1.2 Goals

The statewide and coordinator goals for this effort are as follows.

1. Gradually increase the number of police departments participating in the initiative, including State Police stations, in areas that experience one or more concentrations of aggressive driving, impaired driving, or unbelted injuries and deaths. Participation should be increased by at least 5 percent annually.
2. Gradually increase the number of identified high crash routes in which increased visible enforcement is applied by at least five percent annually.
3. A minimum 15 percent overall reduction in targeted severe injuries and deaths is achieved on the routes where visible enforcement is applied during the first year of targeted enforcement.

Options to Achieve the Goals

Option 1: Create significant levels of visible targeted enforcement in crash prone areas that experience high levels of aggressive driving, impaired driving, and unbelted injury and death. Re-orient the role of the comprehensive highway safety program coordinators to provide leadership and coordination with police departments, Law Enforcement Liaison (LEL) personnel, Sobriety Checkpoint Coordinators, and others to create significant levels of additional visible enforcement in these targeted crash prone areas.

Option 2: Increase the effectiveness of existing enforcement grants. Attempt to increase levels of visible enforcement solely through direct grants to select police departments similar to what is being done now. Since significant levels of increased Federal funding for enforcement is not a realistic possibility, review the criteria and funding levels for existing enforcement grants to determine if efficiencies can be instituted that will free up enough Federal funds that more police will be able to participate in the grant program.

Option 3: Guide the comprehensive county coordinators in determining and using best resources for each of the targeted areas based on the PennDOT strategies list.

D.1.3 Recommended Approach

Options 3 progressing to Options 1 and 2 are recommended. The comprehensive county coordinators in Option 3 can be the catalyst and facilitate the increased enforcement in Options 1 and 2. Option 1 should be given the most emphasis since, if successful, it will expand the level of visible enforcement much more than Option 2 and save more lives.

A model work program has been developed to provide guidance to coordinators in the effective implementation of Option 1. The model work program follows.

Coordinator Role and Responsibilities

The Comprehensive Highway Safety Program Grant Coordinators will play a pivotal role in achieving success in this endeavor. The coordinators will have the following major roles and responsibilities:

1. Convince the police to perform visible enforcement on highway sections with high targeted crashes.
2. In conjunction with the Safety Press Office (SPO) ensure that local press coverage of the initiative occurs and local drivers are aware of the increased enforcement.
3. Ensure that the local District Justices in the area are sensitive to the crash concerns on the targeted sections and the actions the police are taking to reduce future occurrences.

4. Coordinate with the LELs, Pennsylvania State Police, Smooth Operator Program, Buckle Up Program, and the Sobriety Checkpoint Programs, including participating in regional meetings to ensure that all activities complement each other.

Resources

Primary resources for the effort that PennDOT will need to provide to coordinators include:

1. Crash data for police agencies that have highway sections with high numbers of aggressive driving, impaired driving, or unbelted injuries and fatalities. The data will consist of municipal maps for each crash type (aggressive, impaired, and unbelted) that has a high crash section and a one page summary of crash characteristics for each crash type.
2. Tabulation of Buckle Up Grants, Smooth Operator Grants, and Sobriety Checkpoint Grants, including a listing of those enforcement agencies operating within the grants for the coordinator's area. A listing of the LELs and Sobriety Checkpoint Coordinators will also be provided.
3. Excel file forms to identify routes and time periods where visible enforcement is and/or has occurred.

Model Work Program Phases

The coordinators' work can be broken down into distinct work phases as follows.

1. Pre- police meeting phase.
2. Police meeting phase.
3. Visible enforcement implementation phase.
4. Evaluation phase.

<u>Pre-Police Meeting Phase</u>

During this phase the coordinator and the SPO receive the crash data from HSTOD. Each coordinator and SPO should receive the following information:

- Maps and one- to two-page crash summaries for each municipality within the coordinator's jurisdiction that has 30 or more aggressive driving, 30 or more unbelted injuries and fatality crashes, or 30 or more alcohol-related crashes investigated by the municipal police in the past 5 years. Separate municipal maps and crash summaries will be provided for each crash type that is equal to or exceeds these thresholds. The crash summaries will provide crash time characteristics and identify the highways with the highest numbers of these crashes. The coordinator will receive electronic files or several copies of each document produced. The SPOs, Buckle Up PA Coordinators, LELs, Sobriety Checkpoint Coordinators, and the PA

Driving Under the Influence (DUI) Association will also get direct multiple copies of these reports.

- Maps and one- to two-page crash summaries for each State Police station area within the coordinator's jurisdiction that has 30 or more aggressive driving, 30 or more unbelted injury and fatality crashes, or 30 or more alcohol-related crashes investigated by the State Police in the past 5 years. Separate State Police maps and crash summaries will be provided for each crash type that is equal to or exceeds these thresholds. The crash summaries will provide crash time characteristics and identify the highways which have the highest numbers of these crashes. The coordinator will receive electronic files or several copies of each document produced. The SPOs, Buckle Up PA Coordinators, LELs, Sobriety Checkpoint Coordinators, and the PA DUI Association will also get direct multiple copies of these reports.

It is imperative that coordinators fully understand the relevance of all of the data provided and any confusion regarding the information is resolved before proceeding further. If a coordinator does not understand any portion of the crash data provided, he/she should contact personnel in the Safety Management Division of HSTOD, who will ensure that technical assistance is provided to the coordinator.

After the coordinator understands the contents of the crash packages, he/she should meet with the District SPO to review the information. The coordinator should advise the SPO that he/she will be contacting the police chief and station commander at the State Police stations for those areas that have crash problems and the police will be requested to perform visible enforcement on the routes that have concentrations of these crashes. The SPO may attend the meetings with the State Police station commander and municipal police chiefs. If the SPO is unable to attend these meetings, the coordinator should provide a briefing to the SPO on the meetings' outcomes.

The coordinator and the SPO need to discuss and agree on strategies for informing the public of those routes where the police agree to perform visible enforcement. Articles in the local papers and interviews with the police chiefs both for local newspapers and radio stations should be considered along with other media opportunities. The respective roles, frequencies of press coverage, and methods to secure the coverage need to be established at the meeting between the coordinator and the SPO. The SPO is responsible for handling all press coverage. In the event that the SPO will not have sufficient time to provide local press coverage, an agreeable process needs to be established wherein the coordinator can take the lead in providing this service, keeping the SPO informed and involved throughout the process.

The coordinator also needs to meet with the LEL and the Sobriety Checkpoint Coordinator to coordinate enforcement functions. As an example, municipalities that have Buckle Up grants and highways with high numbers of unbelted drivers and occupants do not have to be approached to perform additional seat belt enforcement. The LEL should be given copies of the crash data to ensure that seat belt enforcement is being provided on the high crash routes. Likewise, municipalities with Smooth Operator enforcement grants and routes with high numbers of aggressive driving crashes should be excluded from this effort since they should be covered by the grants. The LEL should be given copies of the crash data to ensure that aggressive driving

enforcement is being provided on the high crash aggressive driving routes. Because the Sobriety Checkpoint program only involves between one and four events per month in the entire checkpoint area, targeted enforcement on individual highways that have high numbers of impaired driving crashes is considered appropriate. The Sobriety Checkpoint Coordinator can provide insight on existing impaired enforcement activities in each police department and potential opportunities to improve the likelihood that police departments will participate in the impaired driving component. The Sobriety Checkpoint Coordinator needs to be aware and given copies of the locations and the actions the Comprehensive Coordinator will be taking with the police chiefs.

The coordinator also needs to meet with the Regional Planning Team and discuss the approach being taken to obtain increased visible enforcement. The coordinator should incorporate the Regional Planning Team's input into the overall approach.

After the coordinator has a good grasp of the crash data, has met with the SPO, LEL, the Sobriety Checkpoint Coordinator, Buckle Up PA Grant Coordinator, the Smooth Operator Coordinator, and the Regional Planning Team, the Comprehensive Highway Safety Grant Coordinator can finalize the listings of municipalities and highways to secure additional visible enforcement and begin setting up meetings with municipal police chiefs and State Police station commanders who have concentrations of targeted crashes on the list. A one and one half hour time slot should be requested for each meeting with police chiefs/station commanders. The purpose of this meeting is to explore the potential for the police to provide visible enforcement on the targeted crash routes to reduce crashes, injuries, and fatalities. The SPO may attend the meetings with the State Police station commander and with municipal police chiefs. If the SPO is unable to attend these meetings, the coordinator should provide a briefing to the SPO on the meetings' outcomes. Meeting should be held with police chiefs/station commanders in close geographic proximity to each other so that multiple meetings can occur on the same day. A sample agenda for the initial police meeting is shown in Table D-1.

Table D-1: Sample Agenda for Initial Police Meeting

Approximate Time Duration	Agenda Item
5 minutes	Introductions and purpose of meeting.
5 minutes	Overview of the aggressive driving, impaired driving, and unbelted crash, injury, and fatality problem.
10 minutes	Review of municipality/station area crash summaries, routes, and maps.
10 minutes	Overview of the visible enforcement initiative on crash routes.
20 minutes	Discussion of type and potential for increased visible enforcement on crash routes (level of effort, additional measures to support enforcement, expected route reductions in crashes, injuries, and deaths).
10 minutes	Questions and answers.
20 minutes	Discussion of routes and level of effort where visible enforcement may be provided.
10 minutes	Next steps.

Police Meeting Phase

Initial Meetings with Police

Over the course of the grant period, the coordinator will be expected to meet and have multiple contacts with each municipal police chief and State Police station commander to ensure that added visible enforcement is applied to a number of the highways that have concentrations of targeted crashes. The objective of the initial meeting with the police chief is to get a commitment from the police that they will perform visible enforcement on one or all of the highway sections with targeted crash concerns. Ideally, the commitment should be for 7 to 10 hours of visible enforcement per week on each highway identified. Preferably the enforcement should be during hours and days when the crashes most frequently occur. The major points to get across at the meeting are as follows.

1. Explain that the municipality or area has a safety problem involving aggressive driving, impaired driving, or unbelted drivers and occupants (based upon the crash data for the municipality) and the problem is concentrated on select targeted highways.
2. Give the police chief or station commander the GIS maps and crash tabulations which list the high targeted crash highways and crash summaries.
3. Explain that the list of routes identifies highways where x number of crashes, y injuries, and z fatalities (broken down by aggressive driving, impaired driving, and unbelted drivers/occupants) have occurred on each route over the past 5 years.
4. Indicate that if nothing is done, these trends will continue into the future and over the next 5 years the same or slightly increased levels of crashes can be expected as traffic volumes increase.

5. Indicate that research has found that increased visible enforcement coupled with publicity to make drivers aware of the increased enforcement can reduce the potential for future crashes or injuries. NHTSA research findings that can be cited are shown in Table D-2.

Table D-2: NTHSA Research on Visible Enforcement

Enforcement Strategy	Research Findings
Aggressive Driving	
High Visibility Enforcement	The best effectiveness evidence from NHTSA demonstrations in three communities had mixed results. In Milwaukee, crashes dropped by 12 percent. However in Indianapolis, while average speeds dropped, crashes increased by 32 percent. In Tucson, aggressive driving crashes decreased by 8 percent. Taken together, the demonstrations suggest that high visibility aggressive driving enforcement campaigns may have promise but success is far from guaranteed.
Impaired Driving	
Checkpoints	A systematic review of eleven high quality studies found that checkpoints reduced alcohol-related fatal, injury, and property damage crashes each by 20 percent.
Saturation Patrols	The effects of saturation patrols on alcohol-related deaths have not been evaluated.
Integrated Enforcement	A three-site evaluation of integrated impaired driving, speed, and safety belt enforcement combined with high publicity concluded that crashes likely to involve alcohol (such as single vehicle nighttime crashes) were reduced from 10 to 35 percent The results were encouraging but not definitive because of the small number of sites.
Unbelted Injuries and Deaths	
Short High Visibility Enforcement	Short high visibility enforcement programs increased safety belt use by about 16 percentage points, with the greatest gains when the pre-program seat belt usage was lower.
Continual Enforcement	There are no studies of the effectiveness of continual enforcement.
Combined High Visibility Enforcement	The one study performed found “encouraging but inconclusive results.” Three demonstration sites were evaluated. One site maintained high visibility enforcement directed towards speed, impaired driving, and safety belt usage. It saw reduced DUI and speeding and maintained a high safety belt usage rate. A second site had only DUI enforcement which had an effect only on DUI. A third control site failed to conduct any form of high visibility enforcement, and saw no impact on crashes.
Night Safety Belt Enforcement	A 2004 high visibility belt enforcement program in Reading, PA increased night seat belt usage from 50 percent to 56 percent.

6. Provide an estimate of the crashes and injuries prevented and lives saved if visible enforcement is applied to the highways and a modest 15 percent reduction in injuries and deaths occur.
7. Indicate that based upon limited research, 7 to ten 10 per week per highway is about the level needed for the traveling public to become aware of the increased level of enforcement.
8. Advise the police chief/station commander that there are no additional funds available for overtime to support added enforcement on the highways.
9. Ask the chief or commander if he/she could provide increased visible enforcement on one or more of the routes by modifying patrol activities to spend more time on these routes, particularly during those times when most of the crashes are occurring.
10. Indicate the type and level of enforcement activity needed. Tables D-3 and D-4 describe this information.

Table D-3: Types of Police Enforcement Activities Required

Type of Problem	Enforcement Activity
Aggressive Driving	Speed, tailgating, proceeding without clearance, and reckless driving enforcement on targeted routes and intersections within the targeted routes.
Impaired Driving	Patrols sensitive to DUI on targeted routes during hours when the crashes are most likely to occur.
Unbelted Injuries and Deaths	Issuance of safety belt citations on targeted routes for secondary violations in conjunction with other enforcement activities.

Table D-4: Ideal Levels of Police Enforcement

Time Frame	Level of Enforcement
0 to 26 weeks	Seven to ten hours of targeted enforcement every week for each designated route.
26 to 52 weeks	Seven to ten hours of targeted enforcement every other week for each designated route.
52 to 78 weeks	Seven to ten hours of targeted enforcement every third week for each designated route.
Greater than 78 weeks	Seven to ten hours of targeted enforcement a week once a month for each designated route.

Some police departments will not be able to commit to the levels indicated in Table D-4, but will participate at a reduced level of visible enforcement. If this is the case, determine, accept, and record the level of periodic (weekly) enforcement offered.

11. Be ready to provide responses to reservations police may express about enforcement. Table D-5 illustrates some possible responses.

Table D-5: Potential Responses to Police Reservations about Enforcement Activities

Issue	Potential Response
Aggressive Driving	
No locations on the highway to perform speed enforcement.	Agree to set up meeting through the SPO with the Maintenance Manager to determine if an area requiring minimal re-grading could be flattened to create a pullover location.
Inconclusive research results on the effectiveness of high visibility enforcement discourage placement of manpower to this effort.	Refer to the top few highways with the most aggressive driving injuries and fatalities and indicate that high visible enforcement is the only viable option to impacting the problem known and ask that they consider participating at least on a trial basis.
Municipal police can not use radar and it is difficult to perform speed enforcement.	Agree that radar would be an effective tool but other speed timing methods can work and until such time that the law is modified to allow radar by local police, the high numbers of aggressive driving crashes on the identified routes will continue occurring.
Impaired Driving	
We already participate in the Sobriety Checkpoint program. Why do we have to participate in another enforcement initiative?	Reviewing the crash data, the top few DUI crash routes have had a number of DUI crashes occurring on them and these have occurred since the Checkpoint program has been in operation (need to verify). In addition, the Checkpoint Program normally conducts one to two checkpoints or roving patrols each month, and the coverage on these high DUI crash routes is probably minimal.
A number of our officers on patrol have not received training on Standard Field Sobriety Testing or methods to recognize potential impaired drivers. We can't effectively implement this effort.	Ask for a list of officers that need training and indicate that you will provide it to PennDOT to incorporate in the police training program. After they are trained, then will municipality commit to enforcement on the high DUI crash routes?
Unbelted Injuries and Deaths	
Seat belt usage is a secondary law in Pennsylvania, and we will not enforce it until it becomes a primary law.	Agree that a primary law would increase enforcement effectiveness and seat belt usage as well as save lives. However, cite the number of unbelted injuries and fatalities that have occurred in the past 5 years in his municipality and indicate that those numbers will probably be about the same over the next 5 years unless some action is taken. The coordinator may also mention that about two-thirds of the unbelted deaths and injuries are a result of aggressive or impaired driving. In addition to a primary law, also indicate that if the police initiated visible enforcement, began issuing secondary seat belt violations, and coupled enforcement with media coverage that the coordinator and SPO could perform, the research indicates seat belt usage would rise significantly and there would be a substantial reduction in the number of unbelted injuries and deaths compared

Issue	Potential Response
	to the number that have occurred over the past 5 years. The coordinator could also suggest that he/she would perform an informal seat belt survey on the route(s) and periodically update to determine changes in usage rates.
Officers are uncomfortable with issuing a second seat belt citation after giving the violator another major fine, particularly if the driver appears to have financial problems.	Agree that this is a concern; particularly if drivers had no advanced warning that secondary violations would be given. Suggest that a phase-in period could be used in which for the first few months unbelted drivers could be given written warnings. In addition, the coordinator and the SPO could work with the local media and prepare articles and press releases advising the people that because of the number of unbelted injuries and fatalities occurring in the municipality, police will more actively issue secondary citations for seat belt violations to encourage the public to wear safety belts. The media releases would also advise of the written warning phase-in period.

12. Advise the police chief or commander that if he/she agrees to provide targeted enforcement on select routes, the SPO and you will work with the local media to publicize the problem and the enforcement effort.
13. Advise the police chief or station commander that if he/she agrees to provide targeted enforcement on select routes, the coordinator will contact the appropriate District Justice in the area and sensitize him/her to the problem, give him/her a copy of the maps and list, and advise him/her of the actions being taken and the results of the research. Invite the police chief to attend the meeting.
14. Ask the police chief or station commander if he/she has any questions or issues that need to be answered. If they do and you can't answer them, indicate that you will find the information and get back to her/him. The coordinator should contact the Safety Management Division of HSTOD to assist in responding to the police inquiries.
15. End the meeting. Advise the police chief or commander that if no action is taken, the number of aggressive driving, unbelted, and impaired driving deaths and injuries that have occurred over the past 5 years on the high crash routes (you may want to cite some of the routes and the crash histories on the routes) will probably stay about the same for the next 5 years. Ask the police chief or commander for a commitment to make some moderate to slight modifications in patrol operations to provide 7 to 10 hours of visible, targeted enforcement on at least some of the priority routes. The response can be an immediate commitment, a deferral in a decision to give some further thought to the initiative and the routes involved, or a declination of participation in the initiative. In all cases, thank the chief for his/her time and cooperation.
    a. Immediate Commitment – If the chief or commander indicates an immediate commitment begin discussions on start dates and coordination efforts with the media and District Justices.

b. Decision Deferral – Advise the chief or commander that you will get back in touch with him in the near future to discuss further. If the deferral is because the chief needs some further information on issues or concerns raised during the meeting, indicate that you will follow through and obtain the information. In the interim, if he/she has any additional questions he/she should call you.

c. Declination to Participate –Find the reason for the declination and thank the chief for his time. Log the reason and include in the Comprehensive Highway Safety Grant Quarterly Report.

Initial Meeting Follow-Up Activities

The initial meeting will place police agencies into three categories: immediate commitment, deferred decision, and declined to participate. Follow-up activities for each of these paths are as follows.

Immediate Commitment

1. If there are any unresolved questions or issues identified at the initial meeting, take action to resolve them.
2. In conjunction with the police chief and SPO, establish a tentative date when the enforcement initiative will be launched.
3. Prior to launching the enforcement, meet with the SPO[1] and establish a strategy for making the initiative visible through the local media. Reach agreement on the message, who will present it, what media will be used, and when and how frequently messages should be released. Define the approval process for release. The message should include information on why the route(s) were selected (high number of aggressive driving, unbelted injuries and deaths, or impaired driving crashes on the route), enforcement actions being taken, and what motorists can do to avoid a targeted crash or citation. Consider having the police chief as the spokesperson for the media release if he/she is agreeable to it. Identify local media in the municipality (local newspapers, radio, etc.). Map out a media release plan for the enforcement initiative that extends over an 18 month period.
4. Prior to launching the enforcement, meet with the District Justice(s) who covers the routes identified and sensitize him/her to the problem and actions being taken to mitigate it. Provide the Justices with copies of the appropriate maps and crash data that align with the enforcement initiative. Ask the Justices to be sensitive to the problem and what the police are trying to accomplish when citations are issued.
5. Prior to the enforcement activity beginning, contact the police chief to establish some targeted crash reduction objectives for the route(s), review the whole effort and individual responsibilities, tie up any loose ends, and finalize when the initiative will begin.

[1] The SPO is responsible for handling all media activities and press coverage.

Deferred Decision

1. If the reason for the indecision related to follow-up activities is that the activities are not within the police's area of responsibility, perform the follow up and obtain the needed information.
2. Upon attainment of the information, or if the chief or commander had to perform an internal assessment, contact the police chief by telephone and provide him/her with the information and try and reach a determination of participation. This contact should occur when the information is secured, or if it is an internal police assessment, 2 to 4 weeks after the initial meeting. Actions to take following the telephone conversation are as follows:
    a. If the police chief or commander agrees to participate, follow the process established in the 'Immediate Commitment' above.
        i. If the police chief or commander still has unresolved issues and can't make a decision, find out what needs to be done to reach a decision, and assist the chief as best you can to reach a decision. Repeat the "decision deferral" process in item 1 of this list.
        ii. If the police chief or commander decides not to participate, determine the reason and thank her/him for considering the initiative. Follow the process in the "declined to participate" section below.

Declined to Participate

1. Review the reason given for non-participation and determine if there are alternatives that could work and alleviate the police chief's or commander's concerns.
2. Approximately 4 to 6 months after the initial meeting, set up a follow-up meeting with the declining police chiefs or commanders.
3. At the follow-up meeting with the police chief or commander, try and accomplish the following:
    a. Review the targeted crash data again to identify where the concentrations of the problem(s) are occurring.
    b. Provide alternatives or options for consideration that could totally or partially mitigate the reasons for the declination.
    c. Without being confrontational, pick a few of the routes and review the number of targeted deaths and injuries that have occurred over the last 5 years on these routes. Indicate that if nothing more is done, we can expect the same number to occur over the next 5 years.
    d. If the police chief or commander decides to participate on selected routes, follow the process set up in the "immediate commitment" section above.

e. If the police chief or commander continues to be reluctant, ask him/her if he/she would at least try the initiative on a trial basis on one of their routes that have the highest number of targeted injuries and deaths. Potentially the coordinator may ask the police if speed or DUI enforcement is conducted anywhere in the municipality. If so, the police could be asked to switch locations to one of the high targeted crash routes. If they accept, follow the procedures in the "immediate commitment" section above. If they continue to decline, thank the chief or commander for his/her time and terminate any further near-term contacts.

Visible Enforcement-Education Phase

Advanced Preparation Activities

Once a commitment to enforce is made, to better ensure success of the initiative, tie up all loose ends before the effort begins.

1. Develop a media plan for the routes with the SPO and agreed to by the police chief or commander.[2]
2. Sensitize the District Justice to the problem and the actions being taken to reduce it. Approximately 2 weeks prior to the actual launch date for the visible enforcement, the coordinator should contact the District Justice by telephone, and advise him/her of the launch date.
3. Contact the police chief or commander through either a personal meeting or by telephone to ensure that any unresolved issues are addressed. As part of that discussion, ask the police chief or commander if he/she would like to establish a goal for the effort (e.g., if over the past 5 years an average of 30 aggressive driving crashes, and six severe injuries and deaths associated with aggressive driving have occurred annually, what reduction level would the police like to try and achieve through visible enforcement). This would be an internal goal and not shared with the public. Also, ask the police chief or commander to collect citation and crash data on the route associated with the targeted crashes if the paperwork is not excessive. This information will be valuable in evaluating the impact of the effort.
4. Notify the Safety Management Division of HSTOD to prepare and send a thank you letter to the police chief or commander for participating in the initiative.

Commencement of Enforcement Activities

1. Set and record date when the visible enforcement initiative begins.

[2] Efforts may not always be individualized for specific departments if enforcement is being conducted as part of a larger statewide effort. In addition, efforts by smaller departments may be combined into one media plan detailing enforcement activities for the county or region.

2. In conjunction with the SPO, ensure that the media release or event is initiated shortly after the enforcement effort begins.[3]
3. If common routes extend across participating police departments, attempt to establish some coordinated route enforcement activities during the same time period and supplement with appropriate media announcing the coordinated effort.
4. Contact the police chief 1 to 2 months into the initiative to determine how the enforcement activity is going and if any problems or issues have developed. If some have developed, discuss and determine if you can be of assistance in resolving them.
5. Carry out the media plan.
6. About 4 to 6 months into the effort, meet with the police chief or station commander and SPO[4] to assess progress. If the chief/commander has agreed to collect targeted citation and crash data on the route, review the data and compare the crash level with previous average levels. If there are shortfalls compared to the goals established, discuss opportunities to reduce the targeted crashes. Based upon the approval of future grants, repeat this meeting at the 12 and 18 month period. If there are significant shortfalls, problems, or issues, initiate a telephone conversation with the police chief to address the problem at the 9 and 15 month period. Report on progress in the quarterly reports to HSTOD.
7. Based upon the approval of future grants, after the 18 month meeting, prepare a letter to the police chief or station commander thanking him/her for the added targeted enforcement on the routes and his/her concern for highway safety. Also ask the police to continue with the limited enforcement initiative on the route.

Evaluation and Measurement Phase

The evaluation and measurement phase will be performed by the coordinators and HSTOD. The coordinators will be responsible for collecting the measurements and HSTOD will be responsible for conducting the evaluation of the measurements taken. This effort will be performed from three perspectives as follows.

1. Police Department Participation – How many of the police departments with targeted driver crash concentrations are participating in the initiative?
    a. Number of police chiefs with reports visited.
    b. Number of police chiefs agreeing to participate.
    c. For those participating police chiefs, the number of District Justices identified and visited.

[3] Not every enforcement activity by every department will merit a press release or media event. The coordinator and SPO should work together to ensure that events are targeted and not over-publicized. Over-publicizing often results in the media discontinuing their coverage.
[4] If the SPO is unable to attend these meetings, the coordinator should provide a briefing the SPO on the meetings' outcomes.

d. Number of District Justices agreeing to cooperate/help with the initiative.

2. Route Enforcement – How many routes that have been identified as aggressive driving, impaired driving, or unbelted injury and death concentrations have been selected by the police for visible enforcement?
   a. Number of routes targeted for specific enforcement.
   b. Number of hours per week of enforcement activity per route.
   c. Number of media events per route.

3. Crash Impacts – What are the average number of crashes, injuries, and deaths that have occurred on each of the routes identified for targeted enforcement and what are actual numbers after the first year of visible enforcement? When did the enforcement begin?
   a. Number of targeted crashes, injuries, and fatalities reduced in the first 12 months of enforcement per route.

This information will allow an assessment of the overall impact (i.e., how many lives are projected to be saved and were saved as a result of this effort).

HSTOD will provide forms for collecting measurements needed for each of these efforts to the coordinators. Information on targeted routes and the average number of targeted crashes, injuries, and deaths for each route will be preloaded into forms for each of the coordinators. Coordinators will enter information on police department participation and routes selected for visible enforcement. Coordinators will also enter after data on crashes, injuries, and deaths if the police kept tabulations. If not, the after data will be entered by PennDOT using information from the crash data system when it becomes available.

D.2 Crash Data to Support the Model Work Program for Aggressive Driving, Impaired Driving, and Unbelted Injuries and Deaths

D.2.1 Background

Aggressive driving, impaired driving, and unbelted drivers and occupants collectively account for over 1,000 highway deaths each year in Pennsylvania. Each of these fatalities involves some violation of a traffic law. Research has found that highly visible targeted enforcement can substantively reduce fatalities and injuries associated with these types of crashes. Unfortunately, police do not have the capacity to enforce all of the laws all of the time on all of the highways. However, these crashes tend not to be uniformly distributed throughout the highway system, but tend to concentrate on certain sections of highway and at certain times of the day. Thus, if the sections of road where concentrations of certain crashes occur are known, highly visible

enforcement may be applied at a potentially acceptable investment in police resources resulting in a substantive reduction in targeted crashes within the high crash section.

The crash data system provides the necessary information to identify these high crash sections. The challenge is to extract high targeted crash section information in a user friendly format that coordinators and police can use to provide visible enforcement.

The vision of this effort to provide user friendly crash data is to achieve measurable comprehensive program area and statewide reductions in aggressive driving, impaired driving, and unbelted travel fatalities through the effective use of crash data both to identify sections of highway which have concentrations of targeted crashes and to apply highly visible enforcement by state and local police.

D.2.2 Goal

The purpose of this effort is to develop reproducible crash statistics and maps that State and local police can easily use to identify high-priority highways for targeted aggressive, impaired, and unbelted enforcement activities.

D.2.3 Recommended Approach

It is recommended that two types of reports be developed, one targeted at the municipal level and the other targeted at the State Police substation level. This section describes the criteria for developing reports and the report types and composition for both State and local police.

Report Criteria

Municipal Police Departments

Reports will be generated for municipalities that have investigated 30 or more aggressive driving, impaired driving, or unbelted reportable crashes in the last 5 years of available crash data.

State Police Stations

Reports will be generated for all State Police stations using county-wide data. Reports will highlight all municipalities within a county in which the State Police has investigated 25 percent or more of the aggressive driving, impaired driving, or unbelted crashes.

Targeted Crash Enforcement Report Types

Six targeted crash enforcement reports will be prepared as follows.

1. Municipal Police Aggressive Driving Targeted Crash Enforcement Report for municipalities that have investigated 30 or more aggressive driving crashes in the last 5 years of available crash data.
2. Municipal Police Impaired Driving Targeted Crash Enforcement Report for municipalities that have investigated 30 or more impaired driving crashes in the last 5 years of available crash data.
3. Municipal Police Unbelted Crash Targeted Crash Enforcement Report for municipalities that have investigated 30 or more unbelted driver or occupant crashes in the last 5 years of available crash data.
4. State Police Targeted Crash Enforcement Aggressive Driving Report by county in which station resides.
5. State Police Targeted Crash Enforcement Impaired Driving Report by county in which station resides.
6. State Police Targeted Crash Enforcement Unbelted Crash Report by county in which station resides.

Targeted Crash Enforcement Report Composition

Reports for Municipal Police

The municipal police targeted crash enforcement reports will be prepared for those municipalities that have the minimum number of aggressive driving, impaired driving, or unbelted crashes and will consist of three components as follows.

1. A summary sheet that provides information on the total and municipal police investigated targeted crashes (aggressive driving, impaired driving, or unbelted crashes) which occurred in the municipality in the last 5 years of available crash data; shift information on when they occurred, driver information on age, sex, and actions drivers took in the crashes; and crash type. (See Understanding and Using Crash Reports to Support Enforcement Activities.)
2. A listing of State and local highways in the municipality which had 12 or more targeted crashes in the last 5 years of available crash data listing the highway with the highest number of targeted crashes first. (See Understanding and Using Crash Reports to Support Enforcement Activities.)
3. An 8.5” x 11” map of the municipality showing the last 5 years of available crash data for targeted crashes by severity and State/local police investigative unit. The mapping process only displays crashes on State highways but the listing in the second attachment list both state and local highways. (See Understanding and Using Crash Reports to Support Enforcement Activities.).

Note that separate reports will be prepared for each municipality for each targeted crash type (aggressive driving, impaired driving, and unbelted crashes) if the eligibility criteria are met for each category.

Reports for State Police Stations

The State Police targeted crash enforcement reports will be prepared for all stations for aggressive driving, impaired driving, and unbelted crashes. A station is defined geographically as a county. Some populous counties have two or more stations. Unfortunately there are no boundaries within the mapping system or codes within the crash data system that distinguish differences between stations, particularly where there is more than one within a county. Consequently, county-wide targeted crash enforcement reports will be prepared, some of which will encompass two or more stations. Thus, an aggressive driving, impaired driving, and unbelted crash State Police targeted crash enforcement report will be prepared for each county. Each report will have three components as follows.

4. A summary sheet that that provides information on the total and State Police investigated targeted crashes (aggressive driving, impaired driving, or unbelted crashes) which occurred in the county in the last 5 years of available crash data. The total targeted crashes will also include municipal investigated crashes for municipalities in which the State Police investigated 25 percent or more of the targeted crashes. Shift information on when the targeted crashes occurred; driver information on age, sex, and actions drivers took in the crashes; and a crash type is also included.
5. A listing of State highways sections 15,000 feet in length in the county, exclusive of those municipalities where the State Police investigated less than 25 percent of the targeted crashes, and which had 12 or more total targeted crashes in the last 5 years of available crash data, listing the highway section with the highest number of targeted crashes first. A supplemental listing of local highways in the county, exclusive of those municipalities where the State Police investigated less than 25 percent of the targeted crashes, and which had 12 or more targeted crashes in the last 5 years of available crash data, listing the local highway with the highest number of targeted crashes first. .
6. An 18” x 24”or larger map of the county showing the last 5 years of available crash data for targeted crashes by severity and investigating unit, exclusive of those crashes in those municipalities where the State Police investigated less than 25 percent of the total targeted crashes. The mapping process only displays crashes on State highways, but the listing in the second attachment includes local roads that meet the criteria.

An additional 18” x 24”or larger map of the county which highlights the sections of State highway with concentrations of targeted crashes.

D.3 Guidelines for Pilot Installation of Pennsylvania Intersection Warning Treatment

This treatment for rural two-way stop-controlled intersections is meant to increase awareness and reduce speeds on major approaches, while encouraging motorists on the secondary approaches to be vigilant for approaching vehicles. Use this treatment on a pilot basis where crash data shows a high occurrence of intersection related and/or angle crashes between vehicles on the primary and secondary roadways. Areas with significant grade differences should be avoided.

D.3.1 Preparatory Work

- Select the top five to ten intersections with five or more intersection related and/or angle crashes.
- Review crash data for each intersection to identify potential patterns.
- Review traffic volumes to determine if the intersection is at or approaching signal volume warrants.
- Review the intersection in the field to determine signing and sight distance status.

The entire treatment consists of the following components:

1. Placement of the SLOW legend, xxMPH, and **+** symbols on the primary roadway.
2. Placement of appropriate signs outlined below on the secondary roadway.

Legend

The SLOW and xxMPH (posted speed limit) legends should be placed on the roadway. Legends should be applied according to Figures D-1 and D-4. The SLOW legend can be installed alone if adequate sight distance is available. If sight distance is restricted, the xxMPH legend should be added as indicated in Figure 1. The xx speed should be based upon the SSD available. See Figure D-4 for legend detail.

- Material – Use standard durable pavement marking material.

Marking (+ Symbols)

The marking consists of a set of two **+** symbols marked on the roadway. For approaches with speed limit of 25 or 30 MPH, only one **+** symbol is acceptable. See Figure D-1 for placement detail. Marking is to be centered in the travel lane. The ratio of width (B) to height (A) for the **+** mark is 1:2 (see Figure D-2 for dimensions) based on standard oblong pavement markings referenced in the *Manual for Uniform Traffic Control Devices* (MUTCD).

- Material – Use standard durable pavement marking material.

- Spacing – The first **+** marking should be placed 50 feet from the xx MPH legend. The second **+** marking should be 50 feet from the first **+** markings.
- Pattern Length – The length of the pattern should be determined from the posted speed limit based on the table in Figure D-1.

Signing

There should be placed a minimum of two signs as follows:

- Intersection warning sign (W2-1) with warning placard "Watch For Entering Vehicles" should be placed before the pattern in both directions at distance Y according to the table in Figure D-1. Distance from intersecting roadway is based on posted speed on the primary roadway.
- "LOOK LEFT-RIGHT-LEFT BEFORE PULLING OUT" sign should be placed on the far side of the intersection as shown in Figure D-1. Ensure that the position of this sign can be readily seen by the stopped motorist and does not interfere with sight distance requirements for stopped motorist on the opposing stopped approach.

Coordinate with the sign shop to order the selected sign. A sign layout, its size, and commodity code is shown in Figure D-3.

For signing layout, see Figure D-1.

D.3.2 Guidelines for Selecting Treatment Locations

- It is very important that drivers, while stopped to make the decision whether to enter the intersection, can plainly view the message. If a stop sign is not easily viewed from a decision point on the secondary road, consider replacing the stop sign with a warning message at an appropriate location.

- Engineering improvements should be considered to ensure visibility of the treatment (e.g., curb adjustment, stop bar adjustment, vegetation control).

- Avoid locations with any of the following conditions:

    1. Intersection is complicated by having more than four legs or by having driveways or roads within pattern limits that may seriously affect the continuity of the treatment.
    2. High traffic volume or heavy congestion exists.
    3. Excess informational signage (e.g., route signing, mileposts, billboards) that may create confusion for the motorist.
    4. Railroad crossing markings exist within pattern length.

- Treatment may be considered for intersections having only one secondary approach ("T" intersection). Treatment of one approach to a four-leg intersection may also be considered. Use engineering judgment as needed.

- Consider treatment only on roadways having no more than two approaches on the through highway (right or left).

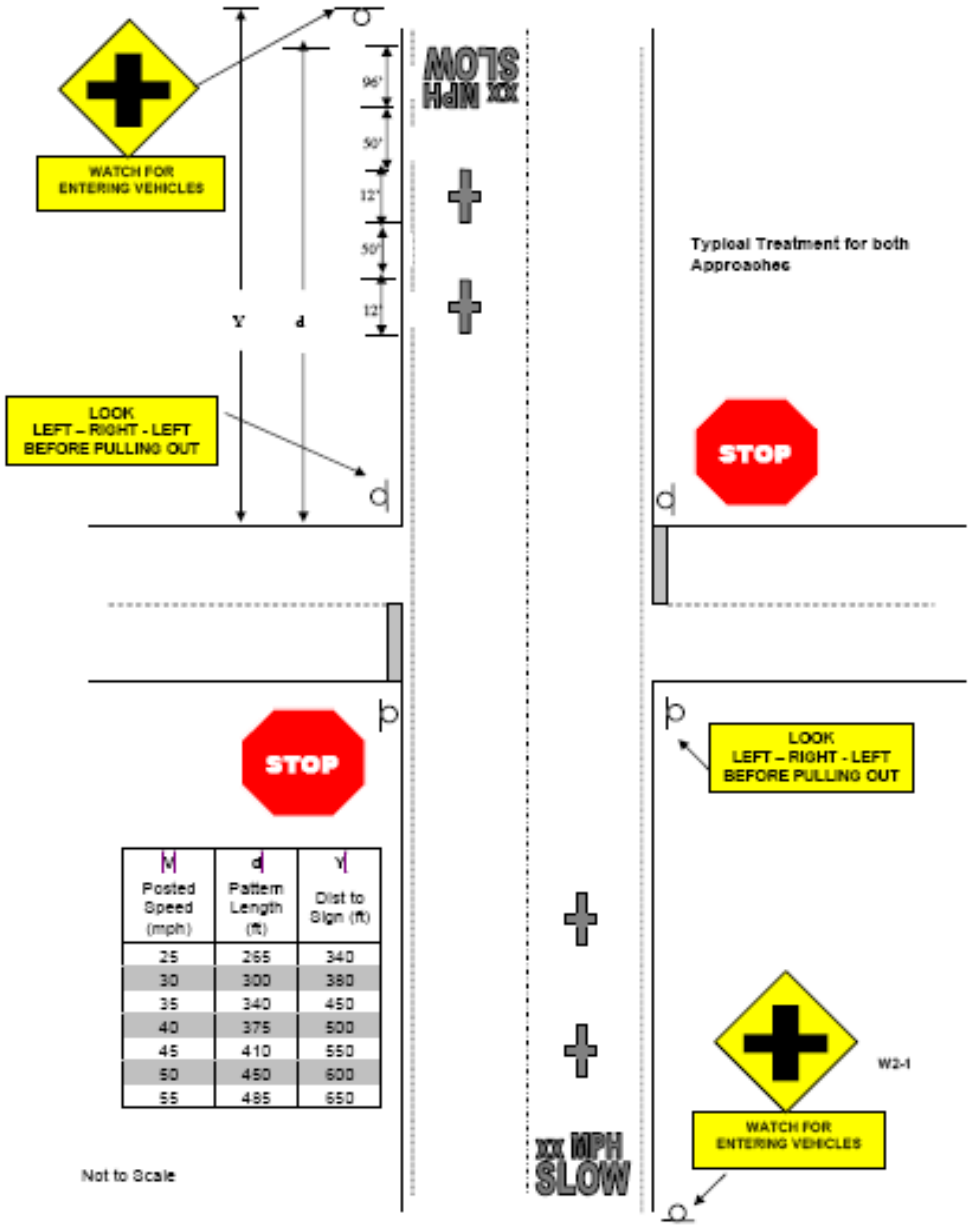
- Intersection warning pavement markings can be installed via projects initiated exclusively for this purpose.

- Deviation from the above specifications and guidelines may be considered by the district; however, they must be approved by the Highway Safety and Traffic Operations Division prior to being implemented.

D.3.3 Other

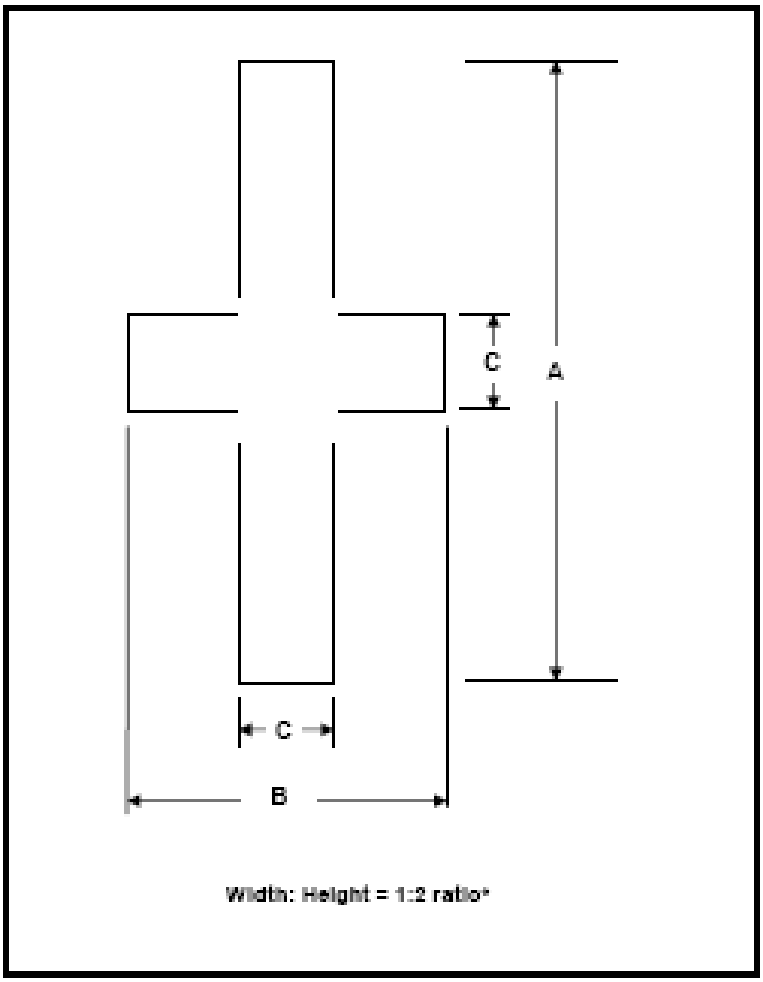
At stop approach:

- Place durable stop bar if some vehicles are stopping too far back where sight distance is substantially lowered.
- Extend the edge line on the through highway by using a short skip pattern to further assist the stopped motorist in determining the travel path of the through vehicles.



M Posted Speed (mph)	d Pattern Length (ft)	Y Dist to Sign (ft)
25	265	340
30	300	380
35	340	450
40	375	500
45	410	550
50	450	600
55	485	650

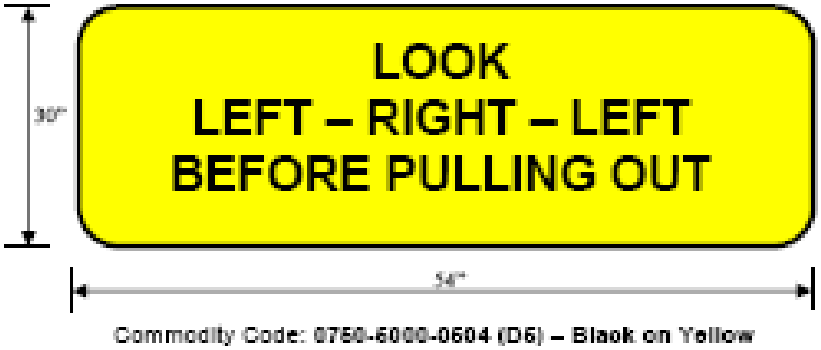
Figure D-1: Intersection Warning Treatment



Not to Scale

Location	A (ft)	B (ft)	C (ft)
Two Lane Highway	12.0	6.0	2.0

Figure D-2: Dimensions for Intersection Warning Treatment



Commodity Code: 0750-6000-0604 (D6) – Black on Yellow

Commodity Code: 0728-8010-3618 (Special Sign) Black on Yellow

Not to Scale

Figure D-3: Sign Layout, Size, and Commodity Code

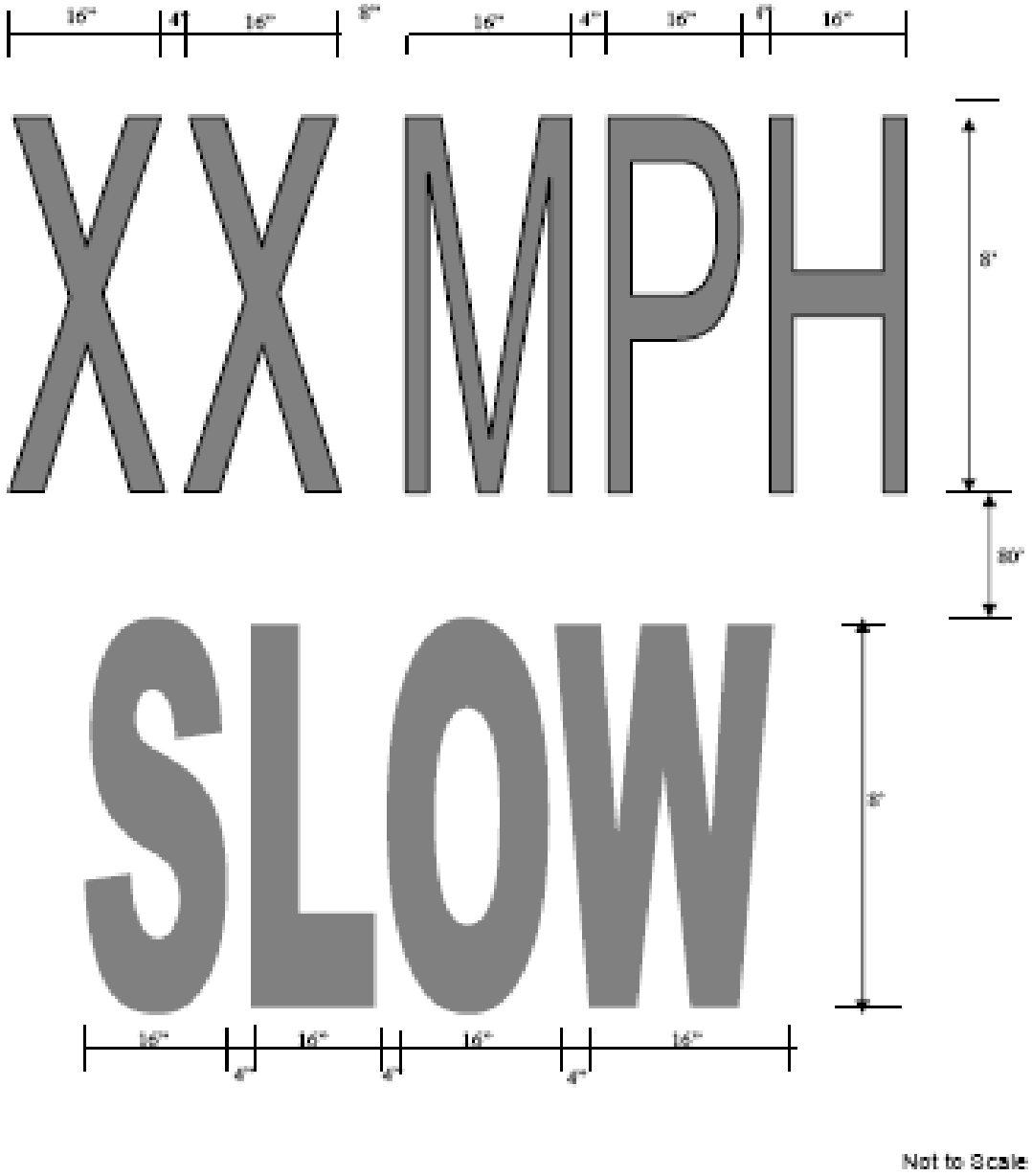


Figure D-4: Legend Detail

District Highway Safety Guidance Manual

Appendix E — **Safety Performance Functions**

December, 2014

Safety Performance Functions

FINAL REPORT

October 8, 2014

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16. Abstract

This project developed safety performance functions for roadway segments and intersections for two-lane rural highways in Pennsylvania. The statistical modeling methodology was consistent with that used in the first edition of the American Association of State Highway and Transportation Officials' *Highway Safety Manual*. Two realistic case study examples are provided to illustrate how to use the safety performance functions developed in this project.

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INTRODUCTION

The American Association of State Highway and Transportation Officials' (AASHTO) *Highway Safety Manual* (HSM) provides transportation professionals with the tools necessary to quantify the safety performance of planned or existing highways. One set of tools available in the current edition of the HSM are safety performance functions (SPFs) for rural two-lane, rural multi-lane, and urban and suburban arterials. The HSM also provides a detailed calibration method to adapt each algorithm to local conditions since the data used to develop the crash prediction algorithms were not acquired from Pennsylvania and thus do not reflect Pennsylvania driving conditions. Alternatively, the HSM indicates that developing SPFs using local data will provide more reliable crash frequency estimates than applying the calibration procedure.

In light of this, the objectives of this project are to develop SPFs for rural two-lane road segments and intersections in Pennsylvania. Statistical models for total crash frequency and fatal and injury crash frequency were created using data from all state-owned two-lane rural roadways with three-digit or lower state route numbers. To ensure that the models developed in this research were similar to those presented in the HSM, the same statistical analysis methods were used.

The report is organized into four subsequent sections. The first describes the data elements and structures that were acquired to estimate the statistical models of crash frequency. The following two sections describe the estimation of roadway segment SPFs and intersection SPFs, respectively. The final section of this report includes two realistic case study examples to illustrate how the SPFs can be used to assess the safety performance of two-lane rural highway segments and intersections, respectively, in Pennsylvania.

DATA COLLECTION

The first part of this section includes a description of the PennDOT Roadway Management System (RMS) data files that were acquired to develop the SPFs and how these files were organized for statistical modeling purposes. These data were supplemented with additional elements that were collected using PennDOT's online vehicle photolog system and Google Earth, which are described in Appendices A and B, respectively. The last part of this section includes information concerning the electronic crash data that were used to develop the roadway and intersection SPFs.

Roadway Management System Data

The RMS data files include information about the roadway cross-section, traffic volume, access control, functional classification, posted speed limit, and intersection locations and traffic control. These data are codified based on PennDOT's linear referencing system, which is defined by the county, state route, and segment number. Two data files

(for the years 2008 and 2012) were acquired from PennDOT for modeling purposes. These two data files were initially compared to determine if segments or intersections were added or deleted during this time period perhaps due to new roadway construction, major reconstruction or changes in the functional classification of a segment. For the most part, roadway infrastructure elements in the data files (e.g., number of lanes, lane width, shoulder type, shoulder width, divisor type, and divisor width) remained unchanged between the years 2008 and 2012; however, any differences were identified. Since a comparison of the segment and intersection data in the 2008 and 2012 files revealed that few differences existed between the two files, the 2012 file was used as the base file since it was the most recently updated.

The only variables that changed significantly across the files were the traffic volumes, expressed as average annual daily traffic (AADT) in units of vehicles per day. To account for changing traffic volumes for the interim years between 2008 and 2012, the research team used linear interpolation of these known volumes. As historical crash data was available starting from 2005, linear extrapolation was used to estimate traffic volumes for the years between 2005 and 2008.

Intersection location information was acquired from the PennDOT RMS Intersection data files. The RMS Intersection data files include the county, state route number, segment, and offset where two roadways on the state-owned roadway network intersect. This intersection location information was appended to the segment data. After merging the RMS segment data with the RMS Intersection data, two separate data files were created for the SPF development process. The first file was used for the development of SPFs on roadway segments, and included the following data elements:

- Linear reference information (county, route, and segment)
- Segment length
- Average annual daily traffic (vehicles/day)
- Commercial vehicle traffic (trucks/day)
- Paved roadway width (including all travel lanes)
- Number of travel lanes in both directions
- Posted speed limit
- Divisor type
- Left- and right-shoulder type
- Left- and right-shoulder paved width (feet)
- Left- and right-shoulder total width

The second file was used for the development of SPFs at intersections and was composed of only the relevant data from intersection locations. These data included the type of control present at each intersection as well as the segment-level data listed above for each intersecting roadway in the intersection data analysis files.

There are several supplemental data elements that were collected as part of this project to enable inclusion of additional roadway and roadside features in the SPFs. At the

segment-level, these included the roadside hazard rating, presence, radius and length of horizontal curves, presence of passing zones, and the presence of various low-cost safety improvements (i.e., shoulder or centerline rumble strips, horizontal curve warning pavement markings, intersection warning pavement marking, and aggressive driving dot pavement markings). For the intersection data files, the additional elements included intersection skew angle, presence of auxiliary lanes on intersections approaches (i.e., left- or right-turn lanes) and the presence of crosswalks on any intersection approach. The presence and type of the traffic control at each intersection was also verified during this stage of the data collection process. Each of these supplemental data collection strategies are described below.

Supplemental Roadway and Intersection Data Elements

This part of the data collection plan is organized into two parts. The first describes the data elements that were collected and codified using PennDOT's online video photolog system. The second describes the data elements that were collected using the Google Earth web-based tool. Appendix A and Appendix B include the instructional guides for the online video photolog and Google Earth data collection methods, respectively.

Online Video Photolog Data Collection

PennDOT's video photolog system can be found online at the following link:

http://www.dot7.state.pa.us/VideoLog/Open.aspx

The web-based application contains a forward-looking view of the roadway and roadside from a driver's perspective. The distance between consecutive images varies from 21 to 210 feet. In addition to the forward-looking display, a map of the segment within the roadway network is displayed within the video photolog application.

Both roadway segment and intersection details were collected using the online video photolog system. The segment data included:

- Roadside hazard rating (RHR): estimated on the 1 to 7 scale proposed by Zegeer et al. (1986)
- Presence of passing zones within the segment.
- Presence of low-cost safety improvements, such as: centerline and shoulder rumble strips on roadway, horizontal curve warning pavement markings, aggressive driving dots, and intersection warning pavement markings.
- Driveway density: the number of driveways or intersections along a segment that are not included in the state-owned intersection analysis database.

Each of these data elements were coded into the RMS data files that are described above for each two-lane rural highway segment. The intersection data elements that were collected using the on-line video photolog system included:

- Presence of intersection auxiliary lanes: left- or right-turn lanes

- Presence of pedestrian crosswalk on intersection approach.
- Verification of the type of intersection traffic control: signalized or stop-controlled intersections

Each of these data elements were coded into the RMS Intersection data files that are described above.

Appendix A of this report includes an instructional guide that describes the data collection procedure and was used to ensure inter-rater consistency among the data collection team for the RHR.

Google Earth Data Collection

The Google Earth tool provides high-quality satellite imagery of Pennsylvania and built-in functions to measure features to scale. This satellite imagery was used to collect horizontal curve and intersection skew angle data. The radius (or degree) and length of each horizontal curve on the two-lane rural roadways were collected at the segment-level. In cases where no horizontal curve existed within a segment or where the entire length of a horizontal curve was contained within the limits of a single segment, these data were coded as such for that particular segment. When horizontal curves crossed into adjacent roadway segments, the length of each curve within each of the adjoining segments was noted. This enabled the research team to use an alignment index to assess the association between horizontal curvature and crash frequency and severity when estimating the SPFs. The horizontal alignment indexes that were considered by the research team included (Fitzpatrick et al., 1999):

$$\frac{\sum DC_i}{L} \tag{1}$$

$$\frac{\sum CL_i}{L} \tag{2}$$

$$\frac{\sum R_i}{n} \tag{3}$$

where:

DC_i = degree of curve for curve i (i = 1, 2, …, n) [degrees];
L = length of segment (miles);
CL_i = length of curve for curve i (i = 1, 2, …, n) [miles];
R_i = Radius of curve i (i = 1, 2, …, n) [ft]; and,
n = number of horizontal curves per segment

Intersection skew angle was determined by using a protractor to measure the angle of the intersecting roadways from Google Earth images. These data were then added to the intersection SPF analysis database.

Appendix B of this report includes an instructional guide that describes the data collection procedure and was used to ensure inter-rater consistency among the data collection team for the horizontal curve and intersection skew angle data elements.

Electronic Crash Data

The research team used the most recent eight years of crash data (2005 through 2012, inclusive) to estimate the roadway segment and intersection SPFs. These data files contained information about the event, driver, and vehicle occupants for each reported crash on the state-owned highway system in Pennsylvania. Only event information was used for the current study. The following data elements were used when developing the segment-level analysis database:

- Crash location: county, state route, segment, and offset
- Crash date: month, day, year
- Crash type: rear-end, head-on, angle, sideswipe, hit fixed object, hit pedestrian, other
- Intersection type: mid-block, four-way intersection, "t" intersection, "y" intersection, traffic circle/roundabout, multi-leg intersection, railroad crossing, other
- Location type: underpass, ramp, bridge, tunnel, toll booth, driveway or parking lot, ramp and bridge
- Work zone type: construction, maintenance, utility company
- Injury severity: fatality, major injury, moderate injury, minor injury, no injury

Several of the crash data elements were used to identify crashes occurring on roadway segments and intersections of interest for the present study. For example, crashes occurring on ramps were used as a check to ensure that the RMS files have correctly eliminated ramps from the analysis database. Crashes in construction work zones were not included in the analysis files as these conditions are temporary.

Crash data were merged with the RMS and supplemental data files based on the location of the crash (county, route, and segment). Crash counts (total, total for each severity level, and total for each crash type) for each roadway segment and intersection were generated for each analysis year. Locations that did not experience a crash during any one or more years were retained in the analysis database and a zero crash count was noted for these locations.

ROAD SEGMENT SAFETY PERFORMANCE FUNCTIONS

This section of the report describes the SPFs developed for rural two-lane highway segments in Pennsylvania. The first part of this section describes the statistical analysis methodology used to generate the safety performance functions. The second part briefly summarizes the data used for model estimation, noting that the data collection methods that were used to assemble the data analysis files were described in the previous section of this report. Statistical models are then reported for total crashes and for total fatal and injury crashes. An interpretation of the regression coefficients is also included in the last part of this section.

Statistical Modeling Methodology

Several cross-sectional modeling approaches were considered to estimate the roadway segment SPFs in the current study. However, in an effort to be consistent with the first edition of the HSM, negative binomial regression was used. Such an approach models the expected number of crashes per mile per year in each roadway segment as a function of one or more explanatory variables. This is a very common approach to model roadway segment crash frequency (e.g., Miaou, 1994; Shankar et al., 1995; Chang et al., 2005; El-Basyouny and Sayed, 2006) because it accounts for the overdispersion that is often observed in crash data. Overdispersion results from the variance exceeding the mean in the crash frequency distribution. The general functional form of the negative binomial regression model is:

$$\ln \lambda_i = \beta X_i + \varepsilon_i \tag{4}$$

where:

- λ_i = expected number of crashes on roadway segment *i*;
- β = vector of estimable regression parameters;
- X_i = vector of geometric design, traffic volume, and other site-specific data; and,
- ε_i = gamma-distributed error term.

The mean-variance relationship for the negative binomial distribution is:

$$Var(y_i) = E(y_i)[1 + \alpha E(y_i)] \tag{5}$$

where:

- $Var(y_i)$ = variance of observed crashes y occurring on roadway segment *i*;
- $E(y_i)$ = expected crash frequency on roadway segment *i*; and,
- α = overdispersion parameter.

The appropriateness of the negative binomial (NB) regression model is based on the significance of the overdispersion parameter. When α is not significantly different from zero, the negative binomial model reduces to the Poisson model. For all the models that were estimated, the estimate of α is reported to verify the appropriateness of the negative binomial approach.

The method of maximum likelihood is used to estimate the model parameters. This method estimates model parameters by selecting those that maximize a likelihood function that describes the underlying statistical distribution assumed for the regression model. The likelihood function for the NB model that was used in this study is shown in equation (6):

$$L(\lambda_i) = \prod_{i=1}^{N} \frac{\Gamma(\theta + y_i)}{\Gamma(\theta) y_i!} \left[\frac{\theta}{\theta + \lambda_i} \right]^{\theta} \left[\frac{\lambda_i}{\theta + \lambda_i} \right]^{y_i} \tag{6}$$

where:

N	= total number of roadway segments in the sample;
Γ	= gamma function; and,
θ	= $1/\alpha$.

To apply the negative binomial regression models estimated in this study, the following functional form should be used:

$$\lambda_i = e^{\beta_0} \times L \times AADT^{\beta_1} \times e^{(\beta_2 X_2 + \ldots + \beta_n X_n)} \tag{7}$$

where:

λ_i	= expected number of crashes on roadway segment i;
e	= exponential function;
β_0	= regression coefficient for constant;
L	= roadway segment length (miles);
$AADT$	= average annual daily traffic (veh/day);
β_1	= regression coefficient for AADT;
$\beta_2, \ldots, \beta_n$	= regression coefficients for explanatory variables, i = 2, …, n; and,
$X_2, \ldots, X_n$	= vector of geometric design, traffic volume, and other site-specific data.

The elasticity of each independent variable included in the model is also computed to help interpret the results of the roadway segment SPFs. The elasticities provide a measure of responsiveness of one variable to a change in another. For the continuous explanatory variables considered in this study (e.g., AADT), the elasticity is interpreted as the percent change in the expected roadway segment crash frequency given a one percent change in that continuous variable. In general, the elasticity of the expected

crash frequency for continuous explanatory variable '*k*' on roadway segment '*i*' during time period '*j*' is defined as:

$$E_{x_{ijk}}^{\lambda_{ij}} = \frac{\partial \lambda_{ij}}{\partial x_{ijk}} \times \frac{x_{ijk}}{\lambda_{ij}} \tag{8}$$

Equation 5 reduces to the following expressions for the log-log (Equation 9) and log-linear (Equation 10) functional forms, respectively. These represent the two types of functional forms considered here. The first represents the relationship modeled between expected crash frequency and the AADT variable and the second represents the relationship modeled between expected crash frequency and all other continuous variables in the roadway segment SPFs.

$$E_{x_{ijk}}^{\lambda_{ij}} = \beta_k \tag{9}$$

$$E_{x_{ijk}}^{\lambda_{ij}} = \beta_k x_{ijk} \tag{10}$$

The elasticity for indicator variables (e.g., presence of passing zones), termed *pseudo-elasticity* by Lee and Mannering (2002), is the percent change in expected crash frequency given a change in the value of the indicator variable from zero to unity. In general, the elasticity of the expected crash frequency for indicator variable '*k*' on roadway segment '*i*' during time period '*j*' is defined as:

$$E_{x_{ijk}}^{\lambda_{ij}} = \exp(\beta_k) - 1 \tag{11}$$

Data Summary

There were 21,340 unique roadway segments included in the data analysis file. Because there were eight years of crash data available for each roadway segment (2005 to 2012), the analysis database consisted of 170,720 observations. Table 1 provides summary statistics of the segment-level data for total crashes, fatal, injury, and PDO crashes, traffic volume, and the roadway and roadside characteristics included in the analysis database.

As shown in Table 1, there are more injury and property damage only (PDO) crashes per segment than fatal crashes per segment. The categorical variables are shown in the lower panel of Table 1. The majority of roadway segments have a roadside hazard rating (RHR) or 4, 5, or 6. Fewer than 2 percent of roadway segments have curve warning, intersection warning, or "aggressive driving dots" traffic control devices.

Table 1. Crash, Traffic Volume, and Site Characteristic Data Summary

Variables	Mean	Standard Deviation	Minimum	Maximum
Total crashes per year	0.667	1.144	0	23
Total fatal crashes per year	0.015	0.123	0	3
Total injury crashes per year	0.347	0.724	0	13
Total property-damage only (PDO) crashes per year	0.306	0.672	0	13
Average annual daily traffic (veh/day)	3282	2933	74	28,674
Segment length (miles)	0.474	0.129	0.003	1.476
Posted speed limit (mph)	47.421	7.650	15	55
Left paved shoulder width (feet)	3.002	2.305	0	22
Right paved shoulder width (feet)	3.048	2.304	0	19
Access density (access points and intersections per mile)	16.300	14.307	0	330
Horizontal curve density (curves per mile)	2.299	2.506	0	42.581
Degree of curve per mile	19.100	44.178	0	1263.478
Length of curve per mile	1004.945	1237.694	0	29,256.37
Categorical Variables	Category		Proportion	
Roadside hazard rating (1 to 7)	1		0.1	
	2		0.5	
	3		5.1	
	4		21.6	
	5		53.1	
	6		19.4	
	7		0.2	
Presence of a passing zone	Yes		28.4	
	No		71.6	
Presence of centerline rumble strips	Yes		21.0	
	No		79.0	
Presence of shoulder rumble strips	Yes		8.1	
	No		91.9	
Presence of curve warning pavement marking	Yes		1.3	
	No		98.7	
Presence of intersection warning pavement marking	Yes		0.5	
	No		99.5	
Presence of “aggressive driving dots”	Yes		0.1	
	No		99.9	

Safety Performance Functions

Two SPFs were developed for two-lane rural roadway segments: one for total crash frequency, and one for the frequency of fatal and injury crashes. Each of the independent variables shown in Table 1 was entered into the preliminary models and their respective signs and statistical significance were assessed. Those variables with the expected sign that were either significant (p-value $\leq$ 0.05) or marginally significant (p-value < 0.3) were retained in the models. All SPFs were estimated in a form consistent with equation (4) above.

Note that several variables included in the Highway Safety Manual's SPFs for two-lane rural roads were excluded from consideration in the SPFs developed for two-lane rural roads in Pennsylvania due to lack of data availability, little variation in data across individual roadway segments, limited confidence in data quality or lack of application within Pennsylvania. These variables include vertical grade, presence of vertical curvature, lane and shoulder width, shoulder type, the presence of lighting and the presence of automated speed enforcement. Furthermore, the preliminary models revealed that some variables were more appropriately treated in a form that differs from the HSM models. For example, the preliminary models revealed that roadside hazard rating could be combined using groups with roadside hazard ratings of 1-3, 4-5, and 6-7, since the safety performance of roadway segments were the same within each of these groups.

Tables 2 and 3 show the results of the SPF estimation. Each table includes the regression coefficients, standard errors, and t-statistics for the independent variables included in the total and fatal and injury crash models, respectively.

Table 2. Total Crash Frequency Safety Performance Function For Segments

Variable	Coefficient	Standard Error	t-statistic	p-value
Constant	-5.934	0.042	-142.71	<0.001
Natural logarithm of AADT	0.754	0.005	161.44	<0.001
Roadside hazard rating 6 or 7 (1 if RHR is 6 or 7; 0 otherwise)	0.101	0.018	5.67	<0.001
Roadside hazard rating 4 or 5 (1 if RHR is 4 or 5; 0 otherwise)	0.091	0.016	5.71	<0.001
Presence of a passing zone (1 if present; 0 otherwise)	-0.239	0.009	-27.56	<0.001
Presence of shoulder rumble strips (1 if present; 0 otherwise)	-0.188	0.013	-14.19	<0.001
Access density	0.008	0.0003	31.36	<0.001
Horizontal curve density	0.030	0.002	14.81	<0.001
Degree of curve per mile	0.002	0.0001	17.16	<0.001
Overdispersion parameter = 0.514 Pseudo R^2 = 0.0874 Log-likelihood at convergence = -174,406.04				

The statistical model outputs in Table 2 are integrated with the functional form of the SPF presented in Equation 7 as follows:

$$N_{cr,pr} = Length \times AADT^{0.754} \times e^{-5.934} \times e^{0.101RHR6,7} \times e^{0.091RHR4,5} \times e^{-0.239PZ} \times e^{-0.188SRS}$$
$$\times e^{0.008AD} \times e^{0.030HCD} \times e^{0.002DCPM}$$

where:

$N_{cr,pr}$	= predicted total crash frequency on the segment (crashes/year);
Length	= length of segment (miles);
AADT	= annual average daily traffic on the segment (veh/day);
RHR6,7	= roadside hazard rating on the segment of 6 or 7 (1 if RHR is 6 or 7; 0 otherwise);
RHR4,5	= roadside hazard rating on the segment of 4 or 5 (1 if RHR is 4 or 5; 0 otherwise);
PZ	= presence of a passing zone in the segment (1 if present; 0 otherwise);
SRS	= presence of shoulder rumble strips in the segment (1 If present; 0 otherwise);
AD	= access density in the segment, total driveways and intersections per mile of segment length (Access Points/Mile);
HCD	= horizontal curve density in the segment, number of curves in the segment per mile (Hor. Curves/Mile); and,
DCPM	= total degree of curvature per mile in the segment, the sum of degree of curvature for all curves in the segment divided by segment length in miles (Degrees/100 ft/Mile).

The same basic procedure can be repeated for any of the SPFs presented in this report to convert the SPFs from the tabular form to the equation form. More details about the SPF equations, included how these SPFs can be reduced into a "short-form" more consistent with the HSM methodology, are provided in Appendix C of this report.

The results presented in Table 2 show that the expected total crash frequency is positively correlated with traffic volume, roadside hazard ratings of 4 or higher, access density, horizontal curve density, and the degree of curvature per mile. The expected total crash frequency is negatively correlated with the presence of a passing zone and the presence of shoulder rumble strips. A more detailed interpretation of these results is provided in the discussion of the elasticities and pseudo-elasticities for each independent variable in Table 4.

Table 3. Fatal and Injury Crash Frequency Safety Performance Function for Segments

Variable	Coefficient	Standard Error	t-statistic	p-value
Constant	-6.363	0.054	-118.91	<0.001
Natural logarithm of AADT	0.735	0.006	122.29	<0.001
Roadside hazard rating 6 or 7 (1 if RHR is 6 or 7; 0 otherwise)	0.051	0.023	2.26	0.024
Roadside hazard rating 4 or 5 (1 if RHR is 4 or 5; 0 otherwise)	0.055	0.020	2.68	0.007
Presence of a passing zone (1 if present; 0 otherwise)	-0.232	0.011	-20.78	<0.001
Presence of shoulder rumble strips (1 if present; 0 otherwise)	-0.184	0.017	-10.81	<0.001
Access density	0.008	0.0003	26.43	<0.001
Horizontal curve density	0.031	0.003	12.13	<0.001
Degree of curve per mile	0.002	0.0001	12.00	<0.001
Overdispersion parameter = 0.624 Pseudo R^2 = 0.0749 Log-likelihood at convergence = -124,096.28				

The results presented in Table 3 show that the expected fatal and injury crash frequency is positively correlated with traffic volume, roadside hazard ratings of 4 or higher, access density, horizontal curve density, and the degree of curvature per mile. The expected fatal and injury crash frequency is negatively correlated with the presence of a passing zone and the presence of shoulder rumble strips. A more detailed interpretation of these results is provided in the discussion of the elasticities and pseudo-elasticities for each independent variable in Table 4.

Table 4 shows the elasticities and pseudo-elasticities for the independent variables in Tables 2 and 3. Note that the elasticities for continuous variables other than AADT (such as access density, horizontal curve density and degree of curve per mile) are all a function of the value at which they are assessed. The elasticities presented in Table 4 are all provided at the mean values of these variables as provided in Table 1.

Table 4. Elasticities for Independent Variables in Total and Fatal and Injury Crash Models

Variable	Total Crashes	Fatal and Injury Crashes
Natural logarithm of AADT	0.754	0.735
Roadside hazard rating 6 or 7 (1 if RHR is 6 or 7; 0 otherwise)	10.6	5.27
Roadside hazard rating 4 or 5 (1 if RHR is 4 or 5; 0 otherwise)	9.57	5.61
Presence of a passing zone (1 if present; 0 otherwise)	-21.3	-20.7
Presence of shoulder rumble strips (1 if present; 0 otherwise)	-17.1	-16.8
Access density	0.130	0.138
Horizontal curve density	0.069	0.071
Degree of curve per mile	0.035	0.031

The elasticities provide the percent change in expected crash frequency when the independent variable is increased by one percent (for continuous variables such as AADT, access density, horizontal curve density and degree of curve per mile) or changed from zero to one (for indicator variables such as roadside hazard rating group, presence of passing zone or shoulder rumble strips). As expected, there is a positive relationship between traffic volume and crash frequency: a one percent change in AADT will increase the expected total crash frequency by 0.754 percent and fatal and injury crash frequency by 0.735 percent, holding all other variables constant. At the average value provided in the dataset, an increase in access point density by one percent will increase the expected total crash frequency (0.130 percent) slightly less than the expected fatal and injury crash frequency (0.138 percent), although both magnitudes are about the same and relatively small. The increase in both total crash frequency and fatal and injury crash frequency is the same for a one percent increase in horizontal curve density (about 0.070 percent) and a one percent increase in degree of curvature per mile (about 0.033 percent) at the mean values observed.

As expected, segments with roadside hazard ratings greater than 3 are associated with significantly higher crash frequencies than those with poor roadside hazard ratings. For the expected total crash frequency, a roadside hazard rating of 4 or 5 is associated with a 9.57 percent increase over the base condition (RHR of 1 to 3) and a roadside hazard rating of 6 or 7 is associated with a 10.6 percent increase over the base condition. For the expected fatal and injury crash frequency, a roadside hazard rating of 4 or 5 is associated with a 5.27 percent increase over the base condition and a roadside hazard rating of 6 or 7 is associated with a 5.61 percent increase over the base condition. The presence of passing zones and shoulder rumble strips are both associated with lower expected crash frequencies relative to the base condition of no passing zones or no shoulder rumble strips, respectively. Passing zones will decrease both expected total and fatal and injury crash frequency by about 21 percent while shoulder rumble strips will decrease both expected total and fatal and injury crash frequency by about 17 percent, holding all other variables in the model constant.

Summary of Findings

This section of the report estimated statistical models of total and fatal and injury crash frequency for roadway segments of state-owned, two-lane rural highway segments in Pennsylvania. This modeling effort found that both crash frequency types were a function of traffic volumes (measured in AADT), roadside hazard rating, presence of shoulder rumble strips and passing zones, densities of access points and horizontal curves, and the degree of horizontal curvature within the roadway segment. As expected, the models predict significantly lower fatal and injury crash frequencies than total crash frequencies. However, the elasticities suggest that almost all independent variables impact total and fatal and injury crash frequency by the same magnitude. The lone exception is roadside hazard rating, for which the impact is about 85% larger for total crash frequency than fatal and injury crash frequency.

Several explanatory variables included in Table 1 were omitted from the models either because they were not statistically insignificant or were found to be unreliable. Examples of the latter include roadway width and speed limit. In many cases, roadway widths provided in the RMS database were unrealistically large (greater than 40 feet) or small (less than 20 feet) for two-lane rural roadways. Similarly, speeds limits as low as 15 mph were recorded in the RMS database, which are typically indicative of warning speeds and not regulatory speeds. More reliable records for these variables should be considered for future modeling efforts.

INTERSECTION SAFETY PERFORMANCE FUNCTIONS

This section of the report describes the SPFs developed for rural two-lane highway intersections in Pennsylvania. Statistical models for total crash frequency and frequency of different levels of crash injury severity were estimated for intersections formed by three-digit state-owned roads on the rural two-lane highways. Included in this section of the report are the statistical modeling methodology, data summary, analysis results, and interpretation of the statistical modeling output. The data elements and structures used to construct the modeling data files were described earlier in this report.

Statistical models are reported for all intersections of two state-owned two-lane rural roads with the following intersection forms:

- 4-leg intersections with signal control
- 3-leg intersections with signal control
- 4-leg intersections with all-way stop control
- 4-leg intersections with minor-street stop control
- 3-leg intersections with minor-street stop control

It should be noted that PennDOT's linear referencing system was used to derive the "influence" area intersection for crash frequency modeling purposes. Many recent safety evaluation studies defined intersection-related crashes as those reported within 250-feet of the point where the two intersecting roadway alignments cross (e.g., Bauer and Harwood, 1996; Harwood et al., 2003; Mitra and Washington, 2012; Wang and Abdel-Aty, 2006). The same influence area is assumed here for each of the state-owned two-lane rural road intersections identified using the RMS data.

Statistical Modeling Methodology

As noted in the roadway segment SPF section of this report, several cross-sectional modeling approaches were considered, but negative binomial regression was used in an effort to be consistent with the first edition of the HSM. In this section of the report, the expected number of intersection crashes per year was modeled as a function of several explanatory variables. Several examples of intersection SPF development using negative binomial regression can be found in the published traffic safety literature (e.g.,

Poch and Mannering 1996; Bauer and Harwood 1996; Washington et al. 2005). Similar to the crash frequency models for segments, this modeling approach accounts for the overdispersion that exists in the crash data. The general functional form of the negative binomial regression model, the mean-variance relationship, and the maximum likelihood function, are shown in Equations (12) through (14). The difference between the roadway segment analysis and the intersection-level analysis is the model specification, which is shown in Equation (12) below for intersections:

$$\lambda_i = e^{\beta_0} \times AADT_{major}^{\beta_1} \times AADT_{\min or}^{\beta_2} \times e^{(\beta_3 X_3 + \ldots + \beta_n X_n)} \quad (12)$$

where:

λ_i	= expected number of crashes at intersection *i*;
e	= exponential function;
β_0	= regression coefficient for constant;
$AADT_{major}$	= average annual daily traffic (veh/day) for major roadway;
$AADT_{minor}$	= average annual daily traffic (veh/day) for minor roadway;
β_1, β_2	= regression coefficients for major and minor road AADT, respectively,
$\beta_3, \ldots, \beta_n$	= regression coefficients for explanatory variables, $i = 3, \ldots, n$; and,
$X_3, \ldots, X_n$	= vector of geometric design and other site-specific data.

When interpreting the intersection SPFs, the elasticity and pseudo-elasticity for the independent variables in the model were computed using Equations (8) through (11).

Data Summary

There were 683 unique intersections included in the data analysis file. The distribution of these intersections based on the type of the intersection was:

- 4-leg signalized - 105 of this form
- 3-leg signalized - 45 of this form
- 4-leg all-way stop-control - 33 of this form
- 4-leg two-way stop-control - 86 of this form
- 3-leg two-way stop-control - 414 of this form

Two-way stop control was provided on the minor approach(es) of the 3- and 4-leg intersections. Because there were eight (8) years of crash data for each intersection, the analysis database consisted of 5,464 unique annual intersection observations.

Tables 5 and 6 provide summary statistics for the total crashes and total fatal and injury crashes recorded for each intersection type. As expected, the total crash frequency is higher than the fatal and injury crash frequency. The signalized intersection forms have the highest mean frequency of severe (fatal and injury) crashes.

Table 5. Summary Statistics for Total Crash Frequency by Intersection Type

Intersection Type	Number of observations	Mean	Standard Deviation	Minimum	Maximum
4-leg, signalized	840	3.136	3.213	0	20
3-leg, signalized	360	1.922	2.559	0	15
4-leg, all-way stop	264	1.97	2.538	0	12
4-leg, two-way stop	688	1.637	2.312	0	15
3-leg, two-way stop	3312	1.383	2.023	0	16
ALL	5464	1.748	2.421	0	20

Table 6. Summary Statistics for Fatal and Injury Crash Frequency by Intersection Type

Intersection Type	Mean	Standard Deviation	Minimum	Maximum
4-leg, signalized	1.677	2.104	0	15
3-leg, signalized	1.203	1.831	0	13
4-leg, all-way stop	1.023	1.594	0	8
4-leg, two-way stop	0.920	1.663	0	11
3-leg, two-way stop	0.766	1.348	0	12
ALL	0.957	1.597	0	15

Tables 7 through 11 present summary statistics for the independent variables considered in the SPF development broken down by the five intersection forms included in this report. The signalized intersections and the 3-leg, two-way stop-controlled intersection forms have the highest traffic volumes. The paved width includes the through lanes, turning lanes, and paved shoulder widths on each of the major and minor approaches; therefore, these widths vary widely within each intersection form, and when compared across the different intersection forms. The number of turn-lanes is generally higher at signalized intersections when compared to stop-controlled intersections. The posted speed limits vary considerably for all intersection types.

Table 7. Summary Statistics for 4-leg Signalized Intersections

Continuous Variable	Mean	Standard Deviation	Minimum	Maximum
Total Crashes per Year	3.136	3.213	0	20
Total Fatal and Injury Crashes per Year	1.677	2.104	0	15
Major Road AADT (veh/day)	7399	4102	793	23,375
Minor Road AADT (veh/day)	3858	2432	285	13,699
Left Shoulder Total Width on Major Road (feet)	3.682	2.885	0	13
Right Shoulder Total Width on Major Road (feet)	3.637	2.885	0	10
Paved Width on Major Road (feet)	27.988	7.872	20	54
Posted Speed Limit on Major Road (mph)	40.851	9.640	25	55
Left Shoulder Total Width on Minor Road (feet)	3.061	2.407	0	10
Right Shoulder Total Width on Minor Road (feet)	3.087	2.489	0	10
Paved Width on Minor Road (feet)	24.136	5.185	19	54
Posted Speed Limit on Minor Road (mph)	39.244	9.476	25	55
Intersection Skew Angle (degree)	76.714	15.560	15	90

Categorical Variable	Description	Proportion
Presence of exclusive left-turn lanes on major road approach	None	70.48
	Present on one approach	22.86
	Present on both approaches	6.67
Presence of exclusive right-turn lanes on major road approach	None	84.76
	Present on one approach	14.29
	Present on both approaches	0.95
Presence of pedestrian crosswalk on major road approach	None	74.52
	Present on one approach	15.00
	Present on both approaches	10.48
Presence of intersection warning on major road approach	None	97.86
	Present	2.14
Presence of exclusive left-turn lane on minor road approach	None	78.10
	Present on one approach	16.19
	Present on both approaches	5.71
Presence of exclusive right-turn lane on minor road approach	None	86.67
	Present on one approach	10.48
	Present on both approaches	2.86
Presence of pedestrian crosswalk on major road approach	None	71.19
	Present on one approach	18.33
	Present on both approaches	10.48
Presence of intersection warning on major road approach	None	95.48
	Present	4.52

Table 8. Summary Statistics for 3-leg Signalized Intersections

Continuous Variable	Mean	Standard Deviation	Minimum	Maximum
Total Crashes per Year	1.922	2.558	0	15
Total Fatal and Injury Crash per Year	1.203	1.831	0	13
Major Road AADT (veh/day)	6710	3815	913	17,265
Minor Road AADT (veh/day)	4127	2819	324	12,501
Left Shoulder Total Width on Major Road (feet)	2.769	2.960	0	10
Right Shoulder Total Width on Major Road (feet)	2.858	3.141	0	10
Paved Width on Major Road (feet)	28.928	7.041	20	50
Posted Speed Limit on Major Road (mph)	38.722	11.072	20	55
Left Shoulder Total Width on Minor Road (feet)	2.297	1.992	0	8
Right Shoulder Total Width on Minor Road (feet)	2.386	2.011	0	8
Paved Width on Minor Road (feet)	24.739	5.139	20	42
Posted Speed Limit on Minor Road (mph)	37.833	9.005	25	55
Intersection Skew Angle (degree)	76.000	17.203	20	90
Categorical Variable	**Description**		**Proportion**	
Presence of exclusive left-turn lane on major road approach	None		71.67	
	Present		28.33	
Presence of exclusive right-turn lane on major road approach	None		93.61	
	Present		6.39	
Presence of pedestrian crosswalk on major road approach	None		76.11	
	Present on one approach		19.44	
	Present on both approaches		4.44	
Presence of exclusive left-turn lanes on minor road	None		95	
	Present		5	
Presence of exclusive right-turn lanes on minor road	None		93.06	
	Present		6.94	
Presence of pedestrian crosswalk on minor road	None		77.22	
	Present on one approach		18.33	
	Present on both approaches		4.44	

Table 9. Summary Statistics for 4-leg All-way Stop-controlled Intersections

Continuous Variable	Mean	Standard Deviation	Minimum	Maximum
Total Crashes per Year	1.970	2.538	0	12
Total Fatal and Injury Crash per Year	1.023	1.594	0	8
Major Road AADT (veh/day)	3763	2745	740	11,351
Minor Road AADT (veh/day)	1973	1356	317	5959
Left Shoulder Total Width on Major Road (feet)	4.254	2.473	0	10
Right Shoulder Total Width on Major Road (feet)	4.432	2.544	0	10
Paved Width on Major Road (feet)	22.659	3.268	20	35
Posted Speed Limit on Major Road (mph)	45.436	9.089	25	55
Left Shoulder Total Width on Minor Road (feet)	2.928	1.845	0	8
Right Shoulder Total Width on Minor Road (feet)	2.932	1.865	0	8
Paved Width on Minor Road (feet)	21.098	2.325	18	32
Posted Speed Limit on Minor Road (mph)	42.746	7.107	25	55
Intersection Skew Angle (degrees)	67.727	17.314	10	90
Categorical Variable	**Description**		**Proportion**	
Presence of exclusive left-turn lane on major road approach	None		96.97	
	Present on both approaches		3.03	
Presence of exclusive right-turn lane on major road approach	None		90.91	
	Present on one approach		6.06	
	Present on both approaches		3.03	
Presence of pedestrian crosswalk on major road approach	None		96.97	
	Present on one approach		3.03	
Presence of intersection warning on major road	None		96.97	
	Present		3.03	
Presence of exclusive left-turn lane on minor road approach	None		96.97	
	Present on one approach		3.03	
Presence of exclusive right-turn lane on minor road approach	None		96.97	
	Present on both approaches		3.03	
Presence of pedestrian crosswalk on minor road approach	None		96.97	
	Present on one approach		3.03	
Presence of intersection warning on minor road	None		90.91	
	Present		9.09	

Table 10. Summary Statistics for 4-leg Two-way Stop-controlled Intersections

Continuous Variable	Mean	Standard Deviation	Minimum	Maximum
Total Crashes per Year	1.637	2.312	0	15
Total Fatal and Injury Crash per Year	0.920	1.663	0	11
Major Road AADT (veh/day)	3913	2761	312	14,387
Minor Road AADT (veh/day)	1681	1278	172	8923
Left Shoulder Total Width on Major Road (feet)	3.610	2.362	0	14
Right Shoulder Total Width on Major Road (feet)	3.750	2.537	0	14
Paved Width on Major Road (feet)	23.968	6.818	20	66
Posted Speed Limit on Major Road (mph)	43.721	8.706	25	55
Left Shoulder Total Width on Minor Road (feet)	2.797	1.833	0	8
Right Shoulder Total Width on Minor Road (feet)	2.762	1.876	0	8
Paved Width on Minor Road (feet)	21.799	3.252	18	40
Posted Speed Limit on Minor Road (mph)	41.919	8.081	25	55
Skew Angle on Major Route (degree)	72.151	18.559	15	90

Categorical Variable	Description	Proportion
Presence of exclusive left-turn lane on major approach	None	96.51
	Present on one approach	2.33
	Present on both approaches	1.16
Presence of pedestrian crosswalk on major road approach	None	96.51
	Present on one approach	3.49
Presence of intersection warning on major road approach	None	99.13
	Present	0.87
Presence of exclusive left-turn lane on minor approach	None	98.84
	Present on both approaches	1.16
Presence of exclusive right-turn lane on minor approach	None	98.84
	Present on one approach	1.16
Presence of pedestrian crosswalk on minor road approach	None	93.02
	Present on one approach	6.98
Presence of intersection warning on minor road approach	None	98.55
	Present	1.45

Table 11. Summary Statistics for 3-leg Two-way Stop-controlled Intersections

Continuous Variable	Mean	Standard Deviation	Minimum	Maximum
Total Crashes per Year	1.383	2.023	0	16
Total Fatal and Injury Crashes per Year	0.766	1.348	0	12
Major Road AADT (veh/day)	4109	2873	138	19,161
Minor Road AADT (veh/day)	1992	1734	74	14,537
Left Shoulder Total Width on Major Road (feet)	4.342	2.473	0	12
Right Shoulder Total Width on Major Road (feet)	4.356	2.449	0	11
Paved Width on Major Road (feet)	23.278	3.714	18	41
Posted Speed Limit on Major Road (mph)	46.443	8.189	15	55
Left Shoulder Total Width on Minor Road (feet)	3.201	1.939	0	12
Right Shoulder Total Width on Minor Road (feet)	3.289	2.001	0	11
Paved Width on Minor Road (feet)	21.920	3.612	16	66
Posted Speed Limit on Minor Road (mph)	44.269	8.561	20	55
Intersection Skew Angle (degree)	65.145	21.136	10	90
Categorical Variable	**Description**		**Proportion**	
Presence of exclusive left-turn lane on major approach	None		94.96	
	Present on one approach		5.04	
Presence of exclusive right-turn lane on major approach	None		96.62	
	Present on one approach		3.38	
Presence of pedestrian crosswalk on major road approach	None		99.52	
	Present on one approach		0.48	
Presence of intersection warning on major road approach	None		99.31	
	Present		0.69	
Presence of exclusive left-turn lane on minor approach	None		96.11	
	Present on one approach		3.89	
Presence of exclusive right-turn lane on minor approach	None		95.41	
	Present on one approach		4.59	
Presence of pedestrian crosswalk on minor road approach	None		99.52	
	Present on one approach		0.48	
Presence of intersection warning on minor road approach	None		99.00	
	Present		1.00	

Safety Performance Functions

Two SPFs were developed for each of the five intersection types: one for total crash frequency, and one for the frequency of fatal and injury crashes. Each of the independent variables shown in Tables 7 through 11 was entered into the preliminary models and their respective signs and statistical significance were assessed. Those variables with the expected sign that were either significant (p-value ≤ 0.05) or marginally significant (p-value < 0.3) were retained in the models. All SPFs were estimated in a form consistent with equation (12) above.

As with the SPFs developed for roadway segments, several variables included in the Highway Safety Manual's SFPs for intersections of two-lane rural roads were excluded from consideration in the SPFs developed for Pennsylvania due to lack of data availability, little variation within the data across all sites, limited confidence in data quality or lack of application within Pennsylvania.

Tables 12 through 16 show the results of the SPF estimation. Each table includes the regression coefficients, standard errors, and t-statistics for the independent variables included in the total and fatal and injury crash models.

The results shown in Table 12 shows that the coefficient of major road AADT is larger in magnitude than the coefficient of minor road AADT for total crash frequency, indicating that the major road traffic volume affects total crash frequency more than minor road AADT at 4-leg, signalized intersections on two-lane rural highways in Pennsylvania. For fatal and injury crash frequency, the two coefficients are almost equal, which indicates that the major and minor road AADT affect fatal and injury crash frequency similarly. All coefficients for the independent variables included in the total and fatal and injury crash models are positive, indicating that a unit increase in these variables is associated with an increase in total and fatal and injury crashes at 4-leg, signalized intersections in Pennsylvania.

Table 12. Safety Performance Function for 4-leg Signalized Intersections

Variable	Coefficient	Standard Error	t-statistic
Total Crashes			
Constant	-5.353	0.552	-9.70
Logarithm of Major Road AADT	0.313	0.073	4.29
Logarithm of Minor Road AADT	0.250	0.071	3.53
Posted Speed Limit on Major Road (mph)	0.025	0.004	5.97
Posted Speed Limit on Minor Road (mph)	0.014	0.004	3.34
Presence of Exclusive Right-Turn Lane on Either Major Approach	0.216	0.092	2.35
Overdispersion Parameter	0.579	0.052	-
Number of Observations = 840 Log-likelihood = -1832.34 Pseudo-R2 = 0.0455			
Fatal and Injury Crashes			
Constant	-4.960	0.715	-6.94
Logarithm of Major Road AADT	0.202	0.094	2.15
Logarithm of Minor Road AADT	0.209	0.091	2.3
Posted Speed Limit on Major Road (mph)	0.028	0.005	5.21
Posted Speed Limit on Minor Road (mph)	0.018	0.006	3.21
Presence of Exclusive Right-Turn Lane on Either Major Approach	0.388	0.117	3.33
Overdispersion Parameter	0.892	0.093	-
Number of Observations = 840 Log-likelihood = -1428.93 Pseudo-R2 = 0.0370			

The results in Table 13 show that the coefficient of major road AADT is larger in magnitude than the minor road AADT, indicating that the major road traffic volume affects total and fatal and injury crash frequency more than minor road AADT at 3-leg, signalized intersections on two-lane rural highways in Pennsylvania. This finding is consistent with the findings of the HSM (AASHTO, 2010). The positive coefficients for AADT and the posted speed limit in both models suggest that an increase in each of these variables is associated with an increase in crash frequency at 3-leg, signalized intersections in Pennsylvania. The coefficients for the presence of crosswalks on the major and minor road approaches are negative in both models, which suggest that the presence of a crosswalk is associated with a decrease in crash frequency at 3-leg, signalized intersections in Pennsylvania.

Table 13. Safety Performance Function for 3-leg Signalized Intersections

Variable	Coefficient	Standard Error	t-statistic
Total Crashes			
Constant	-6.813	1.050	-6.49
Logarithm of Major Road AADT	0.451	0.185	2.44
Logarithm of Minor Road AADT	0.349	0.158	2.21
Posted Speed Limit on Major Road (mph)	0.020	0.006	3.08
Presence of a Crosswalk on Major Road Approach	-0.433	0.188	-2.31
Presence of a Crosswalk on Minor Road Approach	-0.345	0.200	-1.73
Overdispersion Parameter	0.982	0.149	-
Number of Observations = 360 Log-likelihood = -637.61 Pseudo-R2 = 0.0490			
Fatal and Injury Crashes			
Constant	-6.981	1.182	-5.90
Logarithm of Major Road AADT	0.452	0.208	2.17
Logarithm of Minor Road AADT	0.287	0.180	1.59
Posted Speed Limit on Major Road (mph)	0.026	0.007	3.47
Presence of a Crosswalk on Major Road Approach	-0.605	0.218	-2.77
Presence of a Crosswalk on Minor Road Approach	-0.413	0.235	-1.76
Overdispersion Parameter	1.114	0.205	-
Number of Observations = 360 Log-likelihood = -511.26 Pseudo-R2 = 0.0518			

The results in Table 14 show that the coefficient of major road AADT is larger in magnitude than the minor road AADT, indicating that the major road traffic volume affects total and fatal and injury crash frequency more than minor road AADT at 4-leg, all-way stop-controlled intersections on two-lane rural highways in Pennsylvania. This finding is consistent with the findings of the HSM (AASHTO, 2010). The AADT and posted speed limit variables have a positive sign suggesting that 4-leg all-way stop-controlled intersections on two-way rural highways in Pennsylvania with higher traffic volumes and higher posted speed limits on the major approach are associated with higher total and fatal and injury crash frequencies.

Table 14. Safety Performance Function for 4-leg All-way Stop-controlled Intersections

Variable	Coefficient	Standard Error	t-statistic
Total Crashes			
Constant	-5.820	1.221	-4.77
Logarithm of Major Road AADT	0.693	0.146	4.75
Logarithm of Minor Road AADT	0.087	0.169	0.52
Posted Speed Limit on Major Road (mph)	0.057	0.015	3.65
Overdispersion Parameter	1.24	0.200	-
Number of Observations = 264 Log-likelihood = -473.45 Pseudo-R2 = 0.0425			
Fatal and Injury Crashes			
Constant	-6.515	1.439	-4.53
Logarithm of Major Road AADT	0.630	0.183	3.44
Logarithm of Minor Road AADT	0.166	0.199	0.84
Posted Speed Limit on Major Road (mph)	0.046	0.0178	2.58
Overdispersion Parameter	1.547	0.311	-
Number of Observations = 264 Log-likelihood = -350.03 Pseudo-R2 = 0.0372			

The results shown in Table 15 shows that the coefficient of major road AADT is larger in magnitude than the minor road AADT, indicating that the major road traffic volume affects total and fatal and injury crash frequency more than minor road AADT at 4-leg, two-way stop-controlled intersections on two-lane rural highways in Pennsylvania. This finding is consistent with the findings of the HSM (AASHTO, 2010). The positive coefficient for skew angle suggests that 4-leg, two-way stop-controlled intersections on two-lane rural highways in Pennsylvania with larger skew angles are associated with higher total and fatal and injury crash frequencies. This particular trend is surprising, as one would intuitively suspect that intersections with smaller skew angles would present more challenges to drivers judging opposing traffic on the uncontrolled major road. However, the majority of intersections had large skew angles (i.e., near 90-degree angles) and drivers might behave more cautiously when approaching intersections with lower skew angles.

Table 15. Safety Performance Function for 4-leg Two-way Stop-controlled Intersections

Variable	Coefficient	Standard Error	t-statistic
Total Crashes			
Constant	-6.359	0.774	-8.22
Logarithm of Major Road AADT	0.528	0.090	5.84
Logarithm of Minor Road AADT	0.275	0.078	3.51
Intersection Skew Angle (degree)	0.007	0.003	2.34
Overdispersion Parameter	1.348	0.138	-
Number of Observations = 688 Log-likelihood = -1150.67 Pseudo R2 = 0.0322			
Fatal and Injury Crashes			
Constant	-6.156	1.027	-6.00
Logarithm of Major Road AADT	0.512	0.123	4.16
Logarithm of Minor Road AADT	0.176	0.104	1.70
Intersection Skew Angle (degree)	0.008	0.004	1.98
Overdispersion Parameter	2.597	0.301	-
Number of Observations = 688 Log-likelihood = -854.78 Pseudo R2 = 0.0199			

The results in Table 16 show that the coefficient of major road AADT is larger in magnitude than the minor road AADT, indicating that the major road traffic volume affects total and fatal and injury crash frequency more than minor road AADT at 3-leg, two-way stop-controlled intersections on two-lane rural highways in Pennsylvania. This finding is consistent with the findings of the HSM (AASHTO, 2010). The coefficients for exclusive left-turn lanes and exclusive right-turn lanes on the major approach have opposite signs, suggesting somewhat offsetting effects. However, the magnitude of the sign for exclusive right-turn lanes is about twice that of exclusive left-turn lanes, indicating that the presence of an exclusive right-turn lane more significantly affects total and fatal and injury crash frequency at 3-leg, two-way stop-controlled intersections on two-lane rural highways in Pennsylvania.

Table 16. Safety Performance Function for 3-leg Two-way Stop-controlled Intersections

Variable	Coefficient	Standard Error	t-statistic
Total Crashes			
Constant	-6.337	0.311	-20.36
Logarithm of Major Road AADT	0.479	0.043	11.24
Logarithm of Minor Road AADT	0.362	0.035	10.45
Presence of Exclusive Left-Turn Lane on Major Approach	-0.330	0.113	-2.93
Presence of Exclusive Right-Turn Lane on Major Approach	0.507	0.128	3.96
Overdispersion Parameter	1.117	0.060	-
Number of Observations = 3312 Log-likelihood = -5055.11 Pseudo-R2 = 0.0485			
Fatal and Injury Crashes			
Constant	-6.457	0.402	-16.07
Logarithm of Major Road AADT	0.439	0.056	7.86
Logarithm of Minor Road AADT	0.343	0.45	7.57
Presence of Exclusive Left-Turn Lane on Major Approach	-0.267	.0144	-1.85
Presence of Exclusive Right-Turn Lane on Major Approach	0.560	0.163	3.44
Overdispersion Parameter	1.81	0.115	-
Number of Observations = 3312 Log-likelihood = -3756.41 Pseudo-R2 = 0.0366			

Tables 17 to 21 show the elasticities and pseudo-elasticities for the independent variables in Tables 12 to 16. Note that the elasticities for any continuous variables other than AADTs (e.g., posted speed limits or skew angles) are all provided at their average values as provided in Table 7 and Table 11. The elasticities for the AADT variables all hold for the entire range of AADTs observed.

Table 17. Elasticities for Independent Variables in Total and Fatal and Injury Crash Models for 4-leg Signalized Intersections

Variable	Total Crashes	Fatal and Injury Crashes
Logarithm of Major Road AADT	0.313	0.202
Logarithm of Minor Road AADT	0.250	0.209
Posted Speed Limit on Major Road (mph)	1.02	1.14
Posted Speed Limit on Minor Road (mph)	0.549	0.706
Presence of Exclusive Right-Turn Lane on Either Major Approach	24.1	47.4

The elasticities suggest that a one percent increase in major road AADT is associated with a 0.313 percent increase in total crash frequency and a 0.202 percent increase in fatal and injury crash frequency at 4-leg signalized intersections on two-lane rural roads in Pennsylvania. Minor road AADT has a less pronounced effect, as a one percent increase is only associated with a 0.250 percent increase in total crash frequency and 0.209 increase in fatal and injury crash frequency. A one percent increase in the posted speed limit on the major road has a larger impact on total and fatal and injury crash frequency (1.02 and 1.14 percent, respectively) than a one percent increase in the posted speed limit on the minor road (0.549 percent and 0.706 percent, respectively) when both are held constant at their mean values. The presence of an exclusive left-turn lane on either major road approach is associated with an increase in total crash frequency of 24.1 percent and total and injury crash frequency of 47.4 percent. Note that all other elasticity tables can be interpreted similarly.

Table 18. Elasticities for Independent Variables in Total and Fatal and Injury Crash Models for 3-leg Signalized Intersections

Variable	Total Crashes	Fatal and Injury Crashes
Logarithm of Major Road AADT	0.451	0.452
Logarithm of Minor Road AADT	0.349	0.287
Posted Speed Limit on Major Road (mph)	0.774	1.01
Presence of a Crosswalk on Major Road Approach	-35.1	-45.4
Presence of a Crosswalk on Minor Road Approach	-29.2	-33.8

Table 19. Elasticities for Independent Variables in Total and Fatal and Injury Crash Models for 4-leg All-way Stop-controlled Intersections

Variable	Total Crashes	Fatal and Injury Crashes
Logarithm of Major Road AADT	0.693	0.630
Logarithm of Minor Road AADT	0.087	0.166
Posted Speed Limit on Major Road (mph)	2.59	2.09

Table 20. Elasticities for Independent Variables in Total and Fatal and Injury Crash Models for 4-leg Two-way Stop-controlled Intersections

Variable	Total Crashes	Fatal and Injury Crashes
Logarithm of Major Road AADT	0.528	0.512
Logarithm of Minor Road AADT	0.275	0.176
Skew Angle on Major Route (degree)	0.505	0.577

Table 21. Elasticities for Independent Variables in Total and Fatal and Injury Crash Models for 3-leg Two-way Stop-controlled Intersections

Variable	Total Crashes	Fatal and Injury Crashes
Logarithm of Major Road AADT	0.479	0.439
Logarithm of Minor Road AADT	0.362	0.343
Presence of Exclusive Left-Turn Lane on Major Approach	-28.1	-23.4
Presence of Exclusive Right-Turn Lane on Major Approach	66.0	75.1

Summary

This section estimated statistical models of total and fatal and injury crash frequency for five intersection types on two-lane rural highways in Pennsylvania. The major road AADT coefficient was larger than the minor road AADT in most models, which is consistent with the *Highway Safety Manual* SPFs. The other independent variables included in the models are generally consistent with engineering intuition. The elasticities in Tables 17 through 21 show that the total and fatal and injury crash frequency increases as the posted speed limit on the major or minor road increases. These findings are consistent with several models reported by Washington et al., (2005).

The presence of an exclusive left-turn lane on the major road approach was consistently found to be associated with lower expected crash frequencies, while the presence of a right-turn lane on the major road approach was found to be associated with an increase in expected crash frequency, when included in the SPFs. The left-turn lane finding is consistent with the *Highway Safety Manual* crash modification factor for exclusive left-turn lanes; however, the right-turn lane finding is opposite of the crash modification factor reported in the *Highway Safety Manual*. It should be noted that Washington et al., (2005) found the sign of the exclusive right-turn lane indicator variable to be

inconsistent across various intersection SPFs. Future consideration of the positive relationship between right-turn presence on major road approaches and crash frequency is recommended.

The presence of pedestrian crosswalks on the major and minor road approaches was associated with fewer expected crashes when included in the SPF model specification. This finding is consistent with engineering intuition and suggests that driver travel more cautiously when pedestrian crossings are present at an intersection in rural areas.

CASE STUDIES

Two realistic case studies were developed to demonstrate the application of the SPFs for segments and intersections that were developed in the previous two sections, respectively. These case studies all follow the format of the example case studies in the HSM for consistency with that guide. The reader is encouraged to refer to the HSM for more specific details on each of the individual steps.

Case study 1 – Estimating crash frequencies for an existing roadway segment

<u>The site/facility</u>

The section of SR 322 shown in Figure 1 below.

<u>The question</u>

What is the predicted average crash frequency of the roadway segment for the year 2013 when considering the previous crash history?

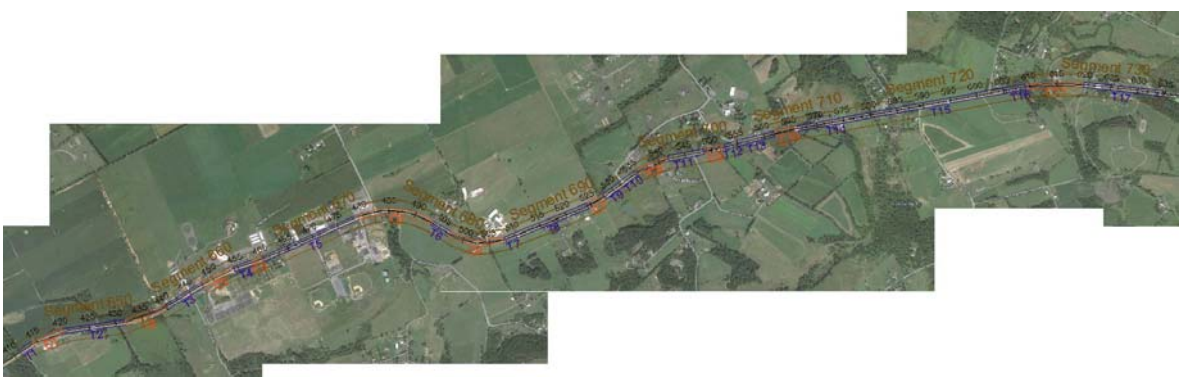

Figure 1. Section of SR 322 considered.

<u>The facts</u>

The section of roadway covers a length of approximately 4.2 miles and contains both curve and tangent sections. A detailed description of the geometric and other characteristics of this roadway section relevant to the safety performance prediction is

provided in Table 22 below. This information has been provided for each of the predefined roadway segments based on the PennDOT Roadway Management System (RMS) database.

Table 22. Geometric and Other Characteristics of Study Area

Segment Number	Length [mi]	Roadside Hazard Rating (RHR)	Passing Zone (PZ)	Shoulder Rumble Strips (SRS)	Access Density (AD) [access points/mi]	Horizontal Curve Density (HCD) [curves per mile)	Deg. Of Curve per Mile (DCPM) [degrees/ 100 feet/ mile)
650	0.4477	4	0	1	8.934	2.234	7.817
660	0.4712	4	0	1	16.977	4.244	10.611
670	0.4261	4	0	1	30.507	2.347	2.347
680	0.5314	4	0	1	16.935	3.763	16.935
690	0.4059	4	0	1	7.392	2.464	9.855
700	0.4367	4	0	1	6.869	4.579	11.447
710	0.4813	4	0	1	14.545	2.078	2.078
720	0.5053	4	0	1	17.811	0.000	0.000
730	0.5259	4	0	1	13.309	1.901	2.852

The first column of Table 22 provides the segment numbers that make up this particular section of SR 322; these segment boundaries are illustrated on Figure 1. The second column provides the length of each segment in miles. The third column provides the roadside hazard rating (RHR) of each segment as defined in Zeeger et al (1986). The roadside hazard rating is a qualitative characterization of the crash potential for roadside designs on two-lane highways. The next column denotes the presence of passing zones (PZ) somewhere within each roadway segment. A binary value is used to represent this information: a value of 0 represents no passing zones while a value of 1 represents that at least one passing zone is present. The following column denotes the presence of shoulder rumble strips (SRS) somewhere within each roadway segment. This is also provided by a binary variable: a value of 0 represents no shoulder rumble strips while a value of 1 represents that shoulder rumble strips are present for at least some portion of the segment. The next column provides the access point density (AD) within the roadway segment in units of access points per mile. Access points are defined as state-owned and non-stated owned intersections and driveways that have access to the roadway segment. The following column presents the horizontal curve density (HCD) within the roadway segment in units of number of horizontal curves per mile. The final column provides the total degree of curvature per mile in the segment, measured in units of degrees per 100 feet per mile. This is obtained by summing the degree of curvature for each individual curve within a segment and dividing this by the total length of the segment in miles. Note that if a single curve penetrates multiple segments, the curve is attributed to the segment that contains the majority of the curve length.

The length of each segment is provided directly in the PennDOT RMS database. The roadside hazard rating, passing zones, shoulder rumble strips and access density

variables were collected using the PennDOT online video photolog system as previously described in this report. This information has been collected for all state-owned, two-lane rural roads within Pennsylvania and the data has been provided to PennDOT for use in safety applications. The curve information (horizontal curve density and degree of curvature per mile) was collected using satellite imagery through the Google Earth tool, as previous described. This information has been collected for three-digit and lower state owned, two-lane rural roads within Pennsylvania and the data has been provided to PennDOT for use in safety applications.

Table 23 also provides estimates of historical traffic volume data for each of the segments identified in Table 22. This data is maintained in and available from PennDOTs RMS database.

Table 23. Traffic Volumes For Road Segments in Study Area

Segment	Average Annual Daily Traffic (AADT) [veh/day]								
	2005	2006	2007	2008	2009	2010	2011	2012	2013
650	11533	11648	11550	11550	11550	11550	11550	11550	11171
660	11533	11648	11550	11550	11550	11550	11550	11550	11171
670	11533	11648	11550	11550	11550	11550	11550	11550	11171
680	11533	11648	11550	11550	11550	11550	11550	11550	11171
690	11533	11648	11550	11550	11550	11550	11550	11550	11171
700	11533	11648	11550	11550	11550	11550	11550	11550	11171
710	11533	11648	11550	11550	11550	11550	11550	11550	11171
720	11533	11648	11550	11550	11550	11550	11550	11550	11171
730	11533	11648	11550	11550	11550	11550	11550	11550	11171

Historical crash frequencies for total crashes and fatal and injury crashes are provided in Table 24 and Table 25 respectively. This crash data was obtained from the PennDOT electronic crash history database.

Table 24. Total Crash Frequencies for Study Area

Segment	2005	2006	2007	2008	2009	2010	2011	2012	Mean
650	1	2	1	1	0	2	2	0	1.125
660	4	0	2	2	2	2	1	4	2.125
670	0	1	1	2	1	1	2	1	1.125
680	2	0	3	5	1	2	7	4	3
690	0	0	0	2	0	1	0	0	0.375
700	1	0	0	1	1	1	0	2	0.75
710	4	1	2	1	1	0	6	0	1.875
720	0	1	1	3	3	1	0	2	1.375
730	0	0	0	5	0	0	4	2	1.375
Total	12	5	10	22	9	10	22	15	13.125

Table 25. Fatal and Injury Crash Frequencies for Study Area

Segment	2005	2006	2007	2008	2009	2010	2011	2012	Mean
650	1	2	2	1	0	0	1	0	0.875
660	1	0	0	2	0	1	0	0	0.5
670	0	0	1	2	0	1	1	1	0.75
680	1	0	1	2	0	1	2	4	1.375
690	0	0	0	1	0	0	0	0	0.125
700	1	0	0	0	0	0	0	0	0.125
710	1	0	2	0	0	0	0	0	0.375
720	0	0	1	2	1	1	0	0	0.625
730	0	0	0	3	0	0	1	1	0.625
Total	5	2	7	13	1	4	5	6	5.375

Assumptions

None

Results

Using the predictive method outlined below and applying the Empirical Bayes correction, the predicted frequency of total crashes for this roadway section is 13.1 crashes per year and the predicted frequency of fatal and injury crashes is 5.5 crashes per year.

Steps

Step 1 – Define the spatial limits of the study
The limit of this study is provided directly by the problem statement and includes only the section of SR 322 illustrated in Figure 1. This section contains roadway segments 650 through 730.

Step 2 – Define the period of interest
In this problem the analysis period of interest is 2013. However, as will be shown below, historical crash and traffic volume data will be required, and estimates of crash frequency estimated, for a period of several years before the analysis year to apply the Empirical Bayes adjustment. As shown in the Facts section, for this segment the data required for these estimations are available for the years 2005 to 2012.

Step 3 – Determine the availability of traffic volume and historical crash data
As per the Facts section, these information are available from the PennDOT RMS database.

Step 4 – Determine geometric design and other site characteristics
As per the Facts section, these information are available from the PennDOT RMS database and the supplemental data collected and provided by Penn State to PennDOT.

Step 5 – Divide the roadway network into individual segments
As per the Facts section, the PennDOT RMS database disaggregates individual roadways into multiple segments as a way to describe geometric and traffic data. Since the required information, such as access density and curve characteristics, has already been collected on the segment level, we will use these segments to perform the safety analysis.

Step 6 – Assign crashes to individual roadway segments
The PennDOT crash database provides the location of each crash in terms of the segment in which it occurred. This information has been provided in the Facts section.

Step 7 – Select an individual site in the study network
We select the first segment in the roadway section (segment 650) to illustrate the application of the safety performance functions (SPFs).

Step 8 – Select an individual analysis year in the period of interest
We select the year 2013 to illustrate the application of the safety performance functions (SPFs).

Step 9 – Determine and apply the appropriate SPF for the selected site
We apply the "short-form" version of the SPFs developed for two-lane rural roadway segments in Pennsylvania to be consistent with the Highway Safety Manual methodology. As described in Appendix C of this report, this short-form SPF assumes HSM base conditions for many of the geometric characteristics. For the total crash frequency, the short form SPF for total crash frequency on two-lane rural roadway segments in Pennsylvania is:

$$N_{cr,pr} = Length \times AADT^{0.754} \times e^{-5.894}$$

where:

$N_{cr,pr}$ = predicted total crash frequency on the segment (crashes/year);
$Length$ = length of segment (miles); and,
$AADT$ = annual average daily traffic on the segment (veh/day).

This equation can be evaluated by plugging the values provided for segment 650 in Table 23 into the equation, as follows:

$N_{cr,pr} = 0.4477 * (11171)^{0.754} * e^{-5.894} = 1.392$ crashes/year.

Therefore, the SPF predicts 1.392 total crashes to occur in 2013 based on the observed traffic volume and length of segment 650 under the "base" conditions.

For fatal and injury crash frequency, the short form SPF is:

$$N_{cr,pr} = Length * AADT^{0.735} * e^{-6.323}$$

where $N_{cr,pr,FI}$ is the predicted fatal and injury crash frequency on the segment (in terms of crashes/year) and the other variables have been previously defined. This equation can be evaluated by plugging the values provided for segment 650 in Table 22 and Table 23 into the equation, as follows:

$N_{cr,pr,FI} = 0.4477 * (11171)^{0.735} * e^{-6.323} = 0.759$ crashes/year.

Therefore, the SPF predicts 0.759 fatal and injury crashes to occur in 2013 based on the observed traffic volume and length of segment 650 under the "base" conditions.

Step 10 – Apply the appropriate CMFs for the segment

We must now adjust the crash frequency predictions to accommodate differences between the geometric characteristics of the segment of interest and the base conditions assumed. As discussed in Appendix C, the short-form version of the SPF for crash frequency on two-lane rural roadway segments assumes the following base conditions: a roadside hazard rating of 3 or less, no passing zones, no shoulder rumble strips, 5 access points per mile, and no horizontal curves. Since these attributes are included in the SPFs presented in Tables 2 and 3, we can use these model outputs to obtain Pennsylvania-specific CMFs for the following characteristics on two-lane rural roadway segments: roadside hazard rating, passing zones, shoulder rumble strips, access density, horizontal curve density and degree of curvature per mile. Differences from this particular set of base conditions can be incorporated using the CMFs based on the SPF models provided in Table 2. Differences in any other variables from the base conditions presented in the HSM (e.g., lane width or shoulder width) must be accommodated using the CMFs provided in the recently developed Pennsylvania CMF guide.

Segment 650 differs from the base conditions since it has a roadside hazard rating of 4, includes the presence of shoulder rumble strips, has access points along the roadway segment, and includes horizontal curves. The individual CMFs for total crash frequency are shown below (see Appendix C for their derivation):

$$Combined\ CMF\ total\ crash\ frequency = e^{0.101RHR_{6,7}} * e^{0.091RHR_{4,5}} * e^{-0.239PZ} * e^{-0.188SRS} * e^{0.008(AD-5)} * e^{0.03HCD} * e^{0.002DCPM},$$

where:

RHR6,7 = roadside hazard rating on the segment of 6 or 7 (1 if RHR is 6 or 7; 0 otherwise);

RHR4,5 = roadside hazard rating on the segment of 4 or 5 (1 if RHR is 4 or 5; 0 otherwise);

PZ = presence of a passing zone in the segment (1 if present; 0 otherwise);
SRS = presence of shoulder rumble strips in the segment (1 If present; 0 otherwise);
AD = access density in the segment, total driveways and intersections per mile of segment length (Access Points/Mile);
HCD = horizontal curve density in the segment, number of curves in the segment per mile (Hor. Curves/Mile); and,
DCPM = total degree of curvature per mile in the segment, the sum of degree of curvature for all curves in the segment divided by segment length in miles (Degrees/100 ft/Mile).

Applying the site-specific conditions for segment 650 provided in Table 22, we find that:

$$Combined\ CMF\ total\ crash\ frequency = e^{0.101(0)} * e^{0.091(1)} * e^{-0.239(0)} * e^{-0.188(1)} * e^{0.008(8.934-5)} * e^{0.03(2.234)} * e^{0.002(7.817)} = 1.017.$$

The predicted total crash frequency for segment 650 in 2013 is simply the product of the predicted value using the short-form SPF and the combined CMF that provides the adjustment from the base conditions: $1.392 * 1.017 = 1.416$ crashes/year.

Similarly, the CMFs for total and injury crash frequency are:

$$Combined\ CMF\ fatal\ and\ injury\ crash\ frequency = e^{0.051RHR_{6,7}} * e^{0.055RHR_{4,5}} * e^{-0.232PZ} * e^{-0.184SRS} * e^{0.008(AD-5)} * e^{0.031HCD} * e^{0.002DCPM}.$$

Applying the site-specific conditions for segment 650 provided in Table 22, we find that:

$$Combined\ CMF\ fatal\ and\ injury\ crash\ frequency = e^{0.051(0)} * e^{0.055(1)} * e^{-0.232(0)} * e^{-0.184(1)} * e^{0.008(8.934-5)} * e^{0.031(2.234)} * e^{0.002(7.817)} = 0.987.$$

The predicted fatal and injury crash frequency for segment 650 in 2013 is simply the product of the predicted value from the short-form SPF and the combined CMF that provides the adjustment from the base conditions: $0.759 * 0.987 = 0.749$ crashes/year.

Step 11 – Multiply the result by the appropriate calibration factor
Since we are applying SPFs created specifically for two-lane rural roads in Pennsylvania, which were developed using historical crash data from Pennsylvania, no calibration factor is required to modify the predictions of the SPFs.

Step 12 – Repeat Steps 8 to 11 for the remaining analysis years
Since crash frequency predictions are eventually needed for years 2005 to 2013, these steps were repeated for those analysis years. The results are summarized in Table 26 below.

Table 26. Crash Frequency Predictions for Segment 650 for All Analysis Years

Year	Predictions from SPFs for Segment 650	
	Total Crashes	Fatal and Injury Crashes
2005	1.450	0.767
2006	1.461	0.773
2007	1.452	0.768
2008	1.452	0.768
2009	1.452	0.768
2010	1.452	0.768
2011	1.452	0.768
2012	1.452	0.768
TOTAL	11.622	6.150

Step 13 – Apply the Empirical Bayes (EB) method to adjust results for observed crash frequency

For a more rigorous statistical prediction, an Empirical Bayes (EB) adjustment can be applied to the crash predictions. The EB method uses a weighted average between observed crash history for a site and the predicted frequency from the SPF to obtain a better estimate of predicted crash frequency, as described in the equation below:

$$N_{EB} = W * N_{pr} + (1 - W) * N_{obs}$$

where:

N_{EB} – EB adjusted predicted crash frequency (crashes/year);
W – weight for EB adjustment;
N_{pr} – predicted crash frequency from the SPF (crashes/year); and,
N_{ob} – observed mean crash frequency from crash history (crashes/year).

The weighting factor, W, is based on the crash frequency predicted by the SPF, number of years of historic crash data, and the overdispersion parameter obtained from the SPF model:

$$W = \frac{1}{1 + \frac{\sum N_{pr,ch}/L}{\varphi}}$$

where:

W – weight for EB adjustment;
$\sum N_{pr,ch}$ – sum of predicted crash frequency for each year of crash history;
L – segment length (miles); and,
φ - overdispersion parameter from the SPF model.

The overdispersion parameter for the total crash frequency SPF is 0.514. Using this information, the weighting factor for the estimate of total crash frequency is:

$$W = \frac{1}{1 + \frac{11.623/0.4477}{0.514}} = 0.019$$

The EB adjusted predicted crash frequency for Segment 650 in 2013 is then:

$$N_{EB} = 0.019 * 1.416 + (1 - 0.019) * 1.125 = 1.131\ crashes/year$$

Because so little weight is given to the SPF prediction, the EB adjusted prediction is much closer to the crash history mean than the prediction. This occurs because there is a lot (eight years) of historical crash data available for the roadway segment. This process can be repeated for the Fatal and Injury crash prediction, for which the SPF has an overdispersion parameter of 0.624.

Step 14 – Apply the methodology to other sites or segments

The results of applying the SPFs and EB adjustment for total crashes on all segments as well as fatal and injury crashes on all segments are shown below in Table 27.

Table 27. Summary of Predict Crash Frequencies and Crash Frequencies Accounting for the EB Adjustment

Segment	Total Crashes				Fatal and Injury Crashes			
	Observed Mean	SPF, No EB	Weight	EB-Adjusted	Observed Mean	SPF, No EB	Weight	EB-Adjusted
650	1.125	1.416	0.019	1.131	0.875	0.749	0.043	0.870
660	2.125	1.697	0.017	2.118	0.500	0.900	0.038	0.515
670	1.125	1.589	0.017	1.133	0.750	0.842	0.037	0.753
680	3.000	1.910	0.017	2.981	1.375	1.013	0.038	1.361
690	0.375	1.282	0.019	0.393	0.125	0.679	0.044	0.149
700	0.750	1.468	0.018	0.763	0.125	0.779	0.041	0.152
710	1.875	1.566	0.019	1.869	0.375	0.829	0.042	0.394
720	1.375	1.579	0.020	1.379	0.625	0.834	0.044	0.634
730	1.375	1.688	0.019	1.381	0.625	0.894	0.043	0.637
Total	13.125	14.196		13.147	5.375	7.519		5.465

Step 15 – Apply the project-level EB adjustment

This step is not applicable for the segment level SPFs developed for the two-lane rural roads in Pennsylvania.

Step 16 – Sum crash frequencies across analysis years and locations

This sum is provided in Table 27 above.

Step 17 – Determine if there is an alternative design to be evaluated

No alternatives are proposed for this roadway section so this step is not needed.

Step 18 – Evaluate and compare results
Since multiple alternatives are not being compared, this step is not needed. The predicted total crash frequency for the roadway section is 13.1 crashes per year and for fatal and injury crash frequency is 5.5 crashes per year.

Case study 2 – Comparing Proposed Alternatives for an Existing Intersection

<u>The site/facility</u>

The intersection of SR 322 and SR 144. A satellite image of its current geometric configuration is provided in Figure 2.

Figure 2. Current Geometric Configuration for the Intersection of SR 322 and SR 144

<u>The question</u>

Geometric design changes are proposed for the intersection of SR 322 and SR 144. Engineers are planning to redesign the intersection from its current configuration (shown in Figure 2) to a simpler, more traditional, 3-leg configuration with stop-control on the minor approach. Four different configuration alternatives are being considered:

1. 3-leg configuration with no exclusive turn lanes.
2. 3-leg configuration with an exclusive left-turn lane on the major approach.
3. 3-leg configuration with an exclusive right-turn lane on the major approach.
4. 3-leg configuration with exclusive left- and right-turn lanes on the major approach.

The question then is which of the configurations will provide the best expected safety performance (i.e., lowest crash frequency) in a future year scenario 2015?

Facts

Traffic volumes (measured in AADT) for the future year scenario for which the project is expected to be completed are provided in Table 28. This information can usually be obtained from the relevant planning office or, as was done here, by extrapolating historical trends to the future year scenario.

Table 28. Future Traffic Volumes for Study Site

Intersecting Route	AADT in 2015 [veh/day]
Major approach (SR 322)	10981
Minor approach (SR 144)	4261

Assumptions

None

Results

Using the predictive method outlined below, the configuration alternative that provides the lowest crash frequency is alternative 2 (a 3-leg intersection with an exclusive left-turn lane only). The predicted frequency of total crashes for this proposed intersection configuration is 2.3 crashes per year and the predicted frequency of fatal and injury crashes is 1.3 crashes per year.

Steps

Step 1 – Define the spatial limits of the study
The limit of this study is the intersection of SR 322 and SR 144. In practice, the influence area of any intersection extends 250 feet upstream of each of the intersection approaches. Thus, the predictions performed here will account for crashes within this influence area.

Step 2 – Define the period of interest
In this problem, the analysis period of interest is the future year 2015.

Step 3 – Determine the availability of traffic volume and historical crash data
As per the Facts section, this information would be either available from the relevant planning authority or can be extrapolated from the current historical trends found in the current PennDOT RMS database.

Step 4 – Determine geometric design and other site characteristics
This information is usually available from the PennDOT RMS database and the supplemental data collected and provided by Penn State to PennDOT. For this problem, the geometric data is provided by the configuration alternatives being considered.

Step 5 – Divide the roadway network into individual sites
As given by the problem statement, only one site is being considered: the intersection of SR 322 and SR 144.

Step 6 – Assign crashes to individual sites
This step is not applicable since the analysis period represents a future year scenario for which historical crash data would not be available.

Step 7 – Select an individual site in the study network
Since only one site is being considered, this is the only site that will be selected.

Step 8 – Select an individual analysis year in the period of interest
Since the period of interest is just the future year 2015, this year is selected.

Step 9 – Determine and apply the appropriate SPF for the selected site
From Table 16, the short-form SPF for total crash frequency on 3-leg minor-stop control intersections of two-lane rural roads in Pennsylvania under the base conditions of no exclusive left-turn or right-turn lanes is:

$$N_{pr,3st} = AADT_{maj}^{0.479} * AADT_{min}^{0.362} * e^{-6.337}$$

where:

$N_{pr,3st}$ = predicted total crash frequency at the intersection (crashes/year);
$AADT_{maj}$ = annual average daily traffic on the major approach (veh/day); and,
$AADT_{min}$ = annual average daily traffic on the minor approach (veh/day).

This equation can be evaluated by plugging in the traffic volumes provided from the site data into the equation, as follows:

$N_{pr,3st} = (10981)^{0.479} * (4261)^{0.362} * e^{-6.337} = 3.142$ crashes/year

Therefore, based on the traffic characteristics of the intersection and proposed configuration, the SPF predicts 3.142 total crashes to occur in the future year scenario 2015 under base conditions.

Similarly, from Table 16, the short-form SPF for fatal and injury crash frequency on 3-leg minor-stop controlled intersections of two-lane rural roads in Pennsylvania under the base conditions of no exclusive left-turn or right-turn lanes is:

$$N_{pr,3st,FI} = AADT_{maj}^{0.439} * AADT_{min}^{0.343} * e^{-6.457}$$

where $N_{pr,3st,FI}$ is the predicted fatal and injury crash frequency at the 3-leg minor-stop controlled intersection (in terms of crashes/year) and the other variables have been previously defined. This equation can be evaluated by plugging in the values provided

from the site data for the proposed configuration alternative 1 into the equation, as follows:

$$N_{pr,3st,FI} = (10981)^{0.439} * (4261)^{0.343} * e^{-6.457} = 1.639\ crashes/year$$

Therefore, based on the traffic characteristics of the intersection and proposed configuration, the SPF predicts 1.639 fatal and injury crashes in the future year scenario 2015 under base conditions.

Step 10 – Apply the appropriate CMFs for the segment
We must now adjust the crash frequency predictions to accommodate differences between the geometric characteristics of the segment of interest and the base conditions assumed. For the SPF developed for 3-leg minor-stop controlled intersections of two-lane rural roadways, the base conditions assume that no exclusive left-turn or right-turn lanes are provided. From the SPF output presented in Table 16, Pennsylvania-specific CMFs can be created for the presence of exclusive left-turn and right-turn lanes. Since the first alternative being considered includes no exclusive turn lanes, these CMFs do not apply and this step can be skipped for this specific alternative.

Step 11 – Multiply the result by the appropriate calibration factor
Since we are applying SPFs created specifically for intersections of two-lane rural roads in Pennsylvania, which were developed using historical crash data from Pennsylvania, no calibration factor is required to modify the predictions of the SPFs.

Step 12 – Repeat Steps 8 to 11 for the remaining analysis years
This step is not required since only a single analysis year is being considered.

Step 13 – Apply the Empirical Bayes (EB) method to adjust results for observed crash frequency
For simplicity, this step is skipped since the future year scenario is 2015 and historical crash data is not available for the preceding years.

Step 14 – Apply the methodology to other sites or segments
Since no other site is being considered, this step is not required.

Step 15 – Apply the project-level EB adjustment
This step is not applicable for the intersection level SPFs developed for the two-lane rural roads in Pennsylvania.

Step 16 – Sum crash frequencies across analysis years and locations
Since only one location and analysis year is being considered, this step is not required.

Step 17 – Determine if there is an alternative design to be evaluated
In this problem, four alternatives are being considered and only the first was analyzed. The SPF equations can be applied to the features of the other configuration alternatives

to assess their safety performance for the future year 2015. A summary of the results are provided in Table 29.

Table 29. Summary of Results of the Four Intersection Configuration Alternatives

Alternative Number	Total crashes	Fatal and injury crashes
1	3.142	1.639
2	2.259	1.255
3	5.217	2.869
4	3.751	2.197

Step 18 – Evaluate and compare results

We now compare the crash frequencies estimated for the various alternatives. As shown in Table 29, configuration alternative 2 has the lowest estimated crash frequencies for both total and fatal and injury crashes of the four possibilities. Thus, this configuration was selected as having the best safety performance in the future year 2015 scenario.

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APPENDIX A

VIDEO PHOTOLOG DATA COLLECTION INSTRUCTIONAL GUIDE

The Video Log system is used by PennDOT to describe the automated collection of panoramic roadway imagery. This online system is beneficial because data collectors can see visual images of roadway conditions without having to drive into the field. In this way, fewer man-hours are required to collect field data that can be obtained visually. In this project, the video log system is used to collect three pieces of information: 1) roadside hazard ratings (RHR) of roadway segments; 2) intersection lane configurations (e.g., presence of left- or right-turn lanes on intersection approaches) at intersections of state-owned two-lane rural roads; and, 3) verify the presence and type of traffic control that exists at these intersections (e.g., two-way vs. all-way vs. signal control).

This document will demonstrate how to collect the data needed for this project using State Route 3009 in Bedford County as an example. Prior to demonstrating the methods to collect the data of interest to the present study, the procedure necessary to access the PennDOT video log system is described.

Step 1: Access the PennDOT Online Video Log system at the following link:
http://www.dot7.state.pa.us/VideoLog/Open.aspx
Internet Explorer will likely display a "pop-up blocker" for state.pa.us – allow this to display.

Step 2. After gaining access to the Pennsylvania Video Log Application, click "I Accept" (Figure 3).

Figure 1. Screenshot of *"I Accept"* Icon

Step 3. In the "Select Area of Interest" box that is shown in Figure 4, select "route segment". Click "Generate Map" when finished.

Figure 4. Screenshot for Select Area of Interest

Step 4. In the "County" and "Select a State Route" boxes shown in Figure 5, select Bedford County and SR 3009 as shown in Figures 6 and 7, respectively. Be sure to choose "Entire Route" when selecting the State Route as this will begin the video log at the first segment within the county.

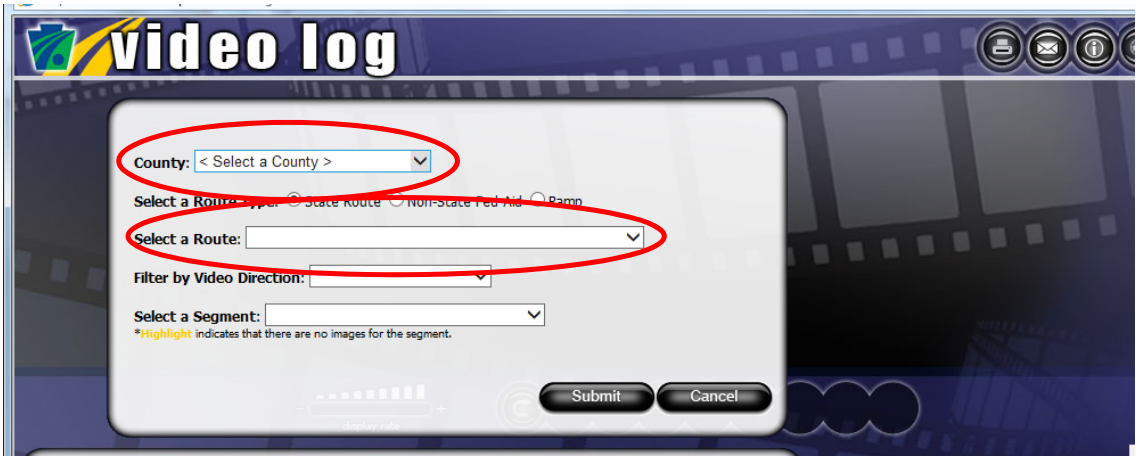

Figure 5. Select a County and Select a Route Screen Capture

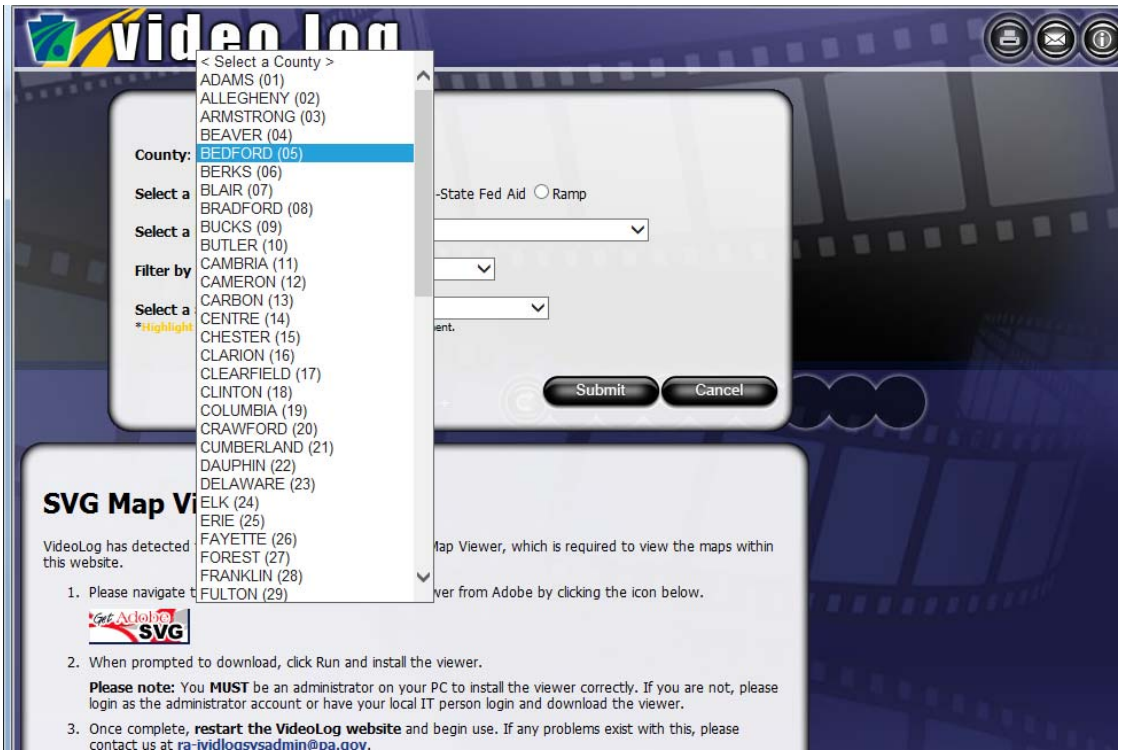

Figure 6. Selecting Bedford County

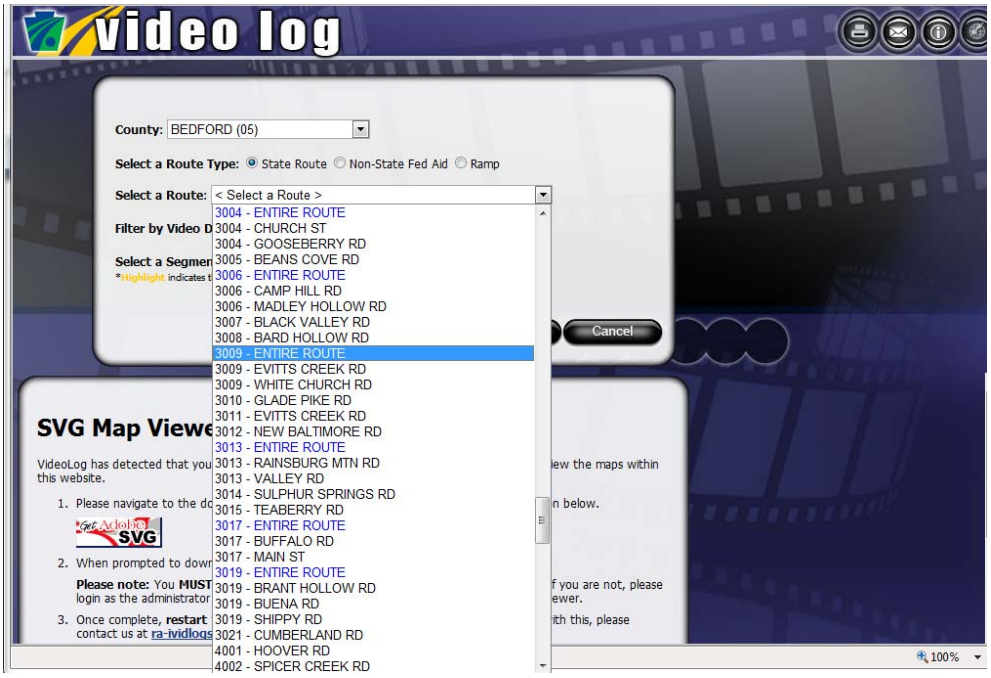

Figure 7. Selecting SR 3009

Step 5. When you gain access to the video log, click "***Activate Map***" (see Figure 8). A map will appear that provides a localized area map of the subject route, SR 3009 (see Figure 9). If you are using a computer that has not yet accessed the Pennsylvania Video Log application, you will need to install a map function (see Figure 10), which has a link just below the video log picture.

Figure 8. The "*Activate Map*" Icon

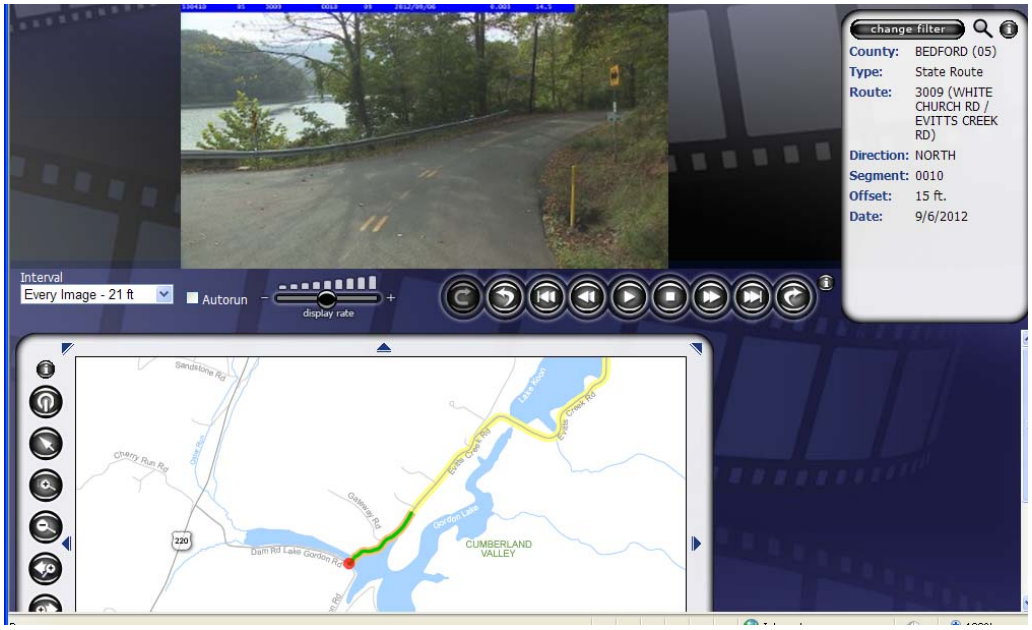

Figure 9. Screenshot for "*Show-up Map*" to locate beginning point for SR 3009

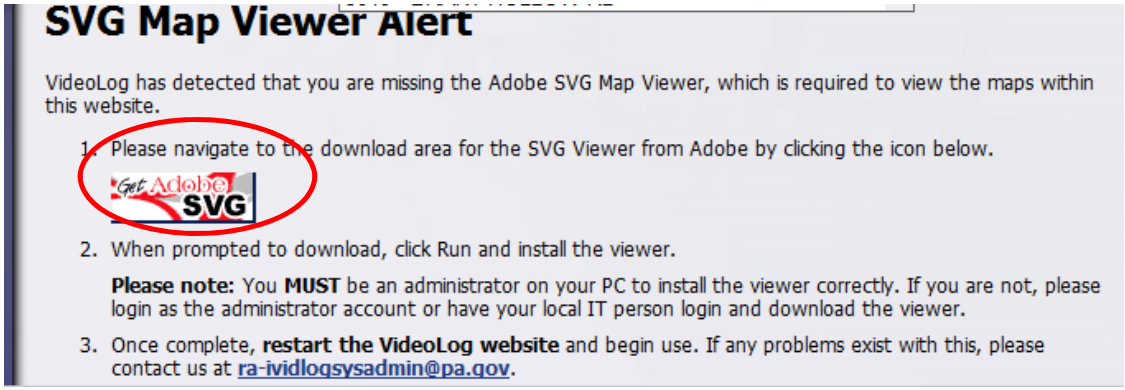

Figure 10. Screenshot for installing a map plug-in

The data that will be collected from the video log system are now described.

Roadside Hazard Rating (RHR)

The roadside hazard rating (RHR) is a qualitative characterization of the crash potential for roadside designs on two-lane highways. These estimates are made by visually inspecting a segment of roadway and assigning it a value based on the guidelines provided in Zegeer et al (1986). In this system, a seven-point categorical scale is used to describe the potential hazards, ranging from 1 (least hazardous) to 7 (more hazardous). For this project, we will utilize the PennDOT online video log system to estimate the RHR for all state-owned roadway segments on two-lane rural highways. A detailed description of roadside design features that "map" to each of the seven RHR categories are shown below, as are example graphics illustrating each rating category (Torbic et al, 2009):

Rating = 1

- Wide clear zones greater than or equal to 9 m (30 ft) from the pavement edge line.
- Side slope flatter than 1V:4H (Vertical:Horizontal).
- Recoverable (*meaning: the driver of a vehicle that departs the roadway section should be able to recover the vehicle and steer back onto the roadway*).

Figure 11. Typical Roadway with Roadside Hazard Rating Equal to 1.

Rating = 2

- Clear zone between 6 and 7.5 m (20 and 25 ft) from pavement edge line.
- Side slope about 1V:4H.
- Recoverable.

Figure 12. Typical Roadway with Roadside Hazard Rating Equal to 2.

Rating = 3

- Clear zone about 3 m (10 ft) from the pavement edge line.
- Side slope about 1V:3H or 1V:4H.
- Rough roadside surface.
- Marginally recoverable.

Figure 13. Typical Roadway with Roadside Hazard Rating Equal to 3.

Rating = 4

- Clear zone between 1.5 and 3 m (5 to 10 ft) from pavement edgeline.
- Side slope about 1V:3H or 1V:4H.
- May have guardrail 1.5 to 2 m [5 to 6.5 ft] from pavement edgeline.
- May have exposed trees, poles, or other objects (about 3 m or 10 ft from pavement edgeline).
- Marginally forgiving, but increased chance of a reportable roadside collision.

Figure 14. Typical Roadway with Roadside Hazard Rating Equal to 4.

Rating = 5

- Clear zone between 1.5 and 3 m (5 to 10 ft) from pavement edgeline.
- Side slope about 1V:3H.
- May have guardrail 0 to 1.5 m [0 to 5 ft] from pavement edgeline.
- May have rigid obstacles or embankment within 2 to 3 m (6.5 to 10 ft) of pavement edgeline.
- Virtually non-recoverable.

Figure 15. Typical Roadway with Roadside Hazard Rating Equal to 5.

Rating = 6

- Clear zone less than or equal to 1.5 m (5 ft).
- Side slope about 1V:2H.
- No guardrail.
- Exposed rigid obstacles within 0 to 2 m (0 to 6.5 ft) of the pavement edgeline.
- Non-recoverable.

Figure 16. Typical Roadway with Roadside Hazard Rating Equal to 6.

Rating = 7

- Clear zone less than or equal to 1.5 m (5 ft).
- Side slope 1:2 or steeper.
- Cliff or vertical rock cut.
- No guardrail.
- Non-recoverable with high likelihood of severe injuries from roadside collision.

Figure 17. Roadway with Roadside Hazard Rating Equal to 7.

Example

Again, consider State Route 3009 in Bedford County as an example. In this example, as in most segments, the roadside hazard rating (RHR) will be different for the two directions of travel within the segment limits. As such, data collectors should estimate the average of the RHR within the segment (i.e., produce only a single RHR measure per segment). Figures 11 through 17 were used to assign a RHR for each segment. Figures 18,19 and Table 29 show the process used to determine that SR 3009, Segment 0010 is category 6.

Figure 18. Video Log for SR 3009, Segment 0010.

Figure 19. Video Log for SR 3009 Segment 0010.

Table 29. The checklist of RHR for SR 3009 Segment 0010.

SR. 3009 seg. 0010 RHR						
	clear zone	side slope	Cliff or Vertical Rock	Guardrail	Rigid Obstacles	Recoverable
Rating 1	>=9 m(30 ft)	Flatter than 1:4	No	No	No	Yes
Rating 2	6-7.5 m(20-25 ft)	1:4			No	Yes
Rating 3	3 m(10 ft)	1:3 or 1:4			Rough roadside surface	Marginally
Rating 4	1.5-3 m(5-10 ft)			Allowable(1.5-2m[5-6.5ft])	About 3m(10ft)	Marginally forgiving
Rating 5		1:3		Allowable(0-1.5m[0-5ft])	2-3m(6.5-10ft)	Virtually non-recoverable
Rating 6	<=1.5 m(5 ft)	1:2		N/A	0-2m(0-6.5ft)	No
Rating 7		1:2 or steeper	Yes		N/A	No(high likelihood of injure)

SR 3009 segment 0010 is an example of a "severe" roadside. An example of a more forgiving roadside is shown in Figures 20 through 22, which is SR 3009, Segment 0090 in Bedford County. This example also illustrates how the RHR can change within the limits of a segment. Figure 20 shows how the RHR from both sides of the segment are averaged, while Figures 21 and 22 show how the RHR is averaged over the length of the segment. This process resulted in Segment 0090 being assigned a RHR of 3.

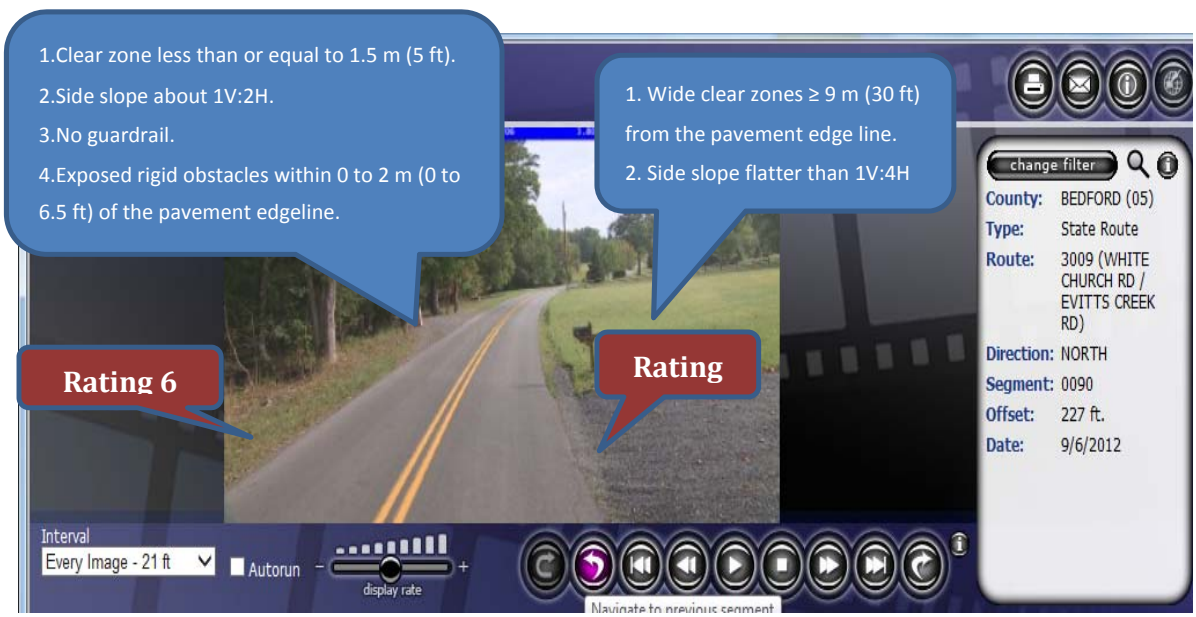

Figure 20. Video log for segment 0090 (1)

Figure 21. Video log for Segment 0090 (2)

Figure 22. Video log for Segment 0090 (3)

Intersection Lane Configurations and Verification of Traffic Control

The video log intersection data collection effort will be used to identify the presence of left or right-turn lanes on intersection approaches, and the type of traffic control present at intersections. For this project, we are only interested in the intersections of two state owned roads. Therefore, you should verify (using Google Maps or some other tool) that the intersection you observe in the video log is another state owned road.

The intersection control types considered in this research are: two-way stop control, all-way stop control, and signalized intersection control. Consider the intersection of SR 3009 with SR 3011 which is located within Segment 0150 in Bedford County. This is a two-way stop-controlled intersection that has no left turn lane or right turn lane.

Figure 23. Intersection Data Collection and Traffic Control

Other Segment-level Data

In the roadway segment data files, the following additional data will be collected and entered into the appropriate columns of the datafile:

- Presence of passing zones
- Presence of centerline or shoulder rumble strips
- Presence of horizontal curve warning pavement markings
- Presence of intersection warning pavement markings
- Presence of aggressive driving "dots"
- Number of driveways and intersections that are not considered the intersection of state-owned roadways.

An example of a passing zone on a two-lane highway is shown in Figure 24. Examples of shoulder (left panel) and centerline (left panel) rumble strips are shown in Figure 25. Figure 26 (left panel) shows an example of a horizontal curve warning pavement marking and the right panel of Figure 26 shows an example of intersection warning pavement markings. Aggressive driving "dots" are shown in Figure 27.

Figure 24. Example of passing zones.

Figure 25. Example of centerline rumble strips (left panel) and shoulder rumble strips (right panel).

Figure 26. Example of horizontal curve warning pavement marking (left panel) and intersection warning pavement marking (right panel).

Figure 27. Example of aggressive driving "dots" sign and pavement markings.

APPENDIX B

GOOGLE EARTH DATA COLLECTION INSTRUCTIONAL GUIDE

Google Earth is a virtual and geographic program where the 3D terrain and roadway features can be detected using detailed aerial maps. Specific tools within the Google Earth programs allow for a relatively precise way to measure linear distances and angles. For this project, Google Earth provides a useful and straightforward way to collect: 1) the geometric parameters describing horizontal curves; and, 2) the skew angle of intersections of two state owned roads.

The Google Earth tool is freely available online at:
http://www.google.com/earth/index.html.

The low resolution of aerial imagery available for rural areas might result in variability in the definition of these horizontal curves among various data collectors. In an effort to alleviate this issue, we will also make use of PennDOT's video log system (available at: http://www.dot7.state.pa.us/VideoLog/Open.aspx) to help define the curve limits from a driver's perspective.

Horizontal Curve Data Collection

The geometric data that we are interested in for each horizontal curve includes: 1) the length of the curve (i.e., its arc length); and, 2) the radius of the curve. The following sections describe the specific processes used to collect this horizontal curve data.

Step 1: Drawing the route path in Google Earth

Since every state-owned rural two-lane route is coded in PennDOT's roadway files at the segment-level, horizontal curve data are defined within the segment boundaries. For each segment, we are interested in the number of horizontal curves that exist, and the radius and arc length of each. Before locating the starting and ending points for segments, we must first draw a path along a given route using Google Earth.

At the top of the order panel, click the "***Add Path***" icon (see Figure 28) . A window will appear to create a new path (see Figure 29). Give the path a name (e.g., SR 3009 in this example) and draw a path along the roadway of interest. This is done by clicking at points along the roadway to create nodes for the path. The nodes should be placed at fairly regular intervals (~500 ft) on straight sections, and should be placed much closer on horizontal curves to capture the curve geometry. After you have finished creating the path, click "***Ok***". **NOTE**: based on the way roadway segments are numbered in the PennDOT system, paths should be created from west to east and from south to north (i.e., direction of increasing segment).

Figure 28. *"Add Path"* Icon

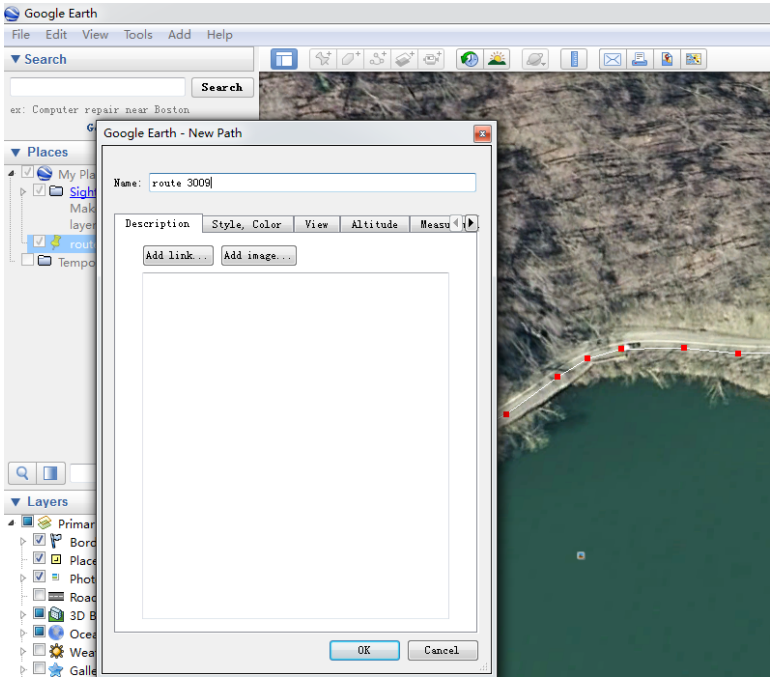

Figure 29. Screenshot for Adding Path

Step 2: Locating the starting and ending point for each segment

We must now determine the starting and ending point of each segment using the PennDOT roadway database. In Table 30, there are 18 contiguous segments on State Route (SR) 3009 in Bedford County. The first segment is 0010 while the last is 0180. The segment length in feet is provided in the fourth column, while a mileage-based segment length is shown in the fifth column. The cumulative length column is a measure of the roadway length within the county beginning at the western- or southern-most county boundary. Adjacent cumulative length values represent the beginning and ending mileposts for each segment along the route, which will be needed to use the Google Earth tool that is described in this document.

First and foremost, we need to find the beginning point for the entire route. Take segment 0010 in Bedford County as an example. When you gain access to the video log, which was illustrated in the video log sheet, a map will appear that provides a localized area map of the subject route, SR 3009 (see Figure 30). This will help you locate the starting point for the entire route. To find all the necessary locations on the Google Earth image, we will use the built-in ruler to add each segment length to the start point. Click ***"Show Ruler"*** (see Figure 31), and change the unit of length to "Feet", as shown in Figure 32.

Table 30. Length of Segments in PennDOT Profile

CNTY	SR	SEG	LENGTH(ft)	LENGTH(mi)	Begin Milepost	End Milepost	Cumulative length(mi)	SPEED	LANES	COUNTY
5	3009	10	2472	0.468182	0	0.468182	0.468182	55	2	BEDFORD
5	3009	20	2769	0.524432	0.468182	0.992614	0.992614	55	2	BEDFORD
5	3009	30	1271	0.240720	0.992614	1.233333	1.233333	55	2	BEDFORD
5	3009	40	3918	0.742045	1.233333	1.975379	1.975379	55	2	BEDFORD
5	3009	50	2929	0.554735	1.975379	2.530114	2.530114	55	2	BEDFORD
5	3009	60	1387	0.262689	2.530114	2.792803	2.792803	55	2	BEDFORD
5	3009	70	2577	0.488068	2.792803	3.280871	3.280871	55	2	BEDFORD
5	3009	80	2508	0.475000	3.280871	3.755871	3.755871	55	2	BEDFORD
5	3009	90	3015	0.571023	3.755871	4.326894	4.326894	55	2	BEDFORD
5	3009	100	2029	0.384280	4.326894	4.711174	4.711174	55	2	BEDFORD
5	3009	110	1963	0.371780	4.711174	5.082955	5.082955	55	2	BEDFORD
5	3009	120	2592	0.490909	5.082955	5.573864	5.573864	55	2	BEDFORD
5	3009	130	1937	0.366856	5.573864	5.940720	5.940720	55	2	BEDFORD
5	3009	140	1744	0.330303	5.940720	6.271023	6.271023	55	2	BEDFORD
5	3009	150	2312	0.437879	6.271023	6.708902	6.708902	55	2	BEDFORD
5	3009	160	1794	0.339773	6.708902	7.048674	7.048674	55	2	BEDFORD
5	3009	170	3978	0.753409	7.048674	7.802083	7.802083	55	2	BEDFORD
5	3009	180	2056	0.389394	7.802083	8.191477	8.191477	55	2	BEDFORD

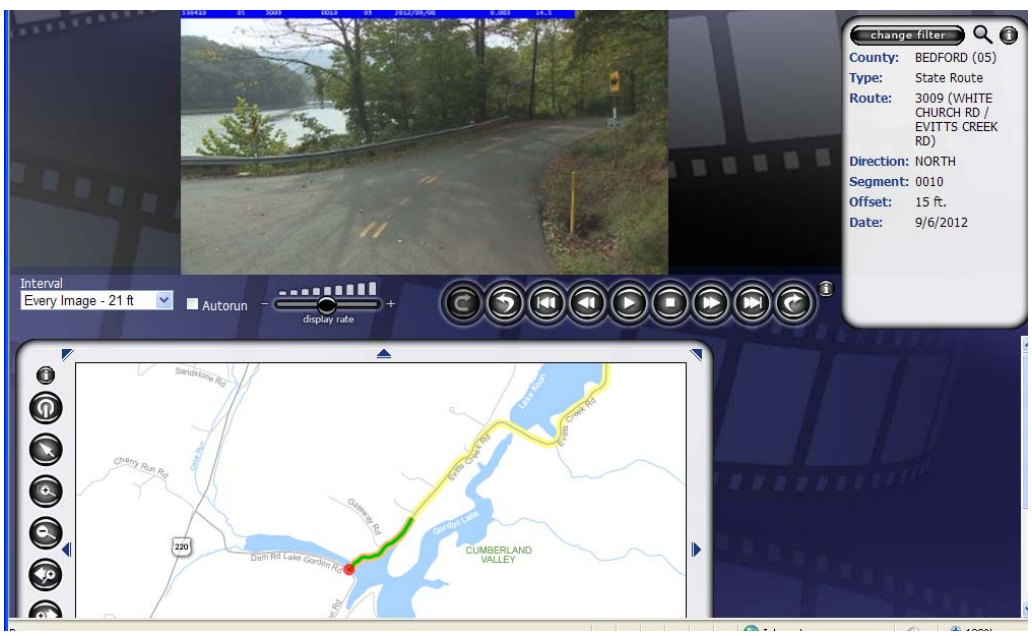

Figure 30. Screenshot for "*Show-up Map*" to locate beginning point for SR 3009

Figure 31. The "Show Ruler" Icon

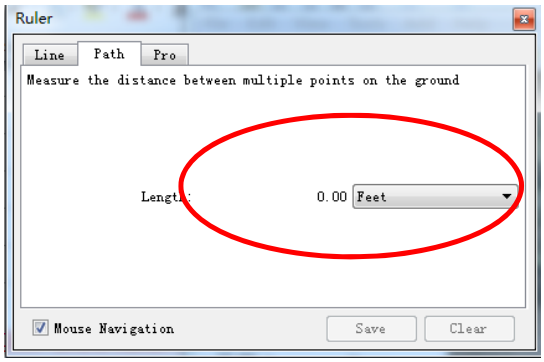

Figure 32. Screenshot for *"Show Ruler"* in The Starting Location

As shown in Table 30, the end of the first segment (0010) is 2472 ft from the start of the route in Bedford County. Using the ruler, measure a distance 2472 ft from the first point on the path. This location represents the end point of segment 0010 and the beginning point (offset 0000) of segment 0020. Save this location on the map. To do this, click ***"Save"*** and then click ***"Add Placemark"*** (see Figures 33 and 34). This will create a placemark that denotes the starting/ending point (see Figures 35 and 36).

Figure 33. The *"Add Placemark"* Icon

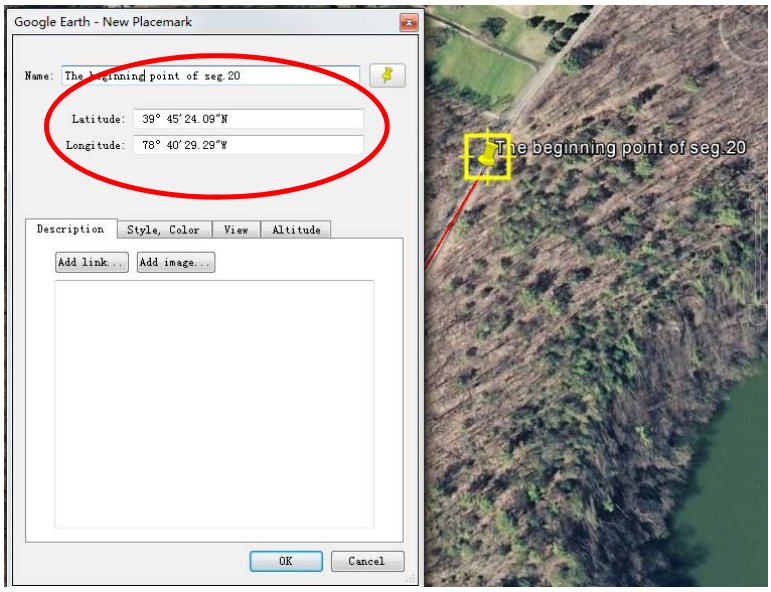

Figure 34. Screenshot for *"Add Placemark"*

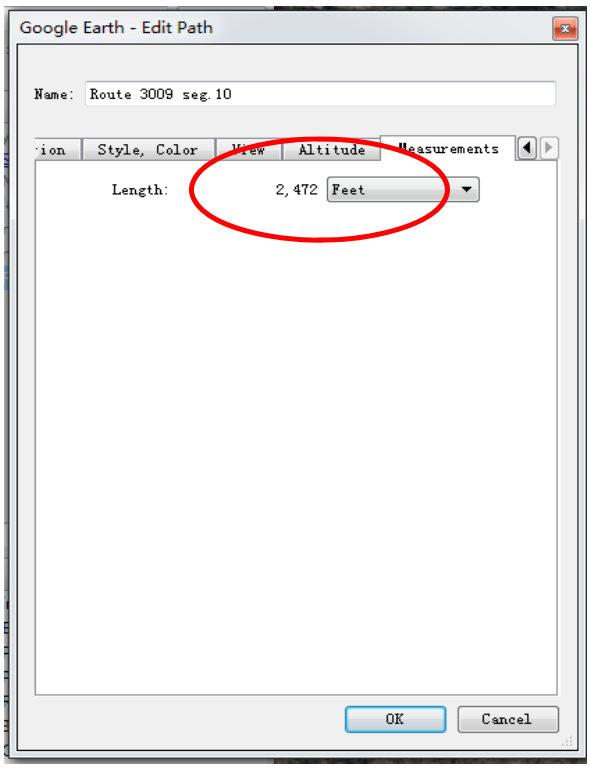

Figure 35. Locating the ending points of seg.10

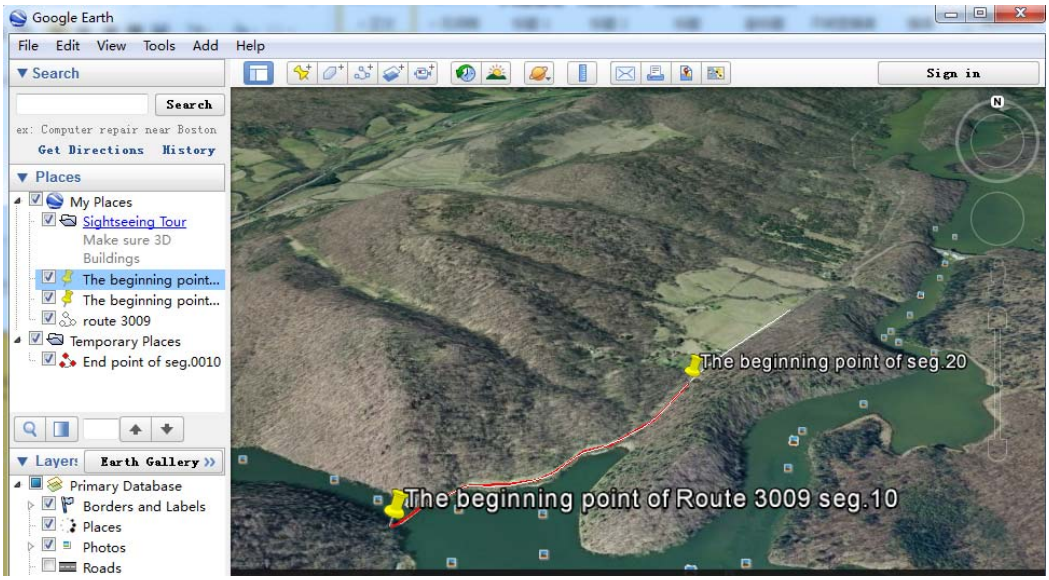

Figure 36. The Starting and Ending Points for Segments

Repeat this process for all segment starting/ending points along the route.

Step 3: Measuring Curves in Google Earth

Visually inspect each segment to identify any horizontal curves that exist based on your review of the video log. Once a curve has been identified from a driver's perspective, check the map below the video log to find the location and then go to Google Earth to confirm it. If this horizontal curve cannot be detected, scroll with the mouse to enlarge the picture. In order to keep consistently across individuals, we set up 1:1592.5cm (4cm: 209ft) as scale legend because the segment almost covers the whole screen in this zooming level (See Figure 37). This level helps when a big horizontal curve exists and stretches itself to another segment. Now, we will start to measure this curve's properties. Figure 38 shows the various components of a simple horizontal curve (AASHTO, 2011). Figure 39 shows how to apply each component on the Google Earth images. The radius of curve is "R" and the length of curve (arc) is denoted "L."

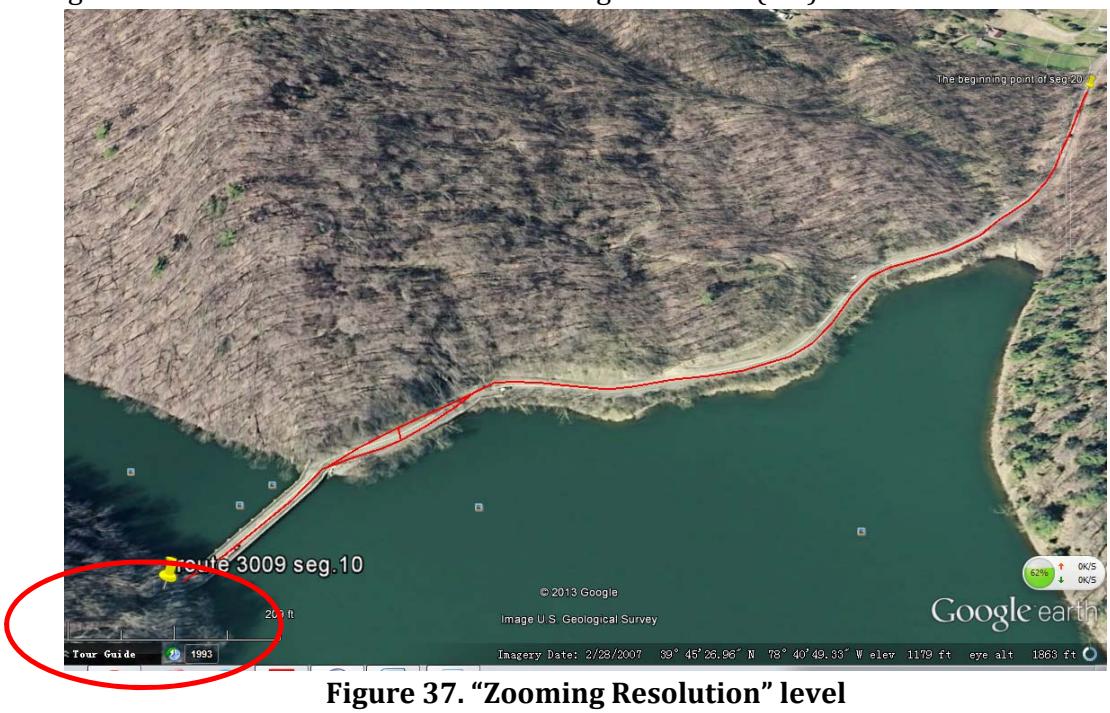

Figure 37. "Zooming Resolution" level

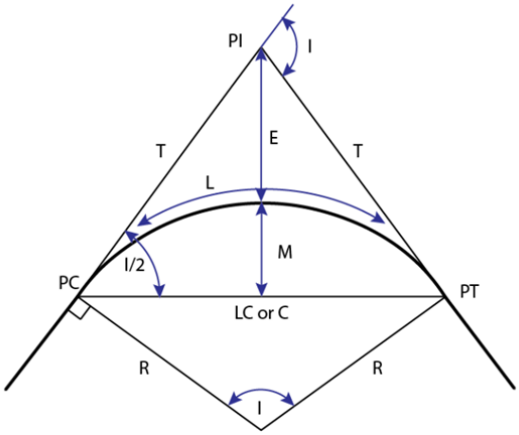

Figure 38. Measuring the length of arc and radius of the curve.

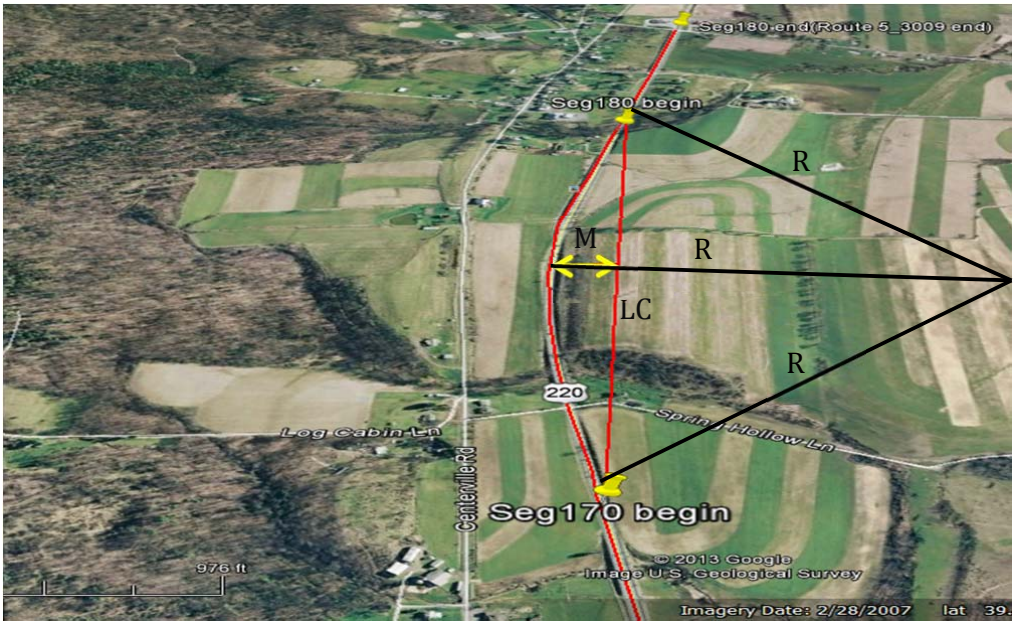

Figure 39. The Relationship between LC, M, and R

Based on the geometry of Figure 38 and Figure 39, the relationship between LC, M, and radius *R* is as follows:

$$(LC/2)^2 + (R-M)^2 = R^2 \qquad (10)$$

$$R = LC^2/8M + M/2 \qquad (11)$$

Consider a horizontal curve in segment 0010 of State Route 3009 in Bedford County, as an example. After identifying the curve using Google Earth, mark the two locations where the arc (length of curve) is adjacent to the intersecting tangents (labeled PC and PT in Figure 38), and record the coordinates of the PC (point of curve or beginning of curve in direction of increasing segment) and PT (point of tangent or end of curve in direction of increasing segment). This is done by clicking ***"Add Placemark"*** so you can move the yellow pin to gain the latitude and longitude information of the two points (an example is shown in Figure 40). Record the coordinates of these two points as shown in Table 31. The second procedure to measure the curve is to draw a chord (line LC or C in Figure 38) to connect the PC and PT. Then, draw a perpendicular line from the chord to the mid-point of the arc (line M in Figure 38), which is illustrated in Figures 41 and 42, respectively. Tables 32 and 33 illustrate how the data collector will populate the length of chord and mid-line length data into the respective cells.

Note that LC is the length of chord and M is the length of mid-point line, which can be calculated from the "***Show Ruler***" tool in Google Earth. The process used to access to the "***Show Ruler***" tool were noted above.

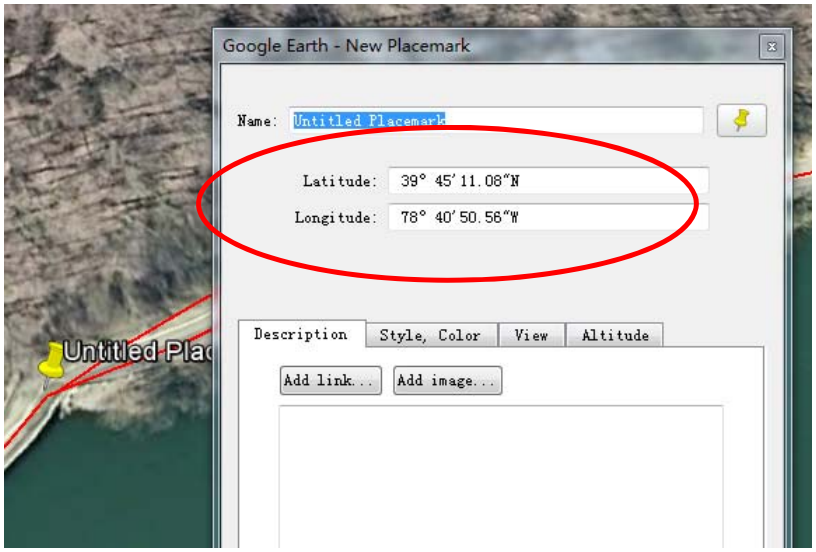

Figure 40. Example of Displaying Coordinates

Table 31. Filling in the Coordinates Data

CNTY	SR	SEG	LENGTH (ft)	Point of Tangents (PT) (1)	Length of chord(1) (LC,ft)	Mid-line length(1) (M,ft)	Radius in map(1) (ft)
5	3009	10	2472	(39°45'11.08"N, 78°40'50.56"W) (39°45'12.67"N, 78°40'47.93"W)	266.10	27.09	340.28

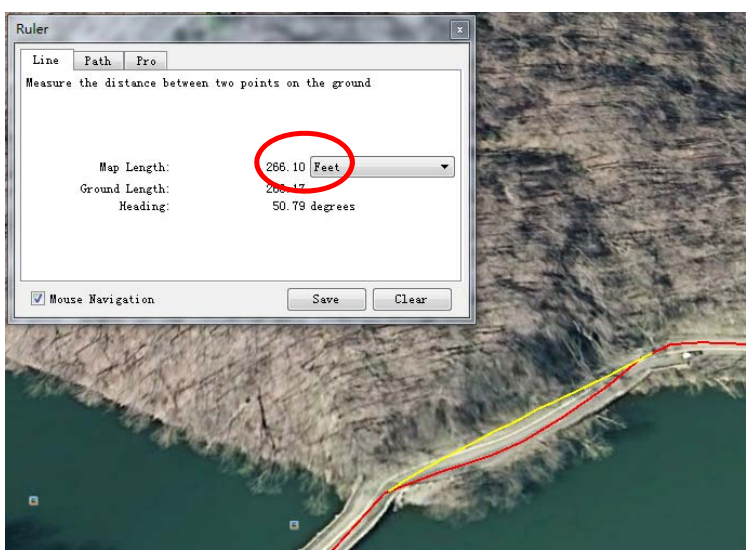

Figure 41. Example of Drawing the Chord

Table 32. Filling in Length of Chord Data

CNTY	SR	SEG	LENGTH (ft)	Point of Tangents (PT) (1)	Length of chord(1) (LC,ft)	Mid-line length(1) (M,ft)	Radius in map(1) (ft)
5	3009	10	2472	(39°45'11.08"N, 78°40'50.56"W) (39°45'12.67"N, 78°40'47.93"W)	266.10	27.09	340.28

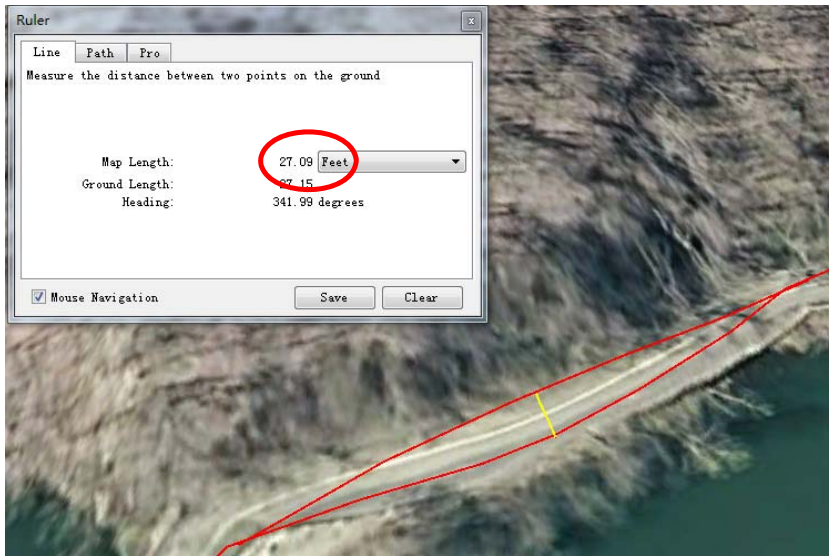

Figure 42. Example of Drawing the Mid-line

Table 33. Filling in Mid-line Data

CNTY	SR	SEG	LENGTH (ft)	Point of Tangents (PT) (1)	Length of chord(1) (LC,ft)	Mid-line length(1) (M,ft)	Radius in map(1) (ft)
5	3009	10	2472	(39°45'11.08"N, 78°40'50.56"W) (39°45'12.67"N, 78°40'47.93"W)	266.10	27.09	340.28

From equation (11), the radius (R) is derived from the LC and M terms. The results are displayed in Table 34. When a segment does not have any curves, put an **"X"** in the curve cells for that particular segment to designate that you have checked the segment and no curves exist. Similarly, if there are more than three curves in a current segment, insert more curve columns to the database, to the right of the existing curve data columns. Note that if a single horizontal curve crosses two adjacent segments, this curve should be "split" into two parts and recorded in the corresponding segment data cells. For example, if a horizontal curve begins in segment 0040 and continues into segment 0050, the horizontal curve component that exists in segment 0040 will be recorded in segment 0040, and the other component of the curve that exists in segment 0050 will be identified as another horizontal curve in segment 0050. The end point of the curve (PT)

in segment 0040 should be equal to the beginning point of the curve (PC) in segment 0050.

Table 34. PT Coordinates, Length of chord, Mid-line Length and Radius of Curve

CNTY	SR	SEG	LENGTH (ft)	Point of Tangents (1) (PT)	Length of chord (1) (LC,ft)	Middle line length (1) (M,ft)	Radius on map (1) (ft)	Point of Tangents (2) (PT)	Length of chord (2) (LC,ft)	Middle line length (2) (M,ft)	Radius in map (2) (ft)	Point of Tangents (3) (PT)	Length of chord (3) (LC,ft)	Middle line length (3) (M,ft)	Radius io map (3) (ft)
5	3009	10	2472	(39°45'11.08"N, 78°40'50.56"W) (39°45'12.67"N, 78°40'47.93"W)	266.1	27.09	340.28	(39°45'12.61"N, 78°40'47.99"W) (39°45'16.01"N, 78°40'38.94"W)	780.00	138.74	617.52	(39°45'16.01"N, 78°40'38.94"W) (39°45'19.69"N, 78°40'32.92"W)	1119.32	113.50	1436.57
5	3009	20	2769	(39°45'40.62"N, 78°40'12.15"W) (39°45'45.77"N, 78°40'6.14"W)	705.97	144.85	502.52	X	X	X	X	X	X	X	X
5	3009	40	3918	(39°46'1.78"N, 78°39'19.77"W) (39°46'3.60"N, 78°39'18.04"W)	222.88	13.06	481.98	X	X	X	X	X	X	X	X
5	3009	50	2929	(39°46'3.60"N, 78°39'18.04"W) (39°46'5.27"N, 78°39'17.78"W)	172.65	8.62	436.56	X	X	X	X	X	X	X	X

Intersection Data Collection

When it comes to the intersection skew angle data collection, we can zoom in the Google Map to enlarge the intersection, and place the protractor on the computer screen to measure the skew angle of the intersection. The skew angle is the smallest angle between the two intersection roads, and should also be less than or equal to 90 degrees.

Figure 43. Intersection skew angle of SR 3009 and SR3012

APPENDIX C

Integrating the Pennsylvania Safety Performance Functions into the Highway Safety Manual Framework

This Appendix describes a process to integrate the safety performance functions (SPFs) developed for two-lane rural roadways in Pennsylvania directly into the Highway Safety Manual (HSM) framework. This is done by considering the roadway segment SPF. It is recommended that the integration of the intersection SPFs be completed in a similar manner. This Appendix includes the HSM framework (left column) and describes (in the right column) the locations where Pennsylvania-specific information can be substituted into the framework, including the SPFs, base conditions, and application of crash modification factors (CMFs).

Highway Safety Manual Framework

The HSM crash prediction algorithm for two-lane rural highways is as follows:

$$N_{predicted} = N_{spf\ x} \times \left(CMF_{1x} \times CMF_{2x} \times \ldots \times CMF_{yx}\right) \times C_x$$

where: $N_{predicted}$ = predicted average crash frequency for a specific year for site type x;
$N_{spf\,x}$ = predicted average crash frequency determined for base conditions of the SPF developed for site type x;
CMF_{1x} = crash modification factors specific to site type x and specific geometric design and traffic control features y; and
C_x = calibration factor to adjust SPF for local conditions for site type x.

In the case of the predictive model shown above, site type x refers to a roadway segment or an intersection. For two-lane rural highway roadway segments, $N_{spf\,x}$ is computed as follows:

$$N_{spf\ x} = AADT \times L \times 365 \times 10^{-6} \times e^{(-0.312)}$$

The base conditions that are associated with $N_{spf\,x}$ are as follows:

- Lane width = 12 feet

Pennsylvania Framework

To integrate the Pennsylvania roadway segment SPF into the HSM framework, consider the general functional form of the SPF as shown below (see equation 7 in report):

$$\lambda_i = e^{\beta_0} \times L \times AADT^{\beta_1} \times e^{(\beta_2 X_2 + \ldots + \beta_n X_n)}$$

In this equation, substitute N_{spf} in place of λ_i for a parallel construct to the HSM framework. The remaining variables are defined as follows:

e = exponential function;
β_0 = regression coefficient for constant;
L = roadway segment length (miles);
$AADT$ = average annual daily traffic (veh/day);
β_1 = regression coefficient for average annual daily traffic on roadway segment;
$\beta_2, \ldots, \beta_n$ = regression coefficients for geometric design and other site-specific explanatory variables, $i = 2, \ldots, n$
$X_2, \ldots, X_n$ = vector of geometric design and other site-specific data;

Use the negative binomial regression coefficients in Table 2 of this report and substitute the values into the regression coefficients (b) to create the roadway segment SPF. The "full" SPF is as follows:

- Shoulder width = 6 feet
- Shoulder type = Paved
- Roadside hazard rating = 3
- Driveway density = 5 driveways per mile
- Horizontal curvature = None
- Vertical curvature = None
- Centerline rumble strips = None
- Passing lanes = None
- Two-way left-turn lanes = None
- Lighting = None
- Automated speed enforcement = None
- Vertical grade = Level (0%)

Note that similar base conditions exist in the HSM for the intersection SPFs for two-lane rural roads.

In Chapter 10 of the HSM, a series of CMFs may be applied to the crash prediction algorithm to adjust for site-specific conditions are not the same as the base conditions.

The HSM calibration procedure may be used to develop a numerical value for C_x in the crash prediction algorithm for jurisdictions whose data were not used to develop the HSM crash prediction algorithm. Because Pennsylvania data were not use to develop the HSM crash prediction algorithm, a C_x value derived from Pennsylvania is needed, or Pennsylvania-specific SPFs and CMFs can be developed. The purpose of the present study was to develop Pennsylvania-specific SPFs, so the HSM calibration factor (C_x) should be set equal to 1.0 for rural two-lane highway segments and intersections.

$$N_{spf} = e^{-5.934} \times L \times AADT^{0.754} \times e^{(0.101 \times RHR67 + 0.091 \times RHR45 - 0.239 \times PZ - 0.188 \times SRS + 0.008 \times AD + 0.030 \times HCD + 0.002 \times DCM)}.$$

where: N_{spf} = predicted average crash frequency for a specific year for a road segment (crashes per mile per year);
L = segment length (miles);
$AADT$= average annual daily traffic (vehicles per day);
$RHR67$ = 1 if roadside hazard rating is 6 or 7, 0 otherwise;
$RHR45$ = 1 if roadside hazard rating is 4 or 5, 0 otherwise;
PZ = 1 if passing zone is present, 0 otherwise;
SRS = 1 if shoulder rumble strips are present, 0 otherwise;
AD = number of intersections and driveways per mile;
HCD = number of horizontal curves per mile;
DCM = degree of curve per mile.

The base conditions assumed for the HSM can also be assumed for Pennsylvania. This includes a roadside hazard rating of 3, an access density of 5 per mile, no passing zones, no shoulder rumble strips, and no horizontal alignment. Applying these base conditions into the Pennsylvania-specific SPF above reduces the equation to the following:

$$N_{spf} = e^{-5.894} \times L \times AADT^{0.754}.$$

This is the "short-form" version of the SPF that is consistent with the HSM analysis framework.

CMFs for lane width, shoulder width, shoulder type, vertical curvature, presence of centerline rumble strips, presence of two-way left-turn lanes, presence of roadway lighting, presence of automated

enforcement, and vertical grade cannot be developed directly from the long-form Pennsylvania-specific SPF above, so the HSM CMFs for these geometric and other site-specific features should be used in Pennsylvania. For the roadside hazard rating, presence of passing zones, access density, presence of shoulder rumble strips, and horizontal alignment, CMFs for Pennsylvania may be derived from the long-form SPF above. These CMFs are as follows:

$$CMF_{RHR} = e^{(0.101 \times RHR67 + 0.091 \times RHR45)}$$

CMF_{RHR} = CMF for roadside hazard rating
RHR67 = 1 if roadside hazard rating is 6 or 7, 0 otherwise;
RHR45 = 1 if roadside hazard rating is 4 or 5, 0 otherwise.

$$CMF_{PZ} = e^{(-0.239 \times PZ)}$$

CMF_{PZ} = CMF for presence of passing zone
PZ = 1 if passing zone is present, 0 otherwise.

$$CMF_{SRS} = e^{(-0.188 \times SRS)}$$

CMF_{SRS} = CMF for presence of shoulder rumble strips;
SRS = 1 if shoulder rumble strips are present, 0 otherwise.

$$CMF_{AD} = e^{0.008 \times (AD - 5)}$$

CMF_{AD} = CMF for access density;
AD = number of intersection and driveways per mile.

$$CMF_{HC} = e^{(0.030 \times HCD + 0.002 \times DCM)}.$$

CMF_{HC} = CMF for horizontal curvature;
HCD = number of horizontal curves per mile;
DCM = degree of curvature per mile.

District Highway Safety Guidance Manual

Appendix F —

Establishing Crash Modification Factors and Their Use

December, 2014

Establishing Crash Modification Factors and Their Use

FINAL REPORT

August 25, 2014

By Vikash V. Gayah and Eric T. Donnell
The Thomas D. Larson
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COMMONWEALTH OF PENNSYLVANIA
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16. Abstract

A critical component in the Association of State Highway and Transportation Officials' (AASHTO) *Highway Safety Manual* (HSM) safety management process is the Crash Modification Factor (CMF). It is used to estimate the change in the expected (average) number of crashes at a site when a specific countermeasure is implemented. This project responds to a request from the Pennsylvania Department of Transportation (PennDOT) to help integrate the use of CMFs into the existing safety management process. The objectives of this project were to assemble a list of CMFs that are consistent with the HSM and are appropriate for use in Pennsylvania, and provide guidelines for their use. Two products were created to help achieve these objectives. The first product is a guidebook that describes the proper implementation procedures for CMFs and contains a complete list of CMFs that are appropriate for use in Pennsylvania. This guidebook is the *Pennsylvania CMF Guide*. The second product is a training presentation for PennDOT entitled *What are CMFs and how do you use them?* This presentation will be used to introduce engineers to CMFs, describe how to implement them, and provide guidance for how to use the *Pennsylvania CMF Guide*. This presentation is geared toward both internal and external training workshops.
The remainder of this report provides details on the development of these two products, which are included as appendices.

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Introduction

The American Association of State Highway and Transportation Officials' (AASHTO) *Highway Safety Manual* (HSM) is transforming the way state and local transportation agencies manage road safety. In addition to providing an overview of many aspects of road safety management, the HSM contains a process for evaluating the effectiveness of alternative safety countermeasures based on previous research.

A critical component in the HSM safety management process is the Crash Modification Factor (CMF). It is used to estimate the change in the expected (average) number of crashes at a site when a specific countermeasure is implemented. This project responds to a request from the Pennsylvania Department of Transportation (PennDOT) to help integrate the use of CMFs into the existing safety management process. The objectives of this project were to: (1) assemble a list of CMFs that are consistent with the HSM and are appropriate for use in Pennsylvania, and (2) provide guidelines for their use. Two products were created to help achieve these objectives. The first product is a guidebook that describes the proper implementation procedures for CMFs and contains a complete list of CMFs that are appropriate for use in Pennsylvania. This guidebook is entitled *Pennsylvania CMF Guide*. The second product is a training presentation for PennDOT, entitled *What are CMFs and how do you use them?* This presentation will be used to introduce engineers to CMFs, describe how to implement CMFs, and provide guidance for use of the *Pennsylvania CMF Guide*. This presentation is geared toward both internal and external training workshops.

The rest of this report provides details on the development of these two products. The next section describes the *Pennsylvania CMF Guide*, and the following section describes the training presentation.

Pennsylvania CMF Guide

The purpose of the *Pennsylvania CMF Guide* is to provide a list of CMFs that are appropriate for use when estimating the safety performance of changes to the highway and street network in Pennsylvania, and to demonstrate how to apply them appropriately. The list of CMFs was compiled by reviewing the relevant literature and identifying high-quality CMFs that might be applicable to Pennsylvania roadways. In compiling this list, the following sources were reviewed:

- Federal Highway Administration (FHWA) CMF Clearinghouse website;
- AASHTO *Highway Safety Manual*;

- FHWA *Desktop Reference for Crash Reduction Factors* (Report FHWA-SA-08-011);
- Governors Highway Safety Association (GHSA) *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices*;
- FHWA Office of Safety, *Proven Safety Countermeasures*;
- FHWA *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes*;
- FHWA *Roadway Departure Countermeasures*;
- *Crash Reduction Factors for Traffic Engineering and Intelligent Transportation Systems (ITS) Improvements: State-of-Knowledge Report* (NCHRP Research Results Digest 299); and,
- Recently published research literature.

Only "high-quality" CMFs are included in this guide and deemed appropriate for application within Pennsylvania. The quality of the CMFs was determined using the star quality rating system proposed by the FHWA CMF Clearinghouse and documented on its website (http://www.cmfclearinghouse.org/). This system assigns each CMF with a numerical value on a scale of 1 to 5, where 5 is the most reliable or highest-quality rating. The ratings are determined based on the following five properties of the CMF and the study used to estimate its value:

- Study Design,
- Sample Size,
- Standard Error,
- Potential Bias, and
- Data Source.

High-quality CMFs were determined to be those having a rating of three stars or higher. The threshold of three stars was selected for the following reasons: It provides a relatively large list of CMFs, since the majority of CMFs in the CMF Clearinghouse are rated three stars; it is consistent with the HSM, since the CMFs provided in the HSM are almost all rated three stars or higher; and it ensures that any CMF with a poor rating for one or more properties also has other properties with an excellent rating (especially for study design and sample size).

Although CMFs with a rating of one or two stars are not deemed appropriate for application within Pennsylvania, a list of these lower-quality CMFs is included in the *Pennsylvania CMF Guide* to provide documentation concerning their use. However, because these CMFs are based on either a small sample size or suffer from a low-quality methodological evaluation, these CMFs are not recommended for use in Pennsylvania.

The CMFs in the guide are presented in 19 different CMF tables that are organized using the categories adopted by the FHWA CMF Clearinghouse. Table 1 provides a description of these categories and the total number of CMFs included within each category.

Table 1. CMF categories and number of CMFs included in each

Category Name	Number of high-quality CMFs included in guide
Access Management	258
Advanced Technology and ITS	100
Alignment	47
Bicyclists	62
Delineation	114
Highway Lighting	52
Interchange Design	52
Intersection Geometry	186
Intersection Traffic Control	310
On-Street Parking	27
Pedestrians	17
Railroad Grade Crossings	13
Roadside Features	69
Roadway Features	331
Shoulder Treatments	567
Signs	88
Speed Management	69
Transit	15
Work Zones	73
TOTAL	2,450

Each of the CMF tables contains the following information:

- Description of the highway change or countermeasure;
- Conditions for which the CMF is applicable;
- Point estimate and standard error of the CMF;
- Star quality rating as determined from the FHWA CMF Clearinghouse methodology; and
- Location of crash data used to estimate the CMF.

The conditions for which each CMF is applicable include the area type, crash severity, crash type, range of traffic volumes (given as a range of average annual daily traffic or AADT), and other considerations. If multiple CMFs are available for a specific set of conditions, a recommended CMF was identified for application in Pennsylvania. This recommendation was made by considering the value of the point estimates, the standard errors, the star-quality ratings, and the location of the crash data used to estimate the CMF. CMFs that were estimated using Pennsylvania crash data were also identified in the CMF tables.

The guidebook also contains a detailed methodology for the application of CMFs that are consistent with those in the HSM. This includes procedures for applying multiple CMFs

simultaneously and references for more information on this topic. Several example problems were developed to demonstrate the CMF application procedure. These examples are included in the guidebook. The training presentation is provided in this report as Appendix A. The example problems follow, as Appendix B. The *Pennsylvania CMF Guide* is incorporated as Appendix C.

Training Presentation - What are CMFs and how do you use them?

The purpose of the training presentation is to introduce practitioners to the concept of CMFs and to demonstrate how to use them properly. The presentation is designed to be used as part of a training workshop for both internal (PennDOT) employees and external consultants and practitioners in Pennsylvania. After completing the training workshop, attendees should be able to:

- Define a CMF;
- Apply a single CMF to a particular site to estimate the impact of a single countermeasure;
- Apply multiple CMFs to a particular site to estimate the impact of multiple countermeasures applied simultaneously;
- Use CMFs to compare multiple alternatives based on their expected safety performance; and
- Select an appropriate CMF for a given countermeasure from the *Pennsylvania CMF Guide*.

The presentation includes a total of 45 slides and a set of example problems that should be done concurrently with the presentation to demonstrate CMF principles. The presentation is provided in Microsoft PowerPoint format, and is included here as Appendix A. Instructor notes are included on each slide in the "Notes" section of the slide. These instructor notes provide a script that can be followed by the instructor leading the training workshop. However, we recommend that the instructor use these notes merely as a guide and integrate their own experiences and knowledge into the workshop presentation to supplement the material provided.

Five example problems are included as a part of the training materials in a separate handout. They are provided in Appendix B. These problems and their solutions are incorporated into the training presentation. The presentation instructor should allow attendees ample time to attempt the example problems on their own at the appropriate time during the presentation before providing the solution. These problems are designed to build in complexity during the presentation and to demonstrate the various steps that should be taken when applying CMFs to a real project. This includes the application of a single CMF, the application of multiple CMFs when a single countermeasure is applied, the application of multiple CMFs simultaneously, the determination of the appropriate CMF to apply for a given countermeasure (using the CMF guide), and the comparison of multiple alternatives using CMFs. Attendees of the training

workshop should be provided a copy of the *Pennsylvania CMF Guide* (or the tables from the appropriate sections) to complete the example problems. The tables required are Table B, Table I, and Table O. It is recommended that the presentation instructor take time to solve these problems before leading the presentation. The *Pennsylvania CMF Guide* is included as Appendix C.

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Appendix A: Presentation - What Are CMFs and How Do You Use Them?

What are CMFs and how do you use them?

Created by

Vikash V. Gayah & Eric T. Donnell
The Pennsylvania State University

The purpose of this presentation is to familiarize you with CMFs, make you comfortable using them and introduce you to the newly developed *Pennsylvania CMF Guide* that contains a collection of CMFs that have been deemed appropriate for application in Pennsylvania.

Objectives

- At the end of this presentation, you should be able to:
  - Define a CMF
  - Apply a single CMF to a particular site to estimate the impact of a single countermeasure
  - Apply multiple CMFs to a particular site to estimate the impact of multiple countermeasures applied simultaneously
  - Use CMFs to compare multiple alternatives based on their expected safety performance
  - Select an appropriate CMF for a given countermeasure from the *Pennsylvania CMF Guide*

The objectives of this presentation are to prepare you to accomplish the following tasks:

- Define a CMF
- Apply a single CMF to a particular site to estimate the impact of a single countermeasure
- Apply multiple CMFs to a particular site to estimate the impact of multiple countermeasures applied simultaneously
- Use CMFs to compare multiple alternatives based on their expected safety performance
- Select an appropriate CMF for a given countermeasure from the *Pennsylvania CMF Guide*

Outline

- What is a CMF?
- How are CMFs estimated?
- Errors in CMFs and confidence intervals
- Applying a single CMF
- Applying multiple CMFs
- The *Pennsylvania CMF Guide*

The following is a brief outline of the presentation

- First, we will describe what is a CMF is and how it can be used.
- Then, we will discuss how CMFs are estimated, which has a significant impact on how CMFs can be applied.
- This will lead to a discussion of errors that exist in CMFs and how we use confidence intervals to account for these errors.
- After this discussion, we will demonstrate how to apply CMFs with the help of a few examples. This will include applying a single CMF to a particular situation and applying multiple CMFs to a particular situation.
- Finally, we will end with an introduction to the *Pennsylvania CMF Guide* and how to use this guide.

What is a CMF?

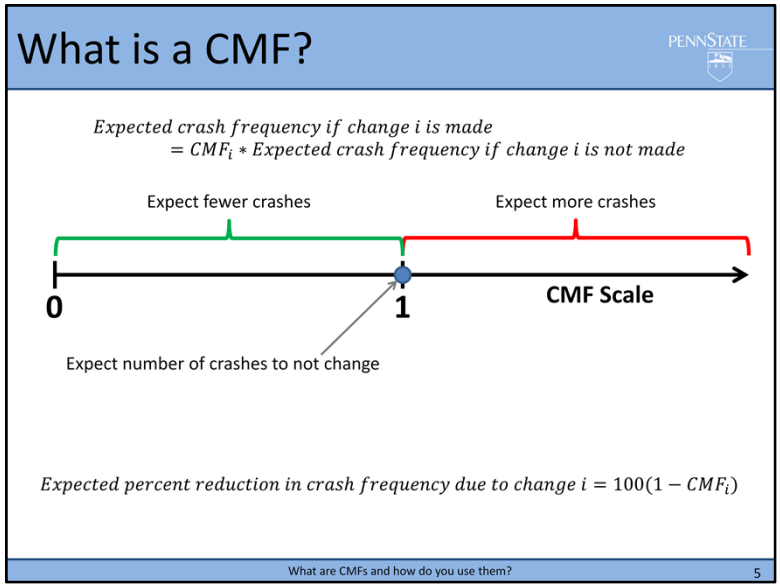
- A Crash Modification Factor (CMF) is "an **index of how much crash experience is expected to change following a modification** in design or traffic control" (Highway Safety Manual, 2010)

$$CMF_i = \frac{Expected\ crash\ frequency\ if\ change\ i\ is\ made}{Expected\ crash\ frequency\ if\ change\ i\ is\ not\ made}$$

So we start by asking the following question: what is a CMF?

CMF stands for crash modification factor. As defined by the Highway Safety Manual, it is "an index of how much crash experience is expected to change following a modification in design or traffic control". Thus, it provides a numeric value that is used to assess how the safety performance of a facility will be impacted by a given countermeasure.

(click for animation) This impact is presented as the ratio of the expected number of crashes after the change is made to the expected number of crashes if the change is not made. Note that the expected crashes should be measured over the same time and spatial interval. What this means is that the "without" change and "with" change should apply to the same geographic location, and the crash counts should be for the same length of time (e.g., crashes/year or crashes/3 year period).



To understand a bit more about the numerical values of the CMF, we can rearrange the previous equation to express the expected number of crashes after the change is made in terms of the CMF and the expected number of crashes without the countermeasure. Thus, as shown here, the CMF is essentially a scaling factor that relates expected crashes without the change to with the change.

(click) A CMF value of 1 suggests that the expected number of crashes with the change is the same as the expected number of crashes without the change. Thus, countermeasures with a CMF of 1 are expected to have no impact on safety.

(click) Countermeasures with CMFs less than one are expected to have a safety benefit because the expected number of crashes with the change will be less than the expected number of crashes without the change. The smaller the value, the more crash frequency is expected to reduce when the change is applied.

(click) Countermeasures with CMFs greater than one are expected to have a safety disbenefit because the expected number of crashes with the change will be greater than the expected number of crashes without the change. The larger the value, the more crash frequency is expected to increase when the change is applied.

CMFs must take positive values (otherwise, as you can see from this equation, we would expect negative crash frequencies when a change is made). Therefore, the lower limit of any CMF is zero. There is no upper limit for a CMF…this means that in theory CMFs can take values up to infinity. In practice, this is not very likely and the majority of CMFs that you will encounter will have values less than or equal to about 3.

(click) CMFs can be alternatively expressed as the expected percent change in crash frequency when a change is made using 100(1-CMF). Let's use the CMF scale to verify that the values obtained here makes sense. A CMF of 1 would be associated with a 0 percent change in crash frequency. A CMF of less than one (say 0.5) would be associated with a 50% reduction in crash frequency. A CMF greater than one (say 2) would be associated with a -100% reduction in crash frequency (or an increase in crash frequency by 100%).

How are CMFs estimated?

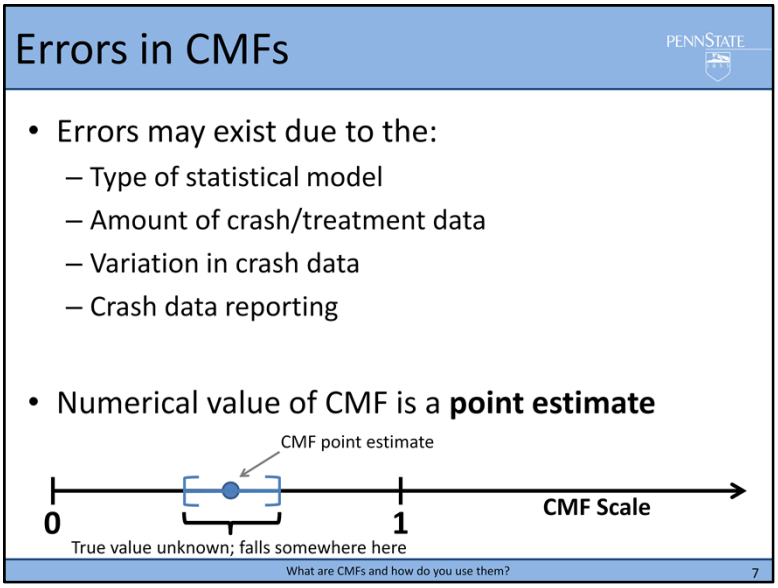
- CMFs are estimated based on statistical analyses of reported crash data
- Types of studies:
  - Simple before/after
  - Before/after with comparison group
  - Cross-sectional study without regression
  - Cross-sectional study with regression

Before we can go into more detail about CMFs and how they can be applied, it is important to understand where CMFs come from.

Each CMF value is estimated as the result of a statistical analysis of reported crash data. To obtain a CMF, analysts use roadway inventory and other databases to identify locations and times in which a specific treatment and those that do not. This database is then populated with the set of reported crash data to compare the safety performance of those sites with the treatment to those without. This is not such a straightforward task and several types of statistical studies have been developed to help estimate these CMFs.

Some examples are:
- In before/after studies, the same set of sites are used and the CMF is estimated by examining safety performance before the treatment was implemented and after the treatment was implemented.
- In the second type, a comparison group of sites at which the treatment is not applied during the same timeframe is used to provide a baseline for how safety performance changes even when the treatment is not applied.
- Cross sectional studies identify sites both with and without treatment in the same time period to compare how the treatment impacts safety performance. Regression is often used to help control for the impacts of other factors that might simultaneously impact safety performance and provides a better estimate of the treatments true impact.

The type of study impacts the accuracy of the estimate. Those with poorer designs (at the top of this list) have higher potential to yield inaccurate estimates than those with better designs (at the bottom).

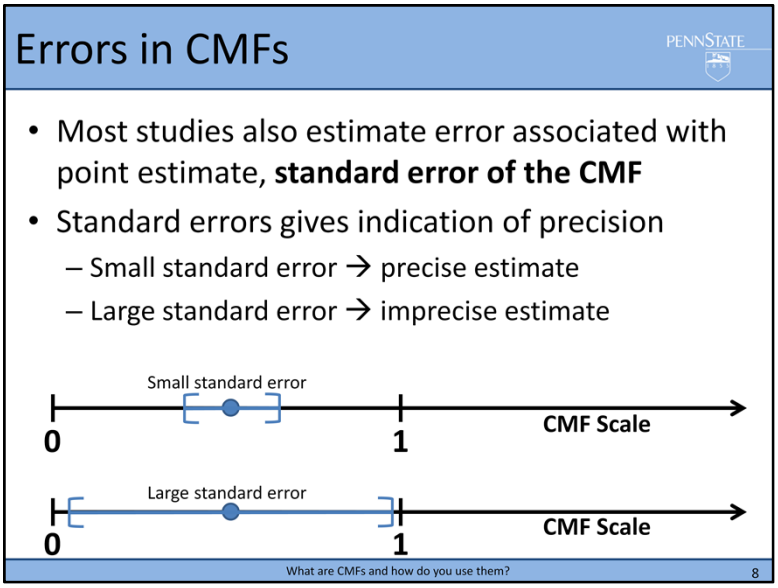


These estimation processes are NOT PERFECT. Because of variations in crash data and the fact that crashes are relatively infrequent events, the CMF values from the statistical models are usually associated with some error.

These errors may be due to:

- The type of statistical model (e.g., some modeling frameworks are more powerful and able to estimate the CMF more accurately than others)
- The amount of crash or treatment data used (e.g., a statistical study estimated from 2 years of crash data is often less accurate than a study estimated from 10 years of crash data. Likewise, CMFs estimated for a treatment that has only been implemented in a handful of locations is often less accurate than a treatment that has been implemented at many sites)
- Variation in the crash data used (e.g., crash data that has a lot of year-to-year or site-to-site variation is typically associated with more error than crash data with less variation).
- Crash data reporting (e.g., not all crashes are reported…therefore, only a subset of crash data are used to estimate the CMF)

(click) Because of this error, the CMFs estimated from these studies are typically a **POINT ESTIMATE** of how a change or countermeasure will impact safety performance. However, this estimate is subject to some amount of uncertainty. The true impact of the change or countermeasure is unknown and exists within some range of the value estimated by the statistical model. So looking back at our line graph, the CMF point estimate is just one value, while the true value of the CMF lies within some range around it **(click)**.



To help account for this, most studies not only provide the point estimate of the CMF but they also provide an estimate of the amount of error associated with the point estimate. This estimate of error is based on the type of statistical model used, amount of variation in the crash data, and amount of data. However, this error cannot account for the fact that the sample of crash data used might not reflect the true population of data.

We call this estimate of the error the **standard error of the CMF**. The standard error provides an indication of the precision of the CMF point estimate. CMFs that have a smaller standard error are much more precise than those with a larger standard error. Therefore, we should trust more in the studies with lower standard errors because we have more confidence about the true impact of the change or countermeasure associated with that CMF.

(click) To illustrate this, let us again look at the CMF scale and consider two CMFs with the same point estimate but different values for standard error. The smaller standard error is associated with a smaller range of values that might contain the actual impact of the countermeasure, whereas the larger standard error is associated with a larger range of values. If we wanted to use one of these CMFs for planning and engineering purposes, which one would we prefer? There is no doubt that the one with the smaller standard error is preferred because the point estimate is more likely to reflect the actual impact of the CMF.

Confidence interval for CMF

- Can combine point estimate and standard error to estimate range of possible impacts
- Estimate **confidence interval for CMF**
  - Range that the true CMF value should be contained within

$$Confidence\ Interval\ for\ CMF = CMF_i \pm Z * ERROR_i$$

- CMF_i – point estimate
- $ERROR_i$ – standard error
- Z – value associated with how certain you would like to be with your confidence interval

When applying CMFs in practice, we cannot ignore the potential errors that exist in the CMF point estimate.

The method we use to account for this error is to combine the point estimate and standard error together to estimate a range of possible impacts. This is done by estimating what is known as the **confidence interval for the CMF**. The confidence interval provides a range of values that contains the actual impact of the countermeasure subject to some probability. The more certain that we would like to be about the range of potential impacts, the larger the confidence interval becomes.

(click) The confidence interval is estimated using the following equation…

The value Z is associated with the level of certainty or confidence that we would like to have.

Confidence interval for CMF

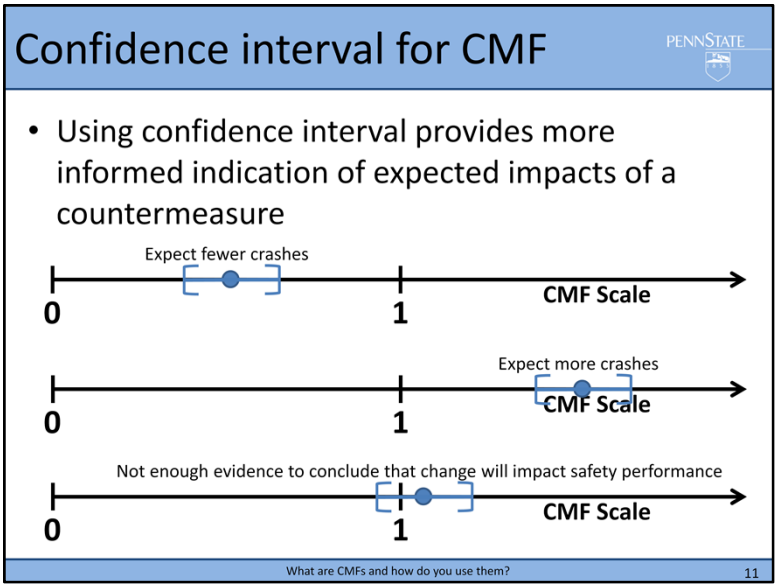
$$Confidence\ Interval\ for\ CMF = CMF_i \pm Z * ERROR_i$$

Type of confidence interval	Z value
90% confidence interval	1.64
95% confidence interval	**1.96**
99% confidence interval	2.58

Some Z values are provided here for typical confidence intervals used for safety applications. In general, the 95% confidence interval is the most widely used and accepted in practice. The others are provided as an example for how the Z value might change.

Let us consider the 95% confidence interval though, since it is the most common. When we create a 95% confidence interval, what we are saying is that we are 95% certain that the actual value of the CMF is obtained within the range specified. In this case, there is still a 5% chance that the true impacts is outside of this range so we are not 100% certain.

In general, we can never be 100% certain of the true impacts, which is why we do not list a Z value for the 100% confidence interval. If we wanted a 100% confidence interval, it would have to contain all possible values that the CMF can take (between 0 and infinity). This is because no matter how large our confidence interval is, there is always some chance (however small) that the true value is outside that range.



Using the confidence interval for the CMF helps to provide us with a better indication of how the change or countermeasure will impact crash frequency. When we were using only the point estimate, we compared that value to 1 to get an indication of the expected impact. When accounting for the errors that might exist, we compare the confidence interval to 1.

(click) If the CMF confidence interval is strictly less than one, we can be very confident that the change or countermeasure will reduce crash frequency. That is because even if the true value of the CMF is near the upper bound (UB) of the confidence interval, that value is still less than one.

(click) If the CMF confidence interval is strictly greater than one, we can be very confident that the change or countermeasure will increase crash frequency. That is because even if the true value of the CMF is near the lower bound (LB) of the confidence interval, the value is still greater than one.

(click) If the CMF confidence interval is includes one, then both possibilities exist: the countermeasure may reduce crash frequency or increase crash frequency. In this case, there is not enough evidence to conclude that the change or countermeasure will impact the safety performance. This is because the LB of the confidence interval is less than 1 (indicating that there is a significant chance the true value of the CMF is less than one) while the UB of the confidence interval is greater than one (indicating that there is a significant chance the true value of the CMF is greater than one).

Errors in CMFs

- If no standard error provided:
  - Confidence interval cannot be determined
  - Application of the CMF will not be reliable
  - Use other CMFs, if available

Unfortunately, there are many CMFs for which no standard error is provided. This could be due to the type of model used (and generally occurs when poorer study designs are used).

In these cases, confidence intervals for the CMFs cannot be determined and the analyst has no indication with the level of uncertainty associated with the CMF estimate.

These CMFs are not very reliable and should be avoided if at all possible. Instead, other CMFs should be used if they exist. If other CMFs do not exist, the point estimate can give a very naïve indication of the expected impacts but it should not be directly applied for modeling and estimation purposes since the analyst has no indication of the level of uncertainty involved.

(refer back to plot on slide 7)

Applying CMFs

- Each CMF value applies to a certain set of conditions
  - Area type
  - Crash type
  - Crash severity
  - Roadway volumes
  - Others
- Example:
  - **Improperly defined:** CMF for edgeline rumble strips
  - **Properly defined:** CMF for edgeline rumble strips on fatal run-off-the-road crashes on two-lane rural roads

Because CMFs are estimated using reported crash data, each only applies to a very specific set of conditions based on the type of data used in the estimation. These conditions can include the following:

- Area type: urban, suburban, rural
- Crash type: all, rear-end only, angle-only, etc
- Crash severity: all, fatality, major injury, minor injury, PDO
- Roadway volumes: typically measured in AADT
- Others: these include roadway geometry (e.g., number of lanes or number of legs at an intersection), traffic control (e.g., speed limit or type of intersection control), etc.

Therefore, the CMFs provided are usually very specific. **(click)** two examples are provided that show a properly defined CMF and an improperly defined CMF. In the former, the analyst has no idea on what types of crashes are affected and other conditions for which the CMF can be applied. The latter is more appropriate, because it outlines the limitations and domain of application for the CMF. The example for the properly defined CMF includes all possible attributes that might be considered in a CMF…crash type, crash severity, area type. Often some of the attributes are missing…e.g., CMF for edgeline run-off-the-road crashes for edgeline rumble strips on two-lane rural roads. In this case, we can either 1) try be more specific about the crash severity; or 2) assume that the CMF refers to all crash severities.

Applying CMFs

- Reasons for set of conditions
  - Countermeasure only impacts specific subset of crash types
  - Countermeasures have different impacts in different driving environments
  - CMFs estimated with only a certain type of reported crash data
- CMFs should NOT be directly applied to other conditions
- Can serve as a guide along with engineering judgment

There are several reasons that CMFs are defined for a narrow set of conditions.

- Often, specific countermeasures are only intended to impact a subset of crashes. For example, edgeline rumble strips are primarily used to reduce run-off-the-road crashes in rural areas. However, this countermeasure is not expected to reduce other types of crashes, like rear-end crashes. Therefore, the CMF is typically defined for this crash type alone and when it is defined in this way it should only be applied to run-off-the-road crashes.
- The effect of some countermeasures changes depending on the environment in which it is applied. For example, intersection treatments can have vastly different impacts depending on the intersection configuration and type of control at the intersection.
- Sometimes only a specific subset of crash data are available. For example, fatal crashes are more consistently and carefully reported than other crash types and might often be the only type of crash information available. CMFs estimated using fatal crash data alone, however, should not be applied to different crash severities like PDO.

Therefore, CMFs should only be applied to the conditions that are specified and should NOT be applied directly to other conditions!
In cases where CMFs do not exist for a specific set of conditions, CMFs for similar conditions can serve only as GUIDE for the potential impacts. However, proper engineering judgment should also be applied in these cases.

Example problem scenario

- 4-leg, signalized intersection
- Frequent red-light running violations
- 12.4 crashes per year expected
  - 50% angle
  - 30% rear-end
  - 20% other

We will now use an example problem to demonstrate how to apply CMFs.

Our example will focus on a four-leg, signalized intersection located in a downtown region. Historical and anecdotal evidence suggests this location experiences frequent red-light running violations and about 50% of all crashes are angle crashes within the intersection footprint associated with these events. The remaining crashes are rear-end crashes on the intersection approaches (30%) and crashes of unknown type (20%). It is expected that crash frequency at this location will be 12.4 crashes per year if no countermeasures are applied.

Example problem 1

- Countermeasure: red-light running cameras
  - CMF for angle crashes
    - Point estimate = 0.75
    - Standard error = 0.03
  - CMF for rear-end crashes
    - Point estimate = 1.15
    - Standard error = 0.04

Our first problem considers the implementation of red-light running cameras as a countermeasure. Two CMFs are available for red-light running cameras…one for angle crashes and the other for rear-end crashes. Both apply to all crash severities. Since the severities are not specified in our problem, we will assume that the previous crash values represent all crash severities.

The point estimates and standard errors for the crash types are provided here.

We would like to know the following:

How many angle crashes are expected after the implementation of the red-light running cameras?

How many rear-end crashes are expected after the implementation of the red-light running cameras?

Example problem 1

Angle crashes after countermeasure

- CMF point estimate < 1
  - Safety benefit
- 95% CI for point estimate
  - $0.75 \pm 1.96(0.03) = 0.69 - 0.81$
  - Safety benefit
- 99% CI for point estimate
  - $0.75 \pm 2.58(0.03) = 0.67 - 0.83$
  - Safety benefit

Let's start with angle crashes.

(click) We first note that we expect some sort of safety benefit from angle crashes since the point estimate is < 1. But to be really sure, we first need to compute the confidence interval for the CMF point estimate.

(click) The 95% confidence interval is computed first.

(click) If we wanted, we can compute other confidence intervals. For example, the 99% confidence interval is provided here. Note, however, that the 95% CI is the most prevalent for practical applications.

Both suggest that there should be a safety benefit for angle crashes when implementing red-light running cameras in urban regions since the CIs are strictly less than one.

Example problem 1

Angle crashes after countermeasure

- Expected angle crashes = $0.5(12.4) = 6.2$ crashes per year

$$Expected\ number\ of\ crashes\ if\ change\ i\ is\ made = CMF_i * Expected\ number\ of\ crashes\ if\ change\ i\ is\ not\ made$$

- Expected value after countermeasure
  - Not accounting for error:
    $6.2(0.75) = 4.7$ crashes per year
  - Accounting for error:
    95% LB: $6.2(0.69) = 4.3$ crashes per year
    95% UB: $6.2(0.81) = 5.0$ crashes per year
    95% CI: $4.3 - 5.0$ crashes per year

We now use these values to calculate the number of crashes expected.

Since the CMF applies to angle crashes only, we need to calculate the number of angle crashes expected.

(click) Then, we calculate the number of angle crashes expected after the implementation of the countermeasure.

(click) First, we do so without accounting for the error associated with the CMF point estimate.

However, this is not as informative as calculating the expected number of crashes while accounting for the error that might exist.

(click) To do this, we calculate the LB and UB for expected number of crashes based on the LB and UB of the CMF point estimate provided by the CI.

This provides a CI for the expected number of angle crashes after the implementation of the countermeasure. In practice, we should always report the confidence interval for expected crash frequency whenever possible to give an indication of the level of uncertainty associated with it.

Example problem 1

Rear-end crashes after countermeasure

- CMF point estimate > 1
  - Safety disbenefit
- 95% CI for point estimate
  - $1.15 \pm 1.96(0.04) = 1.07 - 1.23$
  - Safety disbenefit

To reinforce these concepts, let us repeat the process for rear-end crashes.

(click) Notice that the CMF point estimate and CI are both greater than one. This suggests that the countermeasure is expected to *increase* crashes after implementation and provides an overall safety disbenefit.

(click) Is this reasonable? Given the countermeasure, yes we can expect that rear-end crashes would increase when implementing red-light running cameras! Why? Vehicles will be more likely to stop during the yellow period and this might not be expected by following vehicles.

Example problem 1

Rear-end crashes after countermeasure

- Expected rear-end crashes = $0.3(12.4) = 3.7$ crashes per year

$$Expected\ crash\ frequency\ if\ change\ i\ is\ made = CMF_i * Expected\ crash\ frequency\ if\ change\ i\ is\ not\ made$$

- Expected value after countermeasure
  - Not accounting for error:
    $3.7(1.15) = 4.3$ crashes per year
  - Accounting for error:
    95% LB: $3.7(1.07) = 4.0$ crashes per year
    95% UB: $3.7(1.23) = 4.6$ crashes per year
    95% CI: $4.0 - 4.6$ crashes per year

The same logic as before can be used to estimate the number of rear-end crashes expected.

First, calculate the number of rear-end crashes expected before the implementation of the countermeasure.
(click) Then calculate the expected number of crashes using the CMF point estimate.

(click) The LB and UB of the confidence interval can then be used to estimate a confidence interval for the number of crashes as well.

Again, remember we report the confidence interval for the crash frequency when we can calculate it.

Applying multiple CMFs

- If multiple countermeasures considered at the same location, need to consider their combined effects
- Two scenarios exist:
  - CMFs impact different crash types
  - CMF impact same crash types

The previous slides describe how to apply a single CMF at a time.
Often, however, we must apply multiple CMFs simultaneously at the same location. Now we will discuss the factors that must be considered when applying multiple CMFs simultaneously and how to apply them.

When multiple CMFs are considered, there are two scenarios that might exist.
- The first is that the CMFs impact different crash types
- The second is that the CMFs impact the same crash types.

Applying multiple CMFs

CMFs impact different crash types

- Occurs when:
  - Single countermeasure with CMFs for multiple crash type/severity combinations
  - Multiple countermeasures that each impact a different type of crash
- CMFs treated independently – each is applied directly to the respective crash type impacted
  - Same methods used as before when estimating expected crashes by type

Let's first consider the simpler case in which the CMFs impact different crash types. This could occur if:

- one countermeasure is implemented that has multiple CMFs for different crash types or
- if multiple countermeasures exist and each influences a different crash type.

In this case, each CMF is treated independently and applied directly to the respective crash type that it impacts. This is done using the same methods as before, assuming the other CMFs did not exist, to generate estimates of expected crash frequency by individual crash type.

Our previous problem was actually an example of this. We estimated the number of angle crashes and rear-end crashes using two CMFs for the same intersection. The estimates are correct because there was no overlap in the crash type that was impacted by each CMF.

Applying multiple CMFs

CMFs impact different crash types

- Cannot sum individual CIs to get CI for total crashes
  - Randomness reduces as we aggregate crash counts
- Confidence interval for total crashes is:

$$\sum_i N_i CMF_i \pm Z * \sqrt{\sum_i (N_i ERROR_i)^2}$$

- CMF_i – point estimate of CMF for crash type i
- $ERROR_i$ – standard error of CMF for crash type i
- N_i – expected number of crashes (before countermeasure) for crash type i
- Z – value associated with how certain you would like to be with your confidence interval

However, an interesting question that we might ask is: using these estimates for the individual crash frequencies, how do we get an estimate of the total crash frequency?

One might think that we can simply add together the multiple individual confidence intervals—i.e., add the different LBs to get an overall LB, and add the different UBs to get an overall UB. However, this turns out to greatly overestimate the CI for total crashes. The reason is simple: when we aggregate random variables, the overall variation reduces. Another way to look at it is that the randomness in estimates of individual crash type estimates might cancel each other out when we start adding them together to estimate the total number of crashes.

(click) To account for this, we estimate the CI for the total number of crashes using the simple formula provided here.
This formula accounts for the reduction in variation that is achieved when aggregating the different confidence intervals together.

Example problem 2

- Countermeasure: red-light running cameras
  - CMF for angle crashes
    - Point estimate = 0.75
    - Standard error = 0.03
  - CMF for rear-end crashes
    - Point estimate = 1.15
    - Standard error = 0.04
  - CMF for other crashes
    - Point estimate = 0.74
    - Standard error = 0.03

Let's now expand our example slightly and try this methodology for applying multiple CMFs simultaneously.

(click) Suppose now that we have found a third CMF for the "other" crash type. This takes care of the three crash types expected at our hypothetical intersection.

Now the question we want to ask is, how many TOTAL crashes are expected at this intersection.

Example problem 2

Total crashes after countermeasure

- Since a single countermeasure with CMFs for multiple crash types
  - Treat all impacts as independent

$$95\%\ \mathrm{CI} = \sum_i N_i CMF_i \pm Z * \sqrt{\sum_i (N_i ERROR_i)^2}$$

- 95% CI: $6.2(0.75) + 3.7(1.15) + 2.5(0.74)$ $\pm 1.96 * \sqrt{(6.2 * 0.04)^2 + (3.7 * 0.03)^2 + (2.5 * 0.03)^2}$ $= 10.8 \pm 0.6 = 10.2 - 11.4$ crashes per year

We know that the formula just presented is valid because we have a single countermeasure that has CMFs for multiple crash types. Therefore, we can treat these all independently and apply the formula…

(click) The result stems exactly from the equation.

Example problem 2

Final summary of CIs

- Angle: $4.3 - 5.0$ crashes per year
- Rear-end: $4.0 - 4.6$ crashes per year
- Other: $1.7 - 2.0$ crashes per year

- ~~Adding CIs: $10.0 - 11.6$ crashes per year~~

- Total: $10.2 - 11.4$ crashes per year

Let's take a look at the results for the individual crash types and the total number of crashes.

We didn't do the "other" crash type together but I have left that for each of you to do on your own to verify the results….

(click) Now what happens when we add the CIs . Notice it is crossed out because it is wrong!

(click) Compare to the previously calculated CI.

Notice though that the CI obtained from the equation is smaller than obtained by adding the individual CIs. This is not a calculation/rounding error either, this is a consistent result that will be obtained whenever this equation is used and is the correct way to perform this calculation.

Applying multiple CMFs

CMFs impact same crash types

- In this case, must decide whether the multiple countermeasures act:
  - Independently
    - Effects not expected to overlap
    - Full effects of each countermeasure expected
  - Dependently
    - Overlapping effects
    - Combination of countermeasures might make each less (or more) effective

Now let's consider the more complicated case in which the CMFs impact the same crash types. This can only occur when multiple countermeasures are applied simultaneously at the same location.

There are two sub-cases to consider in this situation.
- the countermeasures act independently
- The countermeasures act non-independently

We select independent if we assume that the effects of each countermeasure do not overlap (i.e., the presence of one of the countermeasures does not make the impacts of the other better or worse than if it were applied by itself). In this case, the full effects of each countermeasure (implemented independently) are expected when applied simultaneously.

We select dependent if we assume that there are some overlapping effects (so if the presence of one countermeasure might enhance or diminish the impacts of the other). In this case, the combined effects might be less (or more) effective than if applied separately. We now examine how to deal with these two cases.

Applying multiple CMFs

CMFs impact same crash types

- Independent countermeasures (less conservative):
  - Combined effects is the product of individual CMFs

$$CMF_C = \prod_i CMF_i,$$

  - CMF_i – point estimate of individual CMF i
  - CMF_C – point estimate of combined CMFs
  - Standard error for combined CMF:

$$ERROR_C = \sqrt{\prod_i \left(CMF_i^2 + ERROR_i^2\right) - \left(\prod_i CMF_i\right)^2}$$

  - $ERROR_i$ – standard error of individual CMF i
  - $ERROR_C$ – point estimate of combined CMFs
  - Combining more than 3 CMFs in this way will overestimate impacts

If the two countermeasures are treated as independent, the full effects of each should be observed. This is the less conservative approach since we expect the full impacts of each.

(click) In this case, the combined impact of the application of these multiple countermeasures simultaneously is given by the product of the individual CMFs.

(click) The standard error of the combination of multiple CMFs is not so straightforward. For some of the reasons previously mentioned, the errors of the individual CMFs become smaller than the sum of the individual errors when aggregated. This combined error can be calculated using the following formula.

(click) Note that in general one should be very conservative when applying multiple CMFs in this way since countermeasures are not likely to be independent in practice. Combining more than 3 CMFs in this way is expected to overestimate their impacts. Therefore, this methodology should not be used when 3 or more CMFs are required. Instead, a more conservative approach might be considered (such as just selecting three of CMFs to apply). Note that this does NOT mean more than 3 COUNTERMEASURES should be applied simultaneously. It only applies to how we estimate their effects.

Applying multiple CMFs

CMFs impact same crash types

- Dependent countermeasures (more conservative):
  - Use only single CMF:
    - most beneficial countermeasure if all provide safety benefit
    - least beneficial countermeasure if one or more provides negative safety impacts
  - Equivalent to worst-case analysis
  - Select value near lower bound of confidence interval if some additional benefits expected by combination of countermeasures

If the two countermeasures are treated as dependent, then the effects would be enhanced or diminished by being applied in combination.

Unfortunately, not much work has been done on this topic so little is known about the combined impact of dependent countermeasures. Therefore, the best practice is to be as conservative as possible. In this case, the conservative approach is to do one of the following…either:

- Use the single CMF for the most effective countermeasure if both provide a benefit
- Use the single CMF of the least beneficial countermeasure if one or more provides a disbenefit (is expected to increase crash frequency)

These conservative assumptions ensure that we do not overstate the combined impacts and underpredict the crash frequency by actually examining the worst-case scenario.

If the combination of the countermeasures is expected to provide some benefit over the use of just the single countermeasure, then a value near the lower bound of the confidence interval could be selected to account for these combined effects. However, this requires that the analyst exercise careful engineering judgment.

Example problem 3

- Original countermeasure: red-light running cameras
  - CMF for rear-end crashes
    - Point estimate = 1.15
    - Standard error = 0.04
- Second countermeasure: replace incandescent signal bulbs with LEDs
  - CMF for rear-end crashes
    - Point estimate = 0.827
    - Standard error = 0.036

Let us now apply this to our example problem.

We previously saw that the implementation of red-light running cameras would increase the expected rear-end crash frequency at our hypothetical intersection. **(click)** In an effort to alleviate this, another countermeasure is considered: the replacement of traditional incandescent bulbs at the signal with LEDs. A CMF exists with the properties shown for rear-end crashes in urban areas for this countermeasure.

Assuming that red-light running cameras and the installation of LED traffic signals are independent, how many rear-end crashes should be expected after their implementation?

Assuming that the two countermeasures are dependent, how many rear-end crashes should be expected after their implementation?

What is the most appropriate estimate to use?

Example problem 3

Rear-end crashes assuming independence

$$CMF_C = \prod_i CMF_i,$$

- Combined CMF point estimate = $1.15(0.827) = 0.951$

$$ERROR_C = \sqrt{\prod_i \left(CMF_i^2 + ERROR_i^2\right) - \left(\prod_i CMF_i\right)^2}$$

- Combined CMF standard error = $\sqrt{(1.15^2 + 0.04^2)(0.827^2 + 0.036^2) - (1.15^2 + 0.04^2)} = 0.053$
- 95% CI: $0.951 \pm 1.96(0.053) = 0.85 - 1.05$

First, let's assume that the two countermeasures are independent and that the full effects of each are experienced.

In this case, we can apply the formulas to predict the combined impact on rear-end crashes…

(click) First calculate the combined CMF point estimate.

(click) Then the combined standard error.
(click) Finally, use this to get the CI for the combined CMF.

Example problem 3

Rear-end crashes assuming independence

- 95% CI: $0.951 \pm 1.96(0.053) = 0.85 - 1.05$
  - CI includes 1
  - No statistically significant change in crashes expected
- Accounting for error:
  95% LB: $3.7(0.85) = 3.1$ crashes per year
  95% UB: $3.7(1.05) = 3.9$ crashes per year
  95% CI: $3.1 - 3.9$ crashes per year

Note that the CI includes 1. Therefore, there is not enough evidence to suggest the combined impacts of the two countermeasures will affect safety performance.

(click) Using the CI for the CMF, we can also get a CI for the expected crashes.

Example problem 3

Rear-end crashes assuming dependence

- Since one countermeasure increases crashes, apply only that value
- 95% CI for point estimate
  - $1.15 \pm 1.96(0.04) = 1.07 - 1.23$
- 95% CI for crashes: $1.07(3.7) - 1.23(3.7) = 4.0 - 4.6$ crashes per year
- Since combination of countermeasures should provide some benefit, value near the LB would be appropriate

Let's now repeat assuming there is some dependence. In this case, we will make the most conservative assumption that only one CMF should be applied. Since one CMF suggests a safety disbenefit (red-light enforcement cameras), we apply that CMF.

Note that we already found the CI for this CMF and the expected crashes using this CMF.

Since in reality we would expect SOME positive benefit from applying the two, we should expect a number of crashes closer to the LB.

Example problem 3

Most appropriate estimate for rear-end crashes

- Assuming independence
  - 95% CI: $3.1 - 3.9$ crashes per year
- Assuming dependence
  - 95% CI for crashes: $4.0 - 4.6$ crashes per year
- Two CIs nearly overlap

- In reality, some combined effects expected
  - Select a value near the intersection of CIs
  - ≅3.9 crashes per year

So a question we might ask in practice is: what is the most appropriate estimate for rear-end crashes?

Let's compare the two solutions. In general, an analyst should present both cases and then suggest a value that he/she finds most reasonable. In this case, we see that the two methods provide nearly overlapping CIs for rear-end crashes.

To determine the most appropriate value, we need to think about these countermeasures being applied. Red-light running cameras will make vehicles in the dilemma zone more likely to stop at the signal, which we expect to increase crash frequency. Installing LED traffic signals would improve the visibility of the signal and might make drivers more aware of the downstream signal. This would make them more likely to stop when the signal is changing intervals. However, this latter countermeasure is typically used in areas with poor visibility. Since we know nothing about the visibility here, we cannot really expect the full effects of this countermeasure to occur, especially in conjunction with the red-light enforcement cameras. Therefore, the assumption of independence might be too liberal and we should go with the more conservative approach.

Therefore, a value near the LB of the conservative (dependent) approach might be appropriate.

Pennsylvania CMF Guide

- The *Pennsylvania CMF Guide* provides list of high-quality Crash Modification Factors appropriate for use in Pennsylvania
- Obtained mainly from FHWA CMF Clearinghouse website, www.cmfclearinghouse.com

So now that we know how to apply CMFs once we have them, we would like to introduce the *Pennsylvania CMF Guide*

This guide provides a list of high-quality CMFs that have been estimated in the literature and are deemed as appropriate for use in PA.

These CMFs were obtained from previous studies that have been documented in the research literature. The team that developed this guide examined multiple sources, although most of the CMFs came from the FHWA CMF Clearinghouse. Other sources include: AASHTO Highway Safety Manual, FHWA Toolboxes for Safety Countermeasures, and research studies.

Assessing CMF quality

- Use rating system proposed by CMF Clearinghouse
- Each CMF assigned score from 1 (worst) to 5 (best) stars based on:
  - Study design
  - Sample size
  - Standard error
  - Potential bias
  - Data source
- Only 3+ star CMF included in guide and suitable for use in PA

We mentioned that the guide contains only high-quality CMFs. To determine the quality of each CMF, we employed the rating system developed by the CMF Clearinghouse. In this system, each CMF is given a star rating between 1 and 5, where 1 is the worst and 5 is the best. This rating is based on five characteristics of the CMFs:

- Study design (which we talked about earlier)
- Sample size (number of crashes / locations considered)
- Standard error of the CMF (lower is better)
- Potential for bias in the estimates (perhaps due to data collection or other factors that might yield an inaccurate measure)
- Data source (small geographic region vs. large geographic region)

Only CMFs rated a 3-star or higher are included in the guide. However, the guide contains a list of low quality CMFs and their sources for countermeasures that did not have higher-quality CMFs. This can provide an analyst with a reference if they are interested in these particular countermeasures. However, we do not recommend that these lower-quality CMFs be applied for safety applications in PA.

Using the CMF Tables

- CMFs categorized into 19 tables
  - Access Management
  - Advanced Technology and ITS
  - Alignment
  - Bicyclists
  - Delineation
  - Highway Lighting
  - Interchange Design
  - Intersection Geometry
  - Intersection Traffic Control
  - On-Street Parking
  - Pedestrians
  - Railroad Grade Crossings
  - Roadside Features
  - Roadway Features
  - Shoulder Treatments
  - Signs
  - Speed Management
  - Transit
  - Work Zones

The CMF guide is split into 19 tables…the categorization used here is the same as provided by the FHWA CMF Clearinghouse. This was done for consistency and to help an analyst look up the CMF in the clearinghouse if more detailed information is desired (e.g., if the analyst wants to find the exact reference that the CMF came from).

Note that individual countermeasures are not duplicated across tables and an analyst might have to check multiple tables to find a specific countermeasure. For example, CMFs for countermeasures at intersections with rail crossings can be found in both the table for Intersection Traffic Control and Railroad Grade Crossings.

Using the CMF Tables

- Each table provides information on the conditions for which the CMF applies, which include:
  - Roadway/area type
  - Crash type
  - Crash severity
  - Level of traffic (AADT)
  - Other implementation notes
- CMFs should only be directly applied to the **same conditions**
- CMFs might serve as a guide for other conditions

The CMF tables are organized as follows:
They contain the name of the countermeasure, the conditions for which it applies, the point estimate and standard error, the star-rating and finally the states for which crash data were obtained to estimate the CMF.

The conditions are broken into five categories as shown here. The only one that might not be self explanatory is “Other implementation notes”. This contains countermeasure specific information that might influence where the CMF could be applied. Examples include: intersection types, number of lanes, speed limits, etc.

As discussed previously, the CMFs should only be applied to the SAME CONDITIONS as listed in the table.

Using the CMF Tables

Countermeasures	Area Type	Crash Severity	Crash Type
Install shoulder rumble strips	Urban	All	Run-off-road
		Fatal and injury	Run-off-road
Install continuous milled-in shoulder rumble strips	All	All	Run-off-road,Single vehicle
		Injury	Run-off-road,Single vehicle
	Rural	All	All
			Run-off-road,Single vehicle
		Injury	All
			Run-off-road,Single vehicle

AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
		0.82		3	notusa
180 - 92757		**1**	**0.0556**	**3**	**MN,MO,PA**
		0.82	0.12	3	
		0.21	0.07	4	
		0.87	0.21	3	
2000 - 50000		0.84	0.13	3	
2000 - 50000		0.9	0.25	3	
		0.79	0.18	3	
2000 - 50000		0.83	0.19	3	
2000 - 50000		0.78	0.33	3	
		0.93	0.28	3	

- Highlighted: recommended values
- **Bolded**: values estimated using PA data

What are CMFs and how do you use them? 39

Shown here is a portion of the CMF table. Note that it is broken to fit on the slide.

Notice the organization is as mentioned previously. For these CMFs, there are no “notes”.

(click) The highlighted values are provided whenever multiple CMFs exist for the same conditions. These highlighted values are the values that are recommended for use in PA. The other values are provided to show the range of potential values as another indication of the uncertainty associated with the CMF.

(click) You might also notice that some values are bolded (the one with AADT 180-92757). These bolded values represent that the CMF was estimated using PA data. Note that the ones estimated with PA data are not always the “best” values as CMFs estimated from a larger geographic region and from more crash data might be more precise. However, this is provided in case the analyst would prefer to use a PA-specific CMF.

Example problem 4

Use the tables to obtain CMFs discussed here

- Red-light enforcement cameras
  - Table B. Advanced Technology and ITS
  - 2 CMFs for angle crashes, use recommended value
    - Point estimate = 0.75
    - Standard error = 0.03
  - 3 CMFs for rear-end crashes, use recommended value
    - Point estimate = 1.15
    - Standard error = 0.04
- Replacement of incandescent signal bulbs with LEDs
  - Table I. Intersection Traffic Control
  - 2 CMFs for rear-end crashes, use recommended value
    - Point estimate = 0.827
    - Standard error = 0.036

We will now use the tables to look up the values obtained here.

(click) Red-light enforcement cameras is in Table B.
We have the following conditions: urban areas, all severities.
(click) For angle crashes, two CMFs exist. We should use the recommended value.
(click) For rear-end crashes, three CMFs exist. We should use the recommended value.

(click) Replacement of incandescent signal bulbs is in Table I.
We have the following conditions: urban areas, all severities, rear-end crashes and 4-leg intersections.
Two CMFs exist. We should use the recommended value.

Note that none of these recommended values are estimated using PA crash data. In fact, for these two countermeasures CMFs from PA-specific data has never been estimated.

Example problem 5

Using CMFs to compare alternatives

- Two-lane rural roadway segment
- Run-off-the-road crashes of all severities considered
- Potential treatments:
  - Continuous milled-in shoulder rumble strips
  - Safety edge treatment

Last problem…

Consider the following conditions:
Two-lane rural roadway segment
Run-off-the-road crashes of all severities (since severity is not specifically mentioned)

Two treatments for consideration:
- Continuous milled-in shoulder rumble strips
- Safety edge treatment

Example problem 5

Determine appropriate CMFs

- Continuous milled-in shoulder rumble strips
  - Table O. Shoulder treatments
  - 2 CMFs for given conditions, use recommended value
    - Point estimate = 0.79
    - Standard error = 0.18
- Safety edge treatment
  - Table O. Shoulder treatments
  - 9 CMFs for given conditions, use recommended value
    - Point estimate = 0.937
    - Standard error = 0.057

To obtain the appropriate CMFs, we must use the CMF tables…

(click) For continuous milled-in shoulder rumble strips, use that specific countermeasure (note: shoulder rumble strips exist but the type isnt specified so let's use the type that we were specifically given)
Two CMFs exist, use the recommended value

(click) For safety edge, 9 CMFs given. Use the recommended value.

Example problem 5

Largest expected reduction in crashes

- Continuous milled-in shoulder rumble strips
  - Point estimate = 0.79
  - Expected percent reduction in crashes: $100(1 - 0.79) = 21\%$
- Safety edge treatment
  - Point estimate = 0.937
  - Expected percent reduction in crashes: $100(1 - 0.937) = 6.3\%$

For the expected change in crash frequency, we can use the point estimate and convert the CMF to the percent reduction in crashes

(click) first for rumble strips
(click) then for safety edge

Shoulder rumble strips provide a much larger expected reduction in crash frequency than safety edge. Thus, if we were only focused on expected reduction in crash frequency we would choose the continuous milled-in shoulder rumble strips

Example problem 5

Largest expected reduction in crashes

- Continuous milled-in shoulder rumble strips
  - Point estimate = 0.79
  - Standard error = 0.18
  - 95% CI for CMF point estimate: $0.44 - 1.14$
  - Worst-case percent reduction in crashes: $100(1 - 1.14) =$ -14%
- Safety edge treatment
  - Point estimate = 0.937
  - Standard error = 0.057
  - 95% CI for CMF point estimate: $0.83 - 1.05$
  - Expected percent reduction in crashes: $100(1 - 1.05) =$ -5%

Now, we are concerned with the worst case scenario. To examine the worst case, we would need to also consider the errors associated with these point estimates.

(click) first for rumble strips. We calculate the 95% CI for the CMF. Which value would provide the "worst-case"? The higher value since larger numbers are associated with more crashes. Then, we examine the percent reduction in crashes associated with this value. **(click)** Repeat the same for the safety edge. From this, we can see that the safety edge provides a best "worst-case" than the continuous milled-in shoulder rumble strips. Therefore, if we were only focused on the worst-case performance and wanted to minimize crash frequency for this case, we might consider the safety edge treatment.

Questions?

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Appendix B: Example Problems Demonstrating the CMF Procedure

Scenario:

Our first four examples focus on a four-leg, signalized intersection located in a downtown region. Historical and anecdotal evidence suggests this location experiences frequent red-light running violations and about 50% of all crashes are angle crashes within the intersection footprint associated with these events. The remaining crashes are rear-end crashes on the intersection approaches (30%) and crashes of unknown type. It is expected that crash frequency at this location will be 12.4 crashes per year if no countermeasures are applied.

Problem 1:

Red-light enforcement cameras are being considered to reduce total crash frequency at this location. Two CMFs are available for red-light enforcement cameras in urban areas. The CMF for angle crashes has a point estimate of 0.75 and a standard error of 0.03, while the CMF for rear-end crashes has a point estimate of 1.15 and a standard error of 0.04.

a) *How many angle crashes are expected after the implementation of the red-light enforcement cameras?*
b) *How many rear-end crashes are expected after the implementation of the red-light enforcement cameras?*

Problem 2:

A third CMF exists for other crash types, which has a point estimate of 0.74 and a standard error of 0.03.

How many total crashes are expected after the implementation of red-light enforcement cameras?

Problem 3:

Signal bulb replacement is also being considered to reduce the additional rear-end crashes that will occur with the implementation of red-light enforcement cameras. The countermeasure would replace existing incandescent traffic signal bulbs with LEDs. A CMF for applying this strategy in urban environments for rear-end crashes has a point estimate of 0.827 and a standard error of 0.036.

a) *Assuming that red-light enforcement cameras and the installation of LED traffic signals are independent, how many rear-end crashes should be expected after their implementation?*
b) *Assuming that the two countermeasures are dependent, how many rear-end crashes should conservatively be expected after their implementation?*
c) *What is the most appropriate estimate to use?*

Problem 4:

Use the CMF tables to obtain the CMF point estimate and standard error for the installation of red-light enforcement cameras and the replacement of incandescent signal bulbs with LEDs for rear-end, angle and other crashes in urban areas for all crash severities.

Problem 5:

Two countermeasures are being considered to reduce run-off-the-road crashes of all severities on a two-lane rural roadway segment. The first is the installation of continuous milled-in shoulder rumble strips. The second is the installation of a safety edge treatment.

a) *What are the appropriate CMFs to use for each of these two treatments?*
b) *Which treatment is expected to provide the largest reduction in crashes?*
c) *For which treatment is the worst-case performance expected to be the worst?*

Appendix C: *Pennsylvania CMF Guide*

PENNSYLVANIA CMF GUIDE

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Introduction

The American Association of State Highway and Transportation Officials' (AASHTO) *Highway Safety Manual* (HSM) is transforming the way state and local transportation agencies manage road safety. In addition to providing an overview of many aspects of road safety management, the manual contains a process for evaluating the effectiveness of alternative safety countermeasures based on previous research.

A critical factor in the use of the HSM safety management process is the Crash Modification Factor (CMF). It is used to estimate the change in the expected (average) number of crashes at a site when a specific countermeasure is implemented. This guidebook responds to a request from the Pennsylvania Department of Transportation (PennDOT) to review the existing CMF literature and make recommendations concerning their use in Pennsylvania. The purpose of this guide is to provide a list of CMFs that are appropriate for use when estimating the safety performance of changes on the highway and street network in Pennsylvania, and to demonstrate how to apply them appropriately. The list of CMFs was compiled by reviewing the relevant literature and identifying high-quality CMFs that might be applicable to Pennsylvania roadways. In compiling this list, the following sources were reviewed:

- Federal Highway Administration (FHWA), CMF Clearinghouse website;
- AASHTO *Highway Safety Manual*;
- FHWA *Desktop Reference for Crash Reduction Factors* (Report FHWA-SA-08-011);
- Governors Highway Safety Association (GHSA), *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices*;
- FHWA Office of Safety, *Proven Safety Countermeasures*;
- FHWA *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes*;
- FHWA *Roadway Departure Countermeasures*;
- *Crash Reduction Factors for Traffic Engineering and Intelligent Transportation Systems (ITS) Improvements: State-of-Knowledge Report* (NCHRP Research Results Digest 299); and
- Recently published research literature.

The complete list of CMFs is summarized in a set of tables provided at the end of this document. For countermeasures not provided in these tables, or that were added to the FHWA CMF Clearinghouse after publication of this document, the reader can refer to the FHWA CMF Clearinghouse website (http://www.cmfclearinghouse.org/), which contains the most up-to-date database of CMFs. It is important to note that the FHWA CMF Clearinghouse contains both high- and low-quality CMFs; however, only high-quality CMFs are recommended for application within Pennsylvania. The determination of high-quality CMFs is discussed in the section of this guide titled "Assessing the Quality of a CMF." A list of low-quality CMFs and their values are also provided at the conclusion of this guide to provide documentation concerning their use. However, because these CMFs are based on either a small sample size, or suffer from a low-quality methodological evaluation, these CMFs are not recommended for use in Pennsylvania.

The rest of this document is organized into five sections. The first section describes what a CMF is and how it is estimated. The next section includes information about how to apply a single CMF to estimate the expected safety performance from a highway improvement or implementation of a countermeasure. Next, a methodology to apply multiple CMFs at a single location is described. The process used to

determine the quality of a CMF is described in the subsequent section. The last section of this report includes a description of the CMF tables, which are provided at the end of the guide.

What is a CMF?

As defined by the *Highway Safety Manual*, a CMF is "an index of how much crash experience is expected to change following a modification in design or traffic control" at a particular location. Each CMF is a numerical value that provides the ratio of the expected number of crashes over some unit of time after a change is made to the expected number of crashes for the same time period had the change not been made. Equation 1 shows how the ratio is applied to develop a CMF for a particular countermeasure i:

$$CMF_i = \frac{Expected\ number\ of\ crashes\ if\ change\ i\ is\ made}{Expected\ number\ of\ crashes\ if\ change\ i\ is\ not\ made}. \qquad \text{(Equation 1)}$$

The percent crash reduction associated with countermeasure i is $(1 - CMF_i) * 100\%$.

The true value of the CMF for any countermeasure will always be unknown. The reported value is only an estimate of the true value obtained from a statistical analysis of reported crash data. This reported value (referred to as a **point estimate**) provides an estimate of the effectiveness of the potential change or countermeasure on crash frequency. CMF values less than 1.0 indicate that the change should reduce crash frequency, while CMF values greater than 1.0 indicate that the change should increase crash frequency. CMF values equal to 1.0 indicate that the change is expected to have no impact on crash frequency.

Since the true CMF value is unknown, there is always some error associated with the point estimate of the CMF. The size of this error provides an indication of the precision of the point estimate. Small errors indicate that the point estimate is precise and the CMF is known with a high degree of certainty, while larger errors suggest that the true CMF may differ significantly from the point estimate. The magnitude of this error depends on several factors, such as the:

- type of study performed,
- analysis method used to obtain the estimate,
- amount of data used to estimate the CMF, and
- variation in the actual crash data used to estimate the CMF.

Various methods exist to estimate CMFs. Rigorous statistical methods to account for variation in the crash data produce less error in the CMF estimates. Studies with more crash data (either from more sites or over a longer period of time) and more geographic variation in the data also provide estimates with smaller errors than those that use little data or data constrained to a smaller geographic area.

Most research studies that estimate a CMF also include an estimate of the amount of error associated with the point estimate. The magnitude of this error is reported as the standard deviation of the error in the point estimate, and this value is referred to as the **standard error** of the CMF. Careful consideration of the standard error is critical to understanding the range of possible impacts that a highway modification or countermeasure may have on expected crash frequency. One way to quantify this range is by calculating

the confidence interval for the true value of the CMF. The confidence interval is calculated using the following equation:

$$Confidence\ Interval\ for\ CMF_i = CMF_i \pm Z * ERROR_i, \qquad \text{(Equation 2)}$$

where CMF_i is the point estimate of the CMF for countermeasure i as defined in Equation 1, $ERROR_i$ is the standard error associated with that point estimate, and Z is a value associated with the statistical significance of the confidence interval. A 95% confidence interval is sufficient for most typical applications; in this case, $Z = 1.96$. Other common Z values are provided in Table 1.

Table 1. Common Z values to obtain confidence intervals

Type of confidence interval	Z value
90% confidence interval	1.64
95% confidence interval	1.96
99% confidence interval	2.58

The confidence interval provides a range that the true value of the CMF should fall within with some degree of certainty. For example, when using a 95% confidence interval, the analyst can claim with 95% confidence that the true value of the CMF falls within this range.

Using the confidence interval for the CMF can provide a more informed indication of the impact of a potential change or countermeasure on crash frequency. If the confidence interval contains the value 1.0, then there is not enough statistical evidence to conclude that applying the change will impact safety performance. If the confidence interval is strictly less than 1.0, the change or countermeasure is expected to reduce crash frequency. If the confidence interval is strictly greater than 1.0, the change or countermeasure is expected to increase crash frequency.

Unfortunately, some sources do not provide estimates of the standard errors associated with CMF point estimates. The point estimates of these CMFs provide a general indication of the expected change in crash frequency. However, if no standard error is provided, the true effects of these countermeasures could vary greatly from the point estimates and the analyst has no indication of the level of uncertainty associated with these estimates. These CMFs should be avoided if at all possible, since their application is unreliable. Instead, the analyst should seek to use CMFs that also provide standard errors, if they are available.

Each CMF is provided for a specific set of conditions (e.g., traffic volumes, roadway types, crash types and severity). These CMFs are only applicable to these specific conditions and should not be applied directly to other situations. There are several reasons for this. Many countermeasures only influence a subset of crash types and/or severities (e.g., shoulder rumble strips will likely reduce run-off-the-road crashes but should not significantly influence rear-end crashes). Therefore, the CMFs for these countermeasures are typically limited in their application to the set of crashes associated with that specific countermeasure. Other countermeasures may have different impacts in different driving environments (e.g., the effectiveness of intersection treatments often varies with the type of control and configuration of the intersection). In addition, CMFs are often only estimated with a subset of crash data (e.g., only using crash records that involve a fatality) and are therefore only useful to describe the influence of a

countermeasure for these crash types. Nevertheless, in this case, CMF values can still serve as a guide that, along with engineering judgment, provides some indication of the expected change in crash frequency under alternative conditions, even if no CMFs are available for the specific alternative conditions.

Applying a Single CMF

An example is used to illustrate how to apply a single CMF to a particular site and how to interpret the results.

Example Problem: Consider a freeway segment in which the expected crash frequency is 10 crashes per year and 50% of these crashes are expected to involve a major injury. A highway engineer is considering installing shoulder rumble strips as a countermeasure to reduce total crash frequency. A CMF for major injury crashes is available for the installation of shoulder rumble strips on freeways. The CMF point estimate is 0.80 and the standard error is 0.08. The engineer would like to know the following: (1) would installing shoulder rumble strips help to reduce the number of crashes expected at this facility? And (2) how many total crashes should be expected after shoulder rumble strips are installed?

1) Would installing shoulder rumble strips help to reduce the number of crashes expected at this facility?

Since the point estimate of the CMF is less than 1.0, the engineer could conclude that the countermeasure is effective at reducing major crash frequency. However, the standard error of the estimate should be considered to make a more informed decision. The 95% confidence interval for the point estimate is equal to: $0.80 \pm 1.96 * 0.08$. Therefore, the engineer can be 95% confident that the true point estimate lies between 0.643 and 0.957. Since this entire confidence interval is below 1.0, the engineer could be 95% confident that the countermeasure should reduce crash frequency on this roadway by between $(1 - 0.957) * 100 = 4.3$ and $(1 - 0.643) * 100 = 35.7$ percent based on Equation 1.

Note that if a 99% confidence interval was used, the point estimate would fall between 0.594 and 1.01. In this case, the confidence interval contains the value 1.0, so the engineer could not be confident that the countermeasure would reduce the crash frequency on this roadway segment. However, for most practical purposes the 95% confidence interval is the most common confidence interval used in traffic safety analyses.

2) How many total crashes should be expected after shoulder rumble strips are installed?

The engineer could apply just the point estimate of the CMF to estimate the number of crashes after installing the countermeasure. Since the CMF applies only to all major injury crashes, it would only affect this specific subset of total crashes. In this case, there are only 5 expected major injury crashes (10 total * 50 percent major injury crashes) per year expected without the countermeasure. Therefore, the expected number of major injury crashes with the countermeasure is: $0.8 * 5 = 4$ major injury crashes. The total

number of crashes expected for this segment when the countermeasure is applied would then be 9 crashes per year, which includes the 5 non-major injury crashes expected per year.

A more informed answer would also report the confidence interval for total number of crashes, which takes into account the error associated with the CMF. The answer to Question 1 indicates that the 95% confidence interval of the CMF estimate is between 0.643 and 0.957. This suggests that when the countermeasure is applied, the expected number of major injury crashes is between 3.22 and 4.79 crashes per year. Therefore, the total number of crashes expected should fall between 8.22 and 9.79 crashes per year when the 5 non-major injury crashes expected per year are included.

Applying Multiple CMFs

Special consideration must be given when applying multiple CMFs simultaneously at the same location. There are two scenarios that might exist when applying multiple CMFs:

- The CMFs impact different crash types
- The CMFs impact the same crash types

Each of the scenarios is discussed below.

<u>CMFs impacting different crash types</u>

This scenario can occur when multiple countermeasures are implemented simultaneously that impact different crash types or when a single countermeasure is implemented that has unique CMFs for different crash types. In this case, the CMFs are treated independently, since the effects of each are not likely to overlap and the full effects of the countermeasures are expected. Each CMF is then applied directly to the set of crashes that it influences in the manner discussed previously. Confidence intervals for the expected crash frequencies of the individual crash types created in this way are valid.

If the confidence interval for the total number of crashes is desired, the CMFs for the different crash types can be combined using the following formula, which relies on the fact that each crash type is treated independently:

CI for total crashes: $\sum_i N_i CMF_i \pm Z * \sqrt{\sum_i (N_i ERROR_i)^2}$, (Equation 3)

where N_i is the expected number of crashes (before the implementation of a countermeasure) for crash type i, CMF_i is the CMF applied to crash type i, $ERROR_i$ is the standard error of the CMF applied to crash type i, and Z is the value associated with the statistical significance of the confidence interval.

An example is used to demonstrate how to apply multiple CMFs for countermeasures that influence different crash types.

Example Problem: Consider the implementation of shoulder rumble strips and a median barrier at a particular site with a predicted crash frequency of 5 run-off-the-road crashes and 6 cross-median crashes

(per year). A CMF is available for shoulder rumble strips, which applies to run-off-the-road crashes. The point estimate is 0.84 and the standard error is 0.08. Another CMF is available for median barriers, which applies to cross-median crashes. The point estimate is 0.35 and the standard error is 0.04. How many of each crash type should be expected if both countermeasures are installed? How many total crashes should be expected?

How many of each type of crash should be expected if both countermeasures are installed?

Since the two countermeasures influence different crash types, the two can be treated independently. The CMF for shoulder rumble strips will be applied to only the run-off-the-road crashes, while the CMF for median barriers will be applied to cross-median crashes. The 95% confidence interval for the rumble strips CMF is $0.84 \pm 1.96 * 0.08$ or 0.683 to 0.997. This is applied only to the run-off-the-road crashes. Therefore, the expected number of run-off-the-road crashes should fall somewhere between 3.42 and 4.99 run-off-the-road crashes per year after the shoulder rumble strips are applied to the site. Similarly, the 95% confidence interval for the CMF for median barriers is $0.35 \pm 1.96 * 0.04$ or 0.272 to 0.428, and the expected number of cross-median crashes should fall somewhere between 1.63 and 2.59 cross-median crashes per year after median barrier is installed to the site.

How many total crashes should be expected?

To determine the 95% confidence interval for the total expected number of crashes, Equation 3 can be directly applied. The confidence interval is $[5(0.84) + 6(0.35)] \pm 1.96 * \sqrt{(5 * 0.08)^2 + (6 * 0.04)^2} = 6.3 \pm 1.96 * 0.466$. This implies that the number of total crashes expected at this location should fall between 5.38 and 7.22 crashes per year after both countermeasures are installed. Notice that this confidence interval is not simply the sum of the confidence intervals for each crash type. This is because when aggregating multiple (independent) confidence intervals, the variability of the final sum decreases due to aggregation.

<u>CMFs impacting the same crash types</u>

This scenario occurs when multiple countermeasures are applied simultaneously at the same location that targets the same crash types. In this case, the analyst must first decide whether to treat the associated countermeasures as if they were independent or dependent.

Independent countermeasures are those with effects that are not expected to overlap and for which the full effects of each countermeasure should be expected. This is the less conservative assumption, since countermeasures that influence the same crash type would generally have overlapping effects. For these independent countermeasures, the current practice suggests that the CMFs be treated multiplicatively. That is, the combined effect is estimated as the product of the individual CMF point estimates, as shown in Equation 4:

$$CMF_C = \prod_i CMF_i, \qquad \text{(Equation 4)}$$

where CMF_i is the point estimate of each individual CMF i and CMF_C is the combined impact of the combination of multiple independent CMFs. In this case, the standard error of the individual CMFs cannot be directly used when applying multiple independent CMFs at a single location. Instead, a combined standard error must be estimated using the point estimates and standard errors of each individual CMF. As described in Lord (2008), this combined standard error is:

$$ERROR_C = \sqrt{\prod_i \left(CMF_i^2 + ERROR_i^2\right) - \left(\prod_i CMF_i\right)^2}, \qquad \text{(Equation 5)}$$

where CMF_i is the point estimate of each individual CMF i, $ERROR_i$ is the standard error of each individual CMF i, and $ERROR_C$ is the combined error of the product of the independent CMFs.

In general, conservative estimates and assumptions should be used when applying multiple independent CMFs simultaneously. Combining three or more CMFs using the above method is likely to significantly overestimate the true safety effects that can be expected from applying the respective countermeasures. Therefore, this methodology should be discouraged when three or more CMFs are required and another, more conservative method like the one described below, should be used instead.

Dependent countermeasures are those expected to have overlapping effects such that the combination of the multiple countermeasures may have different impacts than if the CMFs were applied in a multiplicative fashion. In this case, the true impacts of the combined countermeasures may be greater than, less than, or equal to the product of the CMFs. Since the combined effect of multiple dependent CMFs has not been thoroughly studied, it is usually best practice to assume that the combined effect is not as beneficial as would be expected if the countermeasures were independent. A conservative way to treat these dependent countermeasures is to identify a single CMF for application. The CMF selected should be either:

- the most effective CMF (i.e., the CMF with the lower point estimate) if all CMFs are expected to provide safety benefits, or
- the least effective CMF (i.e., the CMF with the highest point estimate) if one or more CMFs are expected to provide an increase in crash frequency.

In this case, the standard error of the selected CMF is used as the error of the combined treatment. This method is conservative because it is the equivalent of a worst-case analysis of the safety effects of the combined countermeasures and should not overestimate the safety benefits of combined countermeasures. If the combination of countermeasures is expected to provide additional benefits beyond the application of a single CMF, a value near the lower bound of the confidence interval for the single select CMF can be selected to account for the additional benefits. Other methods to estimate the combined CMF for multiple dependent countermeasures can be found in Gross et al. (2012).

In cases for which the analyst is unsure whether the countermeasures are independent or dependent, the combined influence of the multiple CMFs should be determined using both methods to provide a range of potential effects. The independent method would provide an upper bound for the expected safety benefits

of the combined countermeasures, while the dependent analysis would provide a lower bound. Engineering judgment can then be used to select the most appropriate value from this range.

An example is used to illustrate how to apply multiple CMFs for countermeasures that influence the same crash types, including how to interpret the results.

Example Problem: Consider a two-lane rural roadway segment in which the crash frequency is expected to be 10 crashes per year. A highway engineer is considering installing edgeline rumble strips and paved shoulders as countermeasures to reduce crash frequency. CMFs are available for both countermeasures: the CMF for edgeline rumble strips (total crashes) is 0.80 with a standard error of 0.08 and the CMF for paved shoulders (total crashes) is 0.58 with a standard error of 0.054. The engineer would like to know how many crashes should be expected if these two countermeasures are applied simultaneously: (1) assuming they are independent countermeasures, and (2) assuming they are dependent countermeasures. If the engineer is not sure of the combined effects, what is the most appropriate estimate to use?

How many crashes should be expected if both countermeasures are applied simultaneously, assuming the countermeasures are independent?

Equation 3 can be used to determine the point estimate for the combination of these countermeasures assuming independence. The point estimate of the combined effect of both countermeasures will be a product of the two CMFs and equal to $0.80 * 0.58 = 0.464$. The error associated with this point estimate can be estimated using Equation 4: $\sqrt{(0.80^2 + 0.08^2) * (0.58^2 + 0.054^2) - (0.80 * 0.58)^2} = 0.064$. Therefore, the 95% confidence interval for the combined effect of the two countermeasures is: $0.464 \pm 1.96 * 0.064$, which implies that the estimate of the combined countermeasures lies between 0.339 and 0.589. The estimate of total number crashes per year would then be between 3.39 and 5.89 after installing both countermeasures at the site.

How many crashes should be expected if both countermeasures are applied simultaneously, assuming the countermeasures are dependent?

If these two countermeasures are dependent, the conservative approach would be to apply only the CMF associated with the most effective countermeasure, since both are expected to provide safety benefits. In this case, paved shoulders is the most effective countermeasure, since the point estimate of the CMF of paved shoulders is lower than the point estimate for the CMF of edgeline rumble strips. Therefore, the point estimate applied will be 0.58. The standard error of 0.054 for this point estimate is also used. The 95% confidence interval for this combined treatment, using a conservative approach, is $0.58 \pm 1.96 * 0.054$, which implies that the estimate of the combined countermeasures conservatively lies between 0.474 and 0.686. The estimate of total number of crashes per year is between 4.74 and 6.86. This range is higher than the range obtained when assuming the two countermeasures are independent because the independence assumption is generally not conservative.

What is the most appropriate estimate to use?

To determine the most appropriate estimate of crashes after the combined implementation of both countermeasures, the countermeasures being applied must be considered. Both edgeline rumble strips and paved shoulders are typically implemented to prevent run-off-the-road crashes and are likely to have dependent effects. For example, implementing edgeline rumble strips on a roadway segment that already has a paved shoulder might not be as effective as implementing edgeline rumble strips on a roadway segment without a shoulder, since the shoulder would already mitigate some of the run-off-the-road crashes. However, the combined effects of both countermeasures should be more than just paved shoulders alone, because edgeline rumble strips can alert a driver that the driven vehicle is departing the travel lane while the shoulder provides additional space and time for the vehicle to recover. Thus, it might be appropriate to use the conservative approach, but select an estimate of the number of crashes closer to the lower bound to capture the additional benefit of combining the countermeasure. In this case, a value near 5 crashes per year may be appropriate if the combined effects are expected to be significant.

Assessing the Quality of a CMF

Only "high-quality" CMFs are included in this guide for application within the Commonwealth of Pennsylvania. The star quality rating system proposed by the FHWA CMF Clearinghouse and documented on its website (http://www.cmfclearinghouse.org/) was used to assess the quality of each of the CMFs identified. This system assigns each CMF with a numerical value on a scale of 1 to 5, where 5 is the most reliable or highest-quality rating. The ratings are determined based on five properties of the CMF and the study used to estimate its value, including the:

- Study design,
- Sample size,
- Standard error,
- Potential bias, and
- Data source.

Each of these properties is assigned a point value based on the level of rigor. Table 2 (modified slightly from the CMF Clearinghouse website) provides a guideline for assigning point values for each of these properties. These points are then used to assign each CMF an aggregate score using the following equation:

$$\begin{aligned} Aggregate\ CMF\ Score \\ &= (2 * Study\ Design\ Score) + (2 * Sample\ Size\ Score) + Standard\ Error\ Score \\ &+ Potential\ Bias\ Score + Data\ Source\ Score \end{aligned}$$

(Equation 5)

Table 2. Guidelines for assigning points in the CMF star quality rating system

Property	Excellent (2 points)	Fair (1 point)	Poor (0 points)
Study Design	Statistically rigorous study design with reference group or randomized experiment and control	Cross sectional study or other coefficient based analysis	Simple before / after study
Sample Size	Large sample, multiple years, diversity of sites	Moderate sample size, limited years, and limited diversity of sites	Limited homogeneous sample
Standard Error	Small (when compared to 1-CMF value)	Relatively large SE, but confidence interval does not include zero	Large SE and confidence interval includes zero
Potential Bias	Controls for all sources of known potential bias	Controls for some sources of potential bias	No consideration of potential bias
Data Source	Diversity in states representing different geographies	Limited to one state, but diversity in geography within state (e.g., CA)	Limited to one jurisdiction in one state

The final star rating is assigned based on the aggregate CMF score using Table 3.

Table 3. CMF score to star rating conversion

Aggregate CMF Score	Star Rating
14 (max possible)	5 Stars
11 – 13	4 Stars
7 – 10	3 Stars
3 – 6	2 Stars
1 – 2	1 Star
0	0 Stars

High-quality CMFs were determined to be those having a star rating of 3 or higher. The threshold of 3 stars was selected for the following reasons: it provides a relatively large list of CMFs, since the majority of CMFs in the CMF Clearinghouse are rated 3 stars; it is consistent with the HSM, since the CMFs provided in the HSM are almost all rated 3 stars or higher; and it ensures that any CMF with a poor rating for one or more properties also has other properties with an excellent rating (especially for study design and sample size).

Using the CMF Guide

In this guide, CMFs are categorized by the CMF type used in the FHWA CMF Clearinghouse website. This categorization was chosen for consistency so that a user can easily identify additional CMF details using the website (http://www.cmfclearinghouse.org/).

The categories used are:

- Access Management
- Advanced Technology and ITS
- Alignment
- Bicyclists
- Delineation
- Highway Lighting
- Interchange Design
- Intersection Geometry
- Intersection Traffic Control
- On-Street Parking
- Pedestrians
- Railroad Grade Crossings
- Roadside Features
- Roadway Features
- Shoulder Treatments
- Signs
- Speed Management
- Transit
- Work Zones

A separate CMF table is provided for each of the categories listed above; see Tables A through S at the end of this guide. Note that individual countermeasures are not duplicated across tables and an analyst might have to check multiple tables to find a specific countermeasure. For example, CMFs for countermeasures at intersections with rail crossings can be found in both Tables I (Intersection Traffic Control) and L (Railroad Grade Crossings).

Each of these tables contains the following information:

- Description of the highway change or countermeasure,
- Conditions for which the CMF is applicable,
- Point estimate and standard error of the CMF,
- Star quality rating as determined from the FHWA CMF Clearinghouse methodology, and
- Location of crash data used to estimate the CMF.

The "Countermeasure" column provides a brief description of the change or countermeasure considered. Most countermeasures contain multiple CMF point estimates and standard errors, each associated with a different set of conditions provided in the "Area Type," "Severity," "Crash Type," "AADT Range," and "Implementation Notes" columns. A description of common abbreviations used in the CMF tables for Area Type, Severity and Crash Type is provided in Tables 4 through 6. The Implementation Notes column includes additional factors depending on the nature of the countermeasure (e.g., number of lanes

or speed limit). CMFs can only be confidently applied to the set of conditions for which they are associated. Blank cells in Tables A through S for Area Type, Severity, Crash Type, and AADT Range indicate that this information was not specified or readily available. These CMFs should be applied more cautiously than those for which the conditions are provided. CMFs with different conditions than desired might serve as a guide for applying a CMF to the situation of interest. However, an analyst should use conservative and careful engineering judgment when applying these estimates under different conditions.

Table 4. Description of common Area Type abbreviations

Abbreviation	Description
Urban	Urban roadways only
Urban/Suburban	Urban and suburban roadways only
Rural	Rural roadways only

Table 5. Description of common Severity abbreviations

Abbreviation	Description
All	All crash severities
Fatal	Fatal crashes
Incapacitating Injury	Fatal and serious injury crashes
Fatal and Injury	Fatal, serious injury, and minor injury crashes
Injury	Serious injury and minor injury crashes
Serious Injury	Serious injury crashes
Minor Injury	Minor injury crashes
Injury and PDO	Serious injury, minor injury, and property damage only crashes
Minor and PDO	Minor injury and property damage only crashes
PDO	Property damage only crashes

Table 6. Description of common Crash Type abbreviations

Abbreviation	Description
All	All crash types
Angle	Angle crashes only
Cross median	Cross median crashes only
Daytime	Daytime crashes only
Fixed object	Fixed object crashes only
Head-on	Head-on crashes only
Intersection	Intersection related crashes only
Left-turn	Left-turn crashes only
Motorcycle	Motorcycle related crashes only
Multiple vehicle	Multiple vehicle crashes only
Nighttime	Nighttime crashes only
Non-intersection	Non-intersection crashes only
Non-summer	Non-summer period crashes only
Non-winter	Non-winter period crashes only
Parking related	Parking related crashes only
Rear-end	Rear-end crashes only
Right-turn	Right-turn crashes only
Run-off-road	Run-off-road crashes only
Shoulder	Shoulder related crashes only
Sideswipe	Sideswipe crashes only
Single vehicle	Single vehicle crashes only
Speed	Speed related crashes only
Summer	Summer period crashes only
Truck related	Truck related crashes only
Vehicle/bicycle	Vehicle/bicycle crashes only
Vehicle/pedestrian	Vehicle/pedestrian crashes only
Wet road	Wet road crashes only
Winter	Winter period crashes only

The "CMF" column contains the point estimate and standard error of the CMF. In some cases, multiple CMFs are provided for the same set of conditions. In such cases, the CMF highlighted in green is the most appropriate estimate to use. This value was selected by considering the star rating, point estimate, standard error, and study methodology. The other estimates are still provided to give the user of this guide an indication of the range of potential impacts that this highway change or countermeasure may have. One of these other CMFs may be applied only if sufficient justification is provided for its use.

The “Point Estimate” column generally provides the numerical value of the point estimate of the CMF for that countermeasure. However, in some instances an equation or formula is used to estimate the point estimate of the CMF. The equations are designated in the tables as “EQN X,” and the functional form of the equations are provided in Table T at the end of this guide. The information in Table T provides the relevant variables that should be used to estimate the numerical value of the CMF.

The next column of each table contains a value indicating the quality of the CMF using the star quality rating system developed by the FHWA CMF Clearinghouse. As previously described, only CMFs with a 3-star rating or higher are included in this guide. Of these, CMFs with star quality ratings of 4 and 5 are generally those that were estimated using a better study design, include a larger sample size of sites/crashes, have a lower standard error of the point estimate, have less potential bias in the estimate, and contain data from a wider range of sources. In general, these CMFs should be trusted more than CMFs with star quality ratings of 3.

The final column labeled “State” lists the set of states (when reported) from which crash data were obtained to estimate the CMF. The bolded CMFs in each table represent those for which Pennsylvania crash data were used to estimate the point estimate and standard error of the CMF. These CMFs might be more appropriate for application in Pennsylvania, especially in cases where significant variation exists for multiple CMFs provided for the same set of conditions.

The low-quality CMFs are provided in the same basic format at the conclusion of this report. However, these CMFs are not recommended for use in Pennsylvania due to their low quality.

A series of examples are used to demonstrate how to use this guide.

Example Problem 1: A raised median is being considered on a 4-lane road in a suburban region. What change in property damage only (PDO) crashes are expected after this countermeasure is implemented?

To determine the expected change in crashes, the CMF for this scenario needs to be determined. The countermeasure “Provide a raised median” is included in Table A: Access Management. In this table, nearly 60 CMF estimates are included for this countermeasure. However, the “Area Type” and “Crash Severity” columns can be used to identify only those that influence suburban roadway segments and PDO crashes. This narrows the list of CMFs to 7 values. Since the crash type is not specified in the problem, only the CMFs provided for all crash types should be considered, which further narrows the list to 4 CMFs. Each of these has different implementation conditions under the “Implementation Notes” column. Of these four, only one CMF is applicable to 4-lane roadway segments. This CMF should be used. Therefore, the CMF selected should have a point estimate of 0.742 and standard error of 0.034. The 95% confidence interval is $0.742 \pm 1.96 * 0.034$, or between 0.675 and 0.809. This suggests a reduction in PDO crashes of between 19.1% and 32.5%.

Example Problem 2: Centerline rumble strips are being considered on a rural roadway segment in Pennsylvania. What is the most appropriate CMF to use in this scenario to estimate the impact on the total number of crashes?

The countermeasure "Install centerline rumble strips" is included in Table N: Roadway Features. 32 CMFs are provided for this countermeasure, and 28 of them pertain to rural roadway segments. Since total crashes are of interest, all crash types and crash severities should be considered. This reduces the list to 6 CMFs. However, there are no other differentiating characteristics of these 6 CMF estimates. Since no other information is provided, the most appropriate choice is to select the recommended value that has been highlighted. This CMF has a point estimate of 0.91 and a standard error of 0.02. Since the CMF is also bolded, the data used to estimate the CMF came from Pennsylvania, which further validates this selection.

If the analyst has a strong suspicion that centerline rumble strips would be less effective than average at this particular location, then the following two options are available: the analyst can either elect to use a point estimate closer to the upper bound of the confidence interval provided by the CMF chosen above or choose another CMF with a slightly higher point estimate.

Example Problem 3: A CMF is desired to estimate the effect of increasing the retroreflectivity of white edgelines from 100 to 200 mcd/m^2/lux. The effect on all crash types is desired. What is the most appropriate point estimate to use?

The countermeasure "Increase pavement marking retroreflectivity of white edgelines from X to Y mcd/m^2/lux" is included in Table E: Delineation. The point estimate is obtained using Equation 5-6 from the set of equations following this table. The equation has the following functional form:

$$CMF = e^{-0.001(Y-X)},$$

where X and Y are the before and after retroreflectivity of the white edgelines in units of mcd/m^2/lux. In this particular case, $X = 100$ mcd/m^2/lux and $Y = 200$ mcd/m^2/lux. Therefore, the CMF point estimate is:

$$CMF = e^{-0.001(200-100)} = 0.905.$$

Unfortunately, standard errors are not available in cases in which equations are used to obtain the point estimate. Therefore, the CMF point estimate of 0.905 should be used with caution, as there is no indication of the level of uncertainty associated with this value.

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Table A. Access Management

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Provide a raised median		All	All	10000 - 55000		0.61		4	UT
		Incapacitating injury	All	10000 - 55000		0.56		4	UT
	Urban	Fatal and injury	All			0.61	0.06	4	
		Injury	All			0.78	0.02	5	
		PDO	All			1.09	0.01	5	
		All	All	1390 - 51200		0.29	0.184	3	UT
					2 lanes, less than 45 mph speed limit	0.86		3	NJ
			Angle	1390 - 51200		0.45	0.125	3	UT
	Urban/Suburban	Fatal and injury	All	10500 - 57000	2, 4, 6 lanes	0.66	0.028	3	FL
				26224 - 57000	6 lanes	0.582	0.029	3	FL
					35, 40 mph speed limit	0.654	0.086	3	FL
					45, 50, 55 mph speed limit	0.695	0.031	3	FL
			Angle	10500 - 57000		0.641	0.07	3	FL
			Left-turn	10500 - 57000		0.294	0.035	3	FL
			Rear-end	10500 - 57000		0.776	0.051	3	FL
		Injury	All	10500 - 57000	2, 4, 6 lanes	0.659	0.028	3	FL
				26224 - 57000	6 lanes	0.58	0.029	3	FL
					35, 40 mph speed limit	0.643	0.085	3	FL
					45, 50, 55 mph speed limit	0.695	0.031	3	FL
			Angle	10500 - 57000		0.64	0.07	3	FL
			Left-turn	10500 - 57000		0.295	0.035	3	FL
			Rear-end	10500 - 57000		0.777	0.051	3	FL
		PDO	All	10500 - 57000	2, 4, 6 lanes	0.742	0.034	3	FL
				26224 - 57000	6 lanes	0.684	0.036	3	FL
					35, 40 mph speed limit	0.712	0.094	3	FL
					45, 50, 55 mph speed limit	0.783	0.037	3	FL
			Angle	10500 - 57000		0.544	0.065	3	FL
			Left-turn	10500 - 57000		0.397	0.058	3	FL
			Rear-end	10500 - 57000		0.896	0.063	3	FL
		All	All	10500 - 57000	2, 4, 6 lanes	0.697	0.022	3	FL
				26224 - 57000	6 lanes	0.628	0.022	3	FL
					35, 40 mph speed limit	0.682	0.064	3	FL
					45, 50, 55 mph speed limit	0.735	0.024	3	FL
			Angle	10500 - 57000	2, 4, 6 lanes	0.595	0.048	3	FL
				18340 - 50925	6 lanes	0.732	0.124	3	FL
				26224 - 57000	35, 40 mph speed limit	0.558	0.051	3	FL
					45, 50, 55 mph speed limit	0.647	0.054	3	FL
			Daytime	26224 - 57000	6 lanes	0.564	0.025	3	FL
					35, 40 mph speed limit	0.639	0.072	3	FL
					45, 50, 55 mph speed limit	0.684	0.027	3	FL
			Left-turn	10500 - 57000	2, 4, 6 lanes	0.329	0.03	3	FL
				18340 - 50925	6 lanes	0.664	0.126	3	FL
				26224 - 57000	35, 40 mph speed limit	0.262	0.029	3	FL
					45, 50, 55 mph speed limit	0.348	0.033	3	FL
			Nighttime	26224 - 57000		0.859	0.061	3	FL
					45, 50, 55 mph speed limit	0.625	0.119	3	FL
			Other	26224 - 57000		0.827	0.081	3	FL
			Rear-end	10500 - 57000	2, 4, 6 lanes	0.83	0.04	3	FL
				26224 - 57000	6 lanes	0.742	0.041	3	FL
					35, 40 mph speed limit	0.756	0.1	3	FL
					45, 50, 55 mph speed limit	0.881	0.045	3	FL
			Right-turn	10500 - 57000	2, 4, 6 lanes	0.661	0.119	3	FL
					45, 50, 55 mph speed limit	0.663	0.125	3	FL
			Sideswipe	10500 - 57000	2, 4, 6 lanes	0.83	0.101	3	FL
					45, 50, 55 mph speed limit	0.818	0.106	3	FL
			Vehicle/pedestrian	10500 - 57000		0.711	0.139	3	FL
	Rural	Injury	All			0.88	0.03	5	
		PDO	All			0.82	0.02	5	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Replace TWLTL with raised median	Urban	All	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 96080		0.77	0.0616	3	NV
			Angle	4883 - 96080		0.65	0.0728	3	NV
			Rear-end	4883 - 96080		0.81	0.0684	3	NV
			Sideswipe	4883 - 96080		0.79	0.0822	3	NV
			Head-on	4883 - 96080		0.53	0.1473	3	NV
		Injury	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 96080		0.79	0.0721	3	NV
		PDO	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 96080		0.67	0.0692	3	NV
Increase intersection median width by 3 ft increments	Rural	Fatal and injury	Multiple vehicle			0.96	0.02	5	
		All	Multiple vehicle			0.96	0.02	5	
	Urban/Suburban	Fatal and injury	Multiple vehicle		Stop-controlled	1.05	0.01	5	
					Signalized	1.03	0.01	5	
		All	Multiple vehicle		4-leg, Stop-controlled	1.06	0.01	5	
					3-leg, Stop-controlled	1.03	0.01	5	
					4-leg, Signalized	1.03	0.18	5	
Convert a 10-ft traversable median to a 20-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.86	0.02	5	
				1000 - 90000	Partial access control	0.84	0.03	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.89	0.04	5	
				2600 - 282000	5 lanes or more, Full access control	0.89	0.04	5	
				1900 - 150000	4 lanes, Partial access control	0.87	0.04	5	
		All	Multiple vehicle			0.91		4	CA,KY,MN
Convert a 10-ft traversable median to a 30-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.74	0.04	5	
				1000 - 90000	Partial access control	0.71	0.06	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.8	0.07	5	
				2600 - 282000	5 lanes or more, Full access control	0.79	0.07	5	
				1900 - 150000	4 lanes, Partial access control	0.76	0.06	5	
		All	Multiple vehicle			0.83		4	CA,KY,MN
Convert a 10-ft traversable median to a 40-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.63	0.05	5	
				1000 - 90000	Partial access control	0.6	0.07	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.71	0.09	5	
				2600 - 282000	5 lanes or more, Full access control	0.71	0.1	5	
				1900 - 150000	4 lanes, Partial access control	0.67	0.08	5	
		All	Multiple vehicle			0.75		4	CA,KY,MN
Convert a 10-ft traversable median to a 50-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.54	0.06	5	
			Cross median	1000 - 90000	Partial access control	0.51	0.08	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.64	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.63	0.1	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.59	0.1	5	
		All	Multiple vehicle			0.68		4	CA,KY,MN
Convert a 10-ft traversable median to a 60-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.46	0.07	5	
			Cross median	1000 - 90000	Partial access control	0.43	0.09	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.57	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.56	0.1	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.51	0.1	5	
		All	Multiple vehicle			0.62		4	CA,KY,MN

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert a 10-ft traversable median to a 70-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.4	0.07	5	
			Cross median	1000 - 90000	Partial access control	0.36	0.09	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.51	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.5	0.1	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.45	0.1	5	
		All	Multiple vehicle			0.57		4	CA,KY,MN
Convert a 10-ft traversable median to a 80-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.34	0.07	5	
			Cross median	1000 - 90000	Partial access control	0.31	0.09	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.46	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.45	0.1	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.39	0.1	5	
		All	Multiple vehicle			0.51		4	CA,KY,MN
Convert a 10-ft traversable median to a 90-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.29	0.07	5	
			Cross median	1000 - 90000	Partial access control	0.26	0.08	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.41	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.4	0.2	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.34	0.1	5	
Convert a 10-ft traversable median to a 100-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.25	0.06	5	
			Cross median	1000 - 90000	Partial access control	0.22	0.08	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.36	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.35	0.2	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.3	0.1	5	
Decrease freeway ramp spacing from infinity to S (ft) with or without auxiliary lane		All		5134 - 153500		Eqn. 1- 55		4	CA,WA
			Multiple vehicle	5134 - 153500		Eqn. 1- 56		4	CA,WA
		Fatal and injury		5134 - 153500		Eqn. 1- 57		4	CA,WA
Decrease median width from 64 ft to 22 ft	Urban	All	All	5700 - 309000		3.629	0.404	3	FL
			Rear-end	5700 - 309000		5.732	0.673	3	FL
			Sideswipe	5700 - 309000		4.184	0.434	3	FL
		Fatal and injury	All	5700 - 309000		3.227	0.329	3	FL
Decrease median width from 64 ft to 40 ft	Urban	All	All	5700 - 309000		1.071	0.126	3	FL
			Rear-end	5700 - 309000		1.43	0.222	3	FL
			Sideswipe	5700 - 309000		1.151	0.14	3	FL
		Fatal and injury	All	5700 - 309000		1.073	0.099	3	FL
Replace direct left-turn with right-turn/U-turn		Fatal and injury	All	0 - 34000	4, 6, 8 lanes	0.64	0.39	3	
				0 - 34000		0.38	0.21	3	
				0 - 34000	6 lanes	0.69	0.17	3	
				0 - 34000	4, 6, 8 lanes	0.89	0.37	3	
		PDO		0 - 34000		0.56	0.2	3	
				0 - 34000	6 lanes	0.95	0.13	3	
		All		0 - 34000	4, 6, 8 lanes	0.8	0.28	4	
				0 - 34000	4, 6, 8 lanes	0.49	0.15	3	
				0 - 34000	6 lanes	0.86	0.21	3	
			Angle	0 - 34000	4, 6, 8 lanes	0.64	0.25	3	
				0 - 34000	6 lanes	0.67	0.22	3	
			Rear-end	0 - 34000	4, 6, 8 lanes	0.84	0.25	3	
				0 - 34000	6 lanes	0.91	0.05	3	
Restrict left or right-turns	Urban	All	Transit-related			0.72	0.113	3	notusa
			Transit-serviced locations			0.96	0.01	3	notusa
						0.87	0.02	3	notusa
Increase separation distance between driveway exit and downstream U-turn by 10% (m)		All	All	18200 - 86300		0.967	0.0118	3	FL
			Related to in-direct left-turns	18200 - 86300		0.955	0.013	3	FL

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Change in driveway density from X to Y driveways per mile	Rural	All	All		2 lanes	Eqn. 1- 1		3	TX
		Fatal and injury				Eqn. 1- 2		3	TX
	Urban	All	Angle	29320 - 96080	Divided with median	Eqn. 1- 3		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 4		3	NV
			Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 5		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 6		3	NV
			Fixed object,Run off road,Single vehicle	4883 - 71280	Divided with TWLTL	Eqn. 1- 7		3	NV
			Rear-end	29320 - 96080	Divided with median	Eqn. 1- 8		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 9		3	NV
			Sideswipe	4883 - 71280	Divided with TWLTL	Eqn. 1- 10		3	NV
		PDO	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 11		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 12		3	NV
		Injury	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 13		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 14		3	NV
Change in driveway density from 48 to 26-48 driveways per mile	Urban/Suburban	Injury	All			0.71	0.02	5	
Change in driveway density from 26-48 to 10-24 driveways per mile	Urban/Suburban	Injury	All			0.69	0.03	5	
Change in driveway density from 10-24 to <10 driveways per mile	Urban/Suburban	Injury	All			0.75	0.02	5	
Increase freeway on-ramp density from 0 to 1 ramps per mile (total in both directions)	Urban	Fatal and injury	All		8 lanes	1.05	0.02	3	TX
					4 lanes	1.047	0.027	3	TX
	All	Fatal and injury	All			1.033	0.012	3	TX
						1.04	0.016	3	TX
						1.023	0.018	3	TX
Increase freeway on-ramp density from 0 to 5 ramps per mile (total in both directions)	Urban	Fatal and injury	All		8 lanes	1.279	0.12	3	TX
					4 lanes	1.256	0.164	3	TX
	All	Fatal and injury	All			1.174	0.069	3	TX
						1.217	0.094	3	TX
						1.12	0.098	3	TX
Increase freeway on-ramp density from 0 to 10 ramps per mile (total in both directions)	Urban	Fatal and injury	All		8 lanes	1.636	0.31	3	TX
					4 lanes	1.578	0.415	3	TX
	All	Fatal and injury	All			1.379	0.1617	3	TN
						1.48	0.229	3	TX
						1.25	0.22	3	TX
Increase freeway on-ramp density from X to Y ramps per mile (total in both directions)	Urban	Fatal and injury	All		8 lanes	Eqn. 1- 15		3	TX
					4 lanes	Eqn. 1- 16		3	TX
	All	Fatal and injury	All			Eqn. 1- 17		3	TX
Increase freeway on-ramp density from X to Y ramps per mile (total in both directions) (curve sections)	All	Fatal and injury	All			Eqn. 1- 18		3	TX
Increase freeway on-ramp density from X to Y ramps per mile (total in both directions) (tangents)	All	Fatal and injury	All			Eqn. 1- 19		3	TX
Change in signal spacing from X 1000's feet to Y 1000's feet	Urban	All	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 20		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 21		3	NV
			Fixed object,Run off road,Single vehicle	4883 - 71280	Divided with TWLTL	Eqn. 1- 22		3	NV
			Rear-end	29320 - 96080	Divided with median	Eqn. 1- 23		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 24		3	NV
			Sideswipe	29320 - 96080	Divided with median	Eqn. 1- 25		3	NV
		PDO	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 71280	Divided with TWLTL	Eqn. 1- 26		3	NV

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Change in unsignalized cross roads from X to Y unsignalized cross roads per mile	Urban	All	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 71280	Divided with TWLTL	Eqn. 1- 27		3	NV
			Fixed object,Run off road,Single vehicle	29320 - 96080	Divided with Median	Eqn. 1- 28		3	NV
			Head-on	4883 - 71280	Divided with TWLTL	Eqn. 1- 29		3	NV
			Rear-end	4883 - 71280	Divided with TWLTL	Eqn. 1- 30		3	NV
			Sideswipe	29320 - 96080	Divided with Median	Eqn. 1- 31		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 32		3	NV
		Injury	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 71280	Divided with TWLTL	Eqn. 1- 33		3	NV
Change in median opening density from X to Y median openings	Urban	All	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 34		3	NV
			Angle	29320 - 96080	Divided with median	Eqn. 1- 35		3	NV
			Head-on	29320 - 96080	Divided with median	Eqn. 1- 36		3	NV
		Injury	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 37		3	NV
		PDO	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 38		3	NV
Implement home zone design in residential neighborhoods		All	All		Home zones, or shared spaces, are streets designed to be shared by vehicles and pedestrians. Home zones may include: entrance treatments, shared vehicle and pedestrian space, traffic calming, on-street parking, streetscaping, social space, and interface between buildings and roads.	0.71	0.13	3	
Install wide median (>2 m) on major road of a 4-leg signalized intersection	Urban	All	Motorcycle			1.2		3	notusa
Add markings to the major approach of unsignalized 3-leg intersection to serve as a median	All	All	All			0.7	0.1385	3	FL
Convert an open median to a mixed median on the major approach to a 3-leg unsignalized intersection	All	All	All			0.95	0.133	3	FL
Convert an open median to an undivided median on the major approach to an unsignalized 3-leg intersection	All	All	All			0.85	0.083	3	FL
Convert an open median to a closed median on the major approach to unsignalized 3-leg intersection	All	All	All			1.02	0.1106	3	FL
Convert an open median to a TWLTL		All	All			1.45	0.21	3	FL
Convert an open median to a directional median on the major approach of an unsignalized 3-leg intersection	All	All	All			0.86	0.1297	3	FL
Convert an open median to a directional median	Urban/Suburban	Incapacitating injury	All	27000 - 96000		0.76	0.0548	4	FL
		Fatal and injury	All	27000 - 96000		0.77	0.0632	4	FL
		Major injury	All	27000 - 96000		0.82	0.0632	4	FL
		Minor injury	All	27000 - 96000		0.82	0.0894	4	FL
		PDO	All	27000 - 96000		1.13	0.1703	3	FL
		All	All	27000 - 96000		0.93	0.1095	3	FL
			Left-turn	27000 - 96000		0.43	0.0447	3	FL
Convert an open median to a left-in only median	Urban/Suburban	Fatal and injury	All	45000 - 75000		0.93	0.2429	3	FL
		Minor injury	All	45000 - 75000		0.8	0.2236	3	FL
		PDO	All	45000 - 75000		1.13	0.2324	3	FL
		All	All	45000 - 75000		0.95	0.2258	3	FL
		All	Left-turn	45000 - 75000		0.55	0.1183	3	FL
Change the natural log of the upstream distance to the nearest signalized intersection from an unsignalized 3-leg intersection from X to Y	All	All	All			Eqn. 1- 39		3	FL

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Change the natural log of the downstream distance to the nearest signalized intersection for an unsignalized 3-leg intersection from X to Y	All	All	All			Eqn. 1- 40		3	FL
Change the natural log of the downstream distance to the nearest signalized intersection for an unsignalized 4-leg intersection from X to Y	All	All	All			Eqn. 1- 41		3	FL
Change the natural log of the distance between two consecutive unsignalized intersection	All	All	All			Eqn. 1- 42		3	FL
Presence of grade-separated interchange	All	Fatal	All	1094 - 213544	Compared to no access points	1.77	0.78	3	notusa
		Injury	All	1094 - 213544	Compared to no access points	1.02	1.91	3	notusa
Presence of parking entrances	Urban/Suburban	All	Vehicle/bicycle			1.01		3	notusa
Presence of median	Urban/Suburban	All	Vehicle/bicycle			0.97		3	notusa
Absence of access points	Urban	All	All			0.56	0.27	3	notusa
Change number of 3-leg intersections from X to Y	Urban	All	Angle,Cross median,Fixed object,Head-on,Left-turn,Non-intersection,Parking related,Rear-end,Rear to rear,Right-turn,Run off road,Sideswipe,Single vehicle,Truck related		Census block group area	Eqn. 1- 43		3	TX
			Angle,Cross median,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe		Census block group area	Eqn. 1- 44		3	TX
			Fixed object		Census block group area	Eqn. 1- 45		3	TX
			Parking related		Census block group area	Eqn. 1- 46		3	TX
			Vehicle/bicycle		Census block group area	Eqn. 1- 47		3	TX
			Vehicle/pedestrian		Census block group area	Eqn. 1- 48		3	TX
Change number of 4-leg intersections from X to Y	Urban	All	Angle,Cross median,Fixed object,Head-on,Left-turn,Non-intersection,Parking related,Rear-end,Rear to rear,Right-turn,Run off road,Sideswipe,Single vehicle,Truck related		Census block group area	Eqn. 1- 49		3	TX
			Angle,Cross median,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe		Census block group area	Eqn. 1- 50		3	TX
			Fixed object		Census block group area	Eqn. 1- 51		3	TX
			Parking related		Census block group area	Eqn. 1- 52		3	TX
			Vehicle/bicycle		Census block group area	Eqn. 1- 53		3	TX
			Vehicle/pedestrian		Census block group area	Eqn. 1- 54		3	TX
Install median on the minor approach of an unsignalized 3-leg intersection	All	All	All			0.82	0.0903	3	FL
Convert a 3-leg unsignalized intersection at a driveway to a regular 3-leg unsignalized intersection	All	All	All			1.41	0.1095	3	FL
Add Two-Way-Left-Turn-Lane (TWLTL) to the major approach of an unsignalized 3-leg intersection	All	All	All			0.69	0.0894	3	FL
Add Two-Way-Left-Turn-Lane (TWLTL) to the major approach of an unsignalized 4-leg intersection	All	All	All			0.66		3	FL
Convert frontage road from two-way operation to one-way operation		All	Rear-end			0.27		3	TX
		Fatal and injury	All			0.43		3	TX
		Minor injury	All			0.32		3	TX
			All			0.46		3	TX

Table B. Advanced Technology and ITS

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install red-light cameras at intersections	Urban	Fatal	Red light running crashes			0.76		4	CA,MD,AZ,IL,TX,OR,NC,OH,DC,AK,VA,CO,AL,ID,MA,NY,MI,IN
		Injury	Angle,Left-turn			0.84	0.07	4	
			Rear-end			1.24	0.14	4	
		All	All			0.6		3	IA
					3-leg intersection, Camera on major road	0.45		3	notusa
			Angle			0.75	0.03	5	
						0.67	0.08	4	
			Rear-end			1.15	0.04	5	
						1.45	0.11	4	
						1.18	0.03	5	
			Other			0.74	0.03	5	
			Motorcycle		4-leg intersection, Camera on major road	0.63		3	notusa
					4-leg intersection, Camera on minor road	0.75		3	notusa
	All	All	All			0.9		3	TX
						0.76		3	TX
						0.73		3	TX
						0.71		3	TX
						0.72		3	TX
						0.7		3	TX
						0.84		3	TX
						0.76		3	TX
			Angle			0.74		3	TX
						0.61		3	TX
						0.57		3	TX
						0.69		3	TX
						0.78		3	TX
						0.68		3	TX
			Rear-end			2.69		3	TX
						2.06		3	TX
						0.77		3	TX
		All	All			0.8		4	IA
						1.15	0.1046	3	
						0.54	0.17	4	
						1.15	0.1046	3	
			Angle			0.1	0.1276	3	
						0.54		4	notusa
			Rear-end			1.43	0.1276	4	
						1.15		4	notusa
		Fatal and injury	Rear-end			1.13	0.1352	3	
Install red-light cameras with warning signs at all camera locations		Injury	Angle			0.57	0.031	3	
		All	Rear-end			1.46	0.13	3	
Install red-light cameras with warning signs at some locations		All	Angle			0.75	0.028	3	
			Rear-end			1.15	0.031	3	
		Injury	Rear-end			1.24	0.13	3	
Media coverage of automated speed enforcement cameras		All	All			0.92	0.06	3	NC
		Fatal and injury	All			0.9	0.12	3	NC
		PDO	All			0.91	0.11	3	NC
Removal of automated speed enforcement cameras		All	All		Compared to before enforcement	0.81	0.05	4	NC
		Fatal and injury	All		Compared to before enforcement	0.83	0.11	3	NC
		PDO	Nighttime		Compared to before enforcement	0.79	0.09	4	NC
		All	All		Compared to after enforcement	0.97	0.04	3	NC
		Fatal and injury	All		Compared to after enforcement	0.98	0.07	3	NC
		PDO	All		Compared to after enforcement	0.96	0.05	3	NC

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install automated section speed enforcement system	All	Fatal and injury	All			0.83	0.01	5	
	Urban	All	All			0.12	0.09	3	AZ
						0.46	0.07	4	AZ
			Single vehicle			0.37	0.09	4	AZ
			Sideswipe			0.52	0.16	3	AZ
			Rear-end			0.74	0.18	3	AZ
		Fatal and injury	All			0.85	0.11	3	NC
		Injury	All			0.14	0.13	3	AZ
						0.52	0.14	3	AZ
			Single vehicle			0.57	0.25	3	AZ
			Sideswipe			0.36	0.25	3	AZ
			Rear-end			0.77	0.3	3	AZ
		PDO	All			0.82	0.11	3	NC
						0.1	0.1	3	AZ
						0.44	0.08	4	AZ
			Single vehicle			0.33	0.09	3	AZ
			Sideswipe			0.57	0.2	3	AZ
			Rear-end			0.69	0.2	3	AZ
	Urban/suburban	All	All			0.84	0.07	4	NC
		All	All	23000 - 42000	Average speed determned over long distance	0.69	0.04	4	notusa
			Run-off-road	23000 - 42000	Average speed determned over long distance	0.82	0.08	4	notusa
			Rear-end	23000 - 42000	Average speed determned over long distance	0.86	0.1	4	notusa
			Sideswipe	23000 - 42000	Average speed determned over long distance	0.52	0.08	4	notusa
			Daytime	23000 - 42000	Average speed determned over long distance	0.74	0.05	4	notusa
			Nighttime	23000 - 42000	Average speed determned over long distance	0.62	0.05	4	notusa
			Dry weather	23000 - 42000	Average speed determned over long distance	0.69	0.04	4	notusa
			Wet road	23000 - 42000	Average speed determned over long distance	0.69	0.12	4	notusa
				23000 - 42000	Average speed determned over long distance	0.62	0.05	4	notusa
		Incapacitating injury	All	23000 - 42000	Average speed determned over long distance	0.44	0.07	4	notusa
		Minor and PDO	All	23000 - 42000	Average speed determned over long distance	0.73	0.04	4	notusa
Install automated section speed enforcement system on tangents		All	All	23000 - 42000	Average speed determned over long distance	0.72	0.04	4	notusa
Install automated section speed enforcement system on curves		All	All	23000 - 42000	Average speed determned over long distance	0.57	0.08	4	notusa
Temporal effects of automated section speed enforcement system - 6 months		All	All	23000 - 42000	Average speed determned over long distance	0.61	0.07	3	notusa
Temporal effects of automated section speed enforcement system - 12 months		All	All	23000 - 42000	Average speed determned over long distance	0.66	0.07	4	notusa
Temporal effects of automated section speed enforcement system - 18 months		All	All	23000 - 42000	Average speed determned over long distance	0.68	0.07	4	notusa
Temporal effects of automated section speed enforcement system - 24 months		All	All	23000 - 42000	Average speed determned over long distance	0.69	0.07	4	notusa
Temporal effects of automated section speed enforcement system - 30 months		All	All	23000 - 42000	Average speed determned over long distance	0.81	0.07	4	notusa
Install automated speed camera at signalized intersection		PDO	Speed related			0.87		4	notusa
		Injury	Speed related			0.76	0.1059	4	notusa
Implement mobile speed cameras	Rural	Fatal and injury	All			1.09	0.14	4	notusa
		Incapacitating injury	All			1.2	0.29	4	notusa
		All	All		Noticeable visual presence/media coverage	0.91	0.041	3	NC
Install changeable crash ahead warning signs	Urban	Injury	All			0.56	0.17	4	
Install changeable "Queue Ahead" warning signs		Injury	Rear-end			0.84	0.1	3	
		PDO	Rear-end			1.16	0.15	3	
Convert existing barrier tollbooths to open road tolling (ORT) facility						0.76	0.024	4	NJ
Install ramp meter		All	All	53500 - 204000		0.64	0.07	3	CA

Table C. Alignment

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Increase in horizontal curvature by one degree	Urban/suburban	PDO	Run-off-road			1.04	0.01	5	
		Fatal and injury	Run-off-road			1.06	0.01	5	
		All	Run-off-road			1.05	0.01	5	
	Rural	All	Truck related			1.05	0.008	3	OH
Increase in horizontal curvature by two degrees	Rural	All	Truck related			1.11	0.017	3	OH
Increase in horizontal curvature by three degrees	Rural	All	Truck related			1.16	0.027	3	OH
Increase in horizontal curvature by four degrees	Rural	All	Truck related			1.23	0.039	3	OH
Increase in horizontal curvature by five degrees	Rural	All	Truck related			1.29	0.051	3	OH
Increase in horizontal curvature from X to Y degrees	Rural	All	Truck related			Eqn. 3- 1		3	OH
		Fatal and injury	All			Eqn. 3- 2		3	TX
		All	All	6 - 98395		Eqn. 3- 3		3	notusa
Increase degree of curve on freeways from 0 to 5	All	Fatal and injury	All			1.73	0.286	3	TX
	Urban	Fatal and injury	All			1.83	0.66	3	TX
Increase degree of curve on freeways from 0 to 10	All	Fatal and injury	All			2.99	1	3	TX
	Urban	Fatal and injury	All			3.35	2.58	3	TX
Increase degree of curve on freeways from 0 to 15	All	Fatal and injury	All			5.18	2.66	3	TX
	Urban	Fatal and injury	All			6.12	7.82	3	TX
Increase degree of curve on freeways from X to Y	All	Fatal and injury	All			Eqn. 3- 5		3	TX
	Urban	Fatal and injury	All			Eqn. 3- 6		3	TX
Change the number of horizontal curves per mile from X to Y		All	All	3923 - 27149		Eqn. 3- 7		3	notusa
Change the horizontal curve radius from greater than 1500m to less than or equal to 600m	Rural	Fatal and injury	Run-off-road	1200 - 2400		2.44		3	notusa
Change the horizontal curve radius from greater than 1500m to between 600m and 1500m	Rural	Fatal and injury	Run-off-road	1200 - 2400		1.42		3	notusa
Increase in horizontal curve radius from X to Y feet (curves)	Rural	Fatal and injury	All			Eqn. 3- 23		3	TX
Horizontal curves on straight grade	Rural	Fatal and injury	All	169 - 26088		Eqn. 3- 9		3	WA
		PDO	All	169 - 26088		Eqn. 3- 10		3	WA
Tangents at non-level grade	Rural	Fatal and injury	All	169 - 26088		Eqn. 3- 11		3	WA
		PDO	All	169 - 26088		Eqn. 3- 12		3	WA
Change maximum gradient from X to Y		All	All	6 - 98395		Eqn. 3- 8		3	notusa
Change grade from positive or zero to negative	Rural	Fatal and injury	Run-off-road	1200 - 2400		1.3		3	notusa
Increase vertical grade by 1%	Rural	All	Run-off-road,Single vehicle			1.04	0.02	3	
Flatten crest vertical curve	All	Fatal and injury	All			0.49	0.19	3	OH
Horizontal curves on type 1 crest vertical curves	Rural	Fatal and injury	All	175 - 26088		Eqn. 3- 13		3	WA
		PDO	All	175 - 26088		Eqn. 3- 14		3	WA
Tangents at type 1 crest vertival curves	Rural	Fatal and injury	All	169 - 26088		1.00		3	WA
		PDO	All	169 - 26088		1.00		3	WA
Horizontal curves on type 1 sag vertical curves	Rural	Fatal and injury	All	169 - 19373		Eqn. 3- 15		3	WA
		PDO	All	169 - 19373		Eqn. 3- 16		3	WA
Tangenets at type 1 sag vertical curves	Rural	Fatal and injury	All	175 - 26088		Eqn. 3- 17		3	WA
		PDO	All	175 - 26088		Eqn. 3- 18		3	WA
Horizontal curves on type 2 crest vertical curves	Rural	Fatal and injury	All	202 - 20931		Eqn. 3- 19		3	WA
		PDO	All	202 - 20931		Eqn. 3- 20		3	WA
Tangents at type 2 crest vertival curves	Rural	Fatal and injury	All	175 - 21825		1.00		3	WA
		PDO	All	175 - 21825		1.00		3	WA
Horizontal curves on type 2 sag vertical curves	Rural	Fatal and injury	All	175 - 21825		Eqn. 3- 21		3	WA
		PDO	All	175 - 21825		Eqn. 3- 22		3	WA
Tangents at type 2 sag vertical curves	Rural	Fatal and injury	All	169 - 23334		1.00		3	WA
		PDO	All	169 - 23334		1.00		3	WA

Table D. Bicyclists

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install bicycle tracks (2-2.5 m wide)		All	All	5000 - 28000	Intersections and segments	1.1	0.064	3	notusa
					Intersections	1.18	0.036	3	notusa
				5000 - 28000	Segments	0.9	0.092	3	notusa
			Rear-end	5000 - 28000		0.93	0.087	3	notusa
			Angle			0.99	0.061	3	notusa
			Bicycle/pedestrian	5000 - 28000	Ped from right	1.13	0.099	3	notusa
				5000 - 28000	Bike with ped from right	1.8	0.301	3	notusa
			Fixed object	5000 - 28000	Parked vehicle	0.79	0.089	3	notusa
			Left-turn			1.12	0.066	3	notusa
					Left-turn vehicle	1.09	0.143	3	notusa
			Rear-end	5000 - 28000		1.01	0.066	3	notusa
			Right-turn			2.4	0.235	3	notusa
						1.7	0.347	3	notusa
			Single vehicle	5000 - 28000		0.97	0.115	3	notusa
				5000 - 28000		0.92	0.122	3	notusa
			Vehicle/bicycle	5000 - 28000		0.37	0.061	3	notusa
						2.29	0.449	3	notusa
					Left-turn vehicle with bike	1.48	0.27	3	notusa
			Vehicle/pedestrian		Left-turn vehicle with ped	1.01	0.219	3	notusa
				5000 - 28000	Vehicle with ped from right	0.9	0.043	3	notusa
				5000 - 28000	Entering or exiting bus passenger	6.19	3.145	3	notusa
		Fatal and injury	All	5000 - 28000		1.12	0.054	3	notusa
		PDO	All	5000 - 28000		1.06	0.077	3	notusa
	Urban	Incapacitating injury	All	5000 - 28000		1.1	0.061	3	notusa
		Fatal and injury	Vehicle/pedestrian	5000 - 28000		1.19	0.092	3	notusa
				5000 - 28000	Intersections	1.3	0.128	3	notusa
				5000 - 28000	Segments	1.07	0.13	3	notusa
			Vehicle/bicycle	5000 - 28000		1.1	0.077	3	notusa
				5000 - 28000	Intersection	1.24	0.105	3	notusa
				5000 - 28000	Bicycle and moped riders, Segments	0.87	0.107	3	notusa
			All	5000 - 28000		1.04	0.171	3	notusa
				5000 - 28000	Intersections	0.97	0.181	3	notusa
				5000 - 28000	Intersections	1.18	0.064	3	notusa
				5000 - 28000	Segments	0.96	0.074	3	notusa
		Minor injury	All	5000 - 28000		1.08	0.145	3	notusa
	Urban/suburban	All	Vehicle/pedestrian			1.75	0.498	3	notusa
Install bicycle lanes (1.5-2 m wide)	Urban	All	All	5000 - 28000	All	1.05	0.084	3	notusa
					Intersections	1.00	0.087	3	notusa
					Segments	1.057	0.053	3	NY
					Intersections	0.944	0.101	3	NY
			Multiple vehicle			0.44	0.128	3	NY
					Intersections	1.007	0.059	3	NY
			Vehicle/bicycle			1.509	0.583	3	NY
					Intersections	1.281	0.175	3	NY
			Vehicle/pedestrian			0.855	0.21	3	NY
					Intersections	1.065	0.175	3	NY
		Fatal and injury	All	5000 - 28000		1.14	0.171	3	notusa
				5000 - 28000	Segments	1.15	0.166	3	notusa
					Segments	0.946	0.114	3	NY
					Intersections	1.07	0.059	3	NY
		PDO	All	5000 - 28000		1.01	0.094	3	notusa
	Urban/suburban	All	Vehicle/bicycle			0.55	0.167	3	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install cycle-tracks, bicycle lanes or on-street cycling	Urban	Injury	Vehicle/bicycle		Intersections, with or without parking between the bicycle lane and traffic	0.26		3	notusa
					Segments	0.27		3	notusa
					Intersections, with parking between the bicycle lane and traffic	0.41		3	notusa
					Segments	0.41		3	notusa
Install bicycle boulevard	Urban/suburban	All	Vehicle/bicycle			0.37	0.052	3	CA
Replacement of traditional intersection with roundabout with cycle lanes	Urban	All	Vehicle/bicycle			1.93	0.334	3	notusa
Replacement of traditional intersection with roundabout with separated cycle path	Urban	All	Vehicle/bicycle			0.83	0.171	3	notusa
Replacement of traditional intersection with roundabout with a grade separated cycle path	Urban	All	Vehicle/bicycle			0.56	0.691	3	notusa
Installation of red color and high quality markings for bicycle crossings with cyclist priority at intersections	Urban/suburban	All	Vehicle/bicycle			2.53	0.788	3	notusa
Installation of raised bicycle crossing or other speed reducing measure for vehicles entering or leaving the side road	Urban/suburban	All	Vehicle/bicycle			0.49	0.114	3	notusa

Table E. Delineation

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install snowplowable, permanent raised pavement markers	Rural	All	Nighttime	0 - 20000		1.13	0.16	3	
				20001 - 60000		0.94	0.25	3	
				> 60000		0.67	0.25	3	
Install snowplowable, permanent raised pavement markers (Radius greater than 1640 ft)	Rural	All	Nighttime	0 - 5000		1.16	0.03	5	
				5001 - 15000		0.99	0.06	3	
				15001 - 20000		0.76	0.08	4	
Install snowplowable, permanent raised pavement markers (Radius less than or equal to 1640 ft)	Rural	All	Nighttime	0 - 5000		1.43	0.1	4	
				5001 - 15000		1.26	0.11	4	
				15001 - 20000		1.03	0.13	3	
Provide "Stop Ahead" pavement markings	Rural	All	All		All intersections	0.69	0.14	4	
					All-way stop controlled intersections	0.44	0.16	4	
					One-way or two-way stop controlled intersections	0.87	0.22	3	
					3-leg intersections	0.4	0.2	4	
					4-leg intersections	0.77	0.18	3	
			Angle			1.04	0.33	3	
			Rear-end			0.71	0.32	3	
		Injury	All		All intersections	0.78	0.22	3	
					AWSC	0.58	0.27	3	
					OWSC/TWSC	0.92	0.32	3	
					3-leg intersections	0.45	0.3	3	
					4-leg intersections	0.88	0.27	3	
Increase pavement marking retroreflectivity from X to Y mcd/m^2/lux	Rural	All	Cross median,Fixed object,Frontal and opposing direction sideswipe,Head-on,Nighttime,Run-off-road,Sideswipe,Single vehicle			Eqn. 5-1		3	IA
Increase pavement marking retroreflectivity of white edgelines from X to Y mcd/m^2/lux		All	Nighttime target crashes	2752 - 47572	2 lanes	Eqn. 5-2		3	NC
				2752 - 47572	3 lanes	Eqn. 5-3		3	NC
Increase pavement marking retroreflectivity of white skiplines from X to Y mcd/m^2/lux		All	Nighttime target crashes	2752 - 47572		Eqn. 5-4		3	NC
Increase pavement marking retroreflectivity of yellow centerlines from X to Y mcd/m^2/lux		All	Nighttime target crashes	2752 - 47572		Eqn. 5-5		3	NC
Increase pavement marking retroreflectivity of yellow edgelines from X to Y mcd/m^2/lux		All	Nighttime target crashes	2752 - 47572		Eqn. 5-6		3	NC
Resurface and install wider pavement markings (4 to 6 in) and both edgeline and shoulder rumble strips	Rural	Incapacitating injury	All		2 lanes, undivided	0.53	0.167	3	MO
		Fatal and injury	All		2 lanes, undivided	0.62	0.095	4	MO
Install raised pavement markers	Rural	All	All	20000 - 60000		0.81	0.07	3	LA
				> 60000		0.87	0.06	3	LA
Install raised pavement markers with restriping (center and edgelines)	Rural	All	All	20000 - 60000		0.78	0.09	3	LA
				> 60000		0.78	0.06	3	LA
Install post-mounted delineators	Rural	Injury	All			1.04	0.1	3	
		PDO	All			1.05	0.07	3	
Place centerline markings	Rural	Injury	All			0.99	0.06	3	
		PDO	All			1.01	0.05	3	
Add lane lines on multilane roadway segments	Urban	All	All			0.82	0.39	3	
Install distance markers (angle symbols) on roadway segments		Injury	All			0.44	0.26	3	
Placing edgelines and background/ directional markings on horizontal curves	Rural	Injury	Run-off-road			0.81	0.31	3	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install edgelines (curves)	Rural	All	All		Lane widths 9-11 ft, Shoulder widths < 5 ft	0.741	0.024	3	TX
					Lane widths 9 ft, Shoulder widths < 5 ft	0.671	0.063	3	TX
	Urban	All	Run-off-road			0.89	0.031	3	TX
Install edgelines (tangent)	Rural	All	All			0.939	0.027	3	TX
			Run-off-road			0.866	0.035	3	TX
Install edgelines (tangents and curves)	Rural	All	All			0.921	0.019	3	TX
			Run-off-road		Lane widths 9-11 ft, Shoulder widths < 5 ft	0.888	0.023	3	TX
					Lane widths 9 ft, Shoulder widths < 5 ft	0.868	0.065	3	TX
Place standard edgeline marking (4-6 in)	Rural	Injury	All			0.97	0.04	3	
		PDO	All			0.97	0.11	3	
Install edgelines and centerlines	Rural	Injury	All			0.76	0.11	4	
		All	All			0.87	0.14	3	
Install edgelines, centerlines, and post-mounted delineators	All	Injury	All			0.55	0.11	4	
Install wider edgelines (4 in to 5 in)	Rural	All	All			0.699	0.046	3	IL
			Daytime			0.709	0.056	3	IL
			Fixed object			0.705	0.071	3	IL
			Nighttime			0.701	0.078	3	IL
			Nighttime,Single vehicle			0.705	0.086	3	IL
			Nighttime,Wet road			0.643	0.181	3	IL
			Other			0.759	0.096	3	IL
			Single vehicle			0.63	0.053	3	IL
			Single vehicle,Wet road			0.672	0.124	3	IL
			Wet road			0.653	0.114	3	IL
		Fatal and injury	All			0.623	0.061	3	IL
			Daytime			0.64	0.077	3	IL
			Nighttime			0.658	0.106	3	IL
			Single vehicle			0.578	0.07	3	IL
			Nighttime,Single vehicle			0.637	0.115	3	IL
		PDO	All			0.761	0.063	3	IL
Install wider edgelines (4 in to 6 in)	Rural	All	All			0.825	0.028	4	KS
						0.806	0.045	3	MI
			Daytime			0.714	0.043	4	KS
			Fixed object			0.81	0.066	4	KS
			Nighttime			0.962	0.043	4	KS
						0.812	0.059	3	MI
			Nighttime,Single vehicle			0.816	0.084	4	KS
						0.82	0.061	3	MI
			Nighttime,Wet road			0.757	0.147	4	KS
						0.208	0.074	3	MI
			Single vehicle			0.73	0.048	4	KS
						0.813	0.047	3	MI
			Single vehicle,Wet road			0.341	0.073	3	MI
			Wet road			0.771	0.106	4	KS
						0.374	0.073	3	MI
		Fatal and injury	All			0.635	0.052	4	KS
			Nighttime			0.873	0.107	4	KS
			Single vehicle			0.632	0.061	4	KS
			Nighttime,Single vehicle			0.813	0.121	4	KS
			Daytime			0.585	0.066	4	KS
						0.77	0.13	3	MI
		PDO	All			0.877	0.032	4	KS
						0.804	0.047	3	MI

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install wider edgelines (8 in)	Rural	Injury	All			1.05	0.08	3	
		PDO				0.99	0.15	3	
Install wider pavement markings without resurfacing	Rural	Fatal and injury	All			0.78	0.081	4	MO
Resurface and install wider pavement markings (4 to 6 in)	Rural	Incapacitating injury	All		Divided median, Principal arterial other Freeways and expressways	0.79	0.06	4	MO
					Divided median	0.66	0.097	4	MO
					Undivided	0.54	0.156	3	MO
		Fatal and injury	All		Principal arterial other freeways and expressways	0.91	0.037	4	MO
						0.75	0.055	4	MO
	Urban	Incapacitating injury	All			0.62	0.142	4	MO
		Fatal and injury	All		Principal arterial other freeways and expressways	0.96	0.019	4	MO
						0.92	0.022	4	MO
Resurface and install wider pavement markings (4 to 6 in) and edgeline rumble strips	Rural	Incapacitating injury	All		Principal arterial other freeways and expressways	0.75	0.054	4	MO
						0.76	0.065	4	MO
		Fatal and injury	All		Principal arterial other freeways and expressways	0.76	0.031	4	MO
						0.74	0.035	4	MO
	Urban	Fatal and injury	All		Principal arterial other freeways and expressways	0.9	0.027	4	MO
						0.86	0.048	4	MO
Resurface and install wider pavement markings (4 to 6 in) and shoulder rumble strips	Rural	Incapacitating injury	All		Principal arterial other freeways and expressways	0.74	0.088	4	MO
						0.51	0.183	3	MO
		Fatal and injury	All		Principal arterial other freeways and expressways	0.77	0.051	4	MO
						0.75	0.123	4	MO
	Urban	Fatal and injury	All			0.8	0.043	4	MO

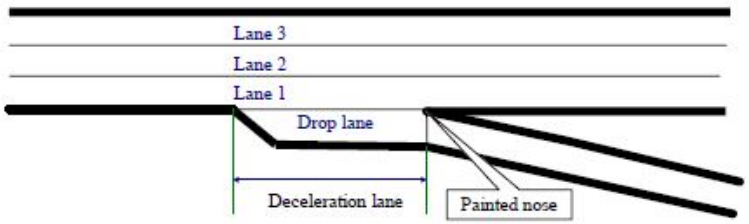
Table F. Highway Lighting

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install lighting	All	Fatal	All			0.31	0.36	3	
			Nighttime			0.51	0.0459	3	notusa
		Injury	All			0.73	0.12	4	
			Nighttime			0.54	0.0204	3	notusa
						0.5	0.01531	3	notusa
						0.69	0.0255	3	notusa
		PDO	All			0.68	0.26	3	
	Rural	Injury	All			0.8	0.12	3	
			All,Nighttime			0.46	0.0102	3	notusa
			Dry weather,Nighttime			0.44	0.01276	3	notusa
			Fixed object,Nighttime			0.46	0.02296	3	notusa
			Nighttime,Rear-end			0.49	0.02041	3	notusa
			Nighttime,Wet road			0.54	0.01786	3	notusa
	Urban	Injury	All			0.69	0.07	4	
		PDO	All			0.84	0.08	4	
		PDO	All			0.69	0.36	3	
Install lighting (highway)	All	Fatal	All	All		0.31	0.36	3	
		Injury	Nighttime			0.72	0.06	4	
		PDO	Nighttime			0.83	0.07	4	
Install lighting (intersection)	All	All	Daytime	40 - 77430		1.05	0.03	3	MN
		All	Nighttime	40 - 77430		0.881	0.054	3	MN
				40 - 77430		0.92	0.035	3	MN
	Rural	All	Angle	420 - 15200		0.67	0.12	3	GA
			Daytime	40 - 77430		1.09	0.06	3	MN
			Nighttime	40 - 77430		1.07	0.074	3	MN
			Vehicle/pedestrian	420 - 15200		0.56	0.14	3	GA
	Urban/suburban	All	Daytime	40 - 77430	Signalized intersection	1.03	0.1	3	MN
				40 - 77430	Signalized intersection	1.05	0.053	3	MN
			Nighttime	40 - 77430	Stop-controlled intersection	0.97	0.15	3	MN
				40 - 77430	Stop-controlled intersection	0.91	0.07	3	MN
		All	Nightime			0.934	0.055	3	MN
						0.953	0.023	3	MN
			Daytime			1.032	0.044	3	MN
						1.028	0.018	3	MN
		Fatal	All			0.23	0.28	3	
			Vehicle/pedestrian			0.19	0.28	3	
		Injury	All			0.5	0.21	3	
			Nighttime			0.62	0.13	4	
			Vehicle/pedestrian			0.41	0.2	4	
			Nighttime,Vehicle/pedestrian			0.58	0.18	4	
		PDO	All			0.69	0.36	3	
						0.52	0.21	3	
Install lighting (interchanges)	All	All	All			0.5	0.166	3	OH
Full to partial interchange lighting	Suburban	All	Daytime			0.984	0.029	3	OR
			Nighttime			1.035	0.047	3	OR
		Injury	Day time			0.913	0.042	4	OR
			Night time			0.886	0.06	3	OR
Full lineal to no or partial lineal lighting	Suburban	All	All			0.905	0.084	3	OR
		Injury	All			0.766	0.103	3	OR
Partial plus to partial interchange lighting	Suburban	All	Daytime			1.036	0.113	3	OR
			Nighttime			0.648	0.109	3	OR
		Injury	Nighttime			0.6	0.141	3	OR

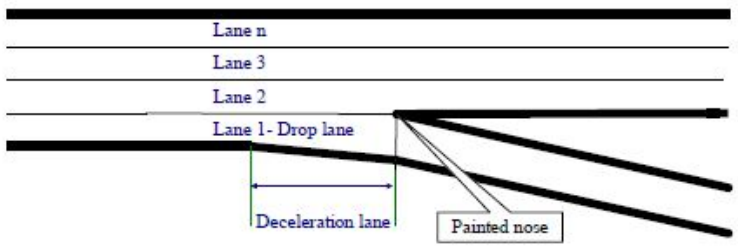
Table G. Interchange Design

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert at-grade intersection into grade-separated interchange		All	All		4-leg intersection	0.58	0.1	4	
					3-leg intersections	0.84	0.17	3	
					3-leg, 4-leg intersection	0.73	0.08	4	
		Injury	All		4-leg intersection	0.43	0.05	5	
					3-leg, 4-leg intersection	0.72	0.11	4	
		PDO	All			0.64	0.14	4	
Provide diamond interchange		All	All			0.93	0.09	3	
						0.62	0.23	3	
						0.98	0.17	3	
						0.91	0.16	3	
			Truck related			0.89	0.12	3	
						1.43	0.09	4	
						0.9	0.1	3	
Provide tight-urban-diamond interchange (TUDI)		All	All			1.02	0.13	3	
Design diamond, trumpet, or cloverleaf interchange with crossroad above freeway		All	All			0.96	0.1	3	
Extend acceleration lane by approx. 98 ft (30 m)		All	All			0.89	0.05	5	
Extend deceleration lane by approx. 100 ft		All	All			0.93	0.06	3	
Extend deceleration lane from 101-200 ft. to 601-700 ft.		All	All			0.064	0.014	3	FL
Extend deceleration lane from 201-300 ft. to 601-700 ft.		All	All			0.155	0.025	3	FL
Provide long ramp instead of shortramp		All	All			0.62	0.1	4	
Provide straight ramp instead of cloverleaf ramp		All	All			0.55	0.2	4	
Provide cloverleaf ramp instead of long ramp		All	All			0.77	0.2	3	
Provide short ramp instead of directional loop ramp		All	All			0.7	0.2	3	
Single-lane exit ramp without taper compared to with taper (right ramp only)		All	All			1.128	0.1136	3	FL
Single-lane entrance ramp and two-lane exit ramp with continuous auxiliary lane vs. single-lane		All	All	28500 - 282000		2.13	0.49	3	FL
		Incapacitating injury	All	28500 - 282000		2.02	0.3	3	FL
Left side off ramp						1.49	0.2628	3	FL
One lane-unbalanced freeway exit ramp vs. one lane-balanced freeway exit ramp		All	All	18800 - 291000		1.43	0.1	3	FL
Change length of deceleration lane on one-lane freeway exit ramp from X to Y miles		All	All	18800 - 291000		Eqn. 7-1		3	FL
Two lane-unbalanced freeway exit ramp vs. two lane-balanced freeway exit ramp		All	All	18800 - 291000		1.23	0.11	3	FL
Unbalanced freeway exit ramp vs. balanced freeway exit ramp		Incapacitating injury	All	18800 - 291000		0.98	0.11	3	FL
Change number of lanes on freeway exit ramp from X to Y		Incapacitating injury	All	18800 - 291000		Eqn. 7-2		3	FL
				18800 - 291000		Eqn. 7-3		3	FL
Change number of lanes on freeway exit ramp from X to Y (one-lane freeway)		All	All	18800 - 291000		Eqn. 7-4		3	FL
Change number of lanes on freeway exit ramp from X to Y (one-lane exit)		All	All	18800 - 291000		Eqn. 7-5		3	FL
Change number of lanes on freeway exit ramp from X to Y (two-lane exit)		All	All	18800 - 291000		Eqn. 7-6		3	FL
Divided vs. undivided cross road at diamond interchange ramps		All	All			0.53		3	WI
Change number of lanes on cross road at diamond interchange ramp from X to Y		All	All			Eqn. 7-7		3	WI

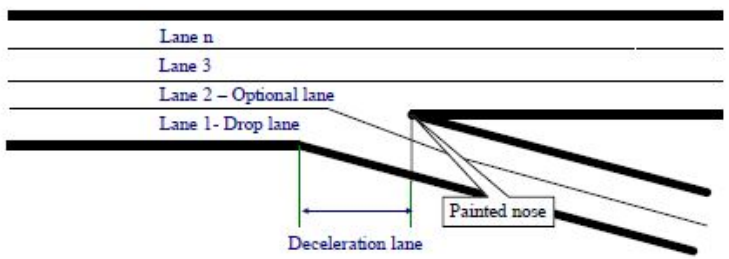
Change spacing distance between two ramp terminals at diamond interchange from X to Y feet		All	All			Eqn. 7-8		3	WI
			Angle			Eqn. 7-9		3	WI
			Rear-end			Eqn. 7-10		3	WI
Convert a Type I exit ramp to a Type II exit ramp*		All	Truck related		Type I is a full width parallel from tangent that leads to either a tangent or flat exiting curve which includes a decelerating taper. The horizontal and vertical alignment of type I exit ramps were based on the selected design speed equal or less than the intersecting roadways. Type II is when the outer lane becomes a drop lane at the exit gore forming a lane reduction. A paved and striped area beyond the theoretical gore were present at this type of exit ramps to provide a maneuver and recovery area. Type III includes two exit lanes while a large percentage of traffic volume on the freeway beyond the painted nose would leave at this particular exit. An auxiliary lane to develop the full capacity of two lane exit was developed for 1500 feet. Type IV is used where one of the through lanes, the outer lane, is reduced and another full width parallel from tangent lane developed with a taper is also forced to exit.	1.21	0.1	3	FL
Convert a Type I exit ramp to a Type III exit ramp*		All	Truck related			0.79	0.07	3	FL
Convert a Type I exit ramp to a Type IV exit ramp*		All	Truck related			1	0.15	3	FL
Convert a Type III exit ramp to a Type IV exit ramp*		All	Truck related			1.26		3	FL
Provide an auxiliary lane between an entrance ramp and exit ramp		All	All			0.8		3	WA
			Single vehicle			0.8		3	WA
			Angle,Rear-end,Sideswipe			0.76		3	WA
		Fatal and injury	All			0.77		3	WA
Modify two-lane-change to one-lane-change merge/diverge area		All	All			0.68	0.04	5	
Closely spaced single-lane entrance and exit ramp vs. single-lane entrance and exit ramps with continuous auxiliary lane		All	All	28500 - 282000		1.46	0.31	3	FL
Two lane-unbalanced freeway exit ramp vs. two lane-balanced freeway exit ramp		Incapacitating injury	All	18800 - 291000		0.97	0.21	3	FL



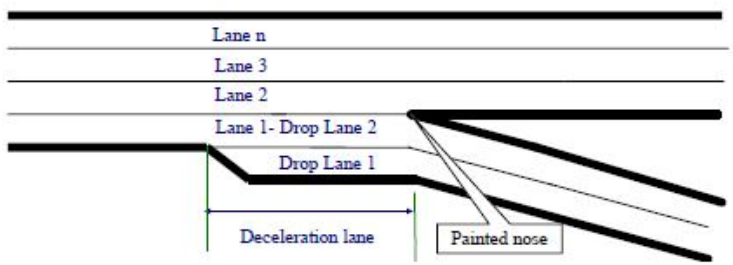
Type I Exit Ramp: Parallel from a Tangent Single-lane Exit Ramp



Type II Exit Ramp: Single-lane Exit Ramp without a Taper



Type III Exit Ramp: Two-lane Exit Ramp with an Optional Lane



Type IV Exit Ramp: Two-lane Exit Ramp without an Optional Lane

Table H. Intersection Geometry

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert a conventional signalized intersection to a signalized superstreet	Rural	All	All			2.11		3	NC
			Angle,Right-turn			3.66		3	NC
			Rear-end			2.93		3	NC
			Left-turn			0.44		3	NC
		Fatal and injury	All			2.09		3	NC
Provide a channelized left-turn lane on both major-road approaches	Rural	Injury	All			0.96	0.21	3	
		PDO	All			0.84	0.39	3	
						0.74	0.22	3	
Provide a channelized left-turn lane on both major- and minor-road approaches	Rural	Injury	All			0.73	0.23	3	
Provide a left-turn lane on one major-road approach		All	All			0.61	0.07	3	FL
	Rural	All	All		3-leg intersection	0.56	0.07	4	
					4-leg intersection	0.72	0.03	5	
		Fatal and injury	All		3-leg intersection	0.45	0.1	4	
					4-leg intersection	0.65	0.04	5	
	Urban	All	All	1500 - 40600	Stop-controlled, 3-leg intersection	0.67	0.15	4	
				1500 - 40600	Stop-controlled, 4-leg intersection	0.73	0.04	5	
				7200 - 55100	Signalized intersection	0.9	0.1	3	
				4600 - 40300	Signalized intersection	0.76	0.03	5	
			Motorcycle		Signalized, 4-leg intersection	1.23		3	notusa
			Motorcycle		Signalized, 3-leg intersection	1.4		3	notusa
		Fatal and injury	All	1500 - 40600		0.71	0.05	5	
						0.79		3	notusa
				7200 - 55100		0.91	0.02	5	
				4600 - 40300		0.72	0.06	4	
		PDO	All			0.8		3	notusa
Provide a left-turn lane on both major-road approaches	Rural	All	All			0.52	0.04	5	
		Fatal and injury	All			0.42	0.04	5	
	Urban	All	All	1500 - 40600		0.53	0.04	5	
				7200 - 55100		0.81	0.13	3	
				4600 - 40300		0.58	0.04	5	
		Fatal and injury	All	1500 - 40600		0.5	0.06	4	
				7200 - 55100		0.83	0.02	5	
				4600 - 40300		0.52	0.07	4	
	All	All	All			0.73		3	FL
						1.36	0.1632	3	FL
		All	All			0.98	0.13	3	FL
Install one left-turn lane on the minor approach of an unsignalized 3-leg intersection	All	All	All			0.75	0.1097	3	FL
Introduce zero or positive offset left-turn lane on crossing roadway	Urban	All	Angle			0.74	0.26	3	
						0.8	0.28	3	
Introduce raised/curb left-turn channelization	Rural	All	Rear-end,Sideswipe			0.75	0.27	3	
			All			0.87	0.28	3	
Provide a right-turn lane on one major-road approach	All	All	All		Stop-controlled, 3-leg intersection	0.83	0.1827	3	FL
					Stop-controlled, 3-leg or 4-leg intersection	0.86	0.06	4	
					Signalized intersection	0.96	0.02	3	
		Fatal and injury	All		Stop-controlled intersection	0.77	0.08	4	
					Signalized intersection	0.91	0.04	5	
		All	All		3-leg intersection	0.8	0.08	3	FL
					4-leg intersection	0.75	0.19	3	FL

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Introduce painted left-turn channelization	Rural	All	Rear-end,Sideswipe			0.61	0.19	3	
			All			0.67	0.18	3	
Provide a right-turn lane on both major-road approaches	All	All	All		Stop-controlled intersection	0.74	0.08	4	
					Signalized intersection	0.92	0.03	5	
Provide a right-turn lane on a signalized 3-leg intersection	Urban	All	Motorcycle		Major road	2.5		3	notusa
					Minor road	1.6		3	notusa
Physical channelization of both major and minor roads	Rural	Fatal and injury	All		3-leg intersection	1.16	0.09	3	
					4-leg intersection	0.73	0.06	4	
		PDO	All			0.87	0.4	3	
Painted channelization of left-turn lane on major road	Rural	Injury	All			0.78	0.25	3	
		PDO	All			0.8	0.34	3	
Painted channelization of both major and minor roads	Rural	Injury	All			0.43	0.12	4	
Addition of left- or right-turn by-pass lanes	Rural	All	All			0.95	0.21	3	
		PDO	All			0.81	0.23	3	
Presence of exclusive left turn (transit-serviced locations)	Urban	All	All			0.88	0.029	3	notusa
Presence of exclusive left or right turn on either approach (transit-serviced locations)	Urban	All	All			0.96	0.013	3	notusa
Increase the number of left-turn lanes on the major road of 2-lane intersections from X to Y	Rural	All	Sideswipe			Eqn. 8-1		3	GA
Increase the number of left-turn lanes on the minor road of 2-lane intersections from X to Y	Rural	All	Angle			Eqn. 8-2		3	GA
Change number of lanes on major road of a 4-leg signalized intersection from X to Y	Urban	All	Motorcycle			Eqn. 8-3		3	notusa
Change number of lanes on minor road of a 4-leg signalized intersection from X to Y	Urban	All	Motorcycle			Eqn. 8-4		3	notusa
Change number of lanes on minor road of a signalized 3-leg intersection	Urban	All	Motorcycle			Eqn. 8-5		3	notusa
Permit through movements from both minor approaches to an intersection instead of from only one minor approach		All	All			0.31	0.09	3	FL
Presence of exclusive right turn phase at diamond interchange ramps		All	All			0.27		3	WI
			Angle			0.13		3	WI
			Rear-end			0.37		3	WI
Change number of 3-leg intersections from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 8-6		3	NY
Change number of 5-leg intersections from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 8-7		3	NY
Convert a 4-leg unsignalized intersection at driveways to a regular 4-leg unsignalized intersection	All	All	All			1.11	0.1117	3	FL
Convert a 3-leg unsignalized intersection at a driveway to a 3-leg unsignalized intersection at a ramp junction	All	All	All			2.29	0.4604	3	FL
Convert 4-leg intersection into two 3-leg intersections	Urban	Injury	All		Minor road AADT: 0~15%	1.35	0.27	3	
					Minor road AADT: 15%~30% of total entering	0.75	0.08	4	
					Minor road AADT: > 30% of total entering	0.67	0.1	4	
		PDO	All		Minor road AADT: 0~15%	1.15	0.11	3	
					Minor road AADT: 15%~30% of total entering	1.00	0.09	3	
					Minor road AADT: > 30% of total entering	0.9	0.09	3	
Presence of 3-leg intersection vs. 4-leg intersection	Urban/suburban	All	Vehicle/bicycle			0.86		3	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Presence of right turning lane on arterial with signal coordination	Urban/suburban	All	Rear-end			0.06	0.02	3	IN
Conversion of intersection into roundabout	Rural	Injury	Vehicle/bicycle			1.01	0.44	3	
	All	Injury	Vehicle/bicycle			1.27	0.34	3	
		Injury	All			0.61	0.08	4	
		Serious injury	All			0.83	0.23	3	
		Minor injury	All			0.62	0.08	4	
Conversion of intersection into single-lane roundabout	All	All	All			0.64	0.123	4	WI
		Fatal and injury	All			0.818	0.154	3	WI
Conversion of intersection into multi-lane roundabout	All	All	All			1.062	0.153	4	WI
		Fatal and injury	All			0.367	0.128	4	WI
Conversion of no control/yield intersection into roundabout	All	All	All			1.242	0.648	3	WI
		Fatal and injury	All			0		3	WI
Conversion of unsignalized intersection into roundabout		Serious injury	All			0.8	0.3	3	
		Injury	All			0.56	0.1	4	
		Minor injury	All			0.54	0.11	4	
Conversion of stop-controlled intersection into single-lane roundabout	Rural	All	All			0.42	0.13	4	
		Injury	All			0.18	0.16	4	
	Urban	All	All			0.28	0.11	4	
						0.95	0.18	3	
		Injury	All			0.12	0.14	4	
Conversion of two-way stop-controlled intersection into roundabout	All	All	All			0.751	0.105	4	WI
						0.56	0.05	5	
		Fatal and injury	All			0.65	0.104	4	WI
		Injury	All			0.18	0.04	5	
	Rural	All	All			0.29	0.05	5	
		Injury	All			0.13	0.04	5	
	Suburban	All	All		1, 2 lanes	0.68	0.08	4	
					1 lane	0.22	0.07	4	
					2 lanes	0.81	0.11	3	
		Injury	All		1, 2 lanes	0.29	0.1	4	
					1 lane	0.22	0.12	4	
					2 lanes	0.32	0.14	4	
	Urban	All	All		1, 2 lanes	0.71	0.11	4	
					1 lane	0.61	0.12	4	
					2 lanes	0.88	0.21	3	
		Injury	All		1, 2 lanes	0.19	0.09	4	
					1 lane	0.22	0.12	4	
Conversion of all-way, stop-controlled intersection into roundabout	All	All	All		1, 2 lanes	1.03	0.18	3	
					2, 4 lanes	1.114	0.259	4	WI
		Fatal and injury	All			0.544	0.196	3	WI
Conversion of intersection into low-speed roundabout	All	All	All			1.099	0.118	4	WI
		Fatal and injury	All			0.473	0.113	4	WI
Conversion of intersection into high-speed roundabout	All	All	All			0.659	0.094	4	WI
		Fatal and injury	All			0.506	0.158	3	WI

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Conversion of high-speed rural intersection into roundabout	Rural	All	All			0.33		4	KS,MD,MN,OR,WA,WI
			Angle			0.17		3	KS,MD,MN,OR,WA,WI
			Fixed object			4.66		3	KS,MD,MN,OR,WA,WI
			Rear-end			0.85		3	KS,MD,MN,OR,WA,WI
			Sideswipe			2.79		3	KS,MD,MN,OR,WA,WI
		Injury	All			0.13		4	KS,MD,MN,OR,WA,WI
			Angle			0.09		3	KS,MD,MN,OR,WA,WI
Conversion of high-speed rural 3-leg intersection into roundabout	Rural	All	All			0.74		3	KS,OR
		Injury	All			0.28		3	KS,OR
Conversion of high-speed rural 4-leg intersection into roundabout	Rural	All	All		1, 2 lanes	0.32		4	KS,MD,MN,OR,WA,WI
					1 lane	0.26		4	KS,MD,MN,OR,WA,WI
					2 lanes	1.41		3	KS,MD,MN,OR,WA,WI
		Injury	All		1, 2 lanes	0.12		4	KS,MD,MN,OR,WA,WI
					1 lane	0.11		4	KS,MD,MN,OR,WA,WI
					2 lanes	0.4		3	KS,MD,MN,OR,WA,WI
Conversion of signalized intersection into roundabout	All	All	All			0.52	0.06	4	
						0.955	0.317	4	WI
		Fatal and injury	All			0.348	0.76	3	WI
		Injury	All			0.22	0.07	4	
	Rural	All	All			0.625		3	MS
		Injury	All			0.4		3	MS
	Suburban	All	All			0.33	0.05	4	
						0.58	0.05	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
						0.576	0.053	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Fatal and injury	All			0.259	0.066	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Injury	All			0.26	0.07	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
	Urban	All	All			0.65	0.16	3	
						0.99	0.14	3	
						1.15	0.09	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
						1.15	0.093	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Fatal and injury	All			0.445	0.1	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Injury	All			0.26	0.25	3	
						0.4	0.14	4	
						0.45	0.1	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Conversion of signalized intersection into roundabout	Urban/suburban	All	All		1, 2 lanes, 3-leg, 4-leg intersections	0.79	0.05	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 3-leg intersections	1.07	0.16	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 4-leg intersections	0.76	0.05	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					2 lanes, 3-leg, 4-leg intersections	0.81	0.06	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1 lane, 3-leg, 4-leg intersections	0.74	0.09	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 3-leg, 4-leg intersections	0.792	0.05	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					2 lanes, 3-leg, 4-leg intersections	0.809	0.061	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1 lane, 3-leg, 4-leg intersections	0.735	0.086	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 3-leg intersections	1.066	0.163	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 4-leg intersections	0.759	0.052	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Fatal and injury	All		1, 2 lanes, 3-leg, 4-leg intersections	0.342	0.058	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					2 lanes, 3-leg, 4-leg intersections	0.288	0.065	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1 lane, 3-leg, 4-leg intersections	0.451	0.115	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 3-leg intersections	0.37	0.172	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 4-leg intersections	0.338	0.061	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Injury	All		1, 2 lanes, 3-leg, 4-leg intersections	0.34	0.06	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 3-leg intersections	0.37	0.17	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 4-leg intersections	0.34	0.06	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					2 lanes, 3-leg, 4-leg intersections	0.29	0.07	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1 lane, 3-leg, 4-leg intersections	0.45	0.12	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Minor injury	All			0.69	0.16	3	
		Serious injury	All			0.87	0.39	3	
		Injury	All			0.68	0.14	4	
Convert traffic signals to unconventional median U-turns	Urban	All	All			1.132	0.06	4	notusa

Table I. Intersection Traffic Control

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert minor-road stop control to all-way stop control	Rural	All	All			0.52	0.04	5	
	Urban	All	Angle			0.25	0.03	5	
			Rear-end			0.82	0.13	3	
			Vehicle/pedestrian			0.57	0.15	4	
		Injury	All			0.3	0.06	4	
Install a traffic signal	All	PDO	All			1.15		3	FL
	Rural	All	All		Stop-controlled intersection	0.56	0.03	5	
					Signalized intersection	0.85		3	FL
			Angle			0.23	0.02	5	
			Left-turn			0.4	0.06	4	
			Rear-end			1.58	0.17	4	
	Urban	All	All			0.83		3	FL
					Major road speed limit >= 40 mph	0.95	0.09	3	
			Angle		Major road speed limit >= 40 mph	0.33	0.06	4	
			Rear-end		Major road speed limit >= 40 mph	2.43	0.37	3	
		Fatal and injury	All		3-leg intersection	0.86	0.38	3	
					4-leg intersection	0.77	0.27	3	
			Angle			0.33	0.24	4	
Remove unwarranted signal (one-lane, one-way streets, excluding major arterials)	Urban	All	Angle,Left-turn,Right-turn			0.76	0.14	4	
			Rear-end			0.71	0.29	3	
			Vehicle/pedestrian			0.82	0.31	3	
		All	All			0.76	0.09	4	
Permit right-turn-on-red		All	All			1.07	0.01	5	No state(s) chosen.
			Vehicle/bicycle			1.82	0.31	3	
			Vehicle/pedestrian			1.43	0.24	4	
						1.57	0.31	3	
			Vehicle/bicycle,Vehicle/pedestrian			1.69	0.1	5	
		Injury	Right-turn			1.6	0.09	4	
		PDO	Right-turn			1.1	0.01	5	
Modify change plus clearance interval to ITE 1985 Proposed Recommended Practice		All	All			0.92	0.1	3	
			Angle			0.96	0.21	3	
			Rear-end			1.12	0.2	3	
			Vehicle/bicycle,Vehicle/pedestrian			0.63	0.16	3	
		Injury	All			0.88	0.11	3	
			Angle			1.06	0.26	3	
			Rear-end			1.08	0.21	3	
			Vehicle/bicycle,Vehicle/pedestrian			0.63	0.19	3	
Prohibit left-turns with "No Left Turn" sign	Urban/suburban	All	Left-turn			0.36	0.15	4	
			All			0.32	0.13	4	
Prohibit left-turns and U-turns with "No Left Turn" and "No U-Turn" signs	Urban/suburban	All	Left-turn,Other			0.23	0.22	4	
			All			0.28	0.22	4	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Provide flashing beacons at stop controlled intersections	All	All	All			0.95	0.04	3	
			Angle			0.87	0.06	4	
						0.72	0.25	3	
						0.88	0.07	3	
						0.42	0.2	4	
						0.87	0.06	4	
						0.86	0.12	3	
			Rear-end			0.92	0.11	3	
		Injury	All			0.9	0.06	3	
	Rural	All	Angle			0.84	0.06	4	
	Suburban	All	Angle			0.88	0.12	3	
	Urban	All	Angle			1.12	0.28	3	
Add 3-inch yellow retroreflective sheeting to signal backplates	Urban	All	All			0.85	0.005	4	notusa
Add signal (additional primary head)	Urban	All	All			0.72		3	notusa
	Urban	All	Rear-end			0.72		3	notusa
	Urban	Fatal and injury	All			0.83		3	notusa
	Urban	PDO	All			0.69		3	notusa
Convert signal from pedestal-mounted to mast arm	All	All	All			0.51	0.031	3	KS
						0.71	0.068	3	IA
		All	Angle			0.26	0.032	3	KS
			Rear-end			0.59	0.07	3	KS
		Fatal and injury	All			0.56	0.068	3	KS
		PDO	All			0.49	0.034	3	KS
Install a stop sign on minor approach of an unsignalized intersection	All	All	All			1.18	0.17	3	FL
Install a stop sign on both minor approaches of an unsignalized intersection	All	All	All			1.4	0.28	3	FL
						0.78		3	FL
Install two-way stop controlled intersections at uncontrolled intersections	Urban/suburban	All	All		Residential streets	0.489	0.066	4	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install stop sign at passive highway-rail crossing		All				**0.68**	**0.00018**	**3**	**AL,AK,AZ,AR,CA,CO,CT,DE,DC,FL,GA,HI,ID,IL,IN,IA,KS,KY,LA,ME,MD,MA,MI,MN,MS,MO,MT,NE,NV,NH,NJ,NM,NY,NC,ND,OH,OK,OR,PA,RI,SC,SD,TN,TX,UT,VT,VA,WA,WV,WI,WY**
						Eqn. 9-1		**3**	**AL,AK,AZ,AR,CA,CO,CT,DE,DC,FL,GA,HI,ID,IL,IN,IA,KS,KY,LA,ME,MD,MA,MI,MN,MS,MO,MT,NE,NV,NH,NJ,NM,NY,NC,ND,OH,OK,OR,PA,RI,SC,SD,TN,TX,UT,VT,VA,WA,WV,WI,WY**
						Eqn. 9-2		**3**	**AL,AK,AZ,AR,CA,CO,CT,DE,DC,FL,GA,HI,ID,IL,IN,IA,KS,KY,LA,ME,MD,MA,MI,MN,MS,MO,MT,NE,NV,NH,NJ,NM,NY,NC,ND,OH,OK,OR,PA,RI,SC,SD,TN,TX,UT,VT,VA,WA,WV,WI,WY**
Install stop signs at alternate intersections in residential areas	Urban	All	All			0.45		3	notusa
		Fatal and injury	All			0.28		3	notusa
Modify signal phasing (implement a leading pedestrian interval)	Urban	All	Vehicle/bicycle,Vehicle/pedestrian			**0.63**	**0.193**	**3**	**PA**
						0.554	**0.235**	**3**	**PA**
Left turn phase improvement	Urban	Fatal and injury	All			0.85		3	notusa
		PDO	All			0.96		3	notusa
Change traffic signal spacing from X to Y signals per mile	Urban	All	All			Eqn. 9-3		3	UT
			Angle			Eqn. 9-4		3	UT
Change left-turn signal phase (Permitted to protected)	Urban	All	All			0.975	0.085	3	NC
			Angle			0.021	0.021	4	NC

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Change left-turn signal phase (Permitted-protected to protected on major approach)	Urban	All	All			0.58	0.34	3	
						0.99	0.13	3	
			Angle			0.04	0.08	4	
						0.01	0.03	5	
Change left-turn signal phase (Permitted to protected-permitted or permitted protected)	Urban	All	All			1.045	0.135	3	NC
						1.031	0.022	4	notusa,NC
					Intersections only	0.958	0.036	4	notusa,NC
			Left-turn			0.862	0.05	4	notusa,NC
					Intersections only	0.787	0.072	4	notusa,NC
			Rear-end		Intersections only	1.05	0.059	4	notusa,NC
						1.075	0.036	4	notusa,NC
		Fatal and injury	All			0.962	0.035	4	notusa,NC
					Intersections only	0.914	0.055	4	notusa,NC
			Left-turn			0.84	0.02	5	
Change left-turn signal phase (Protected to protected-permitted)		All				0.96	0.44	3	
Change left-turn signal phase (Protected-permitted to protected)		All	All			1.02	0.123	3	NC
		All	Angle			0	0.006	3	NC
Change left-turn signal phase (Protected-permitted to permitted-protected)		All	All			0.87	0.42	3	
Change left-turn signal phase (to protected on one or more approaches)	Urban	All	All			0.94	0.1	3	No state(s)
			Left-turn			0.01	0.01	5	
		All	All		Intersections only	1.081	0.027	4	notusa,NC
			Left-turn		Intersections only	0.925	0.067	4	notusa,NC
			Rear-end		Intersections only	1.094	0.045	4	notusa,NC
		Fatal and injury	All		Intersections only	0.995	0.043	4	notusa,NC
Change left-turn phase from at least one permissive approach to flashing yellow arrow (FYA)	Urban	All	All		Intersections only	0.753	0.094	5	NC,OR,WA
			Left-turn		Intersections only	0.635	0.126	5	NC,OR,WA
Change left turn phase from protected-permitted to flashing yellow arrow (FYA)	Urban	All	All		Intersections only	0.922	0.104	4	NC,OR,WA
			Left-turn		Intersections only	0.806	0.146	4	NC,OR,WA
Change left-turn phase (Lag-lag to lead-lag)		All	Angle			0.33		3	TX
Change left-turn phase (Lag-lag to lead-lead)		All	Angle			0.31		3	TX
Change left-turn phase (Lead-lead to lag-lag, protected-only)		All	Angle			2.16		3	TX
Change left-turn phase (Lead-lead to lead-lag, protected-only)		All	Angle			0.69		3	TX
Change left-turn phase (Lead-lead to lead-lag, protected/permissive)		All	Angle			1.57		3	TX
Change left-turn phase (Leading protected to lagging protected exclusive)		All	All			1.15	0.42	3	
Replace 8-inch red signal heads with 12-inch		All	All			0.97	0.06	3	NC
			Angle			0.58	0.07	4	NC
Install dual red signal lenses		All	All			1.18	0.11	3	NC
			Angle			1.05	0.13	3	NC

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Convert yield signal control to signalized control (intersection crashes)	Urban	All	All		3-leg,4-leg,more than 4 leg intersection	0.64	0.07	4	notusa
					3-leg intersection	0.79	0.17	3	
					4-leg intersection	0.61	0.06	4	notusa
					More than 4 leg intersection	0.25	0.17	3	notusa
					4-leg intersection	0.45	0.1	3	notusa
					4-leg intersection	0.62	0.11	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.5		3	notusa
					3-leg intersection	0.65		3	notusa
					4-leg intersection	0.48		3	notusa
					More than 4 legs intersection	0.14		3	notusa
			Angle			0.16		3	notusa
			Left-turn,Right-turn			1.65		3	notusa
			Vehicle/bicycle			0.7		3	notusa
Convert yield signal control to signalized control (end-crossroad crashes 80-200 m away from intersection)	Urban	All	All			0.96	0.1	3	notusa
						0.92	0.08	3	notusa
						0.98	0.06	3	notusa
					Nighttime	1.06	0.08	3	notusa
Convert yield signal control to signalized control (crashes 10-100 m away from intersection)	Urban	All	Main roadway			0.82	0.07	4	notusa
			Minor roadway			0.84	0.12	3	notusa
			All			0.8	0.07	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.8	0.07	4	notusa
					3-leg intersection	0.71	0.14	4	notusa
					4-leg intersection	0.76	0.07	4	notusa
Convert yield signal control to signalized control (crashes 110-200 m away from intersection)	Urban	All	Main roadway			0.93	0.06	3	notusa
			Minor roadway			0.75	0.1	4	notusa
			All			0.84	0.06	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.87	0.05	4	notusa
					3-leg intersection	0.82	0.06	4	notusa
					4-leg intersection	0.97	0.1	3	notusa
Convert yield signal control to signalized control (crashes 210-350 m away from intersection)	Urban	All	Main roadway			0.97	0.06	3	notusa
			Minor roadway			1.12	0.14	3	notusa
			All		3-leg,4-leg,more than 4 leg intersection	1.00	0.05	3	notusa
					3-leg intersection	0.99	0.11	3	notusa
					4-leg intersection	1.00	0.07	3	notusa
						0.92	0.07	3	notusa
Convert yield signal control to signalized control (crashes 360-500 m away from intersection)	Urban	All	Main roadway			0.92	0.07	3	notusa
			Minor roadway			1.27	0.18	3	notusa
			All		3-leg,4-leg,more than 4 leg intersection	0.99	0.06	3	notusa
					3-leg intersection	1.06	0.13	3	notusa
					4-leg intersection	0.97	0.07	3	notusa
						1.11	0.11	3	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Convert yield signal control to signalized control (crashes up to 500 m away from intersection)	Urban	All	Minor roadway			0.96	0.06	3	notusa
	Urban	All	All		3-leg,4-leg,more than 4 leg intersection	0.9	0.04	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.89	0.04	4	notusa
					3-leg intersection	0.95	0.08	3	notusa
					4-leg intersection	0.88	0.03	4	notusa
						0.85	0.04	4	notusa
Convert yield signal control to signalized control (roadway crashes up to 200 m away from intersection)	Urban	All	All		3-leg,4-leg,more than 4 leg intersection	0.87		3	notusa
					3-leg intersection	0.85		3	notusa
					4-leg intersection	0.86		3	notusa
			Angle		3-leg,4-leg,more than 4 leg intersection	0.72		3	notusa
					4-leg intersection	0.68		3	notusa
			Head-on,Rear-end		3-leg,4-leg,more than 4 leg intersection	0.82		3	notusa
					4-leg intersection	0.79		3	notusa
			Left-turn,Right-turn		3-leg,4-leg,more than 4 leg intersection	0.9		3	notusa
					4-leg intersection	0.82		3	notusa
			Single vehicle		3-leg,4-leg,more than 4 leg intersection	0.97		3	notusa
					4-leg intersection	0.92		3	notusa
			Vehicle/bicycle		3-leg,4-leg,more than 4 leg intersection	0.81		3	notusa
					3-leg intersection	1.04		3	notusa
					4-leg intersection	0.7		3	notusa
			Vehicle/pedestrian		3-leg,4-leg,more than 4 leg intersection	0.68		3	notusa
					3-leg,4-leg,more than 4 leg intersection	0.62		3	notusa
					4-leg intersection	0.69		3	notusa
					4-leg intersection	0.62		3	notusa
Convert yield signal control to signalized control (intersection and roadway crashes up to 200 m away from intersection)	Urban	All	All		3-leg,4-leg,more than 4 leg intersection	0.77	0.04	4	notusa
					3-leg intersection	0.81	0.08	4	notusa
					4-leg intersection	0.74	0.04	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.79	0.04	4	notusa
					3-leg intersection	0.79	0.04	4	notusa
					4-leg intersection	0.77	0.05	4	notusa
			Angle		3-leg,4-leg,more than 4 leg intersection	0.49	0.04	4	notusa
					3-leg intersection	0.56	0.09	3	notusa
					4-leg intersection	0.46	0.05	4	notusa
			Head-on,Rear-end		3-leg,4-leg,more than 4 leg intersection	0.89	0.08	3	notusa
					3-leg intersection	1.03	0.17	3	notusa
					4-leg intersection	0.83	0.09	4	notusa
			Left-turn,Right-turn		3-leg,4-leg,more than 4 leg intersection	1.01	0.09	3	
					3-leg intersection	1.00	0.14	3	notusa
					4-leg intersection	1.01	0.11	3	notusa
			Single vehicle		3-leg,4-leg,more than 4 leg intersection	0.97	0.09	3	notusa
					3-leg intersection	1.03	0.17	3	notusa
					4-leg intersection	0.93	0.1	3	notusa
			Vehicle/bicycle		3-leg,4-leg,more than 4 leg intersection	0.8	0.08	4	notusa
					3-leg intersection	1.03	0.13	3	notusa
					4-leg intersection	0.7	0.09	4	notusa
			Vehicle/pedestrian		3-leg,4-leg,more than 4 leg intersection	0.76	0.08	4	notusa
					3-leg intersection	0.76	0.14	3	notusa
					4-leg intersection	0.77	0.1	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.7	0.08	4	notusa
					3-leg intersection	0.68	0.15	3	notusa
					4-leg intersection	0.72	0.1	3	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Convert from yield signal control to signalized control (intersection crashes with 1 signal 200-500 m away)	Urban	All	All			0.59	0.14	3	notusa
Convert yield signal control to signalized control (intersection crashes with 1-2 signals under 200 m away)	Urban	All	All			0.52	0.11	3	notusa
Convert yield signal control to signalized control (intersection crashes with 2 signals 200-500 m away)	Urban	All	All			0.66	0.12	3	notusa
Change difference between actual and ITE-recommended yellow change interval from X to Y seconds at diamond interchange ramps		All	All			Eqn. 9-5		3	WI
			Angle			Eqn. 9-6		3	WI
			Rear-end			Eqn. 9-7		3	WI
Change difference between actual and ITE-recommended red clearance interval from X to Y seconds at diamond interchange ramps		All	All			Eqn. 9-8		3	WI
			Angle			Eqn. 9-9		3	WI
			Rear-end			Eqn. 9-10		3	WI
Change number of traffic signal cycles per hour on arterial with signal coordination from X to Y	Urban/suburban	All	Rear-end			Eqn. 9-11		3	IN
Change number of all-way stop intersections from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 9-12		3	NY
Change number of signalized intersections from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 9-13		3	NY
Convert minor-road stop control to all-way stop control	All	All	All			0.319	0.022	4	NC
			Angle			0.855	0.112	3	NC
			Angle,Head-on,Left-turn,Right-turn			0.247	0.02	4	NC
		Fatal and injury	All			0.23	0.025	4	NC
Convert two-way (without flashing beacons) to all-way stop control (without flashing beacons)	All	All	All			0.393	0.033	4	NC
			Angle	680 - 15100		0.943	0.152	3	NC
			Angle,Head-on,Left-turn,Right-turn			0.299	0.03	4	NC
		Fatal and injury	All			0.276	0.037	4	NC
Convert two-way (without flashing beacons) to all-way stop control (with flashing beacons)	All	All	All			0.183	0.035	4	NC
			Angle	1340 - 9900		0.601	0.201	3	NC
			Angle,Head-on,Left-turn,Right-turn			0.143	0.033	4	NC
		Fatal and injury	All			0.134	0.04	3	NC
Convert two-way (with flashing beacons) to all-way stop control (with flashing beacons)	All	All	All			0.198	0.039	4	NC
			Angle,Head-on,Left-turn,Right-turn			0.156	0.037	4	NC
		Fatal and injury	All			0.135	0.048	3	NC
Improve signal visibility	Urban	All	All			0.93		4	notusa
			Daytime			0.94		4	notusa
			Nighttime			0.93		4	notusa
		Fatal and injury	All			0.97		4	notusa
						0.71		3	notusa
		PDO	All			0.91		4	notusa
						0.79		3	notusa
Improve signal visibility, including signal lens size upgrade, installation of new back-plates, addition of reflective tapes to existing back-plates, and installation of additional signal heads	Urban	Fatal and injury	Daytime		4-leg intersections, 3 or 4 lanes per approach, 50 km/hr posted speed	1.004	0.039	4	notusa
			Nighttime			0.902	0.056	4	notusa
		PDO	Daytime			0.901	0.029	4	notusa
			Nighttime			0.867	0.052	4	notusa
Replace standard stop sign with flashing LED stop sign		All	Angle			0.59	0.25	3	MN

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install dynamic signal warning flashers	All	All	All			0.814	0.062	4	NV,VA
			Angle			0.745	0.086	4	NV,VA
			Rear-end			0.792	0.079	4	NV,VA
			Truck related			0.956	0.177	3	NV,VA
		Fatal and injury	All			0.82	0.083	4	NV,VA
Increase yellow change interval	Urban	All	All			1.14	0.177	3	CA,MD
			Angle			1.076	0.297	3	CA,MD
			Rear-end			0.934	0.237	3	CA,MD
		Fatal and injury	All			1.07	0.216	3	CA,MD
Increase all red clearance interval	Urban	All	All		Between 1-2 second increase	0.798	0.074	4	CA,MD
			Angle		Between 1-2 second increase	0.966	0.164	3	CA,MD
			Rear-end		Between 1-2 second increase	0.804	0.135	3	CA,MD
		Fatal and injury	All		Between 1-2 second increase	0.863	0.114	3	CA,MD
Increase yellow interval and add all red interval	Urban	All	All		Yellow between 0.5-1.6 second increase, Red between 1-2 second increase	0.99	0.146	3	CA,MD
			Angle			0.961	0.217	3	CA,MD
			Rear-end			1.12	0.288	3	CA,MD
		Fatal and injury	All			1.02	0.156	3	CA,MD
Increase total change interval (remains less than ITE recommended practice)	Urban	All	All			0.728	0.077	3	CA,MD
			Angle			0.84	0.195	3	CA,MD
			Rear-end			0.848	0.142	3	CA,MD
		Fatal and injury	All			0.662	0.099	3	CA,MD
Increase total change interval (greater than ITE recommended practice)	Urban	All	All			0.922	0.089	3	CA,MD
			Angle			1.068	0.156	3	CA,MD
			Rear-end			0.643	0.13	4	CA,MD
		Fatal and injury	All			0.937	0.114	3	CA,MD
Installation of an actuated advance warning dilemma zone protection system at high-speed signalized intersections		All	All			0.918	0.058	4	NE
			Angle			0.564	0.056	4	NE
			Rear-end			0.988	0.115	4	NE
			Truck related			0.995	0.133	4	NE
		Injury	All			0.887	0.105	4	NE
Replace Nighttime Flash with Steady Operation	All	All	All			0.52	0.06	4	NC
			Angle,Head-on,Left-turn,Sideswipe			0.43	0.07	4	NC
		Fatal and injury	All			0.47	0.08	4	NC
	Urban	All	Angle,Nighttime			0.66	0.32	3	
			Nighttime			0.65	0.26	3	
		All	All			0.73	0.08	3	NC
			Frontal and opposing direction sideswipe,Head-on			0.52	0.07	3	NC
		Fatal and injury	All			0.77	0.12	3	NC

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Replace Incandescent Traffic Signal Bulbs with Light Emitting Diodes (LEDs)	Urban	All	All		4-leg intersection	1.47	0.042	3	TN
					3-leg intersection	1.042	0.051	3	NC
					4-leg intersection	0.982	0.026	3	NC
			Angle,Head-on,Left-turn		3-leg intersection	1.016	0.094	3	NC
					3-leg intersection	1.078	0.194	3	NC
					4-leg intersection	1.091	0.049	3	NC
					4-leg intersection	0.959	0.075	3	NC
			Nighttime		3-leg intersection	1.109	0.106	3	NC
					4-leg intersection	0.926	0.044	4	NC
			Rear-end		3-leg intersection	1.105	0.084	3	NC
					3-leg intersection	1.177	0.182	3	NC
					4-leg intersection	0.827	0.036	4	NC
					4-leg intersection	0.828	0.069	4	NC
		Fatal and injury	All		3-leg intersection	1.17	0.094	3	NC
					4-leg intersection	1.047	0.045	3	NC
			Nighttime		3-leg intersection	1.122	0.179	3	NC
					4-leg intersection	1.035	0.081	3	NC
Install pedestrian countdown timer		All	Vehicle/pedestrian			0.3		4	MI
Change left-turn phasing from protected to flashing yellow arrow	Urban	All	All		Intersections only	1.338	0.097	5	NC,OR,WA
			Left-turn		Intersections only	2.242	0.276	5	NC,OR,WA
Modify change plus clearance interval to ITE 1985 Proposed Recommended Practice		All	Multiple vehicle			0.95	0.07	3	
		Injury	Multiple vehicle			0.91	0.07	3	

Table J. On-Street Parking

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Prohibit on-street parking	Urban	All	All			0.58	0.08	4	
		Fatal and injury	All	30000 - 40000		0.78	0.05	5	
		Injury	All		Minor arterial	0.8	0.05	5	
					Principal arterial, Other	0.65	0.14	4	
		PDO	All		Minor arterial	0.73	0.02	5	
					Principal arterial, Other	0.52	0.1	4	
				30000 - 40000	Principal arterial, Other	0.72	0.02	5	
Convert free to regulated parking	Urban	Injury	All			0.94	0.08	3	
		PDO	All			1.19	0.05	5	
		All	All			0.89	0.06	3	
			Parking related			0.21	0.09	4	
Convert angle parking to parallel parking	Urban	All	All			0.65	0.07	4	
						0.72	0.11	4	
			Parking related			0.37	0.07	4	
						0.43	0.18	4	
		Fatal and injury	All			0.59	0.27	3	
Mark parking stalls	Urban	All	All			1.51	0.2	4	
Change unrestricted parking hours from X to Y hours	Urban	All	All		All land uses	Eqn. 10-1		3	notusa
					Residential land uses	Eqn. 10-2		3	notusa
					Residential and mixed land uses	Eqn. 10-3		3	notusa
					All land uses, during rush hours	Eqn. 10-4		3	notusa
Change unrestricted left turn hours from X to Y hours	Urban	All	All		All land uses	Eqn. 10-5		3	notusa
					Residential land uses	Eqn. 10-6		3	notusa
					Residential and mixed land uses	Eqn. 10-7		3	notusa
					All lane uses, during rush hours	Eqn. 10-8		3	notusa
					Residential land uses, during rush hours	Eqn. 10-9		3	notusa
					Residential and mixed land uses, during rush hours	Eqn. 10-10		3	notusa

Table K. Pedestrians

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Raised median with marked crosswalk (uncontrolled)	Urban/suburban	All	Vehicle/pedestrian	**> 15000**		**0.54**	**0.48**	**3**	**AZ,CA,FL,KS,LA, MD,MA,MO,NC, OH,OR,PA,TX,UT ,WA,WI**
Implement to Safe Routes to School Program		All	Vehicle/bicycle,Vehicle/pedestrian			0.724	0.0651	3	CA
		Minor injury				0.839	0.0541	3	CA
Install crosswalk on one minor approach	All	All	All			0.35		3	FL
Install high-visibility yellow, continental type crosswalks at schools	Urban	All	Vehicle/pedestrian	567 - 43199		0.63	0.12	3	CA
Installation of a High intensity Activated crossWalK (HAWK) pedestrian-activated beacon at an intersection	Urban/suburban	All	All			0.712	0.065	4	AZ
			Vehicle/pedestrian			0.309	0.156	3	AZ
		Incapacitating injury	All			0.849	0.118	3	AZ
Change number of subway stations from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 11-1		3	NY
Change number of bus stations from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 11-2		3	NY
Change number of bus stops in 50m buffer from X to Y	Urban/suburban	All	Vehicle/bicycle			Eqn. 11-3		3	notusa
Convert Pelican crossing* or farside pedestrian signal to Puffin crossing**		Fatal and injury	All		Mid-block crossing or signalized intersection	0.81		3	notusa
					Signalized intersection	0.74		3	notusa
					Mid-block crossing	0.83		3	notusa
					Mid-block crossing or signalized intersection	0.84		3	notusa
			Vehicle/pedestrian		Mid-block crossing or signalized intersection	0.76		3	notusa
					Mid-block crossing	0.78		3	notusa

Pelican crossing*
These are signal-controlled crossings where flashing amber follows the red 'Stop' light. You must stop when the red light shows. When the amber light is flashing, you must give way to any pedestrians on the crossing. If the amber light is flashing and there are no pedestrians on the crossing, you may proceed with caution.

Puffin crossing**
These are similar to pelican crossings, but there is no flashing amber phase

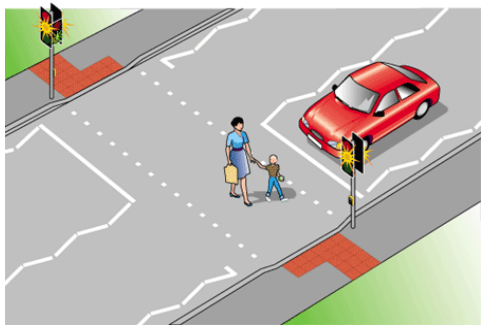


Table L. Railroad Grade Crossings

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Implementing signs and crossbucks at previously unprotected crossings			All			0.75	0.18	3	
Install flashing lights and sound signals		All	All			0.5	0.05	5	
Upgrade signs to flashing lights		All	All		Minor arterials	0.22	0.05	4	
					Multiple tracks	0.31	0.14	4	
					Local roads with single track crossing	0.21	0.04	5	
					Single track crossing at other road types (not local roads)	0.26	0.23	4	
					All	0.23	0.03	5	
Installing gates at crossings with signs		All	All		Minor arterial	0.06	0.02	5	
					Local roads	0.13	0.03	5	
					Local roads	0.09	0.02	5	
					All roads	0.07	0.01	5	
Install automatic gates at crossings that previously had passive traffic control		All	All			0.33	0.09	4	
Install automatic gates at crossings that previously had flashing lights and sound signals		All	All			0.55	0.09	4	

Table M. Roadside Features

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Flatten sideslope from 1V:3H to 1V:4H	Rural	All	Run-off-road			0.82	0.16	3	
		Injury	All			0.58	0.04	5	
		PDO	All			0.71	0.04	5	
Flatten sideslope from 1V:4H to 1V:6H	Rural	All	Run-off-road			0.76	0.21	3	
		Injury	All			0.78	0.04	5	
		PDO	All			0.76	0.02	5	
New guardrail along embankment		All	Run-off-road			0.93	0.31	3	
		Fatal	Run-off-road			0.56	0.1	4	
		Injury	Run-off-road			0.53	0.05	5	
Change barrier along embankment to less rigid type		Fatal	Run-off-road			0.59	0.31	3	
		Injury	Run-off-road			0.68	0.1	4	
Install median barrier	All	All	All			0.14	0.029	3	OH
		Fatal and injury	All			0.12	0.052	3	OH
	Rural	All	All	20000 - 60000		1.24	0.03	5	
		Fatal	All	20000 - 60000		0.57	0.1	4	
		Injury	All	20000 - 60000		0.7	0.06	4	
Install steel median barrier	Rural	Injury	All	20000 - 60000		0.65	0.08	4	
Install cable median barrier	Rural	Injury	All	20000 - 60000		0.71	0.11	4	
		All	Cross median,Frontal and opposing direction sideswipe,Head-on			0.09	0.1	4	IN
			Fixed object,Run-off-road,Single vehicle			1.83	0.76	4	IN
			Rear-end,Sideswipe			0.86	0.36	5	IN
	All	All	Cross median			0.38	0.104	3	UT
		Incapacitating injury	All			0.56	0.104	3	UT
		All	All	10000 - 180000		1.91	0.0622	3	WA
			Cross median	10000 - 180000		0.35	0.037	3	WA
			Other	10000 - 180000		0.47	0.033	3	WA
Install cable median barrier (low tension)	Rural	All	Fixed object,Run-off-road,Single vehicle		Depressed 30-50 ft median without barrier.	0.75	0.58	4	IN
					Depressed 50+ ft median without barrier.	1.87	0.81	3	IN
			Rear-end,Sideswipe		Depressed 30-50 ft median without barrier.	0.74	0.53	4	IN
					Depressed 50+ ft median without barrier.	0.78	0.39	3	IN
Install cable median barrier (high tension)	Rural	All	Cross median,Frontal and opposing direction sideswipe,Head-on			0.04	0.06	3	IN
			Fixed object,Run-off-road,Single vehicle			1.72	0.58	4	IN
			Rear-end,Sideswipe			1.08	0.63	4	IN
		All	Other	37429 - 74191		1.378	0.108	3	FL
		PDO	Other	37429 - 74191		1.881	0.218	3	FL
Install cable median barrier (on curve)	Rural	All	Cross median,Frontal and opposing direction sideswipe,Head-on			0.06	0.1	4	IN
Install cable median barrier (on tangent)	Rural	All	Cross median,Frontal and opposing direction sideswipe,Head-on			0		3	IN
Install concrete guardrail in median	Rural	All	Cross median,Frontal and opposing direction sideswipe,Head-on	10000 - 43000		0		4	CO,IL,IN,MO,NY, OH,OR,WA
			Sideswipe	10000 - 43000		0.8	0.37	4	CO,IL,IN,MO,NY, OH,OR,WA
			Single vehicle	10000 - 43000		2.2	1.13	4	CO,IL,IN,MO,NY, OH,OR,WA
		Injury	All			1.15	0.36	3	
Install beam guardrails on median of divided highway		Fatal	All			0.13	0.41	3	
		PDO	All			1.4	0.34	3	
		All	Cross median			0.22	0.19	4	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install crash cushions at fixed roadside features		Fatal	Fixed object			0.31	0.28	3	
		Injury	Fixed object			0.31	0.1	4	
		PDO	Fixed object			0.54	0.3	3	
Increase triangle sight distance		Fatal	All			**0.44**		**3**	**30+ states**
		PDO	All			0.89	0.15	3	
		Injury	All			0.53	0.29	3	
						0.63		**3**	**30+ states**
Remove or relocate fixed objects outside of clear zone	All	All	All			0.62	0.103	3	OH
		Fatal and injury	All			0.62	0.134	3	OH
Construct gateway monument (on state-owned road)	All	All	All	3300 - 34000		0.98	0.24	3	CA
				3300 - 34000		0.68	0.15	3	CA
Presence of grass land use	Urban	All	All			1.95	0.7	3	IA
Change proportion of commercial land use to total land use from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 13-1		3	NY
Change proportion of industrial land use to total land use from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 13-2		3	NY
Change proportion of open land use to total land use from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 13-3		3	NY
Change total park area (in 1000 acres) from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 13-4		3	NY
Change clear zone from greater than or equal to 8m to less than or equal to 2m	Rural	Fatal and injury	Run-off-road	1200 - 2400		2.19		3	notusa
Change clear zone from greater than or equal to 8m to between 2m and 4m	Rural	Fatal and injury	Run-off-road	1200 - 2400		1.6		3	notusa
Change clear zone from greater than or equal to 8m to between 4m and 8m	Rural	Fatal and injury	Run-off-road	1200 - 2400		1.27		3	notusa
Increase lateral clearance from 10 to 40 feet	Rural	Fatal and injury	Run-off-road,Single vehicle	3500 - 3500	On tangent sections	0.68		3	TX
				3500 - 3500	On horizontal curve sections	0.49		3	TX
Change the lateral offset of utility poles	Rural		Fixed object	377 - 16089		Eqn. 13-5		3	notusa
Change the longitudinal density of utility poles	Rural		Fixed object	377 - 16089		Eqn. 13-6		3	notusa
Increase distance to roadside features from 3.3 ft to 16.7 ft	Rural	All	All			0.78	0.02	5	
Increase distance to roadside features from 16.7 ft to 30 ft	Rural	All	All			0.56	0.01	5	

Table N. Roadway Features

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Increase lane width	Urban	All	All			0.72		3	NJ
Convert lane width (11 ft to 9 ft)	Rural	All	All			1.21	0.12	3	
Convert lane width (11 ft to 10 ft)	Rural	All	All			1.09	0.08	3	
Convert lane width (11 ft to 12 ft)	Rural	All	All			0.95	0.32	3	
Convert lane width (12 ft to 10 ft)	Rural	All	All	186 - 15106		1.05		3	ID
				186 - 400		1.04		3	ID
			Multiple vehicle	186 - 15106		1.04		3	ID
				186 - 400		1.04		3	ID
			Single vehicle	186 - 15106		1.07		3	ID
				186 - 400		1.06		3	ID
Convert lane width (12 ft to 11 ft)	Rural	All	All	186 - 15106		1.02		3	ID
				186 - 400		1.01		3	ID
			Multiple vehicle	186 - 15106		1.03		3	ID
				186 - 400		1.02		3	ID
			Single vehicle	186 - 15106		1.02		3	ID
				186 - 400		1.02		3	ID
Convert lane width (12 ft to 10 ft, with a total shoulder of X ft)	Urban/suburban	Fatal and injury	All	1183 - 47067		Eqn. 14-1		3	IL
Convert lane width (12 ft to 11 ft, with a total shoulder of X ft)	Urban/suburban	Fatal and injury	All	1183 - 47067		Eqn. 14-2		3	IL
Convert lane width (12 ft to 13 ft, with a total shoulder of X ft)	Urban/suburban	Fatal and injury	All	1183 - 47067		Eqn. 14-3		3	IL
Four to five lane conversion	Urban	All	All	79000 - 128000	One direction	1.11	0.05	4	
					Undivided	0.45	0.051	3	LA
		Fatal and injury	All	79000 - 128000		1.11	0.08	3	
		Injury and PDO	All	79000 - 128000		1.1	0.07	3	
	Suburban	All	All			0.43	0.062	3	LA
Five to six lane conversion	Urban	All	All	77000 - 126000		1.03	0.08	3	
		Fatal and injury	All	77000 - 126000		1.07	0.13	3	
		Injury and PDO	All	77000 - 126000		1.04	0.11	3	
Short-term effects of all measures to control snow, slush or ice	All		All	All		0.5	0.2	4	
				All		0.71	0.24	3	
				All		0.96	0.19	3	
Raise standard by one class for winter maintenance	All	Injury	All			0.89	0.02	5	
		PDO	All			0.73	0.02	5	
Effects of use of salt (chemical de-icing) during the whole winter season (baseline = no salt)	All	Injury	All	All		0.85	0.09	3	
				All		1.12	0.14	3	
		PDO	All	All		0.92	0.08	3	
				All		1	0.12	3	
Effects of snow fences and higher state of preparedness for the whole winter season	All	All	All	All		0.89	0.26	3	
						0.92	0.07	3	
Road diet (Convert 4-lane undivided road to 2-lanes plus turning lane)	Urban	All	All		Minor arterial	0.71	0.02	5	
				3510 - 17020		0.95	0.091	3	MI

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Road diet (Convert 4-lane undivided road to 2-lanes plus turning lane)		All	All	3510 - 17020	Target crashes	0.59	0.061	3	MI
				3510 - 17020	High crash areas	0.91		3	MI
				3510 - 17020	Residential areas	0.77		3	MI
				3510 - 17020	Mixed use areas	1.06		3	MI
				3510 - 17020	Commercial areas	1.05		3	MI
				3510 - 17020	Low driveway density	1.07		3	MI
				3510 - 17020	High driveway density	0.81		3	MI
				3510 - 17020	8 or fewer intersections	0.95		3	MI
				3510 - 17020	9 or more intersections	0.93		3	MI
	Suburban	All	All			0.47	0.01	4	
Narrow cross section (4 to 3 lanes with two way left-turn lane)	Urban	All	All			0.63	0.00632	3	MN
			Left-turn			0.76	0.01643	3	MN
			Angle		Right-angle	0.63	0.00949	3	MN
			Rear-end			0.69	0.01517	3	MN
		Fatal and injury	All			1	0.01581	3	MN
		PDO	All			0.54	0.00775	3	MN
Implement truck lane restrictions on multilane freeways (trucks prohibited from left-most lanes)		All	All	17049 - 74079		1.16	0.02	4	VA
				< 10000 vpdpl		0.87	0.041	4	VA
				> 10000 vpdpl		1.28	0.02	4	VA
			Truck related	17049 - 74079		1.15	0.041	4	VA
				< 10000 vpdpl		0.50	0.046	4	VA
				> 10000 vpdpl		1.34	0.051	4	VA
		Fatal and injury	All	17049 - 74079		1.10	0.031	4	VA
				4041 - 24361	4-lane segments, trucks traveling less than 15 mph below the speed limit prohibited on left-most lanes	0.68	0.177	3	VA
				< 10000 vpdpl		0.68	0.046	4	VA
				> 10000 vpdpl		1.23	0.036	4	VA
			Truck related	17049 - 74079		0.99	0.051	4	VA
				< 10000 vpdpl		0.6	0.082	4	VA
				> 10000 vpdpl		1.14	0.066	4	VA
Convert 12-ft lanes and 6-ft shoulders to 10-ft lanes and 3-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.13**	**0.044**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 10-ft lanes and 4-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.2**	**0.051**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 11-ft lanes and 2-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.12**	**0.047**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 11-ft lanes and 3-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.19**	**0.042**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 11-ft lanes and 4-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.14**	**0.035**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 11-ft lanes and 6-ft shoulders	Rural	All	Run-off-road	**> 1000**		**0.84**	**0.046**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 11-ft lanes and 7-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1**	**0.135**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 12-ft lanes and 2-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.16**	**0.082**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 12-ft lanes and 5-ft shoulders	All	All	Run-off-road	**> 1000**		**0.87**	**0.07**	**3**	**PA**
Commercial vs. residential land use	Urban	All	All	1390 - 51200		3.42	1.321	3	UT
			Angle	1390 - 51200		1.77	0.308	3	UT
Refinish concrete pavement with inverted turf of stiff-bristled broom (wet weather crashes)		All	All			0.635	0.048	3	MN

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Refinish pavement with microsurfacing treatment (thickness from 8-10 mm)		All	All	3000/lane - 6999/lane		0.63	0.087	3	notusa
				7000/ane -		0.74	0.056	3	notusa
			Intersection	3000/lane - 6999/lane		0.62		3	notusa
				7000/lane -		0.67		3	notusa
			Rear-end	3000/lane - 6999/lane		0.5		3	notusa
				7000/lane -		0.59		3	notusa
			Wet road	3000/lane - 6999/lane		0.46		3	notusa
				7000/lane -		0.54		3	notusa
		Incapacitating injury	All	3000/lane - 6999/lane		0.57		3	notusa
				7000/lane -		0.74		3	notusa
Improve pavement friction (increase skid resistance)	All	All	All		Not intersection related	0.76	0.03	5	
				3475 - 65850		0.799	0.028	4	NY
					3-leg, Signalized intersection	0.667	0.05	4	NY
					3-leg, Stop-controlled intersection	0.819	0.048	4	NY
					3-leg intersection, Yield sign	0.59	0.114	3	NY
					4-leg, Signalized intersection	0.797	0.052	4	NY
					4-leg, Stop-controlled intersection	1.271	0.143	4	NY
					4-leg intersection, Yield sign	0.589	0.216	3	NY
				1814 - 185570	Not intersection related	0.764	0.023	4	NY
			Angle			1.045	0.078	4	NY
					3-leg, Signalized intersection	0.787	0.125	3	NY
					3-leg, Stop-controlled intersection	0.828	0.218	3	NY
					4-leg, Signalized intersection	0.898	0.117	3	NY
					4-leg, Stop-controlled intersection	1.687	0.323	4	NY
			Angle,Wet road			0.799	0.123	3	NY
					3-leg, Signalized intersection	0.47	0.161	3	NY
					3-leg, Stop-controlled intersection	0.828	0.218	3	NY
					4-leg, Signalized intersection	1.105	0.294	3	NY
					4-leg, Stop-controlled intersection	0.829	0.351	3	NY
			Rear-end		Not intersection related	0.83	0.05	5	
					Not intersection related	0.58	0.07	4	
						0.582	0.034	4	NY
					3-leg, Signalized intersection	0.554	0.065	4	NY
					3-leg, Stop-controlled intersection	0.586	0.057	4	NY
					3-leg intersection, Yield sign	0.304	0.086	3	NY
					4-leg, Signalized intersection	0.585	0.068	4	NY
					4-leg, Stop-controlled intersection	0.943	0.188	3	NY
					4-leg intersection, Yield sign	0.504	0.248	3	NY
				1814 - 185570	Not intersection related	0.828	0.043	4	NY
			Rear-end,Wet road			0.322	0.041	4	NY
				1814 - 185570	Not intersection related	0.575	0.055	4	NY
					3-leg, Signalized intersection	0.261	0.066	4	NY
					3-leg, Stop-controlled intersection	0.335	0.075	4	NY
					3-leg intersection, Yield sign	0.221	0.161	3	NY
					4-leg, Signalized intersection	0.361	0.084	4	NY
					4-leg, Stop-controlled intersection	0.482	0.215	4	NY
			Single vehicle	All	Not intersection related	0.7	0.05	5	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Improve pavement friction (increase skid resistance)	All	All	Wet road	All	Not intersection related	0.43	0.03	5	
					Not intersection related	0.426	0.03	4	NY
					3-leg, Signalized intersection	0.372	0.053	4	NY
					3-leg, Stop-controlled intersection	0.355	0.046	4	NY
					3-leg intersection, Yield sign	0.217	0.103	4	NY
					4-leg, Signalized intersection	0.546	0.07	4	NY
					4-leg, Stop-controlled intersection	0.597	0.137	4	NY
					4-leg intersection, Yield sign	0.361	0.371	3	NY
				1814 - 185570	Not intersection related	0.434	0.024	4	NY
	Rural	All	All		2 lanes, undivided	0.964	0.073	3	NY
						0.684	0.032	4	NY
			Rear-end		2 lanes, undivided	1.047	0.149	3	NY
						0.776	0.068	4	NY
			Rear-end,Wet road		2 lanes, undivided	0.971	0.256	3	NY
						0.474	0.079	3	NY
			Wet road		2 lanes, undivided	0.852	0.126	3	NY
						0.346	0.028	4	NY
	Urban	All	All		2 lanes, undivided	0.599	0.082	4	NY
						0.862	0.038	4	NY
			Rear-end		2 lanes, undivided	0.612	0.142	4	NY
						0.866	0.059	4	NY
			Rear-end,Wet road		2 lanes, undivided	0.344	0.145	3	NY
						0.64	0.084	3	NY
			Wet road		2 lanes, undivided	0.26	0.066	4	NY
						0.538	0.045	4	NY
Install TWLTL on two lane road	All	All	All	8500 - 22500		0.775	0.058	4	AR
						0.686	0.057	4	CA
						0.874	0.073	3	IL
						0.843	0.048	4	NC
						0.797	0.03	5	AR,CA,IL,NC
			Rear-end			0.506	0.073	4	CA
						0.58	0.076	3	IL
						0.783	0.077	4	NC
						0.613	0.04	5	AR,CA,IL,NC
		Fatal and injury	All	8500 - 22500		0.629	0.11	4	AR
						0.725	0.087	4	CA
						0.469	0.119	3	IL
						1.019	0.147	4	NC
						0.739	0.068	5	AR,CA,IL,NC
	Rural	All	All			0.64	0.04	5	
				8500 - 22500		0.488	0.071	4	AR
						0.492	0.057	4	CA
						0.833	0.105	3	IL
						0.727	0.055	4	NC
			Rear-end			0.53	0.05	5	
		Injury	All			0.65	0.08	4	
	Urban	All	All	8500 - 22500		0.962	0.083	3	AR
						1.028	0.134	3	CA
						0.906	0.1	3	IL
						1.05	0.088	4	NC
		All	Rear-end	8500 - 22500		0.501	0.073	4	AR

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install centerline rumble strips	Rural	All	All	5000 - 22000		0.86	0.05	4	
				1336 - 13240		0.89	0.058	4	MN
				574 - 17591		**0.98**	**0.033**	**4**	**PA**
				3167 - 20784		1.02	0.081	4	WA
				574 - 20784		**0.96**	**0.026**	**4**	**MN,PA,WA**
				574 - 20784		**0.91**	**0.02**	**5**	**CA,CO,DE,MD,MN,OR,PA,WA**
			Cross median	200 - 8000		0.328	0.151	4	KS
			Cross median,Frontal and opposing direction sideswipe,Head-on,Run-off-road			0.71		4	notusa
			Head-on,Sideswipe	5000 - 22000		0.79	0.14	4	
				1336 - 13240		0.51	0.073	4	MN
				574 - 17591		**0.74**	**0.179**	**4**	**PA**
				3167 - 20784		0.65	0.292	3	WA
				574 - 20784		**0.63**	**0.053**	**5**	**MN,PA,WA**
				574 - 20784		**0.7**	**0.045**	**5**	**CA,CO,DE,MD,MN,OR,PA,WA**
			Other	200 - 8000		0.708	0.098	4	KS
			Run-off-road	200 - 8000		0.808	0.141	4	KS
		Fatal and injury	All	1336 - 13240		0.78	0.066	4	MN
				574 - 17591		**0.94**	**0.042**	**4**	**PA**
				3167 - 20784		1.04	0.146	4	WA
				574 - 20784		**0.91**	**0.035**	**5**	**MN,PA,WA**
				574 - 20784		**0.88**	**0.028**	**5**	**CA,CO,DE,MD,MN,OR,PA,WA**
				200 - 8000		0.66	0.141	4	KS
			Head-on,Sideswipe	1336 - 13240		0.55	0.067	4	MN
				574 - 17591		**0.56**	**0.308**	**4**	**PA**
				3167 - 20784		0.65	0.292	3	WA
				574 - 20784		**0.55**	**0.064**	**5**	**MN,PA,WA**
		Injury	All	5000 - 22000		0.85	0.08	3	
			Head-on,Sideswipe	5000 - 22000		0.75	0.18	3	
	Urban	All	All	**2338 - 22076**		**1.02**	**0.08**	**4**	**PA**
			Head-on,Sideswipe	**2338 - 22076**		**0.6**	**0.17**	**4**	**PA**
		Fatal and injury	All	**2338 - 22076**		**0.91**	**0.095**	**4**	**PA**
			Head-on,Sideswipe	**2338 - 22076**		**0.36**	**0.269**	**3**	**PA**
Install centerline rumble strips on horizontal curves	Rural	All	All	1336 - 13240		0.83	0.096	4	MN
				574 - 17591		**1.16**	**0.092**	**4**	**PA**
				3167 - 20784		1.03	0.16	4	WA
				574 - 20784		**1.04**	**0.065**	**4**	**MN,PA,WA**
			Head-on,Sideswipe	1336 - 13240		0.48	0.136	3	MN
				574 - 17591		**0.53**	**0.139**	**4**	**PA**
				3167 - 20784		1.46	1.029	3	WA
				574 - 20784		**0.53**	**0.099**	**5**	**MN,PA,WA**
		Fatal and injury	All	1336 - 13240		0.63	0.116	4	MN
				574 - 17591		**1.1**	**0.114**	**4**	**PA**
				3167 - 20784		0.79	0.129	3	WA
				574 - 20784		**0.94**	**0.081**	**4**	**MN,PA,WA**

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Install centerline rumble strips on tangent sections	Rural	All	All	1336 - 13240		0.9	0.055	4	MN
				574 - 17591		**0.9**	**0.084**	**4**	**PA**
				3167 - 20784		1.02	0.093	4	WA
				574 - 20784		**0.92**	**0.043**	**4**	**MN,PA,WA**
			Head-on,Sideswipe	1336 - 13240		0.51	0.079	4	MN
				574 - 17591		**0.57**	**0.184**	**3**	**PA**
				3167 - 20784		0.33	0.19	3	WA
				574 - 20784		**0.51**	**0.069**	**5**	**MN,PA,WA**
		Fatal and injury	All	1336 - 13240		0.82	0.078	4	MN
				574 - 17591		**0.78**	**0.1**	**4**	**PA**
				3167 - 20784		1.1	0.173	4	WA
				574 - 20784		**0.85**	**0.059**	**5**	**MN,PA,WA**
Install rectangular shaped centerline rumble strips	Rural	All	Other	200 - 8000		0.772	0.112	4	KS
			Cross median	200 - 8000		0.396	0.195	4	KS
			Run-off-road	200 - 8000		0.849	0.155	4	KS
		Fatal and injury	All	200 - 8000		0.689	0.155	4	KS
Install football shaped centerline rumble strips	Rural	All	Other	200 - 8000		0.331	0.156	3	KS
			Cross median	200 - 8000		0.097	0.143	3	KS
			Run-off-road	200 - 8000		0.45	0.279	3	KS
		Fatal and injury	All	200 - 8000		0.398	0.288	3	KS
Install edgeline rumble strips	Rural	Fatal and injury	Run-off-road	**6777 - 37112**		**0.71**	**0.139**	**3**	**MO,PA**
				11539 - 37112		0.75	0.1569	3	MO
				4956 - 31692		**0.75**	**0.1311**	**3**	**MN,MO,PA**
				4959 - 31692		0.7	0.1304	3	MN
				4956 - 20763		0.58	0.1446	3	MO
				8267 - 18753		**1.31**	**0.1079**	**3**	**PA**
				180 - 12776		**0.67**	**0.1222**	**4**	**MN,MO,PA**
				180 - 10386		1.08	0.2138	3	MN
				180 - 12776		**0.61**	**0.1556**	**4**	**MN,MO,PA**
				180 - 10386		0.57	0.2066	3	MN
		Fatal and injury	Run-off-road	**180 - 92757**		**0.86**	**0.0855**	**3**	**MN,MO,PA**
Install edgeline rumble strips on roadways with a shoulder width less than 5 feet	Rural	Fatal and injury	Run-off-road	**4956 - 31692**		**0.96**	**0.1554**	**3**	**MN,MO,PA**
				4956 - 20763		1.1	0.0508	3	MO
				180 - 12776		**0.53**	**0.2339**	**3**	**MN,MO,PA**
				180 - 10386		1.27	0.7837	3	MN
Install edgeline rumble strips on roadways with a shoulder width of 5 feet or greater	Rural	Fatal and injury	Run-off-road	11539 - 37112		0.75	0.1569	3	MO
				4956 - 31692		**0.34**	**0.1855**	**4**	**MN,MO,PA**
				4959 - 31692		0.7	0.1304	3	MN
				4956 - 20763		0.46	0.1283	3	MO
				8267 - 18753		**0.52**	**0.1161**	**3**	**PA**
				180 - 12776		**0.57**	**0.1452**	**4**	**MN,MO,PA**
				180 - 10386		1.11	0.5314	3	MN
Install centerline and shoulder rumble strips	Rural	All	Head-on,Run-off-road,Sideswipe			0.34	0.044	3	WA
			Head-on,Sideswipe			0.29	0.046	3	WA
			Run-off-road			0.384	0.064	3	WA
		Incapacitating injury	All			0.82		4	notusa
		All	Cross median,Frontal and opposing direction sideswipe,Head-on,Run-off-road			0.79		4	notusa
Resurface pavement		All	All			1.01	0.02	4	FL
			Rear-end			0.99	0.03	4	FL
		Incapacitating injury	All			0.95	0.05	4	FL
Resurface pavement with groove pavement (GP)	All	All	Wet road			0.5	0.19	3	CA
Resurface pavement with open-graded asphalt concrete (OGAC)	All	All	Wet road			0.59	0.16	3	CA

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Change bridge width (bridge minus roadway width) from X to Y		All	All			Eqn. 14-4		3	IA
Changing pavement macrotexture from X to Y	Rural	All	All	2090 - 11500		Eqn. 14-5		3	NC
Change roadway surface from gravel or dirt to asphalt	Rural	All	All	35 - 1468		Eqn. 14-6		3	WY
Convert High-Occupancy-Vehicle (HOV) lanes to High-Occupancy-Toll (HOT) lanes	Urban	All	All			0.95	0.04	3	MN
		Minor injury	All			1.06		3	MN
						0.96		3	MN
		PDO	All			0.89		3	MN
Presence of two-lane roadway vs. greater than two-lane roadway	Urban	All	All			0.43	0.18	3	IA
Install transverse rumble strips on stop controlled approaches	All	Incapacitating injury	All		4-leg intersection	0.745	0.121	4	IA,MN
	Rural	All	All		Minor arterial	1.223	0.142	4	IA,MN
					4-leg intersection	1.066	0.104	4	IA,MN
					4-leg intersection	1.066	0.104	4	IA,MN
					3-leg intersection	0.798	0.32	3	IA
					4-leg intersection	0.819	0.232	3	IA
					3-leg,4-leg intersection	0.818	0.191	3	IA
					3-leg intersection	0.671	0.278	3	MN
					4-leg intersection	1.357	0.447	3	MN
					3-leg,4-leg intersection	1.182	0.316	3	MN
		Incapacitating injury	All		3-leg intersection	0.903	0.211	3	IA,MN
					3-leg,4-leg intersection	0.785	0.107	4	IA,MN
		Fatal and injury	All		3-leg intersection	1.192	0.207	3	IA,MN
					4-leg intersection	0.913	0.124	4	IA,MN
					3-leg,4-leg intersection	0.987	0.109	4	IA,MN
		PDO	All		3-leg intersection	1.284	0.185	3	IA,MN
					3-leg,4-leg intersection	1.191	0.102	4	IA,MN
		PDO	All		4-leg intersection	1.138	0.121	4	IA,MN
Change proportion of 1-lane roadways to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-7		3	NY
Change proportion of 4-lane roadways to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-8		3	NY
Change proportion of 5-lane roadways to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-9		3	NY
Change proportion of primary roadway (without access restriction) to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-10		3	NY
Change proportion or primary roadway (with limited access) to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-11		3	NY
Change proportion of length of roads with widths less than 30 feet to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-12		3	NY
Change proportion of local rural road to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-13		3	NY
Change proportion of other throughfare roadway to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-14		3	NY
Increase surface width from X to Y feet		All	Truck related		Travel lanes only	Eqn. 14-15		3	FL
Change travel lane plus sealed shoulder width from greater than or equal to 3.5m to less than 3.5m	Rural	Fatal and injury	Run-off-road	1200 - 2400		1.21		3	notusa
Install periodic passing lanes on rural two-lane highways	Rural	Fatal and injury	All	1655 - 7031		0.58	0.09	4	TX
		Fatal and injury	Non-intersection	1655 - 7031		0.65	0.11	4	TX

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert 12-ft inside and outside lanes to 12-ft inside lane and X-ft outside lane	Urban	All	All	25100 - 52500		Eqn. 14-16		3	FL
		Fatal and injury	All	25100 - 52500		Eqn. 14-17		3	FL
		PDO	All	25100 - 52500		Eqn. 14-18		3	FL
Convert 12-ft inside and outside lanes to Y-ft inside lane and X-ft outside lane	Urban	All	All	7480 - 43929		Eqn. 14-19		3	FL
		Fatal and injury	All	7480 - 43929		Eqn. 14-20		3	FL
		PDO	All	7480 - 43929		Eqn. 14-21		3	FL
Installation of passing relief lane	Rural	All	All		Relief lanes 1 to 2.9 miles long	0.67	0.149	3	MI
			Daytime		Relief lanes 1 to 2.9 miles long	0.6	0.132	3	MI
			Dry weather		Relief lanes 1 to 2.9 miles long	0.53	0.119	3	MI
			Head-on,Rear-end,Run-off-road,Sideswipe		Relief lanes 1 to 2.9 miles long	0.53	0.114	3	MI
			Summer		Relief lanes 1 to 2.9 miles long	0.54	0.151	3	MI
			Non-summer		Relief lanes 1 to 2.9 miles long	0.72	0.164	3	MI
		Injury	All		Relief lanes 1 to 2.9 miles long	0.71	0.155	3	MI
Removing mainline barrier toll plazas on highways		All	All			0.528	0.016	4	NJ
		Fatal and injury	All			0.597	0.038	4	NJ
		PDO	All			0.51	0.017	4	NJ
Convert major road of a signalized T intersection from two-way to one-way	Urban	All	Motorcycle			0.4		3	notusa
Install transverse rumble strips at pedestrian crosswalks on rural low-volume roads	Rural	All	All			0.76	0.33	3	

Table O. Shoulder Treatments

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Install shoulder rumble strips	Rural	All	All	**6777 - 37112**		**1.07**	**0.0391**	**4**	**MO,PA**
				11539 - 37112		1.08	0.0413	4	MO
				6777 - 24752		**1**	**0.118**	**4**	**PA**
				4959 - 20763		**1.18**	**0.078**	**5**	**MN,MO,PA**
				4959 - 7459		1.1	0.1468	4	MN
				5326 - 20763		1.22	0.0946	4	MO
				9653 - 18753		**0.87**	**0.3564**	**3**	**PA**
				782 - 10386		**1.06**	**0.057**	**4**	**MN,MO,PA**
				782 - 10386		1.14	0.0801	4	MN
				861 - 6205		1.4	0.18	4	MO
				948 - 9067		**0.76**	**0.0861**	**4**	**PA**
				6777 - 37112		**1.01**	**0.0696**	**3**	**MO,PA**
				11539 - 37112		1.08	0.0717	3	MO
				6777 - 34406		**1.08**	**0.1166**	**3**	**PA**
				4956 - 31692		**1.2**	**0.0954**	**4**	**MN,MO,PA**
				4959 - 31692		1.16	0.0918	3	MN
				4956 - 20763		1.28	0.1423	3	MO
				8267 - 18753		**0.81**	**0.2015**	**3**	**PA**
				180 - 12776		**0.86**	**0.0969**	**3**	**MN,MO,PA**
				180 - 10386		0.96	0.0684	3	MN
				861 - 12776		0.83	1.1599	3	MO
				910 - 10177		**0.76**	**0.1485**	**3**	**PA**
				6777 - 37112		**1.07**	**0.0781**	**3**	**MO,PA**
				11539 - 37112		1.11	0.0763	3	MO
				6777 - 24752		**1.06**	**0.161**	**3**	**PA**
				4956 - 31692		**1.28**	**0.1092**	**4**	**MN,MO,PA**
				4959 - 31692		1.17	0.1367	3	MN
				4956 - 20763		1.28	0.1431	3	MO
				8267 - 18753		**0.74**	**0.2449**	**3**	**PA**
				180 - 12776		**0.94**	**0.1306**	**3**	**MN,MO,PA**
				180 - 10386		1.18	0.1028	3	MN
				861 - 12776		0.85	1.2939	3	MO
				910 - 10177		**0.76**	**0.1485**	**3**	**PA**
			Run-off-road			0.87	0.08	4	MN
						0.66		3	CT
					< 65 mph	0.84		3	CT
					No shoulder rumble strips between on and off ramps on freeways.	0.66		3	CT
					65 mph	0.62		3	CT
					6 or more lanes	0.64		3	CT
					4 lanes	0.68		3	CT
					Undivided	0.74		4	notusa
					All	0.78		4	notusa
				6777 - 37112		**0.9**	**0.0521**	**4**	**MO,PA**
				11539 - 37112		0.92	0.0571	4	MO
				6777 - 24752		**0.82**	**0.1227**	**4**	**PA**
				4959 - 20763		**1.4**	**0.124**	**5**	**MN,MO,PA**
				4959 - 7459		1.38	0.2662	3	MN
				5326 - 20763		1.45	0.1479	4	MO
				9653 - 17018		**0.75**	**0.3744**	**3**	**PA**
				782 - 10386		**0.84**	**0.0807**	**5**	**MN,MO,PA**
				782 - 10386		1.11	0.1707	4	MN

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install shoulder rumble strips	Rural	All	Run-off-road	861 - 6205		1.17	0.2176	3	MO
				948 - 9067		**0.56**	**0.0913**	**4**	**PA**
				6777 - 37112		**0.9**	**0.0666**	**3**	**MO,PA**
				11539 - 37112		0.93	0.0686	3	MO
				6777 - 34406		**0.98**	**0.1332**	**3**	**PA**
				4956 - 31692		**1.41**	**0.1694**	**4**	**MN,MO,PA**
				4959 - 31692		1.39	0.1653	3	MN
				4956 - 20763		1.7	0.2791	3	MO
				8267 - 18753		**0.77**	**0.1319**	**3**	**PA**
				180 - 12776		**0.71**	**0.1196**	**4**	**MN,MO,PA**
				180 - 10386		1.19	0.1587	3	MN
				861 - 12776		0.91	1.0362	3	MO
				910 - 10177		**0.55**	**0.1278**	**3**	**PA**
				6777 - 37112		**0.9**	**0.073**	**3**	**MO,PA**
				11539 - 37112		0.94	0.0727	3	MO
				6777 - 24752		**0.87**	**0.1643**	**3**	**PA**
				4956 - 31692		**1.66**	**0.2319**	**4**	**MN,MO,PA**
				4959 - 31692		1.34	0.1314	3	MN
				4956 - 20763		1.67	0.276	3	MO
				8267 - 18753		**0.77**	**0.1378**	**3**	**PA**
				180 - 12776		**0.74**	**0.1696**	**3**	**MN,MO,PA**
				180 - 10386		1.12	0.2051	3	MN
				861 - 12776		0.94	1.0872	3	MO
				910 - 10177		**0.55**	**0.1278**	**3**	**PA**
						0.822	0.066	4	notusa
			Run-off-road, Nighttime	**6777 - 37112**		**0.73**	**0.0684**	**5**	**MO,PA**
				11539 - 37112		0.74	0.0764	4	MO
				6777 - 24752		**0.67**	**0.1516**	**4**	**PA**
				782 - 10386		**0.89**	**0.1254**	**4**	**MN,MO,PA**
				782 - 10386		1.27	0.2671	3	MN
				861 - 6205		1.2	0.446	3	MO
				948 - 9067		**0.62**	**0.1371**	**4**	**PA**
				6777 - 37112		**0.77**	**0.0867**	**4**	**MO,PA**
				11539 - 37112		0.82	0.1069	3	MO
				6777 - 24752		**0.72**	**0.1518**	**3**	**PA**
				180 - 12776		**0.76**	**0.163**	**3**	**MN,MO,PA**
				180 - 10386		1.11	0.2732	3	MN
				861 - 12776		1.55	2.1783	3	MO
				910 - 10177		**0.6**	**0.1719**	**3**	**PA**
				6777 - 37112		**0.78**	**0.0747**	**4**	**MO,PA**
				11539 - 37112		0.79	0.0872	3	MO
				6777 - 34406		**0.7**	**0.1434**	**3**	**PA**
				180 - 12776		**0.7**	**0.1158**	**4**	**MN,MO,PA**
				180 - 10386		1.11	0.1985	3	MN
				861 - 12776		1.41	1.948	3	MO
				910 - 10177		**0.6**	**0.1719**	**3**	**PA**

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install shoulder rumble strips	Rural	All	Run-off-road,Truck related	**6777 - 37112**		**0.58**	**0.0801**	**5**	**MO,PA**
				11539 - 37112		0.58	0.0838	4	MO
				6777 - 24752		**0.59**	**0.2697**	**3**	**PA**
				782 - 10386		**1.83**	**0.5841**	**3**	**MN,MO,PA**
				782 - 10386		2.82	1.2629	3	MN
				861 - 6205		2.39	1.4201	3	MO
				948 - 9067		**0.81**	**0.5752**	**3**	**PA**
				6777 - 37112		**0.58**	**0.1224**	**4**	**MO,PA**
				11539 - 37112		0.59	0.0954	3	MO
				6777 - 37112		**0.54**	**0.1015**	**4**	**MO,PA**
				11539 - 37112		0.59	0.0878	3	MO
			Run-off-road,Wet road	**6777 - 37112**		**0.82**	**0.073**	**5**	**MO,PA**
				11539 - 37112		0.77	0.0775	4	MO
				6777 - 24752		**1.04**	**0.2002**	**3**	**PA**
				782 - 10386		**1.18**	**0.1538**	**4**	**MN,MO,PA**
				782 - 10386		1.5	0.3023	3	MN
				861 - 6205		1.98	0.4914	3	MO
				948 - 9067		**0.7**	**0.1642**	**3**	**PA**
				6777 - 37112		**0.89**	**0.1105**	**3**	**MO,PA**
				11539 - 37112		0.86	0.1069	3	MO
				6777 - 24752		**1.03**	**0.2908**	**3**	**PA**
				180 - 12776		**1.05**	**0.2378**	**3**	**MN,MO,PA**
				180 - 10386		1.38	0.3518	3	MN
				861 - 12776		2.35	2.3699	3	MO
				910 - 10177		**0.72**	**0.2082**	**3**	**PA**
				6777 - 37112		**0.94**	**0.1031**	**3**	**MO,PA**
				11539 - 37112		0.85	0.1026	3	MO
				6777 - 34406		**1.4**	**0.2554**	**3**	**PA**
				180 - 12776		**1.05**	**0.1523**	**3**	**MN,MO,PA**
				180 - 10386		1.75	0.3079	3	MN
				861 - 12776		2.18	2.0885	3	MO
				910 - 10177		**0.72**	**0.2082**	**3**	**PA**

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install shoulder rumble strips	Rural	Fatal and injury	All	**6777 - 37112**		**0.93**	**0.059**	**4**	**MO,PA**
				11539 - 37112		0.94	0.0641	4	MO
				6777 - 24752		**0.87**	**0.1462**	**4**	**PA**
				4959 - 20763		**0.9**	**0.1022**	**4**	**MN,MO,PA**
				4959 - 7459		0.78	0.1963	3	MN
				5326 - 20763		0.95	0.1231	4	MO
				9653 - 17018		**0.6**	**0.4252**	**3**	**PA**
				782 - 10386		**0.92**	**0.0804**	**4**	**MN,MO,PA**
				782 - 10386		1.05	0.1266	4	MN
				861 - 6205		0.81	0.2182	3	MO
				948 - 9067		**0.82**	**0.1159**	**4**	**PA**
				6777 - 37112		**0.92**	**0.0671**	**3**	**MO,PA**
				11539 - 37112		0.97	0.0837	3	MO
				6777 - 34406		**0.88**	**0.111**	**3**	**PA**
				4956 - 31692		**1.01**	**0.1082**	**3**	**MN,MO,PA**
				4959 - 31692		1.07	0.1008	3	MN
				4956 - 20763		1.05	0.2217	3	MO
				8267 - 18753		**0.58**	**0.1638**	**3**	**PA**
				180 - 12776		**0.72**	**0.0862**	**4**	**MN,MO,PA**
				180 - 10386		0.87	0.0839	3	MN
				861 - 12776		0.6	0.6339	3	MO
				910 - 10177		**0.84**	**0.189**	**3**	**PA**
				6777 - 37112		**0.96**	**0.0842**	**3**	**MO,PA**
				11539 - 37112		0.99	0.0954	3	MO
				6777 - 24752		**0.91**	**0.1413**	**3**	**PA**
				4956 - 31692		**1.05**	**0.1788**	**3**	**MN,MO,PA**
				4959 - 31692		0.82	0.1508	3	MN
				4956 - 20763		1.02	0.2181	3	MO
				8267 - 18753		**0.56**	**0.1704**	**3**	**PA**
				180 - 12776		**0.86**	**0.1156**	**3**	**MN,MO,PA**
				180 - 10386		1.07	0.161	3	MN
				861 - 12776		0.65	0.698	3	MO
				910 - 10177		**0.84**	**0.189**	**3**	**PA**

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install shoulder rumble strips	Rural	Fatal and injury	Run-off-road			0.82	0.12	3	MN
				6777 - 37112		**0.83**	**0.073**	**5**	**MO,PA**
				11539 - 37112		0.84	0.0822	4	MO
				6777 - 24752		**0.77**	**0.1571**	**3**	**PA**
				4959 - 20763		**0.97**	**0.1351**	**4**	**MN,MO,PA**
				4959 - 7459		0.9	0.2863	3	MN
				5326 - 20763		1	0.1584	4	MO
				9653 - 17018		**0.8**	**0.5695**	**3**	**PA**
				782 - 10386		**0.64**	**0.0971**	**5**	**MN,MO,PA**
				782 - 10386		0.68	0.1761	3	MN
				861 - 6205		0.55	0.2316	3	MO
				948 - 9067		**0.63**	**0.1335**	**4**	**PA**
				6777 - 37112		**0.86**	**0.0732**	**3**	**MO,PA**
				11539 - 37112		0.88	0.0857	3	MO
				6777 - 34406		**0.87**	**0.1413**	**3**	**PA**
				4956 - 31692		**1.05**	**0.1444**	**3**	**MN,MO,PA**
				4959 - 31692		1.12	0.1548	3	MN
				4956 - 20763		1.19	0.2574	3	MO
				180 - 12776		**0.63**	**0.1031**	**4**	**MN,MO,PA**
				180 - 10386		1.04	0.1839	3	MN
				861 - 12776		0.41	1.55	3	MO
				910 - 10177		**0.63**	**0.1579**	**3**	**PA**
				6777 - 37112		**0.82**	**0.0829**	**3**	**MO,PA**
				11539 - 37112		0.86	0.0959	3	MO
				6777 - 24752		**0.78**	**0.1574**	**3**	**PA**
				4956 - 31692		**1.15**	**0.2375**	**3**	**MN,MO,PA**
				4959 - 31692		0.85	0.1645	3	MN
				4956 - 20763		1.12	0.2385	3	MO
				180 - 12776		**0.6**	**0.1265**	**4**	**MN,MO,PA**
				180 - 10386		0.77	0.2005	3	MN
				861 - 12776		0.43	1.8224	3	MO
				910 - 10177		**0.63**	**0.1579**	**3**	**PA**
				6777 - 37112		**0.91**	**0.0824**	**3**	**MO,PA**
				11539 - 37112		0.97	0.0811	3	MO
				4956 - 31692		**1.1**	**0.1643**	**3**	**MN,MO,PA**
				4959 - 31692		1.23	0.1755	3	MN
				4956 - 20763		1.28	0.301	3	MO
				8267 - 18753		**0.52**	**0.1957**	**3**	**PA**
				180 - 12776		**0.53**	**0.1378**	**4**	**MN,MO,PA**
				180 - 10386		0.92	0.2406	3	MN
				180 - 12776		**0.58**	**0.2026**	**3**	**MN,MO,PA**
				180 - 10386		1.11	0.3931	3	MN
	Urban	All	All	**11254 - 59391**		**0.99**	**0.0572**	**4**	**PA**
				11254 - 92757		**0.96**	**0.0546**	**3**	**PA**
				11254 - 92757		**0.95**	**0.0569**	**3**	**PA**
			Run-off-road	**11254 - 59391**		**0.94**	**0.0732**	**4**	**PA**
				11254 - 92757		**0.96**	**0.0755**	**3**	**PA**
				11254 - 92757		**0.9**	**0.0964**	**3**	**PA**
		Fatal and injury	All	**11254 - 59391**		**0.84**	**0.0725**	**4**	**PA**
				11254 - 92757		**0.91**	**0.0719**	**3**	**PA**
				11254 - 92757		**0.8**	**0.0778**	**3**	**PA**
			Run-off-road	**11254 - 59391**		**0.93**	**0.0993**	**4**	**PA**
				11254 - 92757		**1.02**	**0.0977**	**3**	**PA**
				11254 - 92757		**0.9**	**0.1158**	**3**	**PA**
				11254 - 92757		**1.02**	**0.0977**	**3**	**PA**

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Install shoulder rumble strips	Urban	All	Run-off-road			0.82		3	notusa
		Fatal and injury	Run-off-road	**180 - 92757**		**1**	**0.0556**	**3**	**MN,MO,PA**
Install continuous milled-in shoulder rumble strips	All	All	Run-off-road,Single vehicle			0.82	0.12	3	
						0.21	0.07	4	
		Injury	Run-off-road,Single vehicle			0.87	0.21	3	
	Rural	All	All	2000 - 50000		0.84	0.13	3	
			Run-off-road,Single vehicle	2000 - 50000		0.9	0.25	3	
						0.79	0.18	3	
		Injury	All	2000 - 50000		0.83	0.19	3	
			Run-off-road,Single vehicle	2000 - 50000		0.78	0.33	3	
						0.93	0.28	3	
Install shoulder rumble strips on illuminated highways	Rural	All	Run-off-road			0.59		3	CT
Install shoulder rumble strips on unilluminated highways	Rural	All	Run-off-road			0.79		3	CT
Install shoulder rumble strips on roadways with a shoulder width equal to 5 feet	Urban	Fatal and injury	Run-off-road	**11254 - 92757**		**0.68**	**0.1431**	**3**	**PA**
	Rural	Fatal and injury	Run-off-road	11539 - 37112		0.97	0.0811	3	MO
				4956 - 31692		**0.52**	**0.2658**	**3**	**MN,MO,PA**
				4959 - 31692		1.23	0.1755	3	MN
				4956 - 20763		1.41	0.2362	3	MO
				8267 - 18753		**0.22**	**0.0742**	**3**	**PA**
				180 - 12776		**0.46**	**0.1255**	**4**	**MN,MO,PA**
				180 - 10386		0.92	0.4679	3	MN
Install shoulder rumble strips on roadways with a shoulder width less than 5 feet	Urban	Fatal and injury	Run-off-road	**11254 - 92757**		**0.66**	**0.1163**	**3**	**PA**
	Rural	Fatal and injury	Run-off-road	**180 - 12776**		**0.35**	**0.7671**	**3**	**MN,MO,PA**
				180 - 10386		1.21	0.8686	3	MN
Install shoulder rumble strips with an offset of 0-8 inches relative to the edgeline	Rural	Fatal and injury	Run-off-road	**6777 - 37112**		**0.71**	**0.1393**	**3**	**MO,PA**
				11539 - 37112		0.75	0.1584	3	MO
				4956 - 31692		**0.74**	**0.1293**	**3**	**MN,MO,PA**
				4959 - 31692		0.71	0.1291	3	MN
				4956 - 20763		0.58	0.1446	3	MO
				180 - 12776		**0.67**	**0.123**	**4**	**MN,MO,PA**
				180 - 10386		1.1	0.2196	3	MN
Install shoulder rumble strips with an offset of 9-20 inches relative to the edgeline	Urban	Fatal and injury	Run-off-road	**11254 - 92757**		**1.02**	**0.0977**	**3**	**PA**
	Rural	Fatal and injury	Run-off-road	**6777 - 37112**		**0.9**	**0.1324**	**3**	**MO,PA**
				11539 - 37112		0.49	0.0276	3	MO
				4956 - 31692		**1.06**	**0.1431**	**3**	**MN,MO,PA**
				4959 - 31692		1.3	0.1827	3	MN
				180 - 12776		**0.62**	**0.149**	**4**	**MN,MO,PA**
				180 - 10386		0.79	0.2406	3	MN
Install shoulder rumble strips with an offset of 21+ inches relative to the edgeline	Rural	Fatal and injury	Run-off-road	**6777 - 37112**		**0.93**	**0.0776**	**3**	**MO,PA**
				11539 - 37112		1.02	0.0839	3	MO
				4956 - 31692		**1.16**	**0.3059**	**3**	**MN,MO,PA**
				4959 - 31692		0.74	0.1352	3	MN
				4956 - 20763		1.28	0.301	3	MO
				180 - 12776		**0.43**	**0.276**	**3**	**MN,MO,PA**
				180 - 10386		1.58	0.6656	3	MN
Reduce shoulder width (6 ft to 0 ft)	Rural	All	All	**95 - 25844**		**1.12**	**0.031**	**3**	**PA**
Reduce shoulder width (6 ft to 1 ft)	Rural	All	All	**95 - 25844**		**1.17**	**0.062**	**3**	**PA**
Reduce shoulder width (6 ft to 2 ft)	Rural	All	All	**95 - 25844**		**1.11**	**0.024**	**3**	**PA**
Reduce shoulder width (6 ft to 4 ft)	Rural	All	All	**95 - 25844**		**1.06**	**0.019**	**3**	**PA**
Reduce shoulder width (6 ft to 5 ft)	Rural	All	All	**95 - 25844**		**1.02**	**0.024**	**3**	**PA**

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Decrease inside shoulder width from 10ft to 4ft	Urban	Fatal and injury	All	5700 - 309000		0.446	0.035	3	FL
Reduce paved shoulder from 3 ft to 0 ft	Rural	All	All	186 - 15106		1.16		3	ID
				186 - 400		1.13		3	ID
			Multiple vehicle	186 - 15106		1.15		3	ID
				186 - 400		1.11		3	ID
			Single vehicle	186 - 15106		1.17		3	ID
				186 - 400		1.14		3	ID
		All	All			1.22		4	CA,KY,MN
		All	Single vehicle			1.17		4	CA,KY,MN
Reduce paved shoulder from 3 ft to 1 ft	Rural	All	All	186 - 15106		1.13		3	ID
				186 - 400		1.11		3	ID
			Multiple vehicle	186 - 15106		1.18		3	ID
				186 - 400		1.13		3	ID
			Single vehicle	186 - 15106		1.07		3	ID
				186 - 400		1.09		3	ID
Reduce paved shoulder from 3 ft to 2 ft	Rural	All	All	186 - 15106		1.03		3	ID
				186 - 400		1.03		3	ID
			Multiple vehicle	186 - 15106		1.03		3	ID
				186 - 400		1.02		3	ID
			Single vehicle	186 - 15106		1.02		3	ID
				186 - 400		1.03		3	ID
Reduce inside paved shoulder width from 4ft to 2ft	Urban	All	All		Outside paved shoulder width = 10ft	0.668	0.1	3	FL
					Outside paved shoulder width = 8ft	0.749	0.1	3	FL
		Fatal and injury	All			0.728	0.1	3	FL
Reduce outside paved shoulder width from 10ft to 4ft	Urban	All	All		Inside paved shoulder width = 4 ft	0.417	0.1	3	FL
Reduce outside paved shoulder width from 10ft to 8ft	Urban	All	All		Inside paved shoulder width = 4ft	0.819	0.1	3	FL
				5700 - 309000		1.081	0.131	3	FL
			Rear-end	5700 - 309000		1.111	0.17	3	FL
		Fatal and injury	All	5700 - 309000		1.172	0.131	3	FL
Install curb and gutter	Suburban	All	All	8333 - 57138		0.89		3	NC
Install gravel right shoulder	Urban	All	All			4.21	1.2	3	IA
		Fatal and injury	All			0.517	0.11	3	IA
Widen shoulder width from 0 to 10 feet	Rural	Fatal and injury	Run-off-road,Single vehicle	3500 - 3500	On tangent sections	0.29		3	TX
				3500 - 3500	On horizontal curve sections	0.13		3	TX
Widen shoulder width from 6 to 7 ft	Rural	All	All	**95 - 25844**		**1.01**	**0.044**	**3**	**PA**
Widen shoulder width from 6 to 8 ft	Rural	All	All	**95 - 25844**		**0.96**	**0.022**	**3**	**PA**
Widen shoulder width from 6 to 9 ft	Rural	All	All	**95 - 25844**		**0.79**	**0.058**	**3**	**PA**
Widen shoulder width from 6 to >9 ft	Rural	All	All	**95 - 25844**		**0.82**	**0.027**	**3**	**PA**
Widen shoulder width from 10 to 11 ft	Urban	Fatal and injury	All	5700 - 309000		0.98	0.178	3	FL
Widen shoulder width from 10 to 12 ft	Urban	Fatal and injury	All	5700 - 309000		0.669	0.092	3	FL
Widen shoulder width to 5 feet or greater	Urban	Fatal and injury	Run-off-road	**11254 - 92757**	**Divided with median**	**0.64**	**0.1258**	**3**	**PA**
	Rural	Fatal and injury	Run-off-road	**4956 - 31692**	**Divided with median**	**0.47**	**0.2388**	**3**	**MN,MO,PA**
				4956 - 20763	Divided with median	1.1	0.1964	3	MO
				8267 - 18753	**Divided with median**	**0.38**	**0.125**	**3**	**PA**
				180 - 12776	**Undivided**	**0.73**	**0.1485**	**3**	**MN,MO,PA**
				180 - 10386	Undivided	1.07	0.5314	3	MN
Widen shoulder width (left shoulder by 1 foot)		Fatal and injury	All			0.925	0.04	3	IA
Widen paved shoulder width (from X to Y ft)	Rural	All	Angle		Intersection of 2-lane roads	Eqn. 15-1		3	GA
			Sideswipe		Intersection of 2-lane roads	Eqn. 15-2		3	GA
			Vehicle/pedestrian		Intersection of 2-lane roads	Eqn. 15-3		3	GA
		All	Truck related		Intersection of 2-lane roads	Eqn. 15-4		3	FL

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Widen paved shoulder width (from 3 to 4 ft)	Rural	All	All	All		0.97	0.07	3	
				186 - 15106		0.97		3	ID
				186 - 400		0.98		3	ID
			Multiple vehicle	186 - 15106		0.97		3	ID
				186 - 400		0.97		3	ID
			Single vehicle	186 - 15106		0.95		3	ID
				186 - 400		0.94		3	ID
		All	All			0.94		4	CA,KY,MN
		All	Single vehicle			0.95		4	CA,KY,MN
Widen paved shoulder width (from 3 to 5 ft)	Rural	All	All	All		0.95	0.13	3	
				186 - 15106		0.95		3	ID
				186 - 400		0.94		3	ID
			Multiple vehicle	186 - 15106		0.95		3	ID
				186 - 400		0.93		3	ID
			Single vehicle	186 - 15106		0.93		3	ID
				186 - 400		0.94		3	ID
		All	All			0.87		4	CA,KY,MN
			Single vehicle			0.9		4	CA,KY,MN
Widen paved shoulder width (from 3 to 6 ft)	Rural	All	All	All		0.93	0.2	3	
				186 - 15106		0.93		3	ID
				186 - 400		0.93		3	ID
			Multiple vehicle	186 - 15106		0.94		3	ID
				186 - 400		0.94		3	ID
			Single vehicle	186 - 15106		0.91		3	ID
				186 - 400		0.9		3	ID
		All	All			0.82		4	CA,KY,MN
			Single vehicle			0.85		4	CA,KY,MN
Widen paved shoulder width (from 3 to 7 ft)	Rural	All	All	All		0.9	0.26	3	
				186 - 15106		0.91		3	ID
				186 - 400		0.9		3	ID
			Multiple vehicle	186 - 15106		0.89		3	ID
				186 - 400		0.88		3	ID
			Single vehicle	186 - 15106		0.92		3	ID
				186 - 400		0.92		3	ID
		All	All			0.76		4	CA,KY,MN
			Single vehicle			0.81		4	CA,KY,MN
Widen paved shoulder width (from 3 to 8 ft)	Rural	All	All	All		0.88	0.32	3	
				186 - 15106		0.87		3	ID
				186 - 400		0.88		3	ID
			Multiple vehicle	186 - 15106		0.83		3	ID
				186 - 400		0.84		3	ID
			Single vehicle	186 - 15106		0.9		3	ID
				186 - 400		0.91		3	ID
		All	All			0.71		4	CA,KY,MN
			Single vehicle			0.77		4	CA,KY,MN
Widen inside paved shoulder width from 4ft to 5ft	Urban	All	All		Outside paved shoulder width = 10 ft	0.573	0.1	3	FL
Widen inside paved shoulder width from 4ft to 6ft	Urban	Fatal and injury	All			0.472	0.1	3	FL
		All	All		Outside paved shoulder width = 10 ft	0.561	0.1	3	FL
					Outside paved shoulder width = 8 ft	0.757	0.1	3	FL
Widen inside paved shoulder width from 4ft to 8ft	Urban	Fatal and injury	All			0.78	0.1	3	FL
		All	All		Outside paved shoulder width = 10 ft	1.224	0.1	3	FL
					Outside paved shoulder width = 8 ft	0.639	0.1	3	FL
Widen inside paved shoulder width from 4ft to 10ft	Urban	Fatal and injury	All			0.665	0.1	3	FL
		All	All		Outside paved shoulder width = 10 ft	0.977	0.1	3	FL
					Outside paved shoulder width = 8 ft	0.776	0.1	3	FL

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Widen inside paved shoulder width from 4ft to 11ft	Urban	Fatal and injury	All			1.173	0.1	3	FL
		All	All		Outside paved shoulder width = 10 ft	1.294	0.1	3	FL
Widen inside paved shoulder width from 4ft to 12ft	Urban	Fatal and injury	All			0.992	0.1	3	FL
		All	All		Outside paved shoulder width = 10 ft	0.946	0.1	3	FL
					Outside paved shoulder width = 8 ft	1.043	0.1	3	FL
Widen outside paved shoulder width from 10ft to 11ft (inside paved shoulder width = 4ft)	Urban	All	All		Inside paved shoulder width = 4 ft	1.169	0.1	3	FL
Widen outside paved shoulder width from 10ft to 12ft (inside paved shoulder width = 4ft)	Urban	All	All		Inside paved shoulder width = 4 ft	0.793	0.1	3	FL
				5700 - 309000		0.774	0.095	3	FL
			Rear-end	5700 - 309000		0.816	0.117	3	FL
		Fatal and injury	All	5700 - 309000		0.9	0.106	3	FL
Change left shoulder width from X to Y (feet)		All	All			Eqn. 15-5		3	FL
Change right shoulder width from X to Y	All	All	All			Eqn. 15-6		3	FL
Upgrade narrow unpaved shoulder (< 5 ft) to wide unpaved shoulder (> 5 ft)	Rural	All	All	65 - 4950		0.71	0.048	3	KS
				65 - 4950		0.58	0.054	3	KS
			Head-on,Run-off-road,Sideswipe	65 - 4950		0.21	0.038	3	KS
				65 - 4950		0.23	0.048	3	KS
		Fatal and injury	All	65 - 4950		0.35	0.051	3	KS
				65 - 4950		0.28	0.048	3	KS
Upgrade unpaved or non-existent shoulders to composite shoulders	Rural	All	All	380 - 2340		1.114	0.129	4	KS
				380 - 2340	Less than or equal to 5 ft (prior condition)	0.861	0.145	4	KS
				380 - 2340	Greater than 5 ft (prior condition)	1.42	0.224	4	KS
			Head-on,Run-off-road,Sideswipe	380 - 2340		0.674	0.163	3	KS
				380 - 2340	Less than or equal to 5 ft (prior condition)	0.389	0.13	3	KS
		Fatal and injury	All	380 - 2340		0.944	0.183	3	KS
		Fatal and injury	All	380 - 2340	Greater than 5 ft (prior condition)	0.692	0.17	3	KS
Convert a 2 ft. turf shoulder to a 3 ft. turf shoulder	Rural	All	Winter			0.96	0.048	3	KS
			Non-winter			0.95	0.054	3	KS
			All			0.96	0.038	3	KS
			Shoulder (winter)			0.74	0.094	3	KS
			Shoulder (Non-winter)			0.91	0.12	3	KS
			Shoulder (All)			0.82	0.077	3	KS
		Fatal and injury	Winter			0.94	0.094	3	KS
			Non-winter			0.98	0.102	3	KS
			All			0.96	0.074	3	KS
Convert a 2 ft. turf shoulder to a 4 ft. turf shoulder	Rural	All	Winter			1	0.051	3	KS
			Non-winter			0.93	0.054	3	KS
			All			0.97	0.041	3	KS
			Shoulder (winter)			0.76	0.099	3	KS
			Shoulder (Non-winter)			0.79	0.112	3	KS
			Shoulder (All)			0.77	0.079	3	KS
		Fatal and injury	Winter			0.67	0.079	3	KS
			Non-winter			0.79	0.092	3	KS
			All			0.72	0.064	3	KS
Convert a 2 ft. turf shoulder to a 6 ft. turf shoulder	Rural	All	Winter			0.95	0.066	3	KS
			Non-winter			0.81	0.066	3	KS
			All			0.89	0.051	3	KS
			Shoulder (winter)			0.59	0.115	3	KS
			Shoulder (Non-winter)			0.59	0.13	3	KS
			Shoulder (All)			0.59	0.087	3	KS
		Fatal and injury	Winter			0.58	0.102	3	KS
			Non-winter			0.71	0.117	3	KS
			All			0.64	0.082	3	KS

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert a 2 ft. turf shoulder to a 6 ft. composite shoulder (first 3 ft. bituminous with remainder turf)	Rural	All	Winter			0.8	0.064	3	KS
			Non-winter			0.88	0.099	3	KS
			All			0.83	0.051	3	KS
			Shoulder (winter)			0.69	0.133	3	KS
			Shoulder (Non-winter)			0.44	0.112	3	KS
			Shoulder (All)			0.58	0.089	3	KS
		Fatal and injury	Winter			0.58	0.105	3	KS
			Non-winter			0.58	0.107	3	KS
			All			0.58	0.077	3	KS
Convert a 2 ft. turf shoulder to an 8 ft. composite shoulder (first 3 ft. bituminous with remainder turf)	Rural	All	Winter			1	0.061	3	KS
			Non-winter			0.85	0.059	3	KS
			All			0.93	0.048	3	KS
			Shoulder (winter)			0.5	0.082	3	KS
			Shoulder (Non-winter)			0.56	0.097	3	KS
			Shoulder (All)			0.52	0.064	3	KS
		Fatal and injury	Winter			0.65	0.087	3	KS
			Non-winter			0.56	0.079	3	KS
			All			0.61	0.066	3	KS
Convert a 2 ft. turf shoulder to a 10 ft. composite shoulder (first 3 ft. bituminous with remainder turf)	Rural	All	Winter			1.01	0.043	3	KS
			Non-winter			0.88	0.041	3	KS
			All			0.95	0.033	3	KS
			Shoulder (winter)			0.41	0.048	3	KS
			Shoulder (Non-winter)			0.43	0.054	3	KS
			Shoulder (All)			0.42	0.041	3	KS
		Fatal and injury	Winter			0.48	0.048	3	KS
			Non-winter			0.59	0.056	3	KS
			All			0.53	0.043	3	KS
Convert a 2 ft. turf shoulder to a 10 ft. composite shoulder (first 3 ft. bituminous with remainder aggregate)	Rural	All	Winter			1.06	0.051	3	KS
			Non-winter			0.85	0.043	3	KS
			All			0.96	0.038	3	KS
			Shoulder (winter)			0.5	0.059	3	KS
			Shoulder (Non-winter)			0.45	0.059	3	KS
			Shoulder (All)			0.47	0.046	3	KS
		Fatal and injury	Winter			0.66	0.064	3	KS
			Non-winter			0.61	0.061	3	KS
			All			0.63	0.051	3	KS
Convert a 2 ft. turf shoulder to a 10 ft. paved shoulder (bituminous base)	Rural	All	Winter			0.84	0.038	3	KS
			Non-winter			0.74	0.036	3	KS
			All			0.79	0.033	3	KS
			Shoulder (winter)			0.4	0.048	3	KS
			Shoulder (Non-winter)			0.4	0.048	3	KS
			Shoulder (All)			0.4	0.041	3	KS
		Fatal and injury	Winter			0.46	0.046	3	KS
			Non-winter			0.42	0.041	3	KS
			All			0.44	0.038	3	KS
Convert a 2 ft. turf shoulder to a 10 ft. paved shoulder (Portland cement concrete)	Rural	All	Winter			0.83	0.056	3	KS
			Non-winter			0.67	0.054	3	KS
			All			0.76	0.046	3	KS
			Shoulder (winter)			0.52	0.084	3	KS
			Shoulder (Non-winter)			0.55	0.094	3	KS
			Shoulder (All)			0.52	0.071	3	KS
		Fatal and injury	Winter			0.6	0.084	3	KS
			Non-winter			0.48	0.074	3	KS
			All			0.53	0.064	3	KS

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Implement shoulder widening in conjunction with shoulder rumble strip installation on freeways		All	All			0.81	0.2	3	
			Run-off-road			0.87	0.24	3	
Paved right shoulder vs. other right shoulder type on freeway ramp		All	All	18800 - 291000		0.81	0.04	3	FL
		Incapacitating injury	All	18800 - 291000		0.9	0.04	3	FL
Pave a 3 to 4 ft sod shoulder	Rural	All	All			0.81	0.09	4	
		Injury	All			0.86	0.18	3	
		PDO	All			0.78	0.12	4	
Installation of safety edge treatment	Rural	All	All	397 - 18697		0.923	0.096	4	GA
				310 - 15000		0.886	0.085	4	GA
				310 - 18697		0.932	0.065	4	GA
				1170 - 14662		0.845	0.144	4	IN
				376 - 13615		1.269	0.24	3	IN
				376 - 14662		1.002	0.126	4	IN
				397 - 18697		0.905	0.08	4	GA,IN
				310 - 15000		0.935	0.079	4	GA,IN
				310 - 18697		0.943	0.057	4	GA,IN
			Other	397 - 18697		0.897	0.094	3	GA
				310 - 15000		0.909	0.087	4	GA
				310 - 18697		0.934	0.065	4	GA
				1170 - 14662		0.912	0.159	3	IN
				376 - 13615		1.796	0.34	3	IN
				376 - 14662		1.197	0.154	3	IN
				397 - 18697		0.874	0.078	3	GA,IN
				310 - 15000		0.955	0.082	4	GA,IN
				310 - 18697		0.944	0.057	4	GA,IN
			Run-off-road	397 - 18697		0.863	0.09	4	GA
				310 - 15000		0.909	0.087	4	GA
				310 - 18697		0.921	0.064	4	GA
				1170 - 14662		0.918	0.158	3	IN
				376 - 13615		1.469	0.278	3	IN
				376 - 14662		1.135	0.144	3	IN
				397 - 18697		0.858	0.076	4	GA,IN
				310 - 15000		0.952	0.081	4	GA,IN
				310 - 18697		0.937	0.057	4	GA,IN
		Fatal and injury	All	397 - 18697		0.89	0.138	4	GA
				310 - 15000		1.156	0.177	4	GA
				310 - 18697		1.06	0.115	4	GA
				1170 - 14662		0.55	0.215	3	IN
				376 - 13615		0.565	0.261	3	IN
				376 - 14662		0.591	0.172	3	IN
				397 - 18697		0.835	0.119	4	GA,IN
				310 - 15000		1.064	0.151	4	GA,IN
				310 - 18697		0.983	0.098	4	GA,IN
			Other	397 - 18697		0.849	0.134	3	GA
				310 - 15000		1.184	0.182	3	GA
				310 - 18697		1.052	0.114	4	GA
				1170 - 14662		0.575	0.229	3	IN
				376 - 13615		0.615	0.287	3	IN
				376 - 14662		0.63	0.186	3	IN
				397 - 18697		0.784	0.115	4	GA,IN
				130 - 15000		1.052	0.152	3	GA,IN
				310 - 18697		0.953	0.097	4	GA,IN

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Installation of safety edge treatment	Rural	Fatal and injury	Run-off-road	397 - 18697		0.808	0.127	3	GA
				310 - 15000		1.181	0.181	3	GA
				310 - 18697		1.036	0.112	4	GA
				1170 - 14662		0.537	0.206	3	IN
				376 - 13615		1.125	0.511	3	IN
				376 - 14662		0.836	0.24	3	IN
				397 - 18697		0.769	0.111	4	GA,IN
				310 - 15000		1.2	0.171	3	GA,IN
				310 - 18697		1.026	0.102	4	GA,IN
		PDO	All	397 - 18697		0.974	0.152	4	GA
				310 - 15000		0.757	0.101	4	GA
				310 - 18697		0.868	0.086	4	GA
				1170 - 14662		0.934	0.184	4	IN
				376 - 13615		1.509	0.335	3	IN
				376 - 14662		1.129	0.165	4	IN
				397 - 18697		0.962	0.116	4	GA,IN
				310 - 15000		0.872	0.099	4	GA,IN
				310 - 18697		0.929	0.076	4	GA,IN
			Other	397 - 18697		0.975	0.152	3	GA
				310 - 15000		0.794	0.105	3	GA
				310 - 18697		0.892	0.088	3	GA
				1170 - 14662		1.026	0.203	3	IN
				376 - 13615		2.317	0.503	3	IN
				376 - 14662		1.41	0.206	3	IN
				397 - 18697		0.947	0.115	3	GA,IN
				310 - 15000		0.921	0.104	3	GA,IN
				310 - 18697		0.956	0.078	4	GA,IN
			Run-off-road	397 - 18697		0.948	0.145	3	GA
				310 - 15000		0.798	0.105	3	GA
				310 - 18697		0.885	0.087	4	GA
				1170 - 14662		1.035	0.213	3	IN
				376 - 13615		1.312	0.304	3	IN
				376 - 14662		1.129	0.174	3	IN
				397 - 18697		0.926	0.112	4	GA,IN
				310 - 15000		0.84	0.096	4	GA,IN
				310 - 18697		0.898	0.074	4	GA,IN

Table P. Signs

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install a combination of chevron signs, curve warning signs, and/or sequential flashing beacons	All	All	All	7400 - 13975		0.606	0.07	4	notusa
				7400 - 13975		0.607	0.08	3	notusa
				7400 - 13975		0.672	0.1	3	notusa
				7400 - 13975	Radius ≤ 300 m	0.478	0.08	3	notusa
				7400 - 13975		0.575	0.11	3	notusa
				7400 - 13975		0.42	0.1	3	notusa
				7400 - 13975	Radius > 300 m	0.746	0.11	3	notusa
				7400 - 13975		0.976	0.18	3	notusa
				7400 - 13975	Deflection Angle ≤ 60 gon	0.757	0.12	3	notusa
				7400 - 13975		0.638	0.12	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.49	0.08	3	notusa
				7400 - 13975		0.577	0.1	3	notusa
				7400 - 13975		0.469	0.1	3	notusa
				7400 - 13975		0.524	0.09	3	notusa
				7400 - 13975		0.477	0.11	3	notusa
			Angle	7400 - 13975		0.635	0.11	3	notusa
			Angle, Fixed object,Frontal and opposing direction sideswipe,Head-on,Rear-end,Rear to rear,Sideswipe,Single vehicle	7400 - 13975		0.72	0.22	3	notusa
				7400 - 13975		0.533	0.19	3	notusa
			Angle, Fixed object,Head-on,Rear-end,Rear to rear,Sideswipe,Single vehicle	7400 - 13975		0.715	0.17	3	notusa
				7400 - 13975		0.616	0.2	3	notusa
			Daytime	7400 - 13975		0.627	0.11	3	notusa
			Nighttime	7400 - 13975		0.592	0.12	3	notusa
				7400 - 13975	Radius ≤ 300 m	0.21	0.09	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.265	0.09	3	notusa
				7400 - 13975		0.231	0.09	3	notusa
			Run-off-road	7400 - 13975		0.585	0.07	4	notusa
				7400 - 13975	Radius ≤ 300 m	0.445	0.08	3	notusa
				7400 - 13975	Radius > 300 m	0.728	0.11	3	notusa
				7400 - 13975	Deflection Angle ≤ 60 gon	0.764	0.13	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.72	0.22	3	notusa
				7400 - 13975		0.518	0.1	3	notusa
			Wet road	7400 - 13975	All Treatment Sites Except Site 3, Which Showed Abnormal Proportion of Wet Road Crashes in the After Period	0.529	0.09	3	notusa
				7400 - 13975	Radius ≤ 300 m	0.535	0.12	3	notusa
				7400 - 13975	Radius > 300 m	0.511	0.12	3	notusa
				7400 - 13975	Deflection Angle ≤ 60 gon	0.545	0.13	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.506	0.12	3	notusa
				7400 - 13975		0.564	0.13	3	notusa
		Fatal and injury	All	7400 - 13975	All Treatment Sites Except Site 3, Which Showed Abnormal Proportion of Wet Road Crashes in the After Period	0.809	0.14	3	notusa
				7400 - 13975	Radius ≤ 300 m	0.608	0.14	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.568	0.13	3	notusa
				7400 - 13975		0.618	0.14	3	notusa
		PDO	All	7400 - 13975		0.438	0.11	3	notusa
				7400 - 13975		0.51	0.07	3	notusa
				7400 - 13975	Radius ≤ 300 m	0.381	0.09	3	notusa
				7400 - 13975	Radius > 300 m	0.612	0.11	3	notusa
				7400 - 13975	Deflection Angle ≤ 60 gon	0.582	0.11	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.43	0.09	3	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install signs to conform to MUTCD	Urban	Injury	All			0.85	0.1	3	
		PDO	All			0.93	0.06	3	
Install combination horizontal alignment/ advisory speed signs		Injury	All			0.87	0.09	3	
		PDO	All			0.71	0.23	3	
Install chevron signs on horizontal curves	All	All	Wet road	7400 - 9746		0.406	0.22	3	notusa
	Rural	All	Head-on,Nighttime,Non-intersection,Run-off-road,Sideswipe	261 - 14790		0.78	0.101	4	WA
			Head-on,Non-intersection,Run-off-road,Sideswipe	261 - 14790		0.94	0.088	4	WA
			Nighttime,Non-intersection	261 - 14790		0.75	0.095	4	WA
			Non-intersection	261 - 14790		0.96	0.089	4	WA
		Fatal and injury	Non-intersection	261 - 14790		0.84	0.104	4	WA
		All	All	7400 - 9746		0.63	0.22	3	notusa
Install chevron signs and curve warning signs		All	All	10434 - 13975		0.592	0.1	3	notusa
				10434 - 13975		0.694	0.16	3	notusa
			Daytime	10434 - 13975		0.556	0.12	3	notusa
			Nighttime	10434 - 13975		0.66	0.19	3	notusa
			Run-off-road	10434 - 13975		0.564	0.1	3	notusa
			Wet road	10434 - 13975		0.489	0.12	3	notusa
		PDO	All	10434 - 13975		0.464	0.1	3	notusa
Install drowsy driving signs		All	Drowsy driving crashes			0.371	0.199	3	UT
Install new fluorescent curve signs or upgrade existing curve signs to fluorescent sheeting	Rural	All	Head-on,Nighttime,Non-intersection,Run-off-road,Sideswipe	895 - 20479		0.66	0.115	4	CT
			Head-on,Non-intersection,Run-off-road,Sideswipe	895 - 20479		0.82	0.084	4	CT
			Nighttime,Non-intersection	895 - 20479		0.65	0.105	3	CT
			Non-intersection	895 - 20479		0.82	0.077	4	CT
		Fatal and injury	Non-intersection	895 - 20479		0.75	0.127	4	CT
Advance street name signs	All	All	All			0.984	0.018	4	AZ,MA,WI
						1.01	0.049	3	AZ,MA,WI
			Rear-end			1.01	0.028	4	AZ,MA,WI
			Sideswipe			0.897	0.054	4	AZ,MA,WI
		Fatal and injury	All			0.99	0.031	4	AZ,MA,WI
Install a "Vehicles Entering When Flashing" (VEWF) system (advance post mounted signs on major and loops on minor)	All	All	All			0.68	0.076	4	NC
			Angle,Head-on,Left-turn,Right-turn			0.68	0.088	4	NC
		Fatal and injury	All			0.73	0.102	4	NC
Install a "Vehicles Entering When Flashing" (VEWF) system (combination of overhead and advance post	All	All	All			0.75	0.115	3	NC
			Angle,Head-on,Left-turn,Right-turn			0.8	0.144	3	NC
Install a "Vehicles Entering When Flashing" (VEWF) system (overhead signs at intersection on major and loops on minor)	All	All	All			1.06	0.098	3	NC
			Angle,Head-on,Left-turn,Right-turn			1.07	0.112	3	NC
		Incapacitating injury	All			0.61	0.236	3	NC
		Fatal and injury	All			0.92	0.108	3	NC
Install a "Vehicles Entering When Flashing" (VEWF) system (overhead signs at intersection on minor and loops on major)	All	All	All			0.95	0.084	3	NC
			Angle,Head-on,Left-turn,Right-turn			1	0.096	3	NC
		Fatal and injury	All			0.93	0.106	3	NC

Table Q. Speed Management

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Area-wide or corridor-specific traffic calming	Urban	All	All			0.68	0.08	4	
		Injury	All			0.67	0.09	4	
						0.67	0.09	4	
				0 - 30000		0.89	0.05	5	
						0.82	0.12	3	
				5000 - 30000		0.94	0.06	3	
		PDO	All			0.75	0.19	3	
				0 - 30000		0.95	0.2	3	
						0.94	0.1	3	
				5000 - 30000		0.97	0.2	3	
Install transverse rumble strips as traffic calming device	Urban/suburban	All	All			0.66	0.11	4	
		Injury	All			0.64	0.12	4	
Install speed humps	Urban/suburban	Injury	All			0.6	0.16	4	
						0.5	0.13	4	
Adjacent to roads with speed humps	Urban/suburban	Injury	All			0.95	0.06	3	
5% reduction in mean speed	All	Fatal	All	All		0.83	0.05	5	
		Injury	All	All		0.93	0.03	5	
		PDO	All	All		0.95	0.04	3	
10% reduction in mean speed	All	Fatal	All	All		0.68	0.09	4	
		Injury	All	All		0.85	0.05	5	
		PDO	All	All		0.9	0.08	3	
15% reduction in mean speed	All	Fatal	All	All		0.56	0.14	4	
		Injury	All	All		0.78	0.08	4	
		PDO	All	All		0.85	0.12	3	
5% increase in mean speed	All	Fatal	All	All		1.19	0.04	5	
		Injury	All	All		1.08	0.03	5	
		PDO	All	All		1.05	0.04	3	
Transverse bar pavement marking at roundabout approaches		Minor injury	Speed			0.48	0.24	4	
		Serious injury	Speed			0.26	0.28	3	
		Injury	Speed			0.43	0.19	4	
			Speed			0.53	0.3	3	
						0.34	0.18	4	
						0.55	0.33	3	
			Speed,Wet road			0.32	0.23	4	
Change 85th percentile speed from X to Y	Rural	All	All	35 - 1468		Eqn. 17-1		3	WY
Change freeway speed limit from X to Y mph		Incapacitating injury	All	18800 - 291000		Eqn. 17-2		3	FL
Lower posted speed	All	All	All			1.01		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
			Fatal and Injury			1.02		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Lower posted speed by 5 mph	All	All	All			1.17		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Lower posted speed by 10 mph	All	All	All			0.96		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Lower posted speed by 15-20 mph	All	All	All			0.94		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Lower posted speed from 100 km/h to 80 km.hr		All	All	3100 - 50300		0.8553	0.0792	4	notusa
			Speed	3100 - 50300		0.9123	0.161	4	notusa
		Incapacitating injury	All	3100 - 50300		1.0358	0.1717	4	notusa
		Minor injury	All	3100 - 50300		0.7915	0.086	4	notusa

Lower posted speed from 80 km/h to 60 km/h	Rural	Fatal	Non-intersection	146 - 4512		0.82		3	notusa
		Fatal	All			0.76		3	notusa
		Fatal	Fixed object	146 - 4512		0.69		3	notusa
Lower posted speed from 80 km/h to 60 km/h at intersections	Rural	Fatal	All			0.56		3	notusa
			Angle			0.53		3	notusa
Lower posted speed from 90 km/h to 70 km/h	Urban	Incapacitating injury	All			0.91	0.079	3	notusa
						0.94	0.13	3	notusa
			Non-intersection			0.64	0.11	3	notusa
		Minor injury	All			0.95	0.038	3	notusa
						1.11	0.054	3	notusa
			Non-intersection			0.89	0.056	3	notusa
Raise posted speed	All	All	All			0.9		4	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
			Fatal and Injury			0.97		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Raise posted speed by 5 mph	All	All	All			0.92		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Raise posted speed by 10 or 15 mph	All	All	All			0.85		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Raise posted speed limit from X to Y mph	Urban/suburban	All	Rear-end			Eqn. 17-3		3	IN
		All	Truck related			Eqn. 17-4		3	FL
Raise posted speed limit of major road of a 4-leg signalized intersection from less than 50 km/h to greater than or equal to 50 km/h	Urban	All	Motorcycle			2.19		3	notusa
Raise posted speed limit of minor road of a signalized 3-leg intersection from less than 50 km/h to greater than or equal to 50 km/h	Urban	All	Motorcycle			3.57		3	notusa
Installation of fixed speed cameras	Urban	All	All			0.7	0.0459	3	notusa
Change mean speed (km/hr)	Rural	Fatal and injury	All	0 - 1000		Eqn. 17-5		3	notusa
Implement speed limit of 50 mph or greater	Urban	All	All			2.27	0.7	3	IA
Install variable speed limit signs	Urban	All	All			0.92		4	MO
Install 10 mph differential speed limit on rural Interstate Highways	Rural	All	All,Truck related			0.914	0.051	3	ID

Table R. Transit

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install transit signal priority (TSP) technology (at transit-serviced locations)	Urban	All	All			1.32	0.049	3	notusa
						1.28	0.062	3	notusa
Install transit signal priority (TSP) technology (transit-related crashes)	Urban	All	All			1.52	0.201	3	notusa
						1.26	0.146	3	notusa
Presence of far-side transit stop location (transit-related crashes)	Urban	All	All			0.55	0.066	3	notusa
Presence of near-side transit stop location (transit-related crashes)	Urban	All	All			1.85	0.205	3	notusa
						1.38	0.146	3	notusa
Presence of transit service	Urban	All	All			1.32	0.05	3	notusa
						1.31	0.049	3	notusa
Use of bus as public transit type rather than streetcar	Urban	All	All			1.73	0.09	3	notusa
						1.67	0.087	3	notusa
						1.23	0.046	3	notusa
						1.24	0.046	3	notusa
Use of bus as public transit type rather than streetcar (transit-related crashes)	Urban	All	All			0.55	0.093	3	notusa
Use of bus as public transit type rather than streetcar (transit-serviced locations)	Urban	All	All			0.87	0.034	3	notusa

Table S. Work Zones

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Active work with temporary lane closure (compared to no work zone)		All	All	0 - 50000		1.77	0.12	4	
				50000 - 100000		1.26	0.19	3	
				> 100000		1.65	0.18	4	
				All		1.66	0.09	4	
			Nighttime	0 - 50000		1.53	0.18	4	
				50000 - 100000		1.57	0.12	4	
				> 100000		1.65	0.09	4	
				All		1.61	0.07	4	
		Injury	All	0 - 50000		1.6	0.18	4	
				50000 - 100000		1.12	0.29	3	
				> 100000		1.26	0.27	3	
				All		1.46	0.13	4	
			Nighttime	0 - 50000		1.32	0.27	3	
				50000 - 100000		1.34	0.18	3	
				> 100000		1.49	0.14	4	
				All		1.42	0.1	4	
		PDO	All	0 - 50000		1.9	0.15	4	
				50000 - 100000		1.34	0.26	3	
				> 100000		1.87	0.24	4	
				All		1.81	0.12	4	
			Nighttime	0 - 50000		1.63	0.23	4	
				50000 - 100000		1.71	0.16	4	
				> 100000		1.8	0.12	4	
				All		1.75	0.09	4	
Active work with no lane closure (compared to no work zone)		All	All	0 - 50000		1.39	0.15	4	
				50000 - 100000		1.32	0.05	4	
				> 100000		1.3	0.04	5	
				All		1.31	0.03	5	
			Nighttime	50000 - 100000		1.29	0.25	3	
				> 100000		1.8	0.26	3	
				All		1.58	0.18	4	
		Injury	All	0 - 50000		1.45	0.26	3	
				50000 - 100000		1.19	0.07	4	
				> 100000		1.13	0.07	3	
				All		1.17	0.05	4	
			Nighttime	50000 - 100000		1.34	0.41	3	
				> 100000		1.4	0.38	3	
				All		1.41	0.27	3	
		PDO	All	0 - 50000		1.37	0.18	3	
				50000 - 100000		1.41	0.07	4	
				> 100000		1.39	0.05	4	
				All		1.4	0.04	5	
			Nighttime	50000 - 100000		1.23	0.3	3	
				> 100000		2.04	0.35	3	
				All		1.67	0.23	4	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
No active with no lane closure (compared to no work zone)		All	All	0 - 50000		1.21	0.05	5	
				50000 - 100000		1.04	0.03	3	
				> 100000		1.16	0.02	5	
				All		1.13	0.02	5	
			Nighttime	0 - 50000		1.09	0.06	3	
				50000 - 100000		1.24	0.06	4	
				> 100000		1.3	0.05	4	
				All		1.24	0.03	5	
		Injury	All	0 - 50000		1.11	0.07	3	
				50000 - 100000		0.94	0.05	3	
				> 100000		1.05	0.04	3	
				All		1.02	0.03	3	
			Nighttime	0 - 50000		1.05	0.1	3	
				50000 - 100000		1.14	0.09	3	
				> 100000		1.11	0.08	3	
				All		1.11	0.05	4	
		PDO	All	0 - 50000		1.27	0.06	4	
				50000 - 100000		1.1	0.04	5	
				> 100000		1.23	0.03	5	
				All		1.2	0.02	5	
			Nighttime	0 - 50000		1.13	0.08	3	
				50000 - 100000		1.31	0.08	4	
				> 100000		1.46	0.07	4	
				All		1.33	0.05	5	
TLTWO (two way traffic operations - crossover closures) in work zones		All	All			1	0.35	3	
Implement mobile automated speed enforcement system (highly enforced sites)		All	All			0.863	0.026	3	NC
Increasing the outside shoulder width inside the work zone by one foot	Urban	All	All			0.948	0.01	3	IN
Increasing the inside shoulder width inside the work zone by one foot	Urban	All	All			0.97	0.01	3	IN

Table T. CMF Equations

Access Management

Equation Number	Equation	X	Y
1 - 1	e^(0.0232(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 2	e^(0.0152(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 3	e^(0.0087(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 4	e^(0.0084(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 5	e^(0.0096(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 6	e^(0.0090(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 7	e^(0.0046(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 8	e^(0.0030(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 9	e^(0.0077(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 10	e^(0.0029(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 11	e^(0.0071(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 12	e^(0.0094(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 13	e^(0.0059(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 14	e^(0.0026(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 15	e^(0.0492(Y-X))	Freeway on-ramp density (Before)	Freeway on-ramp density (After)
1 - 16	e^(0.0456(Y-X))	Freeway on-ramp density (Before)	Freeway on-ramp density (After)
1 - 17	e^(0.0321(Y-X))	Freeway on-ramp density (Before)	Freeway on-ramp density (After)
1 - 18	e^(0.0393(Y-X))	Freeway on-ramp density (Before)	Freeway on-ramp density (After)
1 - 19	e^(0.0224(Y-X))	Freeway on-ramp density (Before)	Freeway on-ramp density (After)
1 - 20	e^(-0.1276(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 21	e^(-0.1144(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 22	e^(0.0977(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 23	e^(-0.1222(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 24	e^(-0.2493(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 25	e^(-0.1684(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 26	e^(-0.1201(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 27	e^(0.0126(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 28	e^(0.0269(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 29	e^(0.0333(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 30	e^(0.0230(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 31	e^(0.0170(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 32	e^(0.0254(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 33	e^(0.0207(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 34	e^(0.0481(Y-X))	Median opening density (Before)	Median opening density (After)
1 - 35	e^(0.0985(Y-X))	Median opening density (Before)	Median opening density (After)
1 - 36	e^(0.1129(Y-X))	Median opening density (Before)	Median opening density (After)
1 - 37	e^(0.0513(Y-X))	Median opening density (Before)	Median opening density (After)
1 - 38	e^(0.0456(Y-X))	Median opening density (Before)	Median opening density (After)
1 - 39	e^(-0.0803(Y-X))	The natural log of the upstream distance to the nearest signalized intersection from an unsignalized 3-leg intersection (Before)	The natural log of the upstream distance to the nearest signalized intersection from an unsignalized 3-leg intersection (After)
1 - 40	e^(-0.0345(Y-X))	The natural log of the downstream distance to the nearest signalized intersection from an unsignalized 3-leg intersection (Before)	The natural log of the downstream distance to the nearest signalized intersection from an unsignalized 3-leg intersection (After)

Equation Number	Equation	X	Y
1 - 41	e^(-0.4815(Y-X))	The natural log of the downstream distance to the nearest signalized intersection from an unsignalized 4-leg intersection (Before)	The natural log of the downstream distance to the nearest signalized intersection from an unsignalized 4-leg intersection (After)
1 - 42	e^(-0.0033(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 43	e^(0.0000(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 44	e^(0.0000(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 45	e^(-0.001(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 46	e^(0.0000(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 47	e^(0.002(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 48	e^(-0.004(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 49	e^(0.013(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)
1 - 50	e^(0.006(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)
1 - 51	e^(0.009(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)
1 - 52	e^(0.004(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)
1 - 53	e^(0.013(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)
1 - 54	e^(0.009(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)

Alignment

Equation Number	Equation	X	Y
3 - 1	e^(0.05084(Y-X))	Horizontal curvature (Before)	Horizontal curvature (After)
3 - 2	e^(0.0831(Y-X))	Horizontal curvature (Before)	Horizontal curvature (After)
3 - 3	e^(0.169(log(Y-X)))	Horizontal curvature (Before)	Horizontal curvature (After)
3 - 4	e^(0.0889(Y-X))	Horizontal curvature (Before)	Horizontal curvature (After)
3 - 5	e^(0.1096(Y-X))	Degree of curve on freeways (Before)	Degree of curve on freeways (After)
3 - 6	e^(0.1208(Y-X))	Degree of curve on freeways (Before)	Degree of curve on freeways (After)
3 - 7	e^(0.0432(Y^2)-0.5870(Y))/e^(0.0432(X^2)-0.5870(X))	Number of horizontal curves per mile (Before)	Number of horizontal curves per mile (After)
3 - 8	e^(0.066(Y-X))	Maximum gradient (Before)	Maximum gradient (After)

Equation Number	Equation			
3 - 9	e^[0.044G+0.19ln(2*5730/R)+4.52(1/R)(1/Lc)]	G = Absolute value of percent grade (0 percent for level tangents; ≥ 1 percent otherwise)	Lc = Horizontal curve length (mi) (not applicable for tangents)	R= Curve radius (ft) (missing for tangents)
3 - 10	e^[0.040G+0.13ln(2*(5730/R)+3.80(1/R)(1/Lc)]	G = Absolute value of percent grade (0 percent for level tangents; ≥ 1 percent otherwise)	Lc = Horizontal curve length (mi) (not applicable for tangents)	R= Curve radius (ft) (missing for tangents)
3 - 11	e^[0.044G]	G = Absolute value of percent grade (0 percent for level tangents; ≥ 1 percent otherwise)		
3 - 12	e^[0.040G]	G = Absolute value of percent grade (0 percent for level tangents; ≥ 1 percent otherwise)		
3 - 13	e^(0.0088(5730/R)Lvc/K)	K = Lvc/A; not applicable for level tangents A=|G1 - G2| (%) G1= initial grade (%), G2= final grade (%)	Lvc = Vertical curve length (ft)	R= Curve radius (ft) (missing for tangents)
3 - 14	e^(0.0046(5730/R)Lvc/K)	K = Lvc/A; not applicable for level tangents A=|G1 - G2| (%) G1= initial grade (%), G2= final grade (%)	Lvc = Vertical curve length (ft)	R= Curve radius (ft) (missing for tangents)
3 - 15	e^[10.51*1/K+0.011*(5730/R)*Lvc/K]	K = Lvc/A; not applicable for level tangents A=|G1 - G2| (%) G1= initial grade (%), G2= final grade (%)	Lvc = Vertical curve length (ft)	R= Curve radius (ft) (missing for tangents)
3 - 16	e^[8.62*1/K+0.010*(5730/R)*Lvc/K]	K = Lvc/A; not applicable for level tangents A=|G1 - G2| (%) G1= initial grade (%), G2= final grade (%)	Lvc = Vertical curve length (ft)	R= Curve radius (ft) (missing for tangents)

Equation Number	Equation			
3 - 17	e^[10.51*1/K]	K = Lvc/A; not applicable for level tangents		
3 - 18	e^[8.62*1/K]	K = Lvc/A; not applicable for level tangents A=|G1 - G2| (%) G1= initial grade (%), G2= final grade (%)		
3 - 19	e^[0.20*ln(2*5730/R)]	R= Curve radius (ft) (missing for tangents)		
3 - 20	e^[0.10*ln(2*5730/R)]	R= Curve radius (ft) (missing for tangents)		
3 - 21	e^[0.188*ln(2*5730/R)]	R= Curve radius (ft) (missing for tangents)		
3 - 22	e^[0.022*ln(2*5730/R)*A]	R= Curve radius (ft) (missing for tangents)	A=|G1 - G2| (%), G1= initial grade (%), G2= final grade (%)	
3 - 23	e^(0.1837*(V^2)/y) / e^(0.1837*(V^2)/X)	X and Y= Horizontal curve radius (ft)	V= Speed limit minimum of 55mph	

Delineation

Equation Number	Equation	X	Y
5 - 1	e^(-0.0021(Y-X))	Pavement marking retroreflectivity (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity (mcd/m^2/lux) (After)
5 - 2	e^(-0.004(Y-X))	Pavement marking retroreflectivity of white edgelines (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity of white edgelines (mcd/m^2/lux) (After)
5 - 3	e^(-0.001(Y-X))	Pavement marking retroreflectivity of white edgelines (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity of white edgelines (mcd/m^2/lux) (After)
5 - 4	e^(-0.002(Y-X))	Pavement marking retroreflectivity of white skiplines (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity of white skiplines (mcd/m^2/lux) (After)
5 - 5	e^(-0.007(Y-X))	Pavement marking retroreflectivity of yellow centerlines (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity of yellow centerlines (mcd/m^2/lux) (After)
5 - 6	e^(0.007(Y-X))	Pavement marking retroreflectivity of yellow edgelines (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity of yellow edgelines (mcd/m^2/lux) (After)

Interchange design

Equation Number	Equation	X	Y
7 - 1	e^(2.198(Y-X))	Length of deceleration lane (miles) (Before)	Length of deceleration lane (miles) (After)
7 - 2	e^(-0.547(Y-X))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 3	e^(-0.330(Y-X))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 4	e^(-0.345(Y-X))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 5	e^(-1.183(Y-X))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 6	e^(-0.387(Y-X))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 7	100*(1-e^(0.551(Y-X)))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 8	100*(1-e^(0.014308(Y-X)))	Spacing distance between two ramp terminals at diamond interchange (Before)	Spacing distance between two ramp terminals at diamond interchange (After)
7 - 9	100*(1-e^(0.01985(Y-X)))	Spacing distance between two ramp terminals at diamond interchange (Before)	Spacing distance between two ramp terminals at diamond interchange (After)
7 - 10	100*(1-e^(0.009803(Y-X)))	Spacing distance between two ramp terminals at diamond interchange (Before)	Spacing distance between two ramp terminals at diamond interchange (After)

Intersection geometry

Equation Number	Equation	X	Y
8 - 1	e^(0.7785(Y-X))	Number of left-turn lanes (Before)	Number of left-turn lanes (After)
8 - 2	e^(0.3495(Y-X))	Number of left-turn lanes (Before)	Number of left-turn lanes (After)
8 - 3	e^(0.125(Y-X))	Number of lanes (Before)	Number of lanes (After)
8 - 4	e^(0.171(Y-X))	Number of lanes (Before)	Number of lanes (After)
8 - 5	e^(0.548(Y-X))	Number of lanes (Before)	Number of lanes (After)
8 - 6	100*(1-e^(-0.003(Y-X)))	Number of 3-leg intersections (Before)	Number of 3-leg intersections (After)
8 - 7	100*(1-e^(-0.033(Y-X)))	Number of 5-leg intersections (Before)	Number of 5-leg intersections (After)

Intersection traffic control

Equation Number	Equation		
9 - 1	e^(-5.5172+0.6322*AADT+0.1103*Trains+0.0891*MaxSpeed)	Trains = number of trains per day	Maxspeed= maximum timetable speed (mph)
9 - 2	e^(-4.6330+0.1346*Trains)	Trains = number of trains per day	

Equation Number	Equation	X	Y
9 - 3	e^(0.919(Y-X))	Traffic signal spacing (signals/mile) (Before)	Traffic signal spacing (signals/mile) (After)
9 - 4	e^(0.453(Y-X))	Traffic signal spacing (signals/mile) (Before)	Traffic signal spacing (signals/mile) (After)
9 - 5	100*(1-e^(-1.8419(Y-X)))	Yellow change interval (seconds) (Before)	Yellow change interval (seconds) (After)
9 - 6	100*(1-e^(-3.504(Y-X)))	Yellow change interval (seconds) (Before)	Yellow change interval (seconds) (After)
9 - 7	100*(1-e^(-2.3424(Y-X)))	Yellow change interval (seconds) (Before)	Yellow change interval (seconds) (After)
9 - 8	100*(1-e^(-0.988(Y-X)))	Red clearance interval from X to Y seconds (Before)	Red clearance interval from X to Y seconds (After)
9 - 9	100*(1-e^(-1.8502(Y-X)))	Red clearance interval from X to Y seconds (Before)	Red clearance interval from X to Y seconds (After)
9 - 10	100*(1-e^(-0.8944(Y-X)))	Red clearance interval from X to Y seconds (Before)	Red clearance interval from X to Y seconds (After)
9 - 11	100*(1-e^(-0.0444(Y-X)))	Number of traffic signal cycles per hour (Before)	Number of traffic signal cycles per hour (After)
9 - 12	100*(1-e^(0.007(Y-X)))	Number of all-way stop intersections (Before)	Number of all-way stop intersections (After)
9 - 13	100*(1-e^(0.077(Y-X)))	Number of signalized intersections (Before)	Number of signalized intersections (After)

On Street Parking

Equation Number	Equation	X	Y
10 - 1	e^(0.00053(Y-X))	Unrestricted parking hours (Before)	Unrestricted parking hours (After)
10 - 2	e^(0.0018(Y-X))	Unrestricted parking hours (Before)	Unrestricted parking hours (After)
10 - 3	e^(0.0006(Y-X))	Unrestricted parking hours (Before)	Unrestricted parking hours (After)
10 - 4	e^(0.002(Y-X))	Unrestricted parking hours (Before)	Unrestricted parking hours (After)
10 - 5	e^(0.00052(Y-X))	Unrestricted left turn hours (Before)	Unrestricted left turn hours (After)
10 - 6	e^(0.0015(Y-X))	Unrestricted left turn hours (Before)	Unrestricted left turn hours (After)
10 - 7	e^(0.0006(Y-X))	Unrestricted left turn hours (Before)	Unrestricted left turn hours (After)
10 - 8	e^(0.0026(Y-X))	Unrestricted left turn hours during rush hours (Before)	Unrestricted left turn hours during rush hours (After)
10 - 9	e^(0.0047(Y-X))	Unrestricted left turn hours during rush hours (Before)	Unrestricted left turn hours during rush hours (After)
10 - 10	e^(0.0026(Y-X))	Unrestricted left turn hours during rush hours (Before)	Unrestricted left turn hours during rush hours (After)

Pedestrians

Equation Number	Equation	X	Y
11 - 1	100*(1-e^(0.114(Y-X)))	Number of subway stations (Before)	Number of subway stations (After)
11 - 2	100*(1-e^(0.012(Y-X)))	Number of bus stations (Before)	Number of bus stations (After)
11 - 3	100*(1-e^(0.133(Y-X)))	Number of bus stops in 50m buffer (Before)	Number of bus stops in 50m buffer (After)

Roadside

Equation Number	Equation	X	Y
13 - 1	100*(1-e^(0.169(Y-X)))	Commercial land use/total land use (%) (Before)	Commercial land use/total land use (%) (After)
13 - 2	100*(1-e^(2.153(Y-X)))	Industrial land use/total land use (%) (Before)	Industrial land use/total land use (%) (After)
13 - 3	100*(1-e^(0.511(Y-X)))	Open land use/total land use (%) (Before)	Open land use/total land use (%) (After)
13 - 4	100*(1-e^(1.389(Y-X)))	Total park area (in 1000 acres) (Before)	Total park area (in 1000 acres) (After)

Equation Number	Equation		
13 - 5	e^(-0.0905(Oa-Ob))	Oa = after offset	Ob = before offset
13 - 6	(Da/Db)^(0.1162)	Da = after density	Db = before density

Roadway

Equation Number	Equation	
14 - 1	3.705*e^(-0.0616*totshld)	totshld = Total width of the outside shoulder (paved and unpaved shoulder, in feet)
14 - 2	1.142*e^(-0.0335*totshld)	totshld = Total width of the outside shoulder (paved and unpaved shoulder, in feet)
14 - 3	1.238*e^(-0.0586*totshld)	totshld = Total width of the outside shoulder (paved and unpaved shoulder, in feet)

Equation Number	Equation	X	Y
14 - 4	e^(-0.116(Y-X))	Bridge width (bridge minus roadway width) (Before)	Bridge width (bridge minus roadway width) (After)
14 - 5	e^(59.9(X-Y))	Pavement macrotexture (inches) (Before)	Pavement macrotexture (inches) (After)
14 - 6	e^(0.1123-0.0003*ADT)		
14 - 7	100*(1-e^(0.214(Y-X)))	Proportion of 1-lane roadways to total roadway length (Before)	Proportion of 1-lane roadways to total roadway length (After)
14 - 8	100*(1-e^(1.243(Y-X)))	Proportion of 4-lane roadways to total roadway length (Before)	Proportion of 4-lane roadways to total roadway length (After)
14 - 9	100*(1-e^(2.896(Y-X)))	Proportion of 5-lane roadways to total roadway length (Before)	Proportion of 5-lane roadways to total roadway length (After)
14 - 10	100*(1-e^(0.530(Y-X)))	Proportion of primary roadway (without access restriction) to total roadway length (Before)	Proportion of primary roadway (without access restriction) to total roadway length (After)
14 - 11	100*(1-e^(-1.050(Y-X)))	Proportion or primary roadway (with limited access) to total roadway length (Before)	Proportion or primary roadway (with limited access) to total roadway length (After)
14 - 12	100*(1-e^(-0.418(Y-X)))	Proportion of length of roads with widths less than 30 feet to total roadway length (Before)	Proportion of length of roads with widths less than 30 feet to total roadway length (After)
14 - 13	100*(1-e^(-0.207(Y-X)))	Proportion of local rural road to total roadway length (Before)	Proportion of local rural road to total roadway length (After)
14 - 14	100*(1-e^(-0.704(Y-X)))	Proportion of other throughfare roadway to total roadway length (Before)	Proportion of other throughfare roadway to total roadway length (After)
14 - 15	e^(-0.0161(Y-X))	Surface width (Before)	Surface width (After)

Equation Number	Equation		
14 - 16	e^(-0.36(X-12))	X = Outside lane width (ft)	
14 - 17	e^(-0.31(X-12))	X = Outside lane width (ft)	
14 - 18	e^(-0.37(X-12))	X = Outside lane width (ft)	
14 - 19	[e^(-0.59(X-12))]*[e^(-0.63(Y-12))]	X = Outside lane width (ft)	Y = Inside lane width (ft)
14 - 20	[e^(-0.50(X-12))]*[e^(-0.75(Y-12))]	X = Outside lane width (ft)	Y = Inside lane width (ft)
14 - 21	e^(-0.41(X-12))	X = Outside lane width (ft)	
14 - 22	1.427*e^(-0.0593*totshld)	totshld = Total width of the outside shoulder (paved and unpaved shoulder, in feet)	
14 - 23	1.085*e^(-0.0082*medwd)	median width (feet) given the roadway is divided (div=1)	

Shoulder treatments

Equation Number	Equation	X	Y
15 - 1	e^(0.0969(Y-X))	Paved shoulder width (ft) (Before)	Paved shoulder width (ft) (After)
15 - 2	e^(0.1820(Y-X))	Paved shoulder width (ft) (Before)	Paved shoulder width (ft) (After)
15 - 3	e^(0.1069(Y-X))	Paved shoulder width (ft) (Before)	Paved shoulder width (ft) (After)
15 - 4	e^(-0.0372(Y-X))	Paved shoulder width (ft) (Before)	Paved shoulder width (ft) (After)
15 - 5	e^(-0.0912(Y-X))	Left shoulder width (ft) (Before)	Left shoulder width (ft) (After)
15 - 6	e^(-0.0017(Y-X))	Right shoulder width (ft) (Before)	Right shoulder width (ft) (After)

Speed management

Equation Number	Equation	X	Y
17 - 1	e^(0.0111(Y-X))	85th percentile speed (Before)	85th percentile speed (After)
17 - 2	e^(-0.017(Y-X))	Freeway speed limit (mph) (Before)	Freeway speed limit (mph) (After)
17 - 3	100*(1-e^(0.158(Y-X)))	Posted speed limit (mph) (Before)	Posted speed limit (mph) (After)
17 - 4	e^(-0.0136(Y-X))	Posted speed limit (mph) (Before)	Posted speed limit (mph) (After)
17 - 5	e^(0.24556(Y-X))	Mean speed (km/hr) (Before)	Mean speed (km/hr) (After)

Lower-quality CMFs

Access Management

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Closure or complete relocation of all driveways from functional area of intersection	Rural	All	All			1.17	3.25	1	
		Injury	All			1.41	4.48	1	
	Urban	All	All			0.93	2.31	1	
		Injury	All			1.67	5.05	1	
Create directional median openings to allow left-turns and U-turns		All	All	14319 - 28154		0.49		2	MI
Convert an open median to a left-in only median	Urban/Suburban	Incapacitating injury	All			1.31	0.4669	2	FL
		Serious injury	All			1.41	0.3286	2	FL
Landscape medians at intersections		All	All	4900 - 49500		1.68	0.71	2	FL
		Fatal and injury	All	4900 - 49500	For medians without trees compared to medians with trees compliant with Florida's design standards.	3.26	2.22	2	FL
				4900 - 49500	When the tree setback from median nose is increased from 100ft to 200ft.	0.82	0.09	2	FL

Advanced Technology and ITS

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Provide active close-following warning signs			Rear-end			0.94	0.72	1	
Provide limited sight distance (LSD) warning signs	Rural	All	All			1.07	0.67	1	
Changeable curve speed warning signs	Rural	All	All			1.13	1.19	1	
			Speed related			1.31	1.87	1	
			Truck related			0.29	0.96	1	
		Injury	All			1.47	2.35	1	
		PDO	All			0.98	1.38	1	
Presence of speed restriction devices (bike crashes)		All	Vehicle/bicycle			0.28	0.22	2	notusa
Install dynamic advance intersection warning system	Rural	All		5500 - 6900		0.27	0.2	2	NC
				7700 - 10100		0.15	0.19	2	NC
			All	5500 - 6900		0.46	0.19	2	NC
				7700 - 10100		0.3	0.11	2	NC
			Angle	5500 - 6900		0.55	0.26	1	NC
				5500 - 6900	Far-side right angle crash	0.33	0.19	2	NC
				5500 - 6900	Near-side right angle crash	3.19	3.66	1	NC
				7700 - 10100		0.33	0.12	2	NC
				7700 - 10100	Far-side right angle crash	0.32	0.12	2	NC
				7700 - 10100	Near-side right angle crash	0.76	1.16	1	NC
		Fatal	All	5500 - 6900		0		1	NC
			All	7700 - 10100		0.38	0.51	1	NC
		Injury	All	5500 - 6900		0.89	0.43	1	NC
			All	7700 - 10100		0.3	0.14	2	NC
		PDO	All	5500 - 6900		0.1	0.12	2	NC
			All	7700 - 10100		0.29	0.17	2	NC
Install icy curve warning system	Rural	All	All			0.82	0.08	2	CA

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Alignment

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Flatten horizontal curve		All	All			0.33	0.32	2	MN
Change in average horizontal curve radius from X to Y (in miles)	Rural	Fatal and injury	All		Major Collector	Eq. LQ 3-1		2	IN
					Minor Arterial	Eq. LQ 3-2		2	IN
					Principal Arterial Other	Eq. LQ 3-3		2	IN
		Injury	All		Major Collector	Eq. LQ 3-4		2	IN
					Minor Arterial	Eq. LQ 3-5		2	IN
					Principal Arterial Other	Eq. LQ 3-6		2	IN
		PDO	All		Major Collector	Eq. LQ 3-7		2	IN
					Minor Arterial	Eq. LQ 3-8		2	IN
					Principal Arterial Other	Eq. LQ 3-9		2	IN

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Bicyclists

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Raised bicycle crossings		Injury	Vehicle/bicycle			1.09	0.53	1	
Change sidewalk width from X to Y meters (bike crashes)		All	Vehicle/bicycle			0		2	notusa
Presence of crosswalk at signalized intersection (bike crashes)		All	Vehicle/bicycle			8.76	13.7	2	notusa
Installation of bicycle lanes at signalized intersections	Urban/Suburban	All	Vehicle/bicycle			1.37		2	notusa
						0.8		2	notusa
					Crossing crashes at 90 degrees from each other	0.63		2	notusa
					Cyclist through, left turning vehicle in oncoming direction	1.33		2	notusa
					Rear end & sideswipe, same direction	1.01		2	notusa
					Cyclist through, right turning vehicle in same direction	2.03		2	notusa
					Cyclist through, right turning vehicle in same direction	0.42		2	notusa
					Other	1.02		2	notusa
Installation of bicycle lanes at signalized intersections with shared through/right turn lanes	Urban/Suburban	All	Vehicle/bicycle			1.4		2	notusa
						0.6		2	notusa
Installation of bicycle lanes at signalized intersections with exclusive right turn lanes	Urban/Suburban	All	Vehicle/bicycle			1.36		2	notusa
						0.97		2	notusa
Installation of colored bicycle lanes at signalized intersections	Urban/Suburban	All	Vehicle/bicycle			0.61		2	notusa
Installation of a cycle track 0-2m from the side of the main road with cyclist priority at intersections	Urban/Suburban	All	Vehicle/bicycle			1.03	0.384	2	notusa
Installation of a cycle track over 5m from the side of the main road with cyclist priority at intersections	Urban/Suburban	All	Vehicle/bicycle			0.93	0.31	2	notusa
Installation of red color for bicycle crossings with cyclist priority at intersections	Urban/Suburban	All	Vehicle/bicycle			1.47	0.412	2	notusa
Installation of high quality markings for bicycle crossings with cyclist priority at intersections	Urban/Suburban	All	Vehicle/bicycle			1.74	0.618	2	notusa
Introduction of restricted visibility from vehicles on a minor road to approaching bicyclists at intersections with cyclist priority	Urban/Suburban	All	Vehicle/bicycle			1.37	0.33	2	notusa
Installation of left-turn lane or left-turn section on the main road where cyclists have priority at the intersection	Urban/Suburban	All	Vehicle/bicycle			1.12	0.207	2	notusa
Installation of a speed hump or other speed reducing measure for through motorized vehicles on the main road	Urban/Suburban	All	Vehicle/bicycle			1.28	0.345	2	notusa
Installation of raised island and left-turn lane	Urban/Suburban	All	Vehicle/bicycle			1.48	0.393	2	notusa
Installation of raised island with a separate space for cyclists	Urban/Suburban	All	Vehicle/bicycle			1.43	0.473	2	notusa
Installation of vehicle travel lanes	Urban/Suburban	All	Vehicle/bicycle			1.67	0.635	2	notusa
Installation of additional travel lanes, a raised island and left-turn lane	Urban/Suburban	All	All			0.96	0.582	2	notusa
Installation of additional travel lanes and a raised island	Urban/Suburban	All	Vehicle/bicycle			1.1	0.456	2	notusa
Moving a separate bicycle crossing to a 4-leg intersection	Urban/Suburban	All	Vehicle/bicycle			1.28	0.518	2	notusa
Moving a separate bicycle crossing to a 3-leg intersection	Urban/Suburban	All	Vehicle/bicycle			0.83	0.331	2	notusa

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Delineation

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install transverse rumble strips, raised pavement markers, and transverse markings	Rural	All	All			1.1	1.26	1	
			Wet road			0.91	1.16	1	
			Nighttime			0.83	1.88	1	
Install transverse rumble strips and raised pavement markers	Rural	All	All			0.47	0.5	2	
			Wet road			0.51	0.55	1	
			Nighttime			0.36	1.37	1	

Highway Lighting

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Partial plus to partial interchange lighting	Suburban	Injury	All			0.862	0.149	2	OR

Interchange Design

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Reverse X-ramp exit and entry ramps	Urban	All	All			0.65	0.106	2	TX
		Incapacitating injury	All			0.33	0.382	1	TX
		Minor injury	All			0.49	0.103	2	TX
		PDO	All			1.13	0.317	1	TX
Convert diamond interchange to Diverging Diamond Interchange (DDI) or Double Crossover Diamond (DCD)	Urban	All				0.81		2	MO
			All			0.54		2	MO
			Left-turn			0		1	MO
			Rear-end			0.71		2	MO
		Minor injury	All			0.28		2	MO
		PDO	All			0.63		2	MO

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Intersection Geometry

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install J-turn intersection		All	All	16900 - 20000		0.39	0.135	2	NC
				16900 - 20000	At Downstream U-turn locations	1.67	1.063	1	NC
				45000 - 47600		0.5	0.188	2	NC
				45000 - 47600	At Downstream U-turn locations	0.91	0.381	2	NC
			Angle	16900 - 20000	Broadside right-angle	0		2	NC
				16900 - 20000	Far-side right-angle	0		2	NC
				16900 - 20000	Near-side right-angle	0		2	NC
				16900 - 20000	U-turn (At main intersection)	1.27	1.199	1	NC
				45000 - 47600	Broadside right-angle	0.08	0.084	1	NC
				45000 - 47600	Far-side right-angle	0		2	NC
				45000 - 47600	Near-side right-angle	0.32	0.372	1	NC
			Left-turn	16900 - 20000	Opposing through	1.41	1.063	1	NC
				45000 - 47600	Opposing through	0.57	0.422	1	NC
			Rear-end	16900 - 20000		0.63	0.509	1	NC
			Sideswipe	16900 - 20000		0.85	0.883	1	NC
				45000 - 47600		0.95	0.959	1	NC
			Single vehicle	16900 - 20000		0.85	1.249	1	NC
				45000 - 47600		1.42	1.309	1	NC
		Fatal	All	16900 - 20000		0.85	1.249	1	NC
				45000 - 47600		0		2	NC
		Injury	All	16900 - 20000		0.2	0.118	1	NC
				45000 - 47600		0.81	0.458	1	NC
		PDO	All	16900 - 20000		0.63	0.294	2	NC
				45000 - 47600		0.36	0.195	1	NC
	Rural	All	All	10670 - 11240		0.08	0.041	1	MD
			Angle	10670 - 11240	Broadside right-angle	0		2	MD
				10670 - 11240	Far-side right-angle	0		2	MD
				10670 - 11240	Near-side right-angle	0		2	MD
			Rear-end	10670 - 11240		0.62	0.898	1	MD
			Sideswipe,Head-on	10670 - 11240		0		2	MD
			Single vehicle	10670 - 11240		0.47	0.365	1	MD
		Fatal	All	10670 - 11240		0		2	MD
		Injury	All	10670 - 11240		0		2	MD
		PDO	All	10670 - 11240		0.25	0.151	1	MD
	Suburban	All	All	28600 - 29200		0.3	0.174	1	NC
				28600 - 29200	At Downstream U-turn locations	0.36	0.148	2	NC
			Angle	28600 - 29200	Broadside right-angle	0		2	NC
				28600 - 29200	Far-side right-angle	0		2	NC
				28600 - 29200	Near-side right-angle	0		2	NC
			Left-turn	28600 - 29200	Opposing through	1.96	2.408	1	NC
			Sideswipe	28600 - 29200		0		2	NC
			Single vehicle	28600 - 29200		0.98	1.392	1	NC
		Fatal	All	28600 - 29200		0		2	NC
		Injury	All	28600 - 29200		0.49	0.427	1	NC
		PDO	All	28600 - 29200		0.28	0.226	1	NC
Install turbo roundabout		All	All			0.239	0.296	2	notusa

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Intersection Geometry (cont)

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install single lane roundabout		All	All			0.213	0.421	2	notusa
						0.319	0.585	2	notusa
Increase the number of right-turn lanes on the major road from X to Y	Rural	All	Rear-end	420 - 15200		0		2	GA
			Sideswipe	420 - 15200		0		2	GA
Install median acceleration lane	Rural	All	All			0.77	0.19	1	MO
			Angle		Broadside right-angle	0.75	0.22	1	MO
					Near-side right-angle	0.8	0.25	1	MO
			Rear-end			0.21	0.22	1	MO
		Injury	All			0.55	0.22	1	MO
Install offset right-turn lane	Rural	All	All	7350 - 8000		0.94	0.48	1	IA
				10000 - 11300		1.02	0.42	1	IA
			Angle	5250 - 5410		0.47	0.42	1	IA
				5755 - 6525		1.37	2	1	IA
				6550 - 7225		1.41	0.91	1	IA
				7350 - 8000	Broadside right-angle	0.31	0.26	2	IA
				7350 - 8000	Near-side right-angle	0.47	0.42	1	IA
				7350 - 8000	Far-side right-angle	0		1	IA
				10000 - 11300	Broadside right-angle	0.96	0.43	1	IA
				10000 - 11300	Near-side right-angle	1.39	0.83	1	IA
				10000 - 11300	Far-side right-angle	0.6	0.43	1	IA
			Left-turn	7350 - 8000		0		1	IA
				10000 - 11300		0		1	IA
			Rear-end	7350 - 8000		0		1	IA
		Fatal	All	10000 - 11300		2.78	3.48	1	IA
		Injury	All	7350 - 8000		1.41	0.92	1	IA
				10000 - 11300		0.7	0.4	1	IA
		PDO	All	7350 - 8000		0.47	0.42	1	IA
				10000 - 11300		1.39	1.01	1	IA
Convert a conventional signalized intersection to a signalized superstreet	Rural	All		21000 - 45000		1.59		2	NC
			Sideswipe	21000 - 45000		1.48		2	NC
Convert a conventional unsignalized intersection to an unsignalized superstreet	Rural	All	Rear-end	5900 - 33500		0.99	0.24	2	NC
			Sideswipe	5900 - 33500		0.87	0.3	2	NC
Change roundabout circulating sight distance from X to Y		All	All	434 - 7300		Eq. LQ 8-1		2	
			Rear-end	434 - 7300		Eq. LQ 8-2		2	
Change roundabout intersection sight distance from X to Y		All	Run-off-road	434 - 7300		Eq. LQ 8-3		2	
Convert high-speed rural intersection to roundabout	Rural	Injury	Rear-end			0.54		2	KS,MD,MN,OR,WA,WI
Presence of an elevated road above intersection	Urban	All	All	7700 - 140300		1.58	0.32	2	

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Intersection Traffic Control

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert stop control to yield control	Urban/Suburban	All	All			2.27	1.26	1	
Add additional signal and upgrade to 12-inch lenses	Urban	All	All		Older driver crashes (ages 65+)	0.69	0.066	2	MI
					Younger driver crashes (age 25-64)	0.83	0.034	2	MI
Install double stop signs	Urban	All	Angle			0.45	0.52	1	NC
Install flashing beacons as advance warning	All	All	Angle			0.38	0.129	2	MD
			Rear-end			0.64	0.138	2	MD
Add centerline and STOP bar, replace 24-inch with 30-inch stop signs	Urban	All	Angle			0.33	0.11	1	NC
Change left turn phasing consistency from 27.3% to 9.1%		All	All			0.976		2	TX
			Angle			0.935		2	TX
Change left turn phasing consistency from 31.6% to 27.3%		All	All			0.922		2	TX
			Angle			0.989		2	TX
Change left turn phasing consistency from 61.9% to 31.6%		All	All			0.691		2	TN
			Angle			0.642		2	TX
Modify nighttime flash operation period		All	All			0.88	0.12	2	NC
			Sideswipe,Head-on			1	0.17	2	NC
		Fatal and injury	All			0.84	0.17	2	NC
Convert from yield signal control to signalized control (intersection crashes)		All	Head-on,Rear-end			1.01		2	notusa
			Single vehicle			0		2	notusa
	Urban	All	All	12000 - 18000		0.71	0.19	2	notusa
				18000 - 40000		0.76	0.18	2	notusa
			Angle		3-leg intersections	0.25		2	notusa
					4-leg intersections	0.14		2	notusa
					5-leg intersections	0		2	notusa
			Head-on,Rear-end		All intersections	1.37		2	notusa
					3-leg intersections	1.9		2	notusa
			Left-turn,Right-turn		All intersections	1.34		2	notusa
					3-leg intersections	0.98		2	notusa
					5-leg intersections	1.48		2	notusa
			Single vehicle		All intersections	1.34		2	notusa
					3-leg intersections	0.83		2	notusa
					4-leg intersections	2.06		2	notusa
			Vehicle/bicycle		3-leg intersections	0.86		2	notusa
					4-leg intersections	0.59		2	notusa
					5-leg intersections	3.21		2	notusa
			Vehicle/pedestrian		All intersections	0.84		2	notusa
					3-leg intersections	0.71		2	notusa
					4-leg intersections	0.94		2	notusa
					5-leg intersections	0		2	notusa
					All intersections	0.74		2	notusa
					3-leg intersections	0.46		2	notusa
					4-leg intersections	0.91		2	notusa
					5-leg intersections	0		2	notusa
Installation of channelizing separator islands on side road approaches with supplemental STOP signs	Rural	All	All			0.32		2	VA
			Angle			0.26		2	VA
			Rear-end			0		2	VA
		Fatal and injury	All			0.26		2	VA
Provide split phases	Urban	All	Angle,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe			0.44		2	NY
			Vehicle/pedestrian			0.61		2	NY
Install flashing yellow arrow		All	Vehicle/pedestrian			1		2	MI

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On-street Parking

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Prohibit parking on one side of road	Urban	Injury	All			1.49	0.78	1	
Convert parallel parking to angle parking	Urban	All	All			2.11	2.56	1	
		All	Parking related			1.18	0.73	1	

Pedestrians

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install raised pedestrian crosswalks	Urban/Suburban	Injury	All			0.64	0.54	1	
						0.7	0.67	1	
			Vehicle/pedestrian			0.55	0.94	1	
Raised median with unmarked crosswalk (uncontrolled)	Urban/Suburban	All	Vehicle/pedestrian			0.61	2.02	2	AZ,CA,FL,KS,LA,MD,MA,MO,NC,OH,OR,PA,TX,UT,WA,WI
Widen sidewalks at intersections		Injury	All			1.12	1.26	1	
Raised intersections		Injury	All			1.05	0.71	1	
		PDO	All			1.13	1.4	1	
Increase cycle length for pedestrian crossing	Urban	All	Angle,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe			0.55		2	NY
			Vehicle/pedestrian			0.5		2	NY
Implement Barnes Dance	Urban	All	Angle,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe			1.1		2	NY
			Vehicle/pedestrian			0.49		2	NY
Install high-visibility crosswalk	Urban	All	Angle,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe			0.81		2	NY
			Vehicle/pedestrian			0.6		2	NY
Increase enforcement		All	Vehicle/pedestrian			0.77		2	
Prohibit right-turn-on-red		All	All			0.97		2	
Install pedestrian overpass/underpass		All	Vehicle/pedestrian			0.14		2	
		Incapacitating injury	Vehicle/pedestrian			0.1		2	
Install refuge islands		All	Vehicle/pedestrian			0.44		2	
Install sidewalk (to avoid walking along roadway)		All	Vehicle/pedestrian			0.12		2	

Roadside Features

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install wire guardrails between lanes of opposing traffic		All	All			1.34	0.74	1	
		Fatal	All			0	2.54	1	
		Injury	All			0.74	0.84	1	

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Roadway Features

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Flatten sideslope from 1V:3H to 1V:4H	Rural	All	Run-off-road			0.82	0.16	3	
		Injury	All			0.58	0.04	5	
		PDO	All			0.71	0.04	5	
Flatten sideslope from 1V:4H to 1V:6H	Rural	All	Run-off-road			0.76	0.21	3	
		Injury	All			0.78	0.04	5	
		PDO	All			0.76	0.02	5	
Convert continuous access HOV lanes to limited-access (HOV and left lane crashes)		All	All			1.54	1.061	2	CA
		Incapacitating injury	All			1.2	1.957	2	CA
Refinish pavement with microsurfacing treatment		All	All			0.86	0.194	2	notusa
Refinish pavement with resurfacing treatment		All	All	0 - 2999/lane		0.86	0.757	2	notusa
				3000 - 6999/lane	All	0.74	0.083	2	notusa
				3000 - 6999/lane	Intersection	0.64		2	notusa
				> 7000/lane		1.06	0.126	2	notusa
			Rear-end			0.67		2	notusa
			Wet road			0.49		2	notusa
Resurface pavement with rubberized open-graded asphalt concrete (R-OGAC)	All	All	Wet road			1.07	0.49	2	CA
Expand truck lane restrictions on 2-lane directional interstate segments (screened)		All	Truck related			0.98	0.12755	2	VA
Install Cargill SafeLane anti-icing pavement overlay system on bridges		All	All			0.61	0.16	2	MN
		Fatal and injury	All			0.27	0.21	1	MN
		PDO	All			0.71	0.21	1	MN
Installation of lane narrowing through rumble strips and painted median at rural stop-controlled approaches	Rural	All	All			0.69		2	FL,KY,MO,PA
			Angle			0.58		2	FL,KY,MO,PA
			Rear-end			1.54		2	FL,KY,MO,PA
		Fatal and injury	All			0.8		2	FL,KY,MO,PA
Change in pavement condition from X to Y	Rural	Fatal and injury	All			Eq. LQ 14-1		2	IN
		Injury	All			Eq. LQ 14-2		2	IN
		PDO	All			Eq. LQ 14-3		2	IN
Convert from two-way to one-way traffic	Urban	All	All			0.53	0.17	2	notusa

Shoulder Treatments

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Barrier curb on the road edge	Suburban	All	All			1.09	1.26	1	
						3.57	26.48	1	
						0.64	1.64	1	
Pave narrow shoulder through curve		All	All			2.04	0.76	1	MN

Signs

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Advance static curve warning signs		Injury	All			0.7	0.71	1	
		PDO	All			0.92	0.76	1	
Install improved advance freeway guidance signage	Rural	All	All	17100 - 43000		1.07	0.18	2	MN
			Angle	17100 - 43000		0.69	0.19	1	MN

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Speed Management

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install transverse rumble strips as traffic calming device	Urban/Suburban	PDO	All			0.73	0.41	2	
Lower posted speed from 80 km/h to 60 km/h	Rural	Fatal	Head-on			0.79		2	notusa
			Parking related			0.44		2	notusa
			Truck related			0.86		2	notusa

Transit

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Installation of new streetcar platforms at unprotected stops	Urban	All	All			0.88		1	notusa
			Vehicle/pedestrian			0.38		1	notusa
			Vehicle/pedestrian		Tram/Pedestrian crashes	1.77		1	notusa

Work Zones

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Single lane closure		All	All			1.56	0.7	1	
Implement left-hand merge and downstream lane shift (Iowa weave)	Rural	All	All			0.54		1	AR
		Fatal and injury	All			2.24		2	AR

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Alignment

Equation Number	Equation	X	Y
LQ 3 - 1	e^(0.0262(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 2	e^(0.0580(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 3	e^(0.0364(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 4	e^(0.0268(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 5	e^(0.0635(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 6	e^(0.0354(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 7	e^(0.0163(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 8	e^(0.0722(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 9	e^(0.0553(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)

Intersection geometry

Equation Number	Equation	X	Y
LQ 8 - 1	Y/X	Circulating sight distance (ft) (Before)	Circulating sight distance (ft) (After)
LQ 8 - 2	Y/X	Circulating sight distance (ft) (Before)	Circulating sight distance (ft) (After)
LQ 8 - 3	Y/X	Intersection sight distance (ft) (Before)	Intersection sight distance (ft) (After)

Roadway

Equation Number	Equation	X	Y
LQ 14 - 1	e^(-0.1962(Y-X))	Pavement Condition (PSI) (Before)	Pavement Condition (PSI) (After)
LQ 14 - 2	e^(-0.1969(Y-X))	Pavement Condition (PSI) (Before)	Pavement Condition (PSI) (After)
LQ 14 - 3	e^(-0.0624(Y-X))	Pavement Condition (PSI) (Before)	Pavement Condition (PSI) (After)

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District Highway Safety Guidance Manual

Appendix G —**SPF Equations and PennDOT Specific CMF's Quick Reference Guide**

December, 2014

Rural 2-Lane Segments SPFs & CMFs

Rural Two-Lane Segments: Total Crashes

Full Equation

$$N_{SPF} = e^{-5.934} \times AADT^{0.754} \times e^{0.101 \times RHR6,7} \times e^{0.091 \times RHR4,5} \times e^{-0.239 \times PZ} \times e^{-0.188 \times ShldRS} \times e^{0.008 \times AD} \times e^{0.030 \times HCD} \times e^{0.002 \times DCM}$$

Base Equation

$$N_{SPF\ Base} = e^{-5.894} \times L \times AADT^{0.754}$$

Base Conditions

- Roadside Hazard Rating = ≤3
- Passing Zone = 0 (Not Present)
- Shoulder Rumble Strips = 0 (Not Present)
- Access Density = 5 accesses/mile
- Horizontal Curve Density = 0 curves/mile
- Degree of Curve per Mile = 0 degrees/mile

CMFs

- Roadside Hazard Rating
  $$CMF_{RHR} = e^{(0.101 \times RHR6,7 + 0.091 RHR4,5)}$$
- Passing Zone
  $$CMF_{PZ} = e^{-0.239 \times PZ}$$
- Shoulder Rumble Strips
  $$CMF_{ShldRS} = e^{-0.188 \times ShldRS}$$
- Access Density
  $$CMF_{AD} = e^{0.008 \times (AD - 5)}$$
- Horizontal Curve Density & Degree of Curve per Mile
  $$CMF_{HC} = e^{(0.030 \times HCD + 0.002 \times DCM)}$$

Rural Two-Lane Segments: Fatal-and-Injury Crashes

Full Equation

$$N_{SPF} = e^{-6.363} \times AADT^{0.735} \times e^{0.051 \times RHR6,7} \times e^{0.055 \times RHR4,5} \times e^{-0.232 \times PZ} \times e^{-0.184 \times ShldRS} \times e^{0.008 \times AD} \times e^{0.031 \times HCD} \times e^{0.002 \times DCM}$$

Base Equation

$$N_{SPF\ Base} = e^{-6.323} \times L \times AADT^{0.735}$$

Base Conditions

- Roadside Hazard Rating = ≤3
- Passing Zone = 0 (Not Present)

- Shoulder Rumble Strips = 0 (Not Present)
- Access Density = 5 accesses/mile
- Horizontal Curve Density = 0 curves/mile
- Degree of Curve per Mile = 0 degrees/mile

<u>CMFs</u>

- Roadside Hazard Rating

$$CMF_{RHR} = e^{(0.051 \times RHR6,7 + 0.055RHR4,5)}$$

- Passing Zone

$$CMF_{PZ} = e^{-0.232 \times PZ}$$

- Shoulder Rumble Strips

$$CMF_{ShldRS} = e^{-0.184 \times ShldRS}$$

- Access Density

$$CMF_{AD} = e^{0.008 \times (AD - 5)}$$

- Horizontal Curve Density & Degree of Curve per Mile

$$CMF_{HC} = e^{(0.031 \times HCD + 0.002 \times DCM)}$$

Rural 2-Lane Intersection SPFs & CMFs

4-Leg Signalized Intersections

Total Crashes

Full Equation

$$N_{SPF} = e^{-5.353} \times AADT_{Major}{}^{0.313} \times AADT_{Minor}{}^{0.250} \times e^{0.025 \times SLMaj} \times e^{0.014 \times SLMin} \times e^{0.216 \times RTMaj}$$

Base Equation

$$N_{SPF\ Base} = e^{-4.183} \times AADT_{Major}{}^{0.313} \times AADT_{Minor}{}^{0.250}$$

Base Conditions

- Major Road Speed Limit = 30 mph
- Minor Road Speed Limit = 30 mph
- Major Road Right Turn Lane = 0 (Not Present)

CMFs

- Major Road Speed Limit

  $$CMF_{SLMaj} = e^{0.025 \times (SLMaj - 30)}$$

- Minor Road Speed Limit

  $$CMF_{SLMin} = e^{0.014 \times (SLMin - 30)}$$

- Major Road Right Turn Lane

  $$CMF_{RTMaj} = e^{0.216 \times RTMaj}$$

Fatal & Injury Crashes

Full Equation

$$N_{SPF} = e^{-4.960} \times AADT_{Major}{}^{0.202} \times AADT_{Minor}{}^{0.209} \times e^{0.028 \times SLMaj} \times e^{0.018 \times SLMin} \times e^{0.388 \times RTMaj}$$

Base Equation

$$N_{SPF\ Base} = e^{-3.580} \times AADT_{Major}{}^{0.202} \times AADT_{Minor}{}^{0.209}$$

Base Conditions

- Major Road Speed Limit = 30 mph
- Minor Road Speed Limit = 30 mph
- Major Road Right Turn Lane = 0 (Not Present)

CMFs

- Major Road Speed Limit

  $$CMF_{SLMaj} = e^{0.028 \times (SLMaj - 30)}$$

- Minor Road Speed Limit

  $$CMF_{SLMin} = e^{0.018 \times (SLMin - 30)}$$

- Major Road Right Turn Lane

  $$CMF_{RTMaj} = e^{0.388 \times RTMaj}$$

3-Leg Signalized Intersections

Total Crashes

Full Equation

$$N_{SPF} = e^{-6.813} \times AADT_{Major}{}^{0.451} \times AADT_{Minor}{}^{0.349} \times e^{0.020 \times SLMaj} \times e^{-0.433 \times XWMaj} \times e^{-0.345 \times XWMin}$$

Base Equation

$$N_{SPF\ Base} = e^{-3.583} \times AADT_{Major}{}^{0.451} \times AADT_{Minor}{}^{0.349}$$

Base Conditions

- Major Road Speed Limit = 30 mph
- Major Road Crosswalk = 0 (Not Present)
- Minor Road Crosswalk = 0 (Not Present)

CMFs

- Major Road Speed Limit

$$CMF_{SLMaj} = e^{0.020 \times (SLMaj - 30)}$$

- Major Road Crosswalk

$$CMF_{XWMaj} = e^{-0.433 \times XWMaj}$$

- Minor Road Crosswalk

$$CMF_{XWMin} = e^{-0.345 \times XWMin}$$

Fatal & Injury Crashes

Full Equation

$$N_{SPF} = e^{-6.981} \times AADT_{Major}{}^{0.452} \times AADT_{Minor}{}^{0.287} \times e^{0.026 \times SLMaj} \times e^{-0.605 \times XWMaj} \times e^{-0.413 \times XWMin}$$

Base Equation

$$N_{SPF\ Base} = e^{-6.201} \times AADT_{Major}{}^{0.452} \times AADT_{Minor}{}^{0.287}$$

Base Conditions

- Major Road Speed Limit = 30 mph
- Major Road Crosswalk = 0 (Not Present)
- Minor Road Crosswalk = 0 (Not Present)

CMFs

- Major Road Speed Limit

$$CMF_{SLMaj} = e^{0.026 \times (SLMaj - 30)}$$

- Major Road Crosswalk

$$CMF_{XWMaj} = e^{-0.605 \times XWMaj}$$

- Minor Road Crosswalk

$$CMF_{XWMin} = e^{-0.413 \times XWMin}$$

4-Leg All-Way-Stop-Controlled Intersections

Total Crashes

Full Equation

$$N_{SPF} = e^{-5.820} \times AADT_{Major}{}^{0.693} \times AADT_{Minor}{}^{0.087} \times e^{0.057 \times SLMaj}$$

Base Equation

$$N_{SPF\ Base} = e^{-4.110} \times AADT_{Major}{}^{0.693} \times AADT_{Minor}{}^{0.087}$$

Base Conditions

- Major Road Speed Limit = 30 mph

CMFs

- Major Road Speed Limit

$$CMF_{SLMaj} = e^{0.057 \times (SLMaj - 30)}$$

Fatal & Injury Crashes

Full Equation

$$N_{SPF} = e^{-6.515} \times AADT_{Major}{}^{0.630} \times AADT_{Minor}{}^{0.166} \times e^{0.046 \times SLMaj}$$

Base Equation

$$N_{SPF\ Base} = e^{-5.135} \times AADT_{Major}{}^{0.630} \times AADT_{Minor}{}^{0.166}$$

Base Conditions

- Major Road Speed Limit = 30 mph

CMFs

- Major Road Speed Limit

$$CMF_{SLMaj} = e^{0.046 \times (SLMaj - 30)}$$

4-Leg Two-Way Stop-Controlled Intersections

Total Crashes

Full Equation

$$N_{SPF} = e^{-6.359} \times AADT_{Major}{}^{0.528} \times AADT_{Minor}{}^{0.275} \times e^{0.007 \times Skew}$$

Base Equation

$$N_{SPF\ Base} = e^{-6.359} \times AADT_{Major}{}^{0.528} \times AADT_{Minor}{}^{0.275}$$

Base Conditions

- Skew Angle = 0 degrees

CMFs

- Skew Angle

$$CMF_{Skew} = e^{0.007 \times Skew}$$

Fatal & Injury Crashes

Full Equation

$$N_{SPF} = e^{-6.156} \times AADT_{Major}{}^{0.512} \times AADT_{Minor}{}^{0.176} \times e^{0.008 \times Skew}$$

Base Equation

$$N_{SPF\ Base} = e^{-6.156} \times AADT_{Major}{}^{0.512} \times AADT_{Minor}{}^{0.176}$$

Base Conditions

- Skew Angle = 0 degrees

CMFs

- Skew Angle

$$CMF_{Skew} = e^{0.008 \times Skew}$$

3-Leg Minor Approach Stop-Controlled Intersections

Total Crashes

Full Equation

$$N_{SPF} = e^{-6.337} \times AADT_{Major}{}^{0.479} \times AADT_{Minor}{}^{0.362} \times e^{-0.330 \times LTMaj} \times e^{0.507 \times RTMaj}$$

Base Equation

$$N_{SPF\ Base} = e^{-6.337} \times AADT_{Major}{}^{0.479} \times AADT_{Minor}{}^{0.362}$$

Base Conditions

- Major Road Left Turn Lane = 0 (Not Present)
- Major Road Right Turn Lane = 0 (Not Present)

CMFs

- Major Road Left Turn Lane

$$CMF_{LTMaj} = e^{-0.330 \times LTMaj}$$

- Major Road Right Turn Lane

$$CMF_{RTMaj} = e^{0.507 \times RTMaj}$$

Fatal & Injury Crashes

Full Equation

$$N_{SPF} = e^{-6.457} \times AADT_{Major}{}^{0.439} \times AADT_{Minor}{}^{0.343} \times e^{-0.267 \times LTMaj} \times e^{0.560 \times RTMaj}$$

Base Equation

$$N_{SPF\ Base} = e^{-6.457} \times AADT_{Major}{}^{0.439} \times AADT_{Minor}{}^{0.343}$$

Base Conditions

- Major Road Left Turn Lane = 0 (Not Present)
- Major Road Right Turn Lane = 0 (Not Present)

CMFs

- Major Road Left Turn Lane

$$CMF_{LTMaj} = e^{-0.267 \times LTMaj}$$

- Major Road Right Turn Lane

$$CMF_{RTMaj} = e^{0.560 \times RTMaj}$$