Improving Safety on Rural Local and Tribal Roads

Safety Toolkit

August 2014

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

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Technical Report Documentation Page

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16. Abstract

Rural roadway safety is an important issue for communities throughout the country and presents a challenge for state, local, and Tribal agencies. The *Improving Safety on Rural Local and Tribal Roads – Safety Toolkit* was created to help rural local and Tribal roadway safety practitioners address these challenges. The Safety Toolkit provides a step-by-step process to assist local agency and Tribal practitioners in completing traffic safety analyses, identify safety issues, countermeasures to address them, and an implementation process. Each step in the Toolkit contains a set of tools, examples, and links to resources appropriate to the needs of safety practitioners. The report presents a seven-step safety analysis process based on a similar process developed in the Highway Safety Manual. The seven steps are: compile data; conduct network screening; select sites for investigation; diagnose site conditions and identify countermeasures; prioritize countermeasures for implementation; implement countermeasures; and evaluate effectiveness of implemented countermeasures. Accompanying the Safety Toolkit are two User Guides (FHWA-SA-14-073 and FHWA-SA-14-074) which present step-by-step processes of example scenarios.

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Introduction

Rural roadway safety is an important issue for communities throughout the country and presents a challenge for local and Tribal agencies. Rural agencies are keenly aware of the need to improve roadway safety; however, because the same few staff members have wide ranging responsibilities that often include planning, engineering, design, landscaping, construction and construction oversight, and maintenance – it can be challenging for them to also address roadway safety. To help rural agency practitioners effectively integrate road safety into their existing responsibilities, the Federal Highway Administration (FHWA) Office of Safety created this Toolkit for improving safety on rural local and Tribal roads (referred to hereafter as the Toolkit) as well as two associated User Guides.

The Toolkit provides practitioners with an easy to use safety analysis process, a set of tools, examples, and links to resources appropriate to their needs. The Toolkit is a step-by-step guide for conducting roadway safety analysis while the User Guides provide hypothetical yet typical scenarios to demonstrate how the Toolkit can be applied.

Who Should Use The Toolkit?

This Toolkit is designed for local and Tribal agency staff responsible for roadway safety. These staff typically have a wide range of expertise and experience, but little formal background in traffic safety. The Toolkit provides plain language guidance to help improve roadway safety on rural and Tribal roads. Throughout the Toolkit local and Tribal agency staff are referred to collectively as "practitioners" or "staff," independent of whether they work for a local or Tribal road agency. Similarly, the road agency is referred to as the "agency" or "jurisdiction" whether it is a Tribal or local road agency.

What Is In The Toolkit?

The Toolkit walks practitioners step by step through the process of analyzing roadway and crash data, identifying safety issues and needs, and selecting and implementing countermeasures to address them. For each step in the process, the Toolkit provides an overview of the step, an example application of the step, guidance related to applying the step, and a summary of state and national resources that provide more information about the step. The next section explains the purpose of each step and the circumstance for when it should be used. Each step then presents detailed information about the step and tools, examples, guidance, and resources associated with each step in the process.

Why Use The Toolkit?

The Toolkit helps practitioners save lives and reduce serious injuries and fatalities on their roadways through the application of the latest highway safety techniques and proven strategies.

What Are The User Guides?

Two User Guides are associated with this Toolkit. Each demonstrates the Toolkit in practice by walking through a typical road safety analysis scenario.

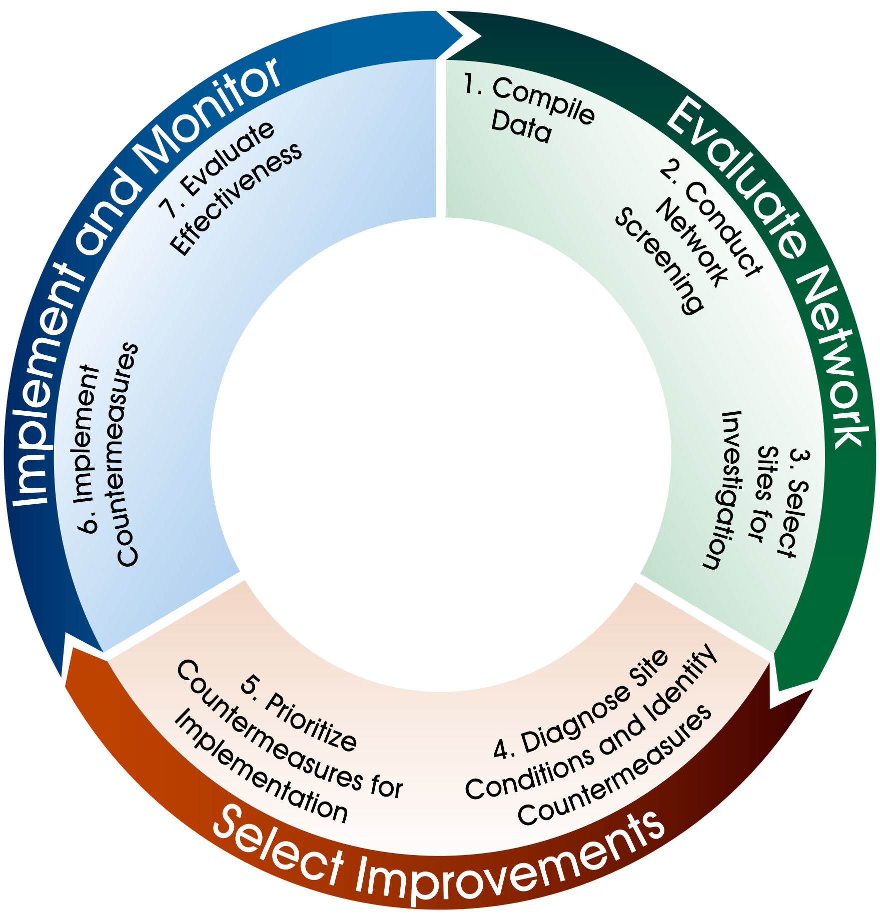
- **User Guide #1 – Improving Safety on Rural Local and Tribal Roads – Site Safety Analysis** describes how to conduct a site-specific safety analysis.
- **User Guide #2 – Improving Safety on Rural Local and Tribal Roads – Network Safety Analysis** describes how to conduct a proactive analysis of a component of the transportation network such as all two-lane road segments, or all stop-controlled intersections.

How to Use the Toolkit and User Guides

Toolkit

Figure 1 illustrates the Toolkit's safety analysis process. This process is based largely on the safety analysis process developed in the Highway Safety Manual (HSM). This section describes each step of the process. For more information, including guidance for conducting a given step or links to other resources, please go to the relevant step in the Toolkit.

Figure 1. Safety Analysis Process



Step 1. Compile Data

The first step in conducting safety analysis is compiling the available data. Valuable safety analysis can be conducted with very little data. However, the type of safety analysis that can be conducted and its level of sophistication vary according to the quantity and quality of the data used. The most common types of quantitative data are crash data, traffic volume data, and roadway characteristics. Non-quantitative anecdotal information also is commonly used in safety analysis.

When to Do this Step

There are typically two situations requiring safety data to be compiled: 1) agency staff or the public are concerned about safety at a particular location; or 2) agency staff seek to better understand safety issues for some portion of the road system, including rural curves and stop-controlled intersections.

Step 2. Network Screening

A "network" is a collection of roads under the jurisdiction of an agency. In network screening, all or some of an agency's roadway network is evaluated from a safety perspective. For example, an agency could conduct a network screening of all collector roads and intersections in the community, or all stop-controlled intersections in the community. The purpose is to focus limited resources on the locations most likely to benefit from traffic safety improvements.

While there are many methods for screening road networks, each with unique benefits and drawbacks, only five are presented in the Toolkit. They are:

1. Network Screening with Maintenance Staff – Training maintenance staff to integrate safety considerations into their day-to-day activities;
2. Network Screening with Crash Data – Frequency, Crash Mapping, and Equivalent Property Damage Only;
3. Network Screening with Crash Data and Traffic Volume Data – Crash Rate;
4. Network Screening utilizing Software; and
5. Network Screening with Systemic Analysis.

The outcome of network screening analysis is a list of sites with potential for safety improvements.

When to Do this Step

Even though it currently is not common practice, network screening is an effective way for an agency to develop lists of candidate sites for safety improvements. This allows the agency to proactively implement a strategic approach to improve safety and, over time, lessen the reactive approach to simply addressing one concern after another.

In cases where the agency is responding to safety concerns at specific location(s), the agency can skip this step and go directly to evaluating conditions at the site (Step 4).

Step 3. Select Sites for Investigation

During this step, the list of sites identified in the network screening process is narrowed down to a subset for detailed investigation. In an ideal situation, every one of the sites identified through network screening would be analyzed in more detail. Depending on the number of sites identified, time and resource constraints may limit detailed evaluation of all of them. Therefore, the agency should focus its attention on the most important sites.

When to Do this Step

Whenever an agency has identified more sites to analyze than it has resources to accomplish, narrowing the list of sites through the use of selection criteria is helpful.

Step 4. Diagnose Site Crash Conditions and Identify Countermeasures

Once the site(s) have been selected for evaluation; crash data, traffic volume data, and roadway characteristics at the selected sites can be studied to identify the factors contributing to the crashes. Stakeholders (e.g., residents, law enforcement officers, maintenance staff) also should be consulted for additional information contributing to safety issues at the sites. This step is referred to as site diagnosis.

The availability of crash data substantially influences the methods available for diagnosis. This step presents information about diagnosing site crash conditions both without and with crash data and identifying countermeasures for a site.

When to Do this Step

This step is conducted for each site selected for detailed investigation.

Step 5. Prioritize Countermeasures for Implementation

If the agency has identified more than one treatment to address crash concerns at a site, the countermeasures are prioritized to identify which have the greatest potential to improve safety. Selecting the most appropriate countermeasure depends on considerations, including – feasibility of implementation, expected safety benefits, cost, public opinion, local and state roadway design policies and guidance.

After prioritizing and selecting the most appropriate countermeasure for each site, it may be necessary to select the sites that will actually receive the improvements. This decision is influenced by several factors, including available funding, other construction or maintenance activities underway in the community, funding/grant availability and restrictions, and the estimated safety benefits. Step 5 describes various methods for conducting this prioritization analysis.

When to Do this Step

This step is needed if more than one optional treatment has been identified for a site and/or the cost of implementing improvements at the study sites is greater than the funds available.

Step 6. Implement Countermeasures

Obtaining the necessary human and financial resources is a major consideration in implementing any safety project or program. While safety funds for project implementation are available from a variety of Federal, Tribal, state, and local programs, harnessing local funding sources and staff resources may be the quickest way to implement projects. For example, maintenance staff can implement low cost projects such as sign replacement, vegetation control, or roadway striping as part of their regular duties.

Agencies also can use locally generated funds as a match to leverage state or Federal dollars. This approach greatly increases the total funding available to implement projects.

While administration of these programs varies throughout the country, this step provides background information about these programs and resources for learning more.

When to Do this Step

Countermeasures are implemented after they have been selected and prioritized.

Step 7. Evaluate Effectiveness

The purpose of this step is to describe how to evaluate the impact of the treatments that have been implemented in terms of crash frequency or severity. A reliable assessment of the effectiveness of safety countermeasures cannot be made immediately after implementation. Some time needs to pass, often two to three years, before enough data can be collected to determine how many crashes, serious injuries, and fatalities have occurred since implementation to then compare it with the same types of data from before implementation.

This step should not be overlooked. Evaluation provides information that can help agencies decide whether or not the investment has reduced crash frequency or severity. Evaluation also can help agency staff demonstrate the value of the safety program to community leaders and the general public.

When to Do this Step

Practitioners should conduct safety effectiveness evaluation two to three years after treatment(s) have been installed.

User Guides

Each of the two User Guides demonstrates different aspects of the toolkit through the use of hypothetical typical examples.

- **User Guide #1 – Improving Safety on Rural Local and Tribal Roads – Site Safety Analysis** describes how to conduct a site-specific safety analysis.
- **User Guide #2 – Improving Safety on Rural Local and Tribal Roads – Network Safety Analysis** describes how to conduct a safety analysis of a component of the transportation network (multiple locations) such as all two-lane road segments, or all stop-controlled intersections.

The User's Guides and Toolkit include sidebars with additional tips, technical definitions, and references to other resources. They provide background information and context for users unfamiliar with the technical terms and provide helpful information related to the tools and identify optional or additional analyses that can be conducted.

Using the User's Guides:

User's Guides are companion documents to the Toolkit and provide realistic examples for users to work through. Although the scenarios may not mirror the issues experienced in your agency, the Guides provide information on how best to use the resources in the Toolkit and example calculations.

Step 1. Compile Data and Resources

Overview

The first step in conducting safety analysis is compiling the available data. The type of safety analysis that can be conducted and its level of sophistication vary according to the quantity and quality of the data used. Valuable safety analysis can be conducted with very little data. The most common types of quantitative data used for safety analysis are crash data, traffic volumes, and roadway characteristics. Qualitative or anecdotal information from stakeholders also is commonly used in safety analysis.

In addition to data, documents and other readily available resources along with information and assistance from a variety of organizations and agencies can be referenced and enlisted as support for safety analysis.

This section provides information about:

- Anecdotal data;
- Quantitative data, including crash data, traffic volumes, and roadway characteristics;
- Data from existing resources and documents; and
- Organizations and agencies that can provide additional safety analysis support.

These types of data and resources are described in further detail below.

Data Examples

Anecdotal Data

Anecdotal data include phone calls from concerned citizens, community member survey results, news items, and local staff and police knowledge about a particular site or segment of roadway. These data provide a range of perspectives about potential safety issues, including speeding, limited sight distance, lack of signage, and roadway segments that frequently experience icy conditions. They are particularly useful in identifying sites with potential for safety improvements. Additional information, as well as ideas for potential solutions, can be gathered from these stakeholders as well.

Quantitative Data

Quantitative data include information from police reports, crash data, traffic volume data, and roadway characteristics.

Crash Data

Typical sources of crash data include local and state crash databases as well as local police crash reports and the National Highway Traffic Safety Administration (NHTSA) Fatal Analysis Recording System (FARS).

Local and State Crash Data. Local law enforcement agencies usually keep records of all crashes their officers have recorded. These crash reports are recorded on crash forms that are uniform across the state, but often differ between states. Despite differences in the forms, crash reports across all states generally contain data related to:

- Crash date, time, and location;
- Drivers and passengers (age, impairment, gender),
- Road condition at the time of the crash,
- Crash type,
- Crash severity,
- Weather conditions at the time of the crash, and
- Lighting conditions.

Most crash reports include a key that describes the meaning of the codes used in the form. Figure 2 is an example of a crash report form from Michigan.

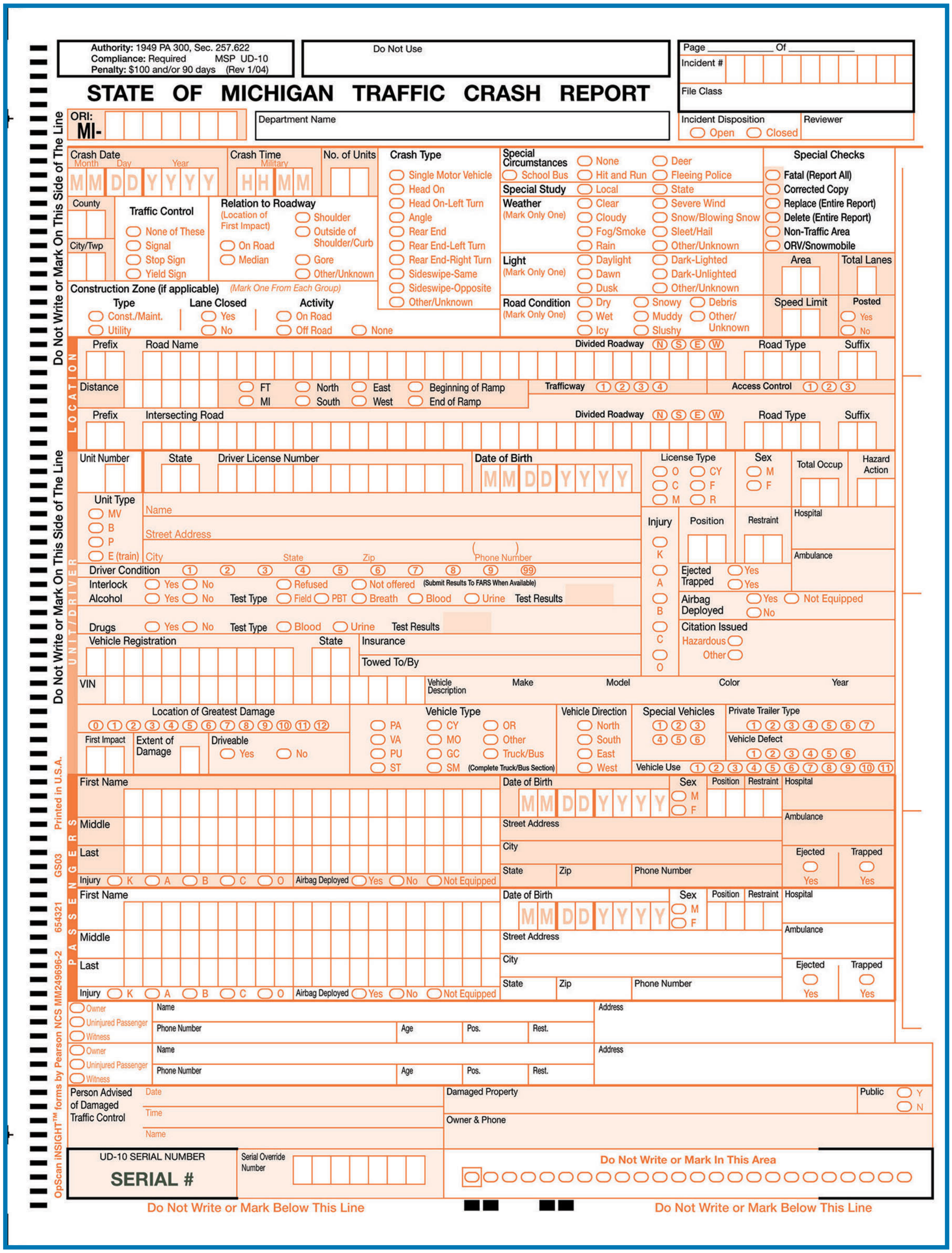
In some states, the DOT collects and maintains crash data for all public roads. In others, the state police maintain a comparable data system. These databases enable summary crash data to be analyzed and reports to be generated. Many states also publish summary crash reports that can be useful to understand crash trends and provide contact information for data requests or support. For example, an Oregon Department of Transportation annual crash report can be found at: http://www.oregon.gov/ODOT/TD/TDATA/car/docs/2011CrashSummaryBook.pdf.

Quantitative versus Qualitative?

Quantitative: Deals with measurable data, such as speed, time of day, traffic volumes, numbers, and rates of crashes or fatalities.

Qualitative: Deals with things that can be observed but not easily measured, such as an individual's perception of safety on a roadway, public attitudes towards DUI checkpoints, and various other descriptive information.

Figure 2. Example Crash Report Form from Michigan

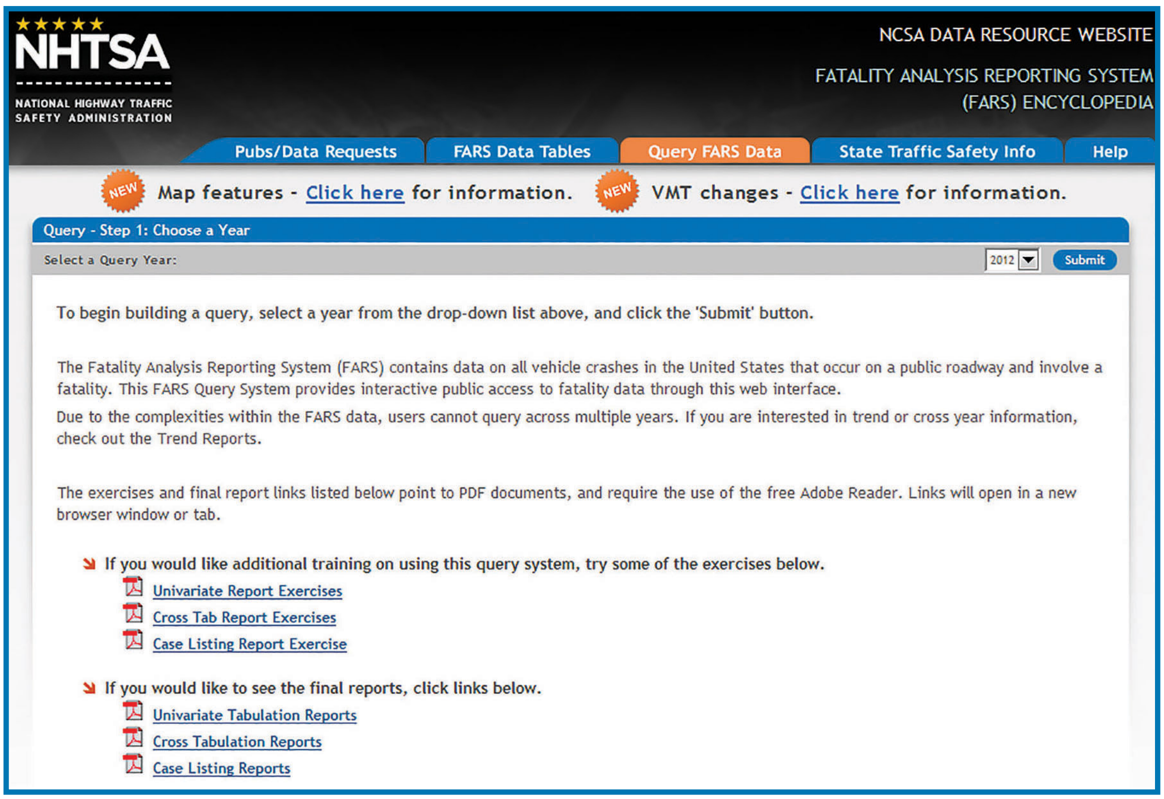

Authority: 1949 PA 300, Sec. 257.622
Compliance: Required MSP UD-10
Penalty: $100 and/or 90 days (Rev 1/04)
Do Not Use
Page ____ Of ____
Incident #
STATE OF MICHIGAN TRAFFIC CRASH REPORT
File Class
ORI: MI-
Department Name
Incident Disposition: Open / Closed
Reviewer
Crash Date (Month Day Year) MM DD YYYY
Crash Time (Military) HH MM
No. of Units
Crash Type: Single Motor Vehicle; Head On; Head On-Left Turn; Angle; Rear End; Rear End-Left Turn; Rear End-Right Turn; Sideswipe-Same; Sideswipe-Opposite; Other/Unknown
Special Circumstances: None; Deer; School Bus; Hit and Run; Fleeing Police
Special Study: Local; State
Weather (Mark Only One): Clear; Severe Wind; Cloudy; Snow/Blowing Snow; Fog/Smoke; Sleet/Hail; Rain; Other/Unknown
Light (Mark Only One): Daylight; Dark-Lighted; Dawn; Dark-Unlighted; Dusk; Other/Unknown
Road Condition (Mark Only One): Dry; Snowy; Debris; Wet; Muddy; Other/Unknown; Icy; Slushy
Special Checks: Fatal (Report All); Corrected Copy; Replace (Entire Report); Delete (Entire Report); Non-Traffic Area; ORV/Snowmobile
Area; Total Lanes
Speed Limit; Posted: Yes / No
County; City/Twp
Traffic Control: None of These; Signal; Stop Sign; Yield Sign
Relation to Roadway (Location of First Impact): Shoulder; Outside of Shoulder/Curb; On Road; Median; Gore; Other/Unknown
Construction Zone (if applicable) (Mark One From Each Group)
Type: Const./Maint.; Utility
Lane Closed: Yes; No
Activity: On Road; Off Road; None
LOCATION
Prefix; Road Name; Divided Roadway N S E W; Road Type; Suffix
Distance: FT / MI; North / South; East / West; Beginning of Ramp / End of Ramp
Trafficway 1 2 3 4; Access Control 1 2 3
Prefix; Intersecting Road; Divided Roadway N S E W; Road Type; Suffix
UNIT/DRIVER
Unit Number; State; Driver License Number; Date of Birth MM DD YYYY; License Type: O, CY, C, F, M, R; Sex: M, F; Total Occup; Hazard Action
Unit Type: MV; B; P; E (train)
Name; Street Address; City; State; Zip; ( ) Phone Number
Injury: K; A; B; C; O
Position; Restraint; Hospital; Ambulance
Driver Condition 1 2 3 4 5 6 7 8 9 99
Interlock: Yes No; Refused; Not offered (Submit Results To FARS When Available)
Alcohol: Yes No; Test Type: Field; PBT; Breath; Blood; Urine; Test Results
Ejected: Yes; Trapped: Yes
Airbag Deployed: Yes; No; Not Equipped
Drugs: Yes No; Test Type: Blood; Urine; Test Results
Citation Issued: Hazardous; Other
Vehicle Registration; State; Insurance; Towed To/By
VIN; Vehicle Description; Make; Model; Color; Year
Location of Greatest Damage: 0 1 2 3 4 5 6 7 8 9 10 11 12
First Impact; Extent of Damage; Driveable: Yes / No
Vehicle Type: PA; CY; OR; VA; MO; Other; PU; GC; Truck/Bus; ST; SM (Complete Truck/Bus Section)
Vehicle Direction: North; South; East; West
Special Vehicles: 1 2 3 4 5 6
Private Trailer Type: 1 2 3 4 5 6 7
Vehicle Defect: 1 2 3 4 5 6
Vehicle Use: 1 2 3 4 5 6 7 8 9 10 11
PASSENGERS
First Name; Date of Birth MM DD YYYY; Sex M F; Position; Restraint; Hospital
Middle; Street Address; Ambulance
Last; City; Ejected; Trapped
Injury K A B C O; Airbag Deployed Yes No Not Equipped; State; Zip; Phone Number; Yes; Yes
First Name; Date of Birth MM DD YYYY; Sex M F; Position; Restraint; Hospital
Middle; Street Address; Ambulance
Last; City; Ejected; Trapped
Injury K A B C O; Airbag Deployed Yes No Not Equipped; State; Zip; Phone Number; Yes; Yes
Owner; Uninjured Passenger; Witness — Name; Address; Phone Number; Age; Pos.; Rest.
Owner; Uninjured Passenger; Witness — Name; Address; Phone Number; Age; Pos.; Rest.
Person Advised of Damaged Traffic Control: Date; Time; Name
Damaged Property; Public Y / N
Owner & Phone
UD-10 SERIAL NUMBER
SERIAL #
Serial Override Number
Do Not Write or Mark In This Area
Do Not Write or Mark Below This Line
Do Not Write or Mark On This Side of The Line
Printed in U.S.A. GS03 654321 MM249696-2
OpScan INSIGHT™ forms by Pearson NCS

Source: *Michigan Department of Transportation, UD-10 Traffic Crash Report Manual.* *http://www.michigan.gov/documents/UD-10_Manual_2004_91577_7.pdf.*

Crash data can be requested from the DOT or State Police. Staff in the traffic engineering or safety division of the DOT or Local Technical Assistance Program (LTAP)/Tribal Technical Assistance Program (TTAP) can provide guidance on requesting crash data. Typically, these staff study both engineering and behavioral-related (behavioral, including seat belts, driving under the influence of alcohol or drugs, texting/cell phone usage) crash issues and are therefore good resources for data analysis assistance and information about safety-related activities at the DOT. Be aware that due to processing and reporting issues crash data summaries are often published six to nine months after the end of a given calendar year.

NHTSA Fatal Analysis Recording System. All motor vehicle crashes with fatal injuries are recorded in the NHTSA Fatal Analysis Reporting System (FARS) database,[1] as illustrated in Figure 3. FARS is an on-line database which can be queried to learn about fatal crashes in any jurisdiction.

Figure 3. Example from NHTSA FARS On-line Database



Source: http://www-fars.nhtsa.dot.gov//QueryTool/QuerySection/SelectYear.aspx.

Traffic Volume Data

Traffic volume data are routinely collected for traffic operations analyses, transportation planning activities, and analysis of traffic patterns. These data can be used in combination with crash data to calculate crash rates. Calculating crash rates is helpful because the number of crashes at a given location depends not only on roadway characteristics and driver behavior, but also on the volume of traffic or “exposure.” It is best to use crash rates as a tool to compare safety performance for sites with comparable traffic volume and roadway characteristics.

1 http://www.nhtsa.gov/FARS.

The types of traffic volume information that contribute to safety analysis include:

- **Average Annual Daily Traffic** (AADT). If AADT is not available, Average Daily Traffic (ADT) can be used to estimate AADT.
- **Vehicle Miles Traveled** (VMT). VMT is traffic volume on a segment of road multiplied by a segment length.
- **Major and minor street AADT** (or ADT) or total entering volume (TEV) for intersections. Intersection TEV is the sum of the traffic entering the intersection at all approaches.

Traffic volumes tend to vary with the type of roadway facility, the season, day of week, and the level of development. If an agency has a public works, engineering, planning, or traffic engineering department, it already may collect and record traffic volume data for local roads. State DOTs typically collect and record traffic volume data on state-owned roads (and in some cases non state-owned roads as well). The Handbook of Simplified Practice for Traffic Studies (see resources) provides information about collecting traffic volume data if none are available.

Roadway Characteristic Data

Many safety analysis tools use roadway characteristics data as an element of the analysis, including:

- **Roadway Segment Characteristics.** Characteristics of roadway segments include such items as roadway functional classification, number of lanes, length of medians or guardrail, and width and type of shoulder.
- **Intersection Characteristics.** Typical intersection characteristics include traffic control and signal phasing (if appropriate), number and type of lanes at each approach, sight distance, skew angle, and number of approaches.

Agency public works, planning, or traffic engineering specialists may be familiar with or have access to roadway characteristics information. State DOTs have much of this information, at least for state-owned roads, because they are required to provide it for the National Highway Performance Monitoring System (HPMS) database. If roadway characteristics data cannot be obtained through these sources, they can be collected through field reviews or identified through review of on-line satellite images.[2]

Functional Classification

Streets and highways are grouped into classes, or systems, according to the character of traffic service that they are intended to provide.

Common functional classifications in a local environment are arterial, collector, and local roads. A road is planned and designed to be an arterial, collector, or local road based on the character of the traffic (i.e., local or long distance), the degree of land access provided and travel speeds.

Arterial – Provides the highest level of service at the greatest speed for the longest uninterrupted distance, with some degree of access control.

Collector – Provides a less highly developed level of service at a lower speed for shorter distances by collecting traffic from local roads and connecting them with arterials.

Local Roads – Consists of all roads not defined as arterials or collectors; primarily provides access to land with little or no through movement.

HPMS Information: Among many purposes, the state Highway Performance Monitoring System (HPMS) is used for understanding national highway system performance analysis, funding allocation analyses, and reporting to Congress. Roadway extent, use, condition, and performance data are described in the HPMS database which all states provide on-line.

[2] Several sources can be used including Google Maps™ mapping service or Bing® Maps.

Step 1

Data in Existing Reports, Plans, and Documents

Often, crash data, traffic volume data, and roadway geometrics data are provided as part of the safety analyses conducted for various projects and reports. Statewide safety policy and planning documents also may contain information useful to local or Tribal practitioners studying safety. Example resources include:

- **Strategic Highway Safety Plan (SHSP).** Every state is required to have an SHSP. The SHSP provides a statewide strategic approach to reducing fatal and serious injury crashes on all public roads. It identifies the key safety issues in the state and provides approaches for addressing them. SHSPs typically contain information such as:
  - Crash types that are common across the state, and therefore potentially useful to the practitioner;
  - Treatments or actions to address these crash types for consideration statewide; or
  - Other state, local, and/or Tribal practitioners working on roadway safety issues.

  More information about SHSPs is available on the FHWA web site: http://safety.fhwa.dot.gov/hsip/shsp/. This site also provides links to all state SHSPs (http://safety.fhwa.dot.gov/hsip/shsp/state_links.cfm).

> **State SHSPs** present emphasis areas and strategies statewide and provide valuable information about the most important safety issues from the state's perspective. Because of their broad, statewide scope however, they may not provide practitioners with localized data.

- **Other Useful Reports or Information.** State DOTs usually have processes and procedures in place for studying state roadways and identifying sites with potential for safety improvements. If a state-owned roadway traverses a local or Tribal jurisdiction, state planners and engineers are likely to have crash data, traffic volumes, and roadway characteristic information available. In some cases, a state or regional long-range transportation plan also may have a chapter devoted to roadway safety. This could also be a resource for information about crash trends, data sources, or staff available to support local analysis.

> Most state DOTs have Tribal Government Liaison staff that are charged with working with sovereign Tribal governments on transportation issue. Tribal Liaison staff can be an easy access point for Tribal governments interfacing with the state DOTs or local agencies in their area.

Organizations or Agencies That May Be a Resource

Many organizations provide safety training, information, contacts, advocacy, and analysis support, including:

- **LTAP/TTAP.** Local Technical Assistance Programs (LTAP) and Tribal Technical Assistance Programs (TTAP) centers serve every state. Seven regional TTAP centers serve tribal governments by region across the country. The goal of these programs is to provide training, information, and resources to local and Tribal practitioners to address safety, security, congestion, capacity, and other issues on local and Tribal roads. Information about specific centers can be found at: http://www.ltap.org/centers/.

Kentucky, Florida, Idaho, Iowa, New York, Pennsylvania, West Virginia, and the Northern Plains Tribal Assistance Program have Safety Circuit Riders. Safety Circuit Riders provide safety-specific training, resources and support for analyzing safety issues, studying sites, and identifying low-cost safety countermeasures. FHWA has published a best-practices guide for safety circuit riders.[3] The purpose of the guide is to help state DOTs and LTAP/TTAPs enhance existing Safety Circuit Rider programs. If a state does not have a Safety Circuit Rider, safety training, resources, and support are available through the LTAP/TTAP.

LTAP and TTAP Centers

Every state plus Puerto Rico has a LTAP center. There are also seven tribal centers (TTAP).

LTAP and TTAP Centers are charged with helping local and tribal agencies with transportation problems through training and technical support.

- **State DOT Local Assistance.** State DOTs support some form of local assistance program or office. Staff in these offices are focused on helping local agencies solve transportation-related problems and also may administer Federal and state funds for local agencies. Staff in these offices are often excellent resources that understand project funding opportunities. They can also provide connections to key people within the DOT.
- **State Highway Safety Office.** Every state and territory has a Highway Safety Office (HSO). Representatives from the HSO are valuable resources and know a great deal about critical behavioral safety issues (behavioral safety issues include impaired driving, occupant protection, distracted driving, driving while drowsy) in the state. They can provide access to crash data as well as information about effective behavioral countermeasures and grant funding opportunities. State Highway Safety Offices submit annual Highway Safety Plans to NHTSA documenting strategies, actions, and performance-related to specific NHTSA performance measures.[4]
- **Regional Transportation Planning Organizations (RTPO)/Metropolitan Planning Organizations (MPO).** Many RTPOs/MPOs have long-range transportation plans with information about existing and planned transportation networks and/or provide transportation safety-related support and technical assistance to local agencies. This support can include: compiling crash data, analyzing data, developing funding applications, or facilitating road safety audits.
- **The Governor's Highway Safety Association (GHSA)** is a national advocacy and leadership organization that provides support to the Highway Safety Offices. The GHSA web site http://www.GHSA.org provides a wealth of information about behavioral safety issues, programs, funding sources, and a variety of other safety resources.
- **FHWA State Division Offices.** Each state has an FHWA Division Office. Staff from FHWA Division Offices provide support on a wide array of transportation planning and engineering topics, including roadway safety. Division Office staff can provide information about best practices appropriate to local and Tribal roads, solutions to specific safety issues, and connections to other available resources.[5]

FHWA division offices generally have a Local Agency Engineer/Specialist that is specifically charged with interfacing with local and Tribal governments in their area.

3 http://safety.fhwa.dot.gov/local_rural/training/fhwasa09019/.
4 Links to State Highway Safety Offices can be found at: http://www.ghsa.org/html/links/shsos.html.
5 A list of FHWA Division Offices and other information about them can be found at: http://www.fhwa.dot.gov/about/field.cfm.

- **National Association of County Engineers.** The National Association of County Engineers (NACE) is an association for practitioners responsible for county roads and bridges. The organization provides advocacy, networking opportunities, training support, and many other resources for county/parish engineers, transportation directors, highway superintendents, road supervisors, and highway administrators. The organization provides connections to other professionals working on transportation safety issues as well as on-line resources on a variety of transportation topics, including roadway safety. The web site is http://www.countyengineers.org.
- **American Public Works Association.** The American Public Works Association (APWA) is an education and networking resource for professionals, organizations and agencies responsible for "building, maintaining, and improving our communities."[6] APWA (http://www.apwa.net) is a resource for staff seeking to learn more about managing transportation and road safety in their community.

Application

After compiling and reviewing the available safety data, its quality should be assessed. Answers to the following questions provide a good indication of data quality:

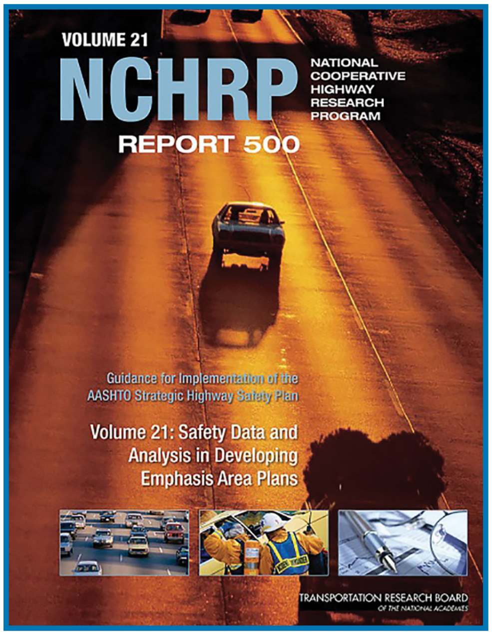
- **How complete is the data.** Does the data sufficiently cover the roadways and locations of interest?
- **How current is the data.** Does the data reflect current conditions at the site?
- **How accurate is the data.** Are there errors in the data that are readily apparent?
- **How consistent or uniform is the data.** If evaluating multiple sites, are the data more comprehensive for some sites than they are for others?

The type and quality of available data determine the type and quality of analysis that can be conducted. The more comprehensive and accurate the data, the more options there are for in-depth analysis. However, valuable results can be obtained even with limited data.

In some instances estimating data using best judgment is sufficient to advance the analysis. In such cases, documenting how the estimate was made and why objective data was not used, helps everyone involved understand the limitations associated with the estimation process and the results obtained from it.

[6] APWA web site, http://www.apwa.net.

Resources For Step 1: Compile Data



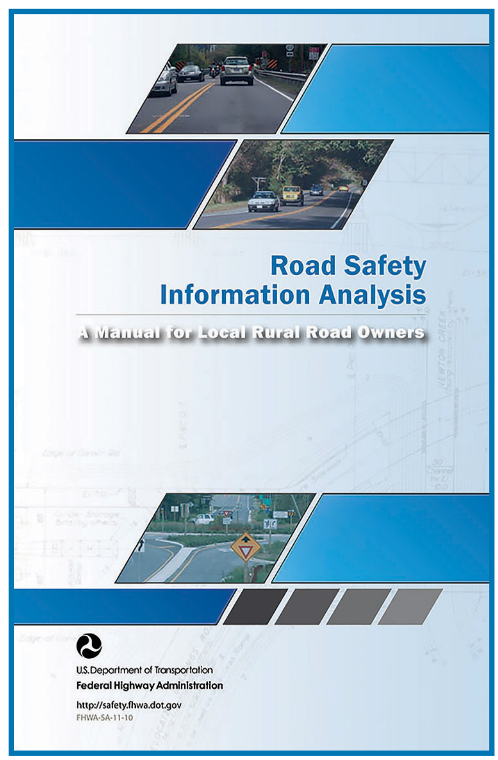
Source: National Cooperative Highway Research Program.

NCHRP 500 Safety Data and Analysis for Developing Emphasis Area Plans (Volume 21). Section II of this document provides additional information about resources, opportunities and barriers associated with collecting and applying many of the data sources described above. Section III of this document also provides a process for identifying, evaluating, and identifying treatments for a specific safety concern. This publication can be found at: (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v21.pdf).

Road Safety Information Analysis: A Manual for Local Rural Road Owners. This manual was published in 2011 by the FHWA to provide information on crash data collection and analysis techniques specifically applicable to local practitioners with limited resources. It is intended to help improve safety on local rural roads by providing a background on data driven decisions. The manual is written in nontechnical language and designed to meet the needs of local road professionals, regardless of their educational background or experience.

Pages 4 to 12 of the manual summarizes the three common types of data needs for a safety project or program: crash data, roadway characteristics data, and exposure data. This manual can be downloaded at the following link: http://safety.fhwa.dot.gov/local_rural/training/fhwasaxx1210/lrro_data.pdf.

The manual is FHWA Report Number: FHWA-SA-11-10.



Source: FHWA.

Step 2

Step 2. Conduct Network Screening

A "network" refers to the collection of roads under the jurisdiction of an agency. Network screening is the process of studying safety conditions on all of a road network or a subset of the network (e.g., all collector roads or all stop-controlled intersections). The safety analysis is conducted using the same method at each location so that the results can be compared and prioritized. There are a variety of methods available to conduct network screening.

While there are many methods for screening road networks, each with unique benefits and drawbacks, only five are presented in this section. They are:

1. Network Screening with Maintenance Staff;
2. Network Screening with Crash Data – Frequency, Crash Mapping, and Equivalent Property Damage Only;
3. Network Screening with Crash Data and Traffic Volume Data – Crash Rate;
4. Network Screening utilizing Software; and
5. Network Screening with Systemic Analysis.

To learn about other network screening methods, please refer to the comprehensive list of resources provided at the end of this section and in particular see Chapter 4 of the AASHTO Highway Safety Manual.

Network Screening with Maintenance Staff

Overview

Local agency maintenance staff spend a significant amount of time driving on local roads and usually have extensive on-the-job experience and knowledge of community roads. These staff can be a valuable source of institutional knowledge about issues, performance, maintenance needs and opportunities for improvement.

Often agencies train road maintenance staff on how to identify safety issues. This training, combined with their knowledge of the roadway network, qualifies maintenance staff as excellent sources of information on locating safety concerns. Educating and relying on maintenance staff to identify safety issues is sometimes referred to as one component of *developing a safety culture*.[1] In fact, some agencies adopt formal policies on the frequency, type, and content of safety inspections. The following example from the United Kingdom (UK) is a case in point.

> The FHWA Roadway Safety 365 workshop is a great source of training for non-technical agency staff. For more detail see the resources section at then end of this section.

[1] Another way to describe "developing a safety culture" is: Challenging employees to incorporate safety into their everyday activities regardless of their formal job function.

Example

Formal safety inspection plans are widely employed in city and county councils[2] in the United Kingdom (UK). The Aberdeen (Scotland) City Council, for example, employs a safety inspection program defined in the Aberdeen Roads Safety Inspection Manual.[3] The Manual describes the guiding principles for conducting safety inspections, defines required inspection frequencies, provides guidance on the methodology to be used for inspections, and establishes time frames for implementing corrective actions.

Figure 4 (from the Aberdeen Roads Safety Inspection Manual) shows a repair time matrix that gives guidance on the speed that specific types of safety issues need to be addressed. This time matrix gives performance targets and sets expectations for maintenance crews, as well as informs them on when it is necessary to include a repair in a future work program.

Figure 5 shows an example of inspection criteria for assessing ruts or depressions in the roadway surface. The Aberdeen manual has inspection criteria for each type of safety defect or concern which provides objective criteria for determining if a safety issue is present and what activity is necessary. Note that the color bars in Figure 5 relate to the response necessary from the key on Figure 4.

Figure 4. Aberdeen Roads Safety Inspection Manual

Inspection Manual
Revision B

Safety Defect Repair Times

Key	Timescale for the repair of safety defects
	No action – review condition of defect at next inspection
	Repair within 3 months or erect warning notices to advise of inadequate highway condition
	Repair within 28 days
	Repair or make safe within 7 working days
	Repair or make safe within 2 hours
	Other – pass to Technical & TM Team

Source: Aberdeen City Council Scotland, Roads Safety Inspection Manual, 2012.

2 Councils are a form of local government similar in function to cities and counties in the United States.

3 http://www.aberdeencity.gov.uk/web/files/Roads/road_safety_inspection_manual.pdf.

Figure 5. Example Repair Time Matrix Aberdeen Roads Safety Inspection Manual

CROWNING, RUTTING, EDGE DETERIORATION, OVER-RIDING & DEPRESSIONS

Crowning, rutting, edge deterioration, over-riding and depressions will be classed as safety defects when they are greater than 75mm over a short distance.

CWAY CROWNING, RUTTING, EDGE DETERIORATION, OVER-RIDING & DEPRESSIONS				
Depth	**Local Access**	**Link Roads**	**Strategic & Secondary**	**Town Centres**
< 75 mm				**As for potholes**
> 75 mm (CAT 1)				

Source: Aberdeen City Council Scotland, Roads Safety Inspection Manual, 2012.

Application

There are several opportunities to complete routine safety inspection in conjunction with other field activities to save time and increase effectiveness of field staff. Annual pavement condition assessments for asset management activity lend themselves to looking for safety issues, as well as weekly or monthly maintenance inspections that some agencies already complete.

Local agency implementation of road inspections can be as informal as training staff on how to recognize safety issues, or as formal as an officially sanctioned process specifying inspection frequencies and methods to be followed as in the Aberdeen example. The training material from the FHWA class Road Safety 365: A Workshop for Local Governments (see resources section) is a good primer for a basic understanding of safety issues and would be valuable for informal inspection processes. Whether informal or formal, training staff on how to recognize safety issues is a low cost method of empowering staff to improve traffic safety and can lead to early detection and correction of safety issues.

Network Screening with Crash Data – Frequency

If crash data are available, crash frequency and crash mapping, are methods that can be used for network screening.

Overview

The crash frequency method is a basic network screening method. This method counts the number of crashes that have occurred at a given location[4] over a specified time period, typically three to five years. The results are ranked from highest to lowest crash frequency. Locations with relatively higher crash frequency are selected as possible sites for detailed investigation.

Some agencies further segregate crash frequency data by crash type or crash severity to identify locations with high crash severity or focus on a specific crash type – for example roadway departure crashes.

[4] Along a roadway section or at an intersection.

Crash frequency is an attractive quantitative screening technique because the only data required are crashes and their physical locations. Other data like traffic volume and roadway features are not necessary for using this technique, making it relatively quick and easy.

Example

The most basic method of displaying and evaluating crash frequency data is to summarize the total number of crashes over the analysis period by location. It is then possible to identify those locations with the highest crash frequencies. Crash frequencies also can be calculated by crash type, such as fatal crashes or incapacitating injury crashes. Table 1 shows a summary of hypothetical crash data organized from highest to lowest total crash frequency.

Definition of KABCO Crash Severity Designation

The KABCO Scale is one tool to classify crashes by injury severity. The letters represent injury levels:

- K – involves a fatal injury,
- A – incapacitating injury,
- B – non-incapacitating injury,
- C – possible injury, and
- O – no injury or a PDO – property damage only crash.

The severity of a crash is based on the greatest level of severity of injury occurring in the crash. For example: if someone is killed in a crash, the crash is labeled as a “K” or fatal crash.

Table 1. Example Crash Frequency and Severity Data

		Injury Crashes		
Intersection	Total Crashes (2007-2011)	Fatal and Incapacitating Injury	Minor Injury	Property Damage Only
1	43	2	2	39
2	33	0	3	30
3	20	1	2	17
4	18	1	0	17
5	15	2	1	12
6	15	3	0	12
7	14	0	3	11
8	8	0	1	7
9	6	0	1	5

Step 2

Application

Crash frequency screening relies solely on crash data. However, it does have shortcomings. The crash frequency method does not take traffic volumes into account. Because higher volume locations are likely to have more crashes than lower volume locations, this method has an intrinsic bias toward higher volume locations.

Another drawback to this method is that it does not account for the natural variation in crash frequency that occurs at any given site. On an annual basis, the number of crashes at a site will fluctuate up and down. Overtime, if nothing changed at the site (e.g., traffic volume, surrounding land use, weather, driver demographics), the frequency of crashes at the site would converge on an average crash frequency. This is called regression to the mean. Regression to the mean is the tendency for a site to experience a period with a comparatively high crash frequency followed by a period with comparatively low crash frequency.

If regression to the mean is not accounted for, a site might be selected for study because the annual number of crashes that occurred was higher than "usual" due to a random fluctuation in the data. Conversely, a site that should be selected for study might be overlooked because an unusually low number of annual crashes occurred there.

To reduce the influence of regression to the mean the agency should calculate the average of the most recent three to five years of crash data to determine the average crash frequencies. This minimizes year-to-year fluctuations in data and is appropriate if site conditions (e.g., traffic volume, land use, driveway access, roadway configuration) have not changed. However, if site conditions have changed significantly during the analysis period, it may be more appropriate to monitor the site and evaluate safety after conditions have stabilized.

Figure 6 demonstrates regression to the mean and the effects of average crash frequency across multiple years. The dark blue line shows hypothetical 1990 to 2010 annual crash frequency at a site. The crash frequency varies up and down from year to year. The gray line represents the long-term average crash frequency at the same hypothetical site. As shown the long-term average stabilizes at approximately 14 crashes per year. The gold line represents the five-year rolling average. For example, the first five-year average is from 1990-1994 and is plotted in 1994, the second is from 1991 to 1995 and plotted on 1995. As shown the five-year rolling average more closely approximates the long-term average then the annual crash frequency alone.

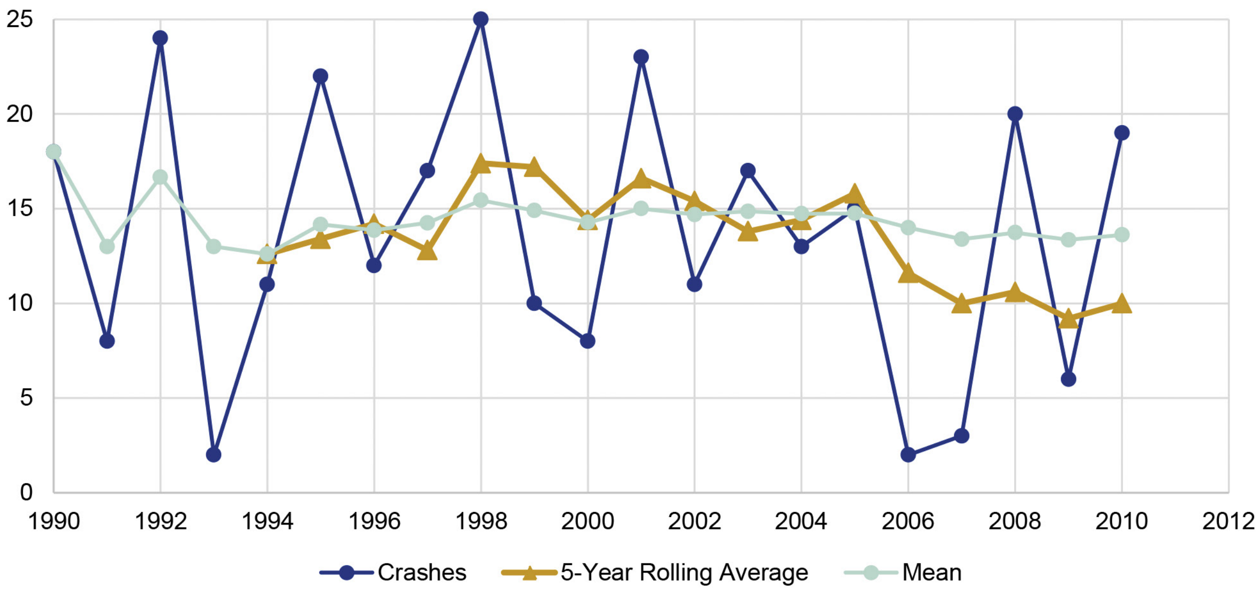
Regression to the Mean

Calculating the average crash frequency over multiple years for a site will smooth out the normal year-to-year variations in crash data and mitigate the effect of the regression to the mean phenomena.

Example: A rural two-lane roadway segment averages 7 crashes per year. In any given year however, the total crashes will likely be higher or lower than the average.

Consider a year with more than 12 crashes. Using this single annual data point to estimate the next year's crash level (12 crashes) would be a bad idea because it is much more likely for the next year's crashes to be closer to the average (7 crashes) than it is for it to be closer to the previous year's level (12 crashes). This illustrates the regression to the mean phenomena – the next data point in a series will tend to be closer to the true mean than to the previous data point, especially if the previous data point is an outlier. It also illustrates why the average of multiple years of data will tend to be closer to the true mean than a single year's data will be.

Figure 6. Example of Regression to the Mean



Network Screening with Crash Data – Crash Mapping

Overview

The crash mapping method involves mapping the locations of crashes over a given time period (usually three to five years). Each crash is represented by an icon or marker on a map detailing the type of crash that occurred. Locations with high crash densities are termed "dark spots" and can be visually identified on the map.

This method can be applied without the use of computer technology by simply using a paper map and push pins. It also can be done using the electronic mapping functions within geographic information systems (GIS) or mapping software. The resources listed at the end of this section describe each of these methods in more detail.

Application

The crash mapping method does not take traffic volumes into account so, like the crash frequency method, it tends to be biased toward higher volume locations.

Network Screening with Crash Data – Equivalent Property Damage Only (EPDO)

Overview

The equivalent property damage only (EPDO) method is documented in the Highway Safety Manual. In this method, weighting factors related to the societal costs of fatal, injury, and property damage-only crashes are assigned to crashes by severity (typically, at a given location over three to five years) to develop an equivalent

Step 2

property damage-only score that considers frequency and severity of crashes. The sites are ranked from high to low EPDO score. Those sites at the upper end of the list may be selected for investigation.

To apply the EPDO method for ranking sites, it is necessary to know the number of crashes per year, and the severity of crashes per year. In this method, all injury crashes (incapacitating, non-incapacitating, minor injury) are grouped together.

If crash maps are used, crashes also can be assigned labels to crash type and/or crash severity. Crash types include angle, head-on, and rear-end. The crash type is determined by the person investigating the crash based on how the vehicles collide. The crash severity could be recorded using the KABCO scale.

Example

The EPDO method is conducted as follows:

- **Compile crash severity cost data –** The state DOT may have societal crash costs specific to the state. If the state does not the 2010 Highway Safety Manual provides the following crash costs by crash severity:

Severity	Comprehensive Crash Cost
Fatal	$4,008,900
Injury A, B, and C	$82,600
Property Damage Only (PDO)[a]	$7,400

[a] *2010 AASHTO Highway Safety Manual, Chapter 7.*

- Calculate the severity weighting factors as a function of the Property Damage Only (PDO) crash cost. The fatal crash EPDO weighting factor is:

$$\textit{Fatal Crash Weighting Factor} = \frac{\textit{Fatality Crash Cost}}{\textit{PDO Crash Cost}}$$

$$\textit{Fatal Crash Weighting Factor} = \frac{\$4{,}008{,}900}{\$7{,}400}$$

$$\textit{Fatal Crash Weighting Factor} = 541.7$$

- The injury EPDO weighting factor is:

$$\textit{Injury Crash Weighting Factor} = \frac{\textit{Injury Crash Cost}}{\textit{PDO Crash Cost}}$$

$$\textit{Injury Crash Weighting Factor} = \frac{\$82{,}600}{\$7{,}400}$$

$$\textit{Injury Crash Weighting Factor} = 11.2$$

- The PDO weighting factor is:

$$\textit{PDO Crash Weighting Factor} = \frac{\textit{PDO Crash Cost}}{\textit{PDO Crash Cost}}$$

$$\textit{PDO Crash Weighting Factor} = \frac{\$7{,}400}{\$7{,}400}$$

$$\textit{PDO Crash Weighting Factor} = 1.0$$

Calculate the EPDO score for each site. The EPDO score is:

= (Fatal Weighting Factor × Fatal Crashes) + (Injury Weighting Factor × Injury Crashes) + (PDO Weighting Factor × PDO Crashes)

Table 2 shows a hypothetical summary of five intersections, their crashes by severity, and their EPDO score. Ranked by their EPDO score, the top three intersections are Intersections 1, 2, and 3; however, ranked by frequency the top three intersections are 3, 1, and 4.

Example calculations for Intersection 1 are:

$$\textit{EPDO} = (541.7 \times 1) + (11.2 \times 6) + (1 \times 12)$$

$$\textit{EPDO} = 541.7 + 67.2 + 12$$

$$\textit{EPDO} = 620.9\text{; rounded to } 621$$

Table 2. Example Crash Severity, Frequency, and EPDO Score

	Severity				
Intersection	Fatal	Inj (A-C)	PDO	Total	EPDO
1	1	6	12	19	621
2	1	4	7	12	593
3	0	9	13	22	113
4	0	6	10	16	77
5	0	3	9	12	42

Application

Since the societal cost of fatal crashes is many times higher than the societal cost of severity and PDO crashes, the EPDO score tends to be skewed upward for any site experiencing fatal crashes. In the example shown in Table 2, the EPDO method ranked Intersection 1 higher than Intersection 3 because Intersection 1 had one fatal crash, despite having fewer crashes than Intersection 3. Practitioners should be cautious as sites that have high frequencies of severe injury crashes also warrant further investigation.

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Network Screening with Crash Data and Traffic Volume Data – Crash Rate

Overview

Crash rates describe the number of crashes in a given period as compared to the traffic volume (or exposure) to crashes. Crash rates are calculated by dividing the total number of crashes at a given roadway section or intersection over a specified time period (typically three to five years) by a measure of exposure. While traffic volume is the most typically used measure of exposure, others such as population, lane or roadway miles, and licensed drivers within a community also can be used. The locations are then ranked from high to low by crash rate. Crash rate screening is able to identify low volume, high crash risk locations that do not necessarily experience a high total number of crashes.

Example

A crash rate is the number of crashes that occur at a given location during a specified time period (usually three to five years) divided by a measure of exposure for the same period. Typical measures of exposure for intersections and roadway segments are identified below.

- **Intersections –** the measure of exposure is the total number of vehicles entering the intersection during the specified time period – usually one year. The total number of vehicles entering the intersection is called Total Entering Vehicles (TEV). If intersection traffic counts are not available to calculate the TEV, average annual daily traffic (AADT) volumes on each approach roadway can be used instead. Because the number of vehicles entering an intersection throughout the year can be quite large, the TEV is usually expressed as Million Entering Vehicles (MEV). MEV is used as a scaling factor and is calculated by dividing the total number of vehicles per day per year by 1,000,000.

  The equation for MEV is:

  $$\text{MEV} = \frac{\textit{TEV per day} \times 365 \times \textit{number of years}}{1{,}000{,}000}$$

- **Segments –** the measure of exposure is the total number of vehicles traveling on the road segment during the specified time period. This is called vehicle miles of travel (VMT). VMT is usually expressed as Million Vehicle Miles (MVM).

  The equation for MVM is:

  $$\text{MVM} = \frac{\textit{AADT} \times \textit{segment length} \times 365 \times \textit{number of years}}{1{,}000{,}000}$$

Note: 1) AADT stands for Annual Average Daily Traffic

Crash rates are then calculated by dividing the number of crashes by the measure of exposure. The equations are:

- **Intersections (Crash Rates for *n* years):**

$$\text{Intersection Crate Rate} = \frac{\text{Number of Crashes in the } n \text{ Year Period}}{\text{MEV of the } n \text{ Year Period}}$$

- **Segments (Crash Rates for *n* years):**

$$\text{Segment Crate Rate} = \frac{\text{Number of Crashes in the } n \text{ Year Period}}{\text{MVM of the } n \text{ Year Period}}$$

Note: To calculate crash rate for multiple number of years, the number of crashes and the measure of exposure should be over the same number of years.

Table 3 illustrates crash frequency and crash rate network screening to identify high crash locations. Intersection A has the highest number of crashes (crash frequency) as well as the highest traffic volume, giving it a relatively low crash rate. Conversely intersection C has a lower number of crashes but also a much lower traffic volume, giving it a crash rate which is nearly twice that of either intersection A or intersection B.

Crash rates tend to over-emphasize sites with lower traffic volumes. It is best to use crash rates as a comparison tool only for sites that have similar functional classifications, number of lanes, surrounding land uses, and traffic volume.

Table 3. Crash Rate versus Crash Frequency for Three Intersections

Intersection	Total Crashes (3-Year Period)	ADT[a]	Million Entering Vehicles (MEV)	Crash Rate (Crashes/MEV)
Intersection A	8	10,000	10.95	0.73
Intersection B	6	8,000	8.76	0.68
Intersection C	4	2,000	2.19	1.83

[a] *ADT does not change over the three-year period.*

Application

To compensate for short-term random fluctuations in annual crash numbers, it is recommended that three or five years of crash and exposure data (commonly traffic volume) be used to calculate crash rates. In cases where traffic volume data are not available, they can be estimated based on known traffic volumes on roads of similar functional class or use. For example, if many of the two-lane paved rural roads that are designated with the national functional classification of “local” in a agency have average daily traffic volumes between 100 and 400, it is likely that other comparable roads will have similar traffic volume.

Network Screening Utilizing Software

Overview

Several software tools are available for screening road networks. These typically require extensive road network data and significant time to set up. However, these tools have advantages over "manual" or hand calculated methods, including:

- Once the software is set up, analyses can be completed and repeated easily;
- Inputs and outputs can be modified and the analysis re-run with little effort; and
- Complex data analysis can be completed in a relatively short amount of time.

Example

United States Road Assessment Program

Technical Definition: Systemic Safety Solutions: Low cost and widely applicable treatments that can be applied across a road network to reduce crash frequency and/or severity.

The U.S. Road Assessment Program (usRAP), sponsored by the AAA Foundation for Traffic Safety, systematically assesses risk to identify locations where fatal and serious injury crashes can be reduced. To do this, usRAP utilizes a risk-mapping protocol to create maps that show variations in the level of crash risk across a road network. These maps can guide the prioritization of highway infrastructure improvements and targeted enforcement strategies. usRAP also provides *usRAP Tools* which is software that can develop a recommended program of location-specific crash countermeasures for any road network based on benefit-cost analysis.[5]

One strength of the usRAP Tools software is that it uses roadway and traffic control feature data to assess risk and does not require site-specific crash data. Roadway characteristics data do need to be collected and input into the software however, usually through a combination of video data collection and manual data input. For more information on usRAP, see http://www.usrap.us.

SafetyAnalyst

SafetyAnalyst is an AASHTOWare highway safety management software product. *SafetyAnalyst* can help an agency improve the programming of site-specific highway safety improvements. *SafetyAnalyst* incorporates state-of-the-art safety management principles into computerized analytical tools for identifying safety improvement needs and developing a systemwide program of improvement projects. *SafetyAnalyst* has a strong basis in cost-effectiveness analysis; thus, it can be helpful in ensuring that agencies get the greatest possible safety benefit per dollar spent. Comprehensive electronic, geolocated crash, traffic volume, and roadway characteristics databases are required by the software.

SafetyAnalyst was developed as a cooperative effort by FHWA and participating state and local agencies. AASHTO manages licensing, distribution, technical support, maintenance, and enhancement of *SafetyAnalyst*. For more information visit: http://www.safetyanalyst.org.

[5] See Step 5 for a description of benefit/cost analysis.

Application

These software are data intensive and in most cases, a local rural or Tribal agency is not likely to implement either of these software-based network screening programs due to the start-up time and costs. However if an agency does choose to invest the time and resources required to utilize these programs, the safety analysis benefits can be tremendous.

Network Screening with Systemic Analysis

Overview

Crashes on rural low volume roads are typically spread over a large geographic area with few repeat crashes at any given location. Low crash concentrations make identifying crash patterns by screening for high crash frequency or crash rate difficult due to the lack of data points (crashes) in any one location. In these cases, employing a systemic safety approach is often helpful. A systemic safety approach works by identifying high-risk roadway characteristics/geometry, including curves, skewed intersection, or limited sight distance across the road network. Once these problematic roadway characteristics are known, locations with these characteristics can be identified, and countermeasures targeting them implemented so that crash risks are reduced across the road network.

Although Systemic analysis is data based it is useful in situations where little data are available. Systemic analysis helps the practitioner link local roadway characteristics to expected crash types.[6] Roadway characteristics data consist of road geometry details – such as curve radii, shoulder width, lane width, and super elevation – for the network under investigation and are required for the analysis.

There are economies of scale to using systemic analysis to identify countermeasures, because once a road characteristic of concern has been identified, a single set of countermeasures can be applied to all locations sharing that characteristic. Typically, countermeasures identified through systemic analysis are low cost and can be readily implemented across the system.

Example

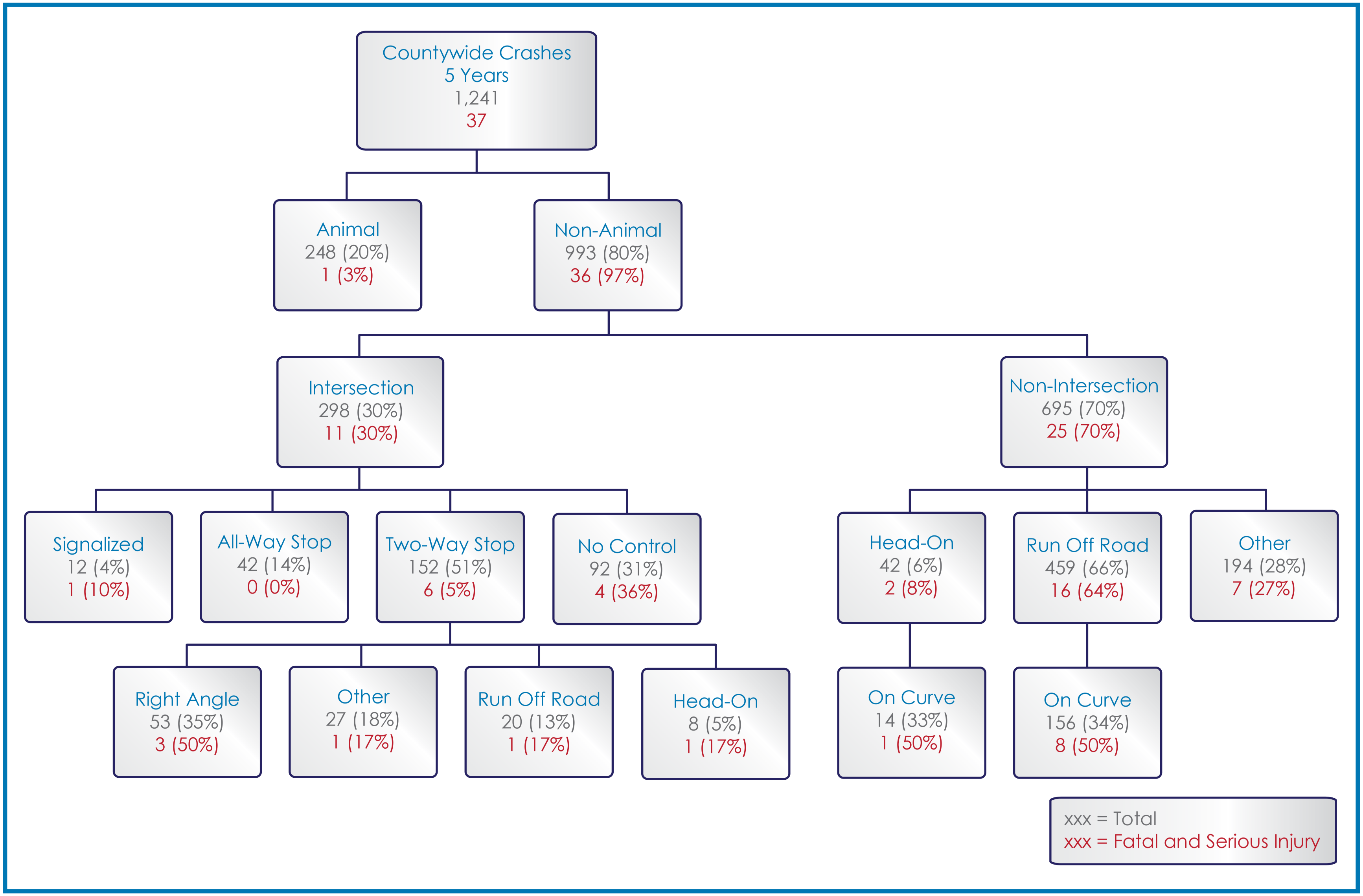
Figure 7 shows a hypothetical "crash tree" developed to demonstrate the first step in the Systemic Process: Identify Focus Crash Types and Risk Factors. A crash tree is created by dividing the total number of crashes into smaller and smaller categories of crashes. For example, as shown in Figure 7, 97 percent of the countywide fatal and serious injury crashes are non-animal related. Non-animal related crashes are summarized by intersection or non-intersection location. The data is continually sub-divided into different categories. The intersection crashes are summarized by four intersection categories: signalized, all-way stop, two-way stop, and no control. The two-way stop crashes are finally summarized by crash type: head-on, run-off-road, right angle, or other.

Systemic versus Spot Safety Analysis. Spot safety analysis is based on crash history at individual locations and results in identification of high crash locations. The systemic approach analyzes crash history on an aggregate basis to identify roadways that have high-risk characteristics, and countermeasures to address these characteristics are identified. Plans are then developed to prioritize widespread implementation of countermeasures across the roadway network.

[6] This linking of roadway characteristics and crash types is done based on research done at the national level.

From this disaggregation of crash data, it can be seen that the majority of fatal and serious injury crashes during the study are non-animal-related (97 percent). Of the fatal and serious injury crashes that are non-animal related, the majority are not intersection related (70 percent), and results from vehicles running off the road (64 percent). From this information the practitioner can understand likely crash types for locations in their jurisdiction. As also shown in Figure 7, the disaggregation can be conducted for many different categories of information.

Figure 7. Example of "Crash Tree"



Note: In some cases counts do not total to higher-level numbers because counts were not completely disaggregated.

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With this knowledge, a local or tribal agency can pursue a program of countermeasures related to minimizing the occurrence or lessening the severity of run off the road crashes in rural areas. Potential countermeasures include edge line rumble strips, better signing at curves, and aggressive removal of roadside fixed objects, among others. Systemic improvements like these could then be deployed on a regular basis as part of other on going agency activities like roadside maintenance or pavement maintenance programs.

Application

The major steps[7] in the systemic process are:

- Identify Focus Crash Types and Risk Factors:
  - Select Focus Crash Types;
  - Select Focus Facilities; and
  - Identify and Evaluate Risk Factors.
- Screen and Prioritize Candidate Locations:
  - Identify Network Elements to Analyze;
  - Conduct Risk Assessment; and
  - Prioritize Focus Facility Elements.
- Select Countermeasures:
  - Assemble Comprehensive List of Countermeasures;
  - Evaluate and Screen Countermeasures; and
  - Select Countermeasures for Deployment.
- Prioritize Projects:
  - Create a Decision Process for Countermeasure Selection;
  - Develop Safety Projects; and
  - Prioritize Project Implementation.

See the resources section for more information.

The degree to which an agency collects and analyzes data during a systemic safety analysis is based on the resources and technical expertise at their disposal. As with all safety analysis methodologies, more data will lead to a more complete analysis; however even if data are not complete or comprehensive using as much as are available is a great start.

[7] These steps are thoroughly described in the FHWA Systemic Safety Project Selection Tool document published in 2013.

Resources For Step 2: Conduct Network Screening

Resources for Network Screening with Maintenance Staff

Road Safety 365: A Workshop for Local Governments. The FHWA developed a one-day workshop to provide participants with practical guidance on improving road safety. The workshop is focused on rural roads owned by local agencies and is appropriate for audiences such as public works employees, law enforcement officers, and elected officials. The workshop promotes the development of a safety culture by showing participants how construction and maintenance activities impact safety.

Source: FHWA.

The workshop includes the following modules:

1. Course introduction,
2. The need for safety,
3. Road safety myths versus reality,
4. Reading the road,
5. Making roads safer,
6. Group safety activity,
7. How to do more with less,
8. Spreading the word about safety, and
9. Course wrap-up.

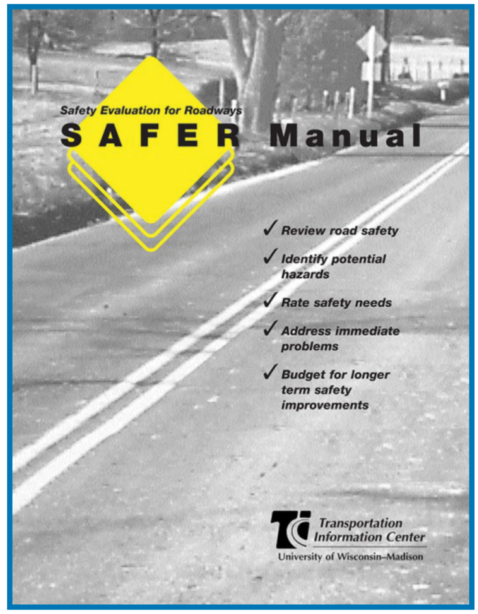
Check with TTAP/LTAP Centers for offerings of this workshop.

Step 2

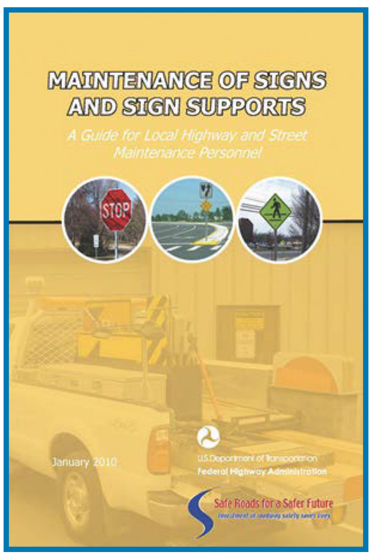
Safety Evaluation for Roadways (SAFER) Manual. The Wisconsin Transportation Information Center at the University of Wisconsin Madison produces the Safety Evaluation for Roadways (SAFER) Manual. The Manual was originally produced in 1996; however, the content is still relevant for use in maintenance inspections. The SAFER Manual includes a one-to-five rating scale to rate roads based on the urgency of the corrective action that is necessary.

The manual includes over 100 photographs of common safety concerns on topics such as roadsides, intersections, rail crossings, geometric issues, signing and pavement markings, road maintenance, and other special conditions.

An electronic copy of the SAFER Manual is available here: http://epdfiles.engr.wisc.edu/pdf_web_files/tic/other/SAFER_96.pdf.



Source: University of Wisconsin.



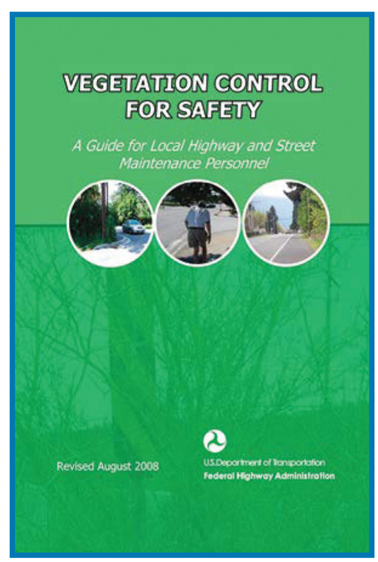
Source: FHWA.

FHWA Maintenance of Signs and Supports. The FHWA produced this guide to aid local agency practitioners and maintenance staff in ensuring that their agency's signs are maintained to meet road user needs. Section 8 of the guide can be useful for maintenance staff conducting routine investigations. It discusses inspection methods and offers maintenance staff a sign inspection checklist. An electronic copy of the Manual is available here: http://safety.fhwa.dot.gov/local_rural/training/fhwasa09025/fhwasa09025.pdf. The manual is FHWA Report Number: FHWA-SA-09-025.

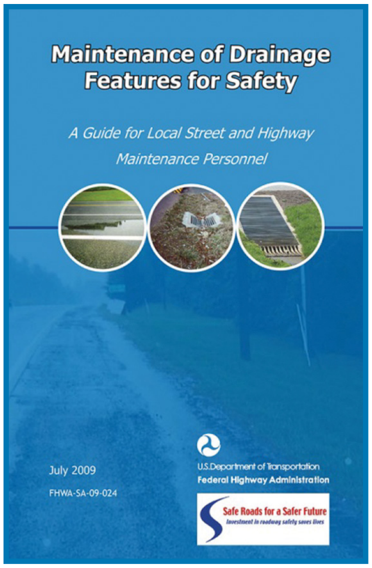
Vegetation Control for Safety.

The FHWA produced this guide in 2008 to assist local agency maintenance staff with identifying locations where vegetation control can be improved to enhance traffic and pedestrian safety. This document provides staff with specific items to check, and safe ways to mow, cut brush, and control roadside vegetation. Chapter 2 of the guide focuses on vegetation control items that maintenance staff should check to identify sites with potential for improvements.

An electronic copy of the Manual is available here: http://safety.fhwa.dot.gov/local_rural/training/fhwasa07018/vegetationfv1108.pdf. The manual is FHWA Report Number: FHWA-SA-07-018.



Source: FHWA.



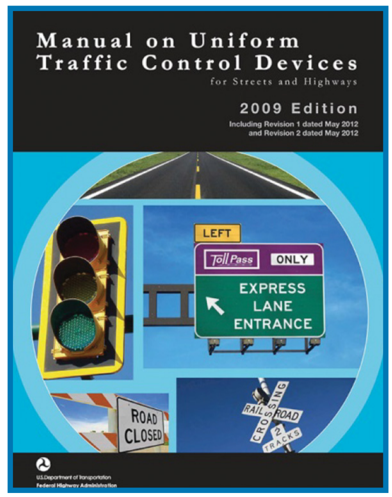
Source: FHWA.

Maintenance of Drainage Features for Safety. The FHWA produced this guide in 2009 to help local maintenance staff understand the importance of maintaining and upgrading drainage features on their road system and the potential impacts to road safety. The document guides staff to recognize drainage problems and how to correct drainage features. Page 11 of the guide offers a field inspection check list with conditions indicative of a drainage problem.

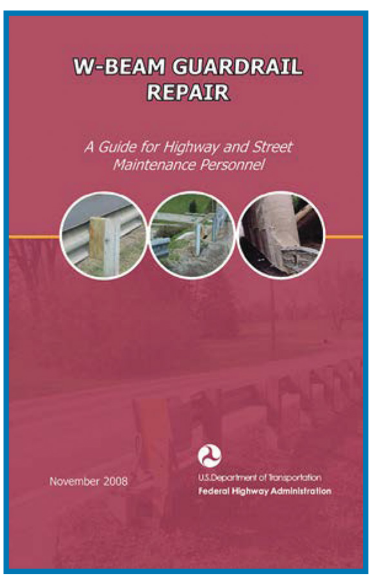
An electronic copy of the manual is available here: http://safety.fhwa.dot.gov/local_rural/training/fhwasa09024/. The manual is FHWA Report Number: FHWA-SA-09-024.

Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD defines the standards used by road managers nationwide to install and maintain traffic control devices on all public streets, highways, bikeways, and private roads open to public traffic. The MUTCD has been administered since 1971, and updated periodically to address changing transportation needs and new safety technologies and management techniques. The most current edition of the MUTCD is from 2009, with additional revisions made in 2012.

An electronic copy of the MUTCD is available here: http://mutcd.fhwa.dot.gov/. The manual also can be purchased from the AASHTO Bookstore: https://bookstore.transportation.org/item_details.aspx?ID=1550.



Source: FHWA.



Source: FHWA.

Guardrail Repair. The FHWA produced this guide in 2008 to provide practitioners with up-to-date information on how to repair W-beam guardrails. Chapter 2 of the manual offers guidance on identifying the extent of guardrail damage to assess its continued safety performance. Page nine of the manual offers practitioners a W-beam assessment checklist.

An electronic copy of the manual is available here: http://safety.fhwa.dot.gov/local_rural/training/fhwasa08002/. The manual is FHWA Report Number: FHWA-SA-08-002.

Resources for Network Screening with Crash Data

Crash frequency is described in many road safety documents. The two resources that provide the most thorough discussion on the topic are *Road Safety Information Analysis: A Manual for Local Rural Road Owners* and the *AASHTO Highway Safety Manual.*

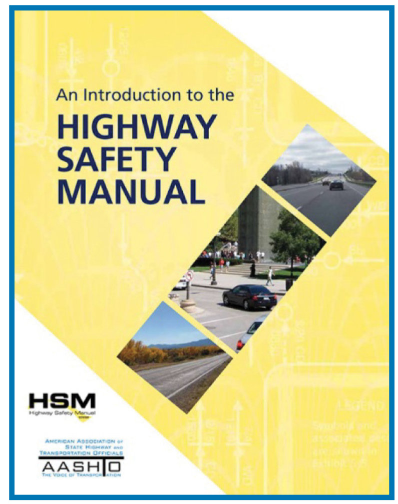
Road Safety Information Analysis: A Manual for Local Rural Road Owners. This manual was developed by the FHWA to provide information on crash data collection and analysis techniques specifically applicable to local practitioners with limited resources.

Pages 13 to 18 of the manual provide a review of common uses of crash frequency screening; including crash averaging, crash trend analysis, and crash mapping.

This manual can be downloaded at the following link: http://safety.fhwa.dot.gov/local_rural/training/fhwasaxx1210/lrro_data.pdf. The manual is FHWA Report Number: FHWA-SA-11-10.

AASHTO Highway Safety Manual. The first edition AASHTO Highway Safety Manual (HSM) was published in 2010. There are four major sections of the manual: fundamentals, roadway safety management, predictive method, and crash modification factors. Chapter 4: Network Screening explains the crash frequency and equivalent property damage only methods (and many others). This chapter also discusses regression to the mean and regression to the mean bias that can be a concern when high crash locations are selected for analysis.

The HSM is available to order at the AASHTO bookstore at: https://bookstore.transportation.org/search.aspx?Text=hsm-1. ISBN Number: 1-56051-477-0.



Source: AASHTO.

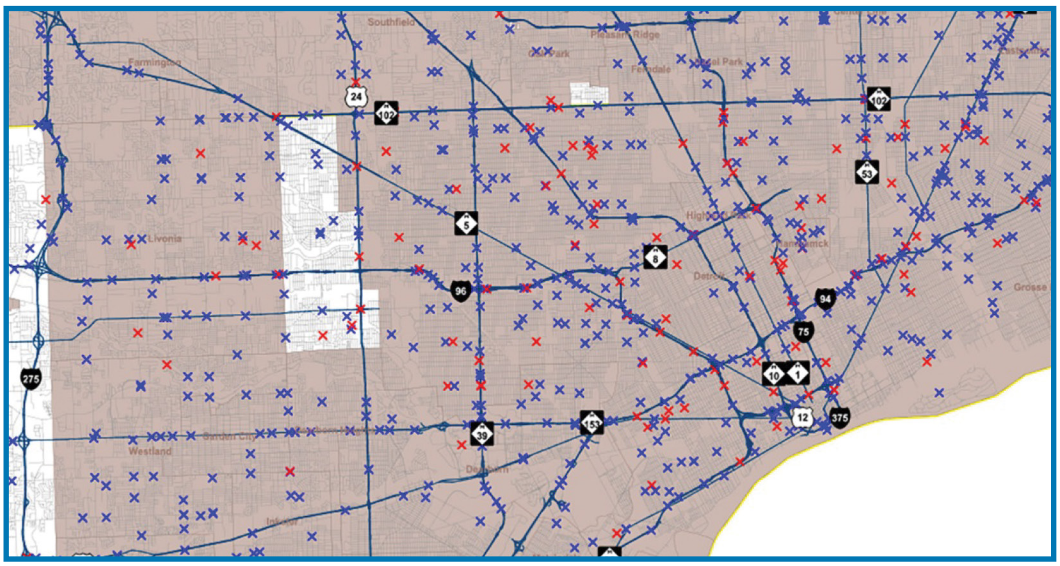
Resources for Crash Mapping

Examples of popular crash mapping tools are provided below. They are arranged from least complex to most complex in the following categories: static maps, web portals with mapping functionality, and GIS tools.

Static Crash Maps. Many state DOTs create static maps in PDF or printed format for distribution to users. These maps can be a vital resource for local agencies without the technical capabilities or manpower to dedicate to crash mapping. Figure 8 provides an example of a PDF crash map produced for the State of Michigan.

More information on Michigan crash maps can be found at the following link: http://www.michigan.gov/mdot/0,4616,7-151-9615_11261-182140-,00.html.

Figure 8. State-Level Static Maps Showing Severe and Fatal Crashes



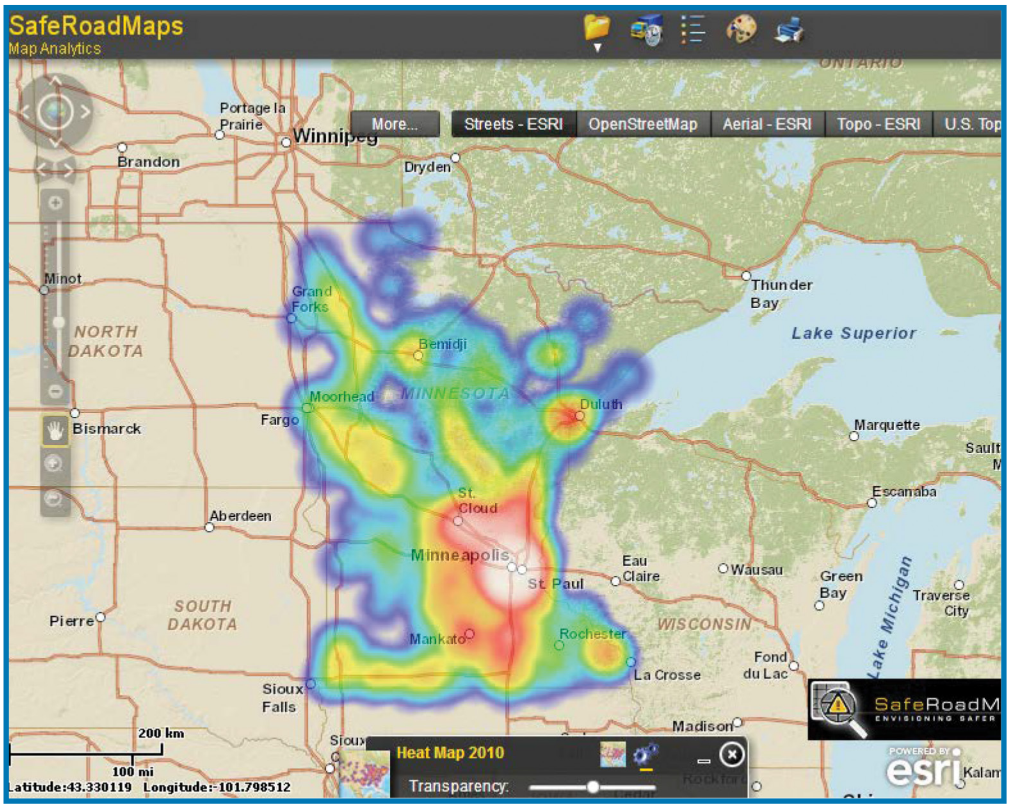
Source: [*http://www.michigan.gov/documents/mdot/MDOT_Crash_Metro_2012_417345_7.pdf*](http://www.michigan.gov/documents/mdot/MDOT_Crash_Metro_2012_417345_7.pdf).

Web Portals with Mapping Functionality – Safe Road Maps. Safe Road Maps is developed and supported by Center for Excellence in Rural Safety (CERS), which is based at the University of Minnesota. This web-based mapping portal provides a GIS-based interface that can build maps using 2010 FARS data for the entire United States. The tool produces standard pin maps as well as "heat maps."

Figure 9 below provides an example of a heat map. Heat maps show crash density on the roadway system. "Hotter" colors indicate a higher crash density then the cooler colors. The tool also can be used to search for fatal crashes in the vicinity of specific locations.

The *Safe Roads Map* tool can be accesses at the following link: http://134.173.236.103/map_gallery/index.html.

Figure 9. Heat Map of FARS Data for Minnesota Produced by the On-Line Mapping Site Safe Road Maps

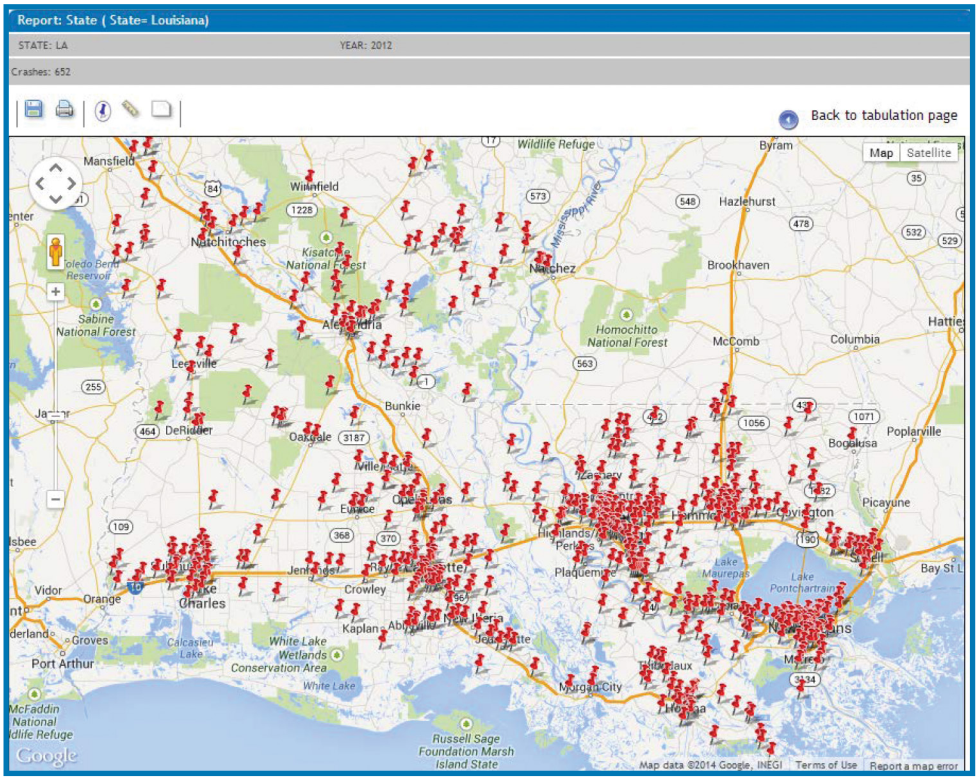


Source: *http://134.173.236.103/srm_2012/index.html?config=MapAnalytics.xml.*

Web Portals with Mapping Functionality – FARS Encyclopedia Mapping Function. The NHTSA FARS is a crash data resource; it is also a web encyclopedia that includes a mapping function. This tool accesses FARS 1994 to 2011 data and provides query-based reports in tabular or map formats. It can produce pin maps at nearly any zoom level. Figure 10 below illustrates an example of the FARS encyclopedia mapping functionality.

The FARS Encyclopedia can be accessed at the following link: http://www-fars.nhtsa.dot.gov/QueryTool/QuerySection/SelectYear.aspx. A help file describing the mapping features of the FARS encyclopedia is located at the following link: http://www-fars.nhtsa.dot.gov/common/FARS%20Encyclopedia%20Mapping%20Tool%20Features.pdf.

Figure 10. Fatal Crash Location Pin Map Produced by the FARS Encyclopedia Mapping Function



Source: *http://www-fars.nhtsa.dot.gov/QueryTool/QuerySection/SelectYear.aspx.*

Geographic Information Systems. Geographical information systems (GIS) have simplified the creation of crash maps. GIS also allows highlighting or attribution of data elements, such as crash type or crash severity, by modifying the color of crash markers. The ability to graphically represent data in reports, charts, maps, and tables adds significantly to the value of a GIS and other mapping tools. Figure 11 below provides an example of a crash map developed from a GIS system.

Google Earth™ mapping service is a free mapping tool that also can be used to plot data that has GPS coordinates associated with it. Google Earth™ mapping service comes populated with a road map of the entire United States and includes multiple years of aerial imagery and a terrain maps for most areas of the United States. Google Earth™ mapping service also has access to street level photography.

Google Earth™ mapping service does not come pre-populated with crash data, however, it can import data using several GIS-friendly formats plus crash records can be entered individually. Crash maps created in Google Earth™ mapping service can be saved and shared with other Google Earth™ mapping service users.

A download of the Google Earth™ mapping service application is available at the following link: http://www.google.com/earth/download/ge/agree.html. A tutorial of creating a map with Google Earth™ mapping service is available at the following link: http://www.google.com/earth/outreach/tutorials/index.html.

Figure 11. Crash Frequency Data Plotted in a GIS System for an Example Intersection

Source: Roadsoft® Version 7.6, Michigan Technologic University.

Example of State-Specific Web Portals with Mapping Functionality. Several states have developed web-based mapping tools which local or Tribal agencies can access for crash mapping analysis. One such tool is the Minnesota Crash Mapping Analysis Tool (MnMAT). The tool provides access to a state-level crash database using a GIS interface. Figure 12 provides an example of the data than can be displayed using MnMAT. MnMAT is available to Minnesota agencies free of charge.

Crash Data Tools at a State Level

The degree to which States have adopted tools to simplify local and tribal agency access to crash data varies greatly between States. Similarly how States market these programs to external users varies as well. Users are encouraged to explore resources in their own State by contacting their State DOT traffic safety unit as well as other traffic safety professionals at peer agencies.

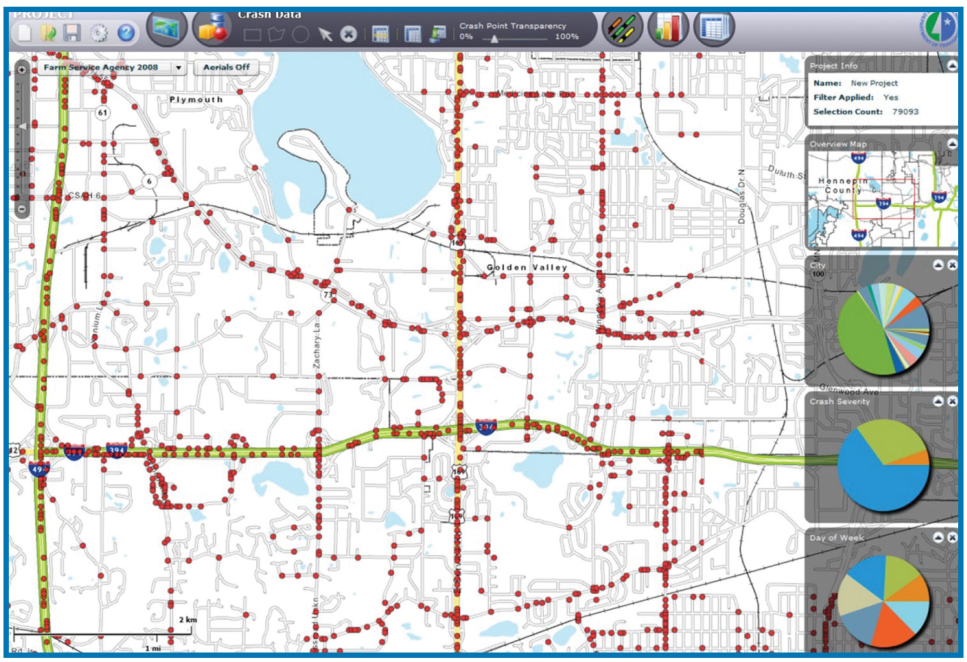
Other examples are Roadsoft in Michigan and the Crash Mapping Analysis Tool (CMAT) developed by Iowa DOT. These resources and results may provide useful information about the type of data and road characteristics that may be important to a particular crash type. Also, while these tools are only available and relevant to agencies within their home states, they are good example of what features and functionality are possible if state and local agencies work together to further data access.

MnMAT is available at the following link: http://gisservices2.dot.state.mn.us/MnCMAT/MnCMAT.html. Users will be prompted to request permission from MnDOT to access the tool.

Information regarding Roadsoft is available at the following link: http://www.roadsoft.org/.

Information regarding CMAT is available at: http://www.iowadot.gov/crashanalysis/cmatmain.htm.

Figure 12. Crash Mapping Using the MnMAT On-Line Tool



Source: http://gisservices2.dot.state.mn.us/MnCMAT/MnCMAT.html.

Resources Network Screening with Crash Data and Traffic Volume Data – Crash Rate

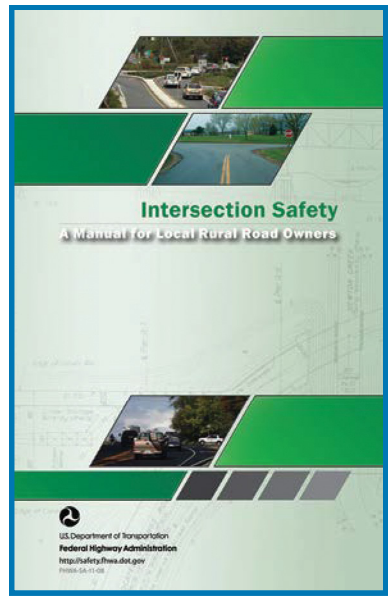
Road Safety Information Analysis. A Manual for Local Rural Road Owners. This manual was developed by the FHWA to provide information on crash data collection and analysis techniques that are specifically applicable to local practitioners. Pages 18 to 22 of the manual show sample crash rate calculations. The calculations measure exposure in traffic volumes or roadway mileage. The manual also discusses how crash rate can be used to compare relative safety to other similar roadways, segments, or intersections in the jurisdiction, region, and state.

This manual can be downloaded at: http://safety.fhwa.dot.gov/local_rural/training/fhwasaxx1210/lrro_data.pdf. The manual is FHWA Report Number: FHWA-SA-11-10.

FHWA Intersection Safety: A Manual for Local Rural Road Owners. This manual was developed by the FHWA to provide information on effectively identifying intersection safety issues in local areas, choosing the countermeasures that address them, and evaluating the benefits of these countermeasures.

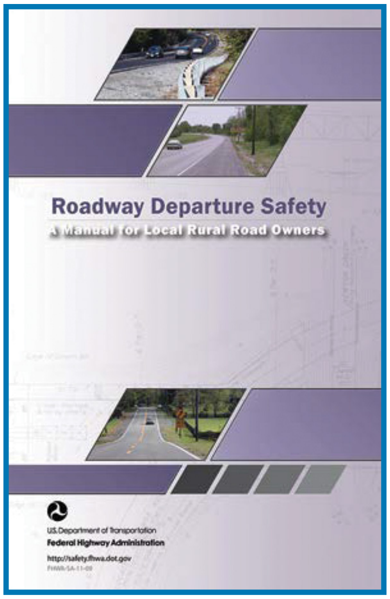
Pages 16 to 18 of the manual offer calculation steps for intersection crash rate that factor for level of exposure at each intersection. The manual shows an example of intersection crash rate comparison.

This manual can be downloaded at no expense from the following link: http://safety.fhwa.dot.gov/local_rural/training/fhwasa1108/fhwasa1108.pdf. The manual is FHWA Report Number: FHWA-SA-11-08.



Source: FHWA.

FHWA Roadway Departure Safety: A Manual for Local Rural Road Owners. This manual was developed by the FHWA to provide local practitioners information on identifying locations with historical or potential rural roadway departures crashes, and countermeasures to address these locations.



Source: FHWA.

Page 20 of the manual explains how crash rates can be effective in comparing different network segments and can account for the level of exposure. Appendix C of the document includes formulas for crash rate calculation, and examples of calculation by vehicle miles traveled and by roadway mileage.

This manual can be downloaded at no expense from the following link: http://safety.fhwa.dot.gov/local_rural/training/fhwasa1109/fhwasa1109.pdf. The manual can be ordered in hard copy at the FHWA report center: http://www.fhwa.dot.gov/research/library/reportsources.cfm. Report Number: FHWA-SA-11-09.

Resources for Network Screening with Systemic Analysis

Source: FHWA.

FHWA Systemic Safety Project Selection Tool. The systemic safety approach works by evaluating the road network and crashes to identify road characteristics, including road width, shoulder width, and sight distance that are present at a large number of crash sites across the road network. Then countermeasures are identified and implemented to address these common risk factors. The FHWA Office of Safety developed the Systemic Safety Project Selection Tool guidebook to provide practitioners a step-by-step process for conducting systemic safety planning, considerations for balancing investments in spot specific and systemic safety improvements, and analytical techniques for quantifying the benefits of a systemic safety program.

Step 3. Select Sites for Investigation

Overview

The outcome of a network screening activity (Step 2) is either a list of high crash locations or a crash map. In an ideal situation, every identified site would be analyzed in more detail. However, due to time and resource constraints, it may not be possible to study all sites in depth. In this step, the locations identified in Step 2 (network screening) are reviewed and evaluated to determine which of them should be selected for detailed analysis (Steps 4 through 7). Selecting sites for detailed analyses will be a qualitative process and will rely on considerations like relative severity and frequency of crashes at the site, traffic volumes, stakeholder concerns, potential solutions. While not an exhaustive list at all, some reasons to select a site for more detailed analysis could be:

- The site is ranked high on a screening list when using quantitative screening criteria – e.g., crashes, crash rates;
- There is a grant funding program targeted at issues comparable to those expected at the site;
- There is an upcoming maintenance or construction project in the vicinity of the site where the safety improvement could be integrated into the project;
- Improving the site would be consistent with other agency plans, policies or programs; or
- Of the crashes that have occurred, a large proportion have resulted in fatalities or serious injuries.

Application

The number of sites selected for detailed analysis depends greatly on the staff or consultant resources available to the agency as well as the extent to which the agency can fund corrective actions. A site summary selection process example is shown in Table 4. The table displays the types of information practitioners might consider in the site selection process, i.e., background data, evaluation considerations, and the results of site evaluation and prioritization processes. Note that Location D would rank high based on network screening using crash rates, however in this hypothetical it is not selected for further investigation for two reasons: 1) the traffic volume through the intersection is extremely low; and 2) there was only one crash at this location and it was a property damage only crash. Therefore, relatively speaking, there is no significant issue at this site. This example also demonstrates how the best use for crash rates is when the sites have comparable traffic volumes and comparable roadway characteristics.

Site selection can be finalized collaboratively among staff familiar with the community, or determined by the responsible staff member. Site selection decisions should be documented by noting which sites were and were not selected as well as the reasons behind the decision. Community members or stakeholders familiar with the safety issues also can provide valuable input to the site selection process. If there is sufficient interest, a standing community traffic safety committee could be organized to provide input and advocate for traffic safety. User Guide #2 provides a detailed example of the site selection process across multiple sites.

Documentation: It is important to document safety analysis findings. Documentation allows others to verify the findings and to repeat the activity again in the future.

Table 4. Example Summary of Site Selection Process

Location	Total Crashes (Three-Year Period)	ADT[a]	Three-Year Average Crash Rate (Crashes/ MEV)	Evaluation Considerations	Selected?	Explanation
A	8	10,000	0.73	Traffic signal being installed this summer	No	Signal may address current crash issues. Reevaluate after signal installation
B	6	8,000	0.68	Some of the crashes are severe, site is in downtown redevelopment district	Yes	Relatively high crash severity and intersection modification may be consistent with community plans
C	4	2,000	1.83	Low-severity crashes, Staff is familiar with issue, landscaping may address issue	Yes	If landscaping addresses issue, low-cost easy improvement
D	1	50	18.26	Low volume, PDO crash	No	Extremely low volume and low severity crash. Monitor to see if trends change

[a] *ADT does not change over the three-year period.*

Step 4. Diagnose Site Crash Conditions and Identify Countermeasures

Once the site(s) have been selected for evaluation; crash data, traffic volume data, and roadway characteristics at the selected sites should be studied to identify the factors contributing to the crashes. Stakeholders also should be consulted to better understand their impressions of conditions and issues at the sites. This step is referred to as site diagnosis.

The availability of data substantially influences the methods available for diagnosis. This step presents information about diagnosing site crash conditions both without and with crash data and identifying countermeasures for a site.

Site Diagnosis – Diagnosis without Crash Data

Overview

In this step, the crash data, crash patterns, past studies, and physical characteristics of the site(s) are studied to understand crash contributing factors and identify potential countermeasures to address them.

Crash contributing factors are driver behaviors, events, or roadway infrastructure characteristics that contribute to the occurrence of the crash. Examples include texting while driving, low roadway friction around a curve, sight distance constraints, or inadequate lighting. Countermeasures/treatments refer to strategies implemented to reduce a specify crash type or crash severity.

Options for conducting site diagnosis without crash data are:

- Utilize existing expertise;
- Conduct a road safety audit; and
- Apply the predictive method from the AASHTO Highway Safety Manual.

Existing Expertise. A variety of agency staff, including maintenance workers, public works staff, engineers, planners, landscapers, law enforcement officers, and public transportation providers, travel the road network everyday. These professionals are very familiar with the roadways and can provide information about locations with safety issues, including broken guard rails, standing water, skid marks, repeated sign maintenance requirements, scarred landscaping. They can help identify potential safety issues, conduct field assessments, and identify countermeasures to address safety issues.

Module four of the FHWA Road Safety 365: A Workshop for Local Governments provides information about “reading the road” which could be useful for these practitioners. “Reading the road” asks practitioners to look for indications along the road or at a site that indicate road users may be having problems traveling through the section. Typical example indicators are damaged guard rail or road signs or roadway skid marks.

Road Safety Audits. A RSA is a formal safety examination process of an existing or future road or intersection by an independent team. The team may include some or all of the following: planners, engineers, maintenance staff, enforcement staff, stakeholders, emergency services staff, and/or pedestrian or bicyclist safety experts.

The aim of an RSA is to answer the following questions:

- What elements of the road may present safety concerns: to what extent, to which road users, and under what circumstances?
- What opportunities exist to eliminate or mitigate the identified safety concerns?[1]

The major steps in conducting an RSA are:

1. Road owner identifies the location(s);
2. Road owner selects a multidisciplinary audit team;
3. Road owner and multidisciplinary audit team meet to review the project;
4. Multidisciplinary audit team conducts field reviews;
5. Multidisciplinary audit team conducts analysis and prepares a report for the owner;
6. Multidisciplinary audit team presents findings;
7. Road owner prepares formal audit response; and
8. Road owner incorporates findings.

RSAs are inexpensive, focus on feasible and effective solutions, and are relatively quick to conduct.

Highway Safety Manual. A more advanced approach to diagnosing site conditions is provided in the Highway Safety Manual (HSM). The predictive method described in Part C of the HSM uses equations known as Safety Performance Functions (SPF) to estimate the number of crashes to be expected on a given facility and tests the likely impacts of various countermeasures. While this method does not require crash data, it does require detailed information about roadway cross-sectional features, traffic volumes, and a calibrated SPF. Please see Part C of the HSM for additional information.

Application

Utilizing existing expertise, conducting RSAs, and using the HSM predictive method benefit from, but do not require crash data. Even without crash data these methods can provide reasonable estimates of safety conditions; improved understanding of issues contributing to the safety conditions; and potential countermeasures to address them.

Step 4

[1] Source: http://safety.fhwa.dot.gov/rsa/.

Site Diagnosis with Crash Data

Overview

Several tools/techniques are available to diagnose safety concerns when crash data are available.

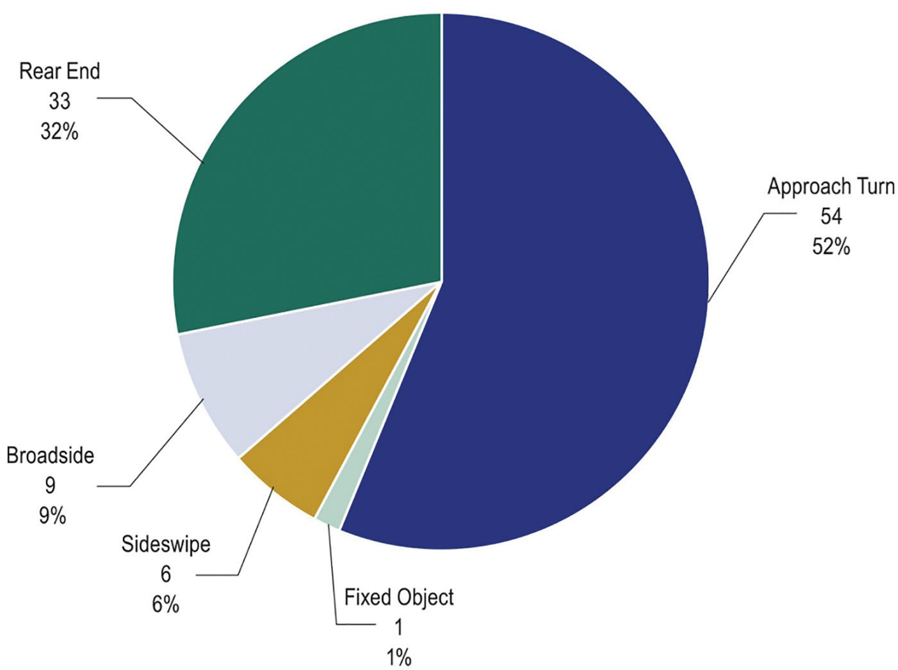
- A review of crash report forms provide detailed information about individual crashes at a site.
- The Haddon Matrix can help relate the series of events leading up to and following a crash (i.e., pre-crash, crash, and post-crash) to typical categories of contributing factors (i.e., human, roadway, and vehicle). This can be used to identify safety issues at a site and possibly countermeasures.
- Crash diagrams can be used to summarize all of the crashes at a site.

The following is a brief overview of each tool/technique. Resources related to them are identified in "Resources" summary.

Crash Report Forms. Crash reports for a particular site can be studied and compared to determine if there are any common factors among the crashes. Sometimes the prevalence of a single crash type or common contributing factor or other recognizable patterns may become apparent. These patterns provide clues to identifying the underlying factors contributing to crashes at the location. For example, in some cases, repeated rear end collisions may be evident, in others, nighttime crashes might be a common feature.

These findings can be summarized in tables or pie charts, as shown in Table 5 and Figure 13. Table 5 provides a table of basic crash data for a given site indicating that the major crash type is angle crashes.

Figure 13. Example of Graphical Representations of Crash Data



Source: FHWA.

Table 5. Example Collision Summary

No.	Date	Time	Type	Ped Bike	Fatal	Injuries	Property Damage	Day/ Night	Wet/ Dry	Contributing Cause
1	01/06/07	3:25 p.m.	Angle	0	0	0	$2,000	Day	Dry	FTYROW[a]
2	01/21/07	5:15 p.m.	Rear End	0	0	0	$1,500	Day	Dry	Followed too closely
3	02/06/07	6:40 p.m.	Angle	0	0	1	$3,000	Night	Dry	FTYROW[a]
4	04/01/07	4:50 p.m.	Angle	0	0	0	$2,000	Day	Dry	FTYROW[a]
5	04/20/07	4:00 p.m.	Angle	0	0	2	$2,500	Day	Dry	FTYROW[a]
6	06/09/07	5:30 p.m.	Angle	0	0	0	$1,500	Day	Wet	FTYROW[a]
7	07/19/07	7:00 p.m.	Angle	0	0	0	$2,000	Night	Dry	FTYROW[a]
8	10/30/07	6:10 p.m.	Angle	0	0	1	$3,000	Day	Dry	FTYROW[a]
9	12/01/07	5:00 p.m.	Angle	0	0	0	$1,500	Day	Dry	FTYROW[a]
10	12/19/07	10:00 a.m.	Rear End	0	0	0	$1,000	Day	Dry	Followed too closely
11	01/02/08	4:45 p.m.	Rear End	0	0	1	$1,500	Day	Dry	Followed too closely
12	01/09/08	5:25 p.m.	Rear End	0	0	0	$1,000	Day	Dry	Followed too closely
13	02/19/08	6:30 p.m.	Rear End	0	0	0	$1,500	Night	Wet	Followed too closely
14	04/27/08	5:00 p.m.	Angle	0	0	3	$3,000	Day	Dry	FTYROW[a]
15	06/21/08	4:55 p.m.	Angle	0	0	1	$2,000	Day	Dry	FTYROW[a]
16	10/09/08	6:15 p.m.	Angle	0	0	0	$2,000	Day	Dry	FTYROW[a]
17	11/23/08	5:30 p.m.	Angle	0	0	0	$1,500	Night	Dry	FTYROW[a]

[a] *FTYROW: Failure to Yield Right of Way.*

Source: FHWA.

Haddon Matrix. The Haddon Matrix (Table 6) is a tabular summary of site crash conditions designed to help practitioners understand crash contributing factors. A unique feature of the Haddon Matrix is the specific categories of summary information. The rows correspond to stages of the crash event (pre-crash, during the crash event and post-crash), and the columns correspond to categories of contributing factors (human error, vehicle/equipment, physical environment, and socioeconomic) involved in the majority of crashes. These categories are standard for the Haddon Matrix. The table is filled as the practitioner reviews and interprets the crash reports related to the location under consideration. More information about the Haddon Matrix is in Chapter 3 and Chapter 6 of the Highway Safety Manual.

Contributing Factors or Causal Factors? While it is common to refer to the "cause" of a crash, in reality, most crashes cannot be related to a singular causal event. Instead, crashes are the result of a convergence of a series of events that are influenced by a number of contributing factors, including time of day, driver attentiveness, speed, vehicle condition, and road design.

Contributing factors fall into three major categories: human, vehicle, and roadway.

Table 6. Hypothetical Haddon Matrix

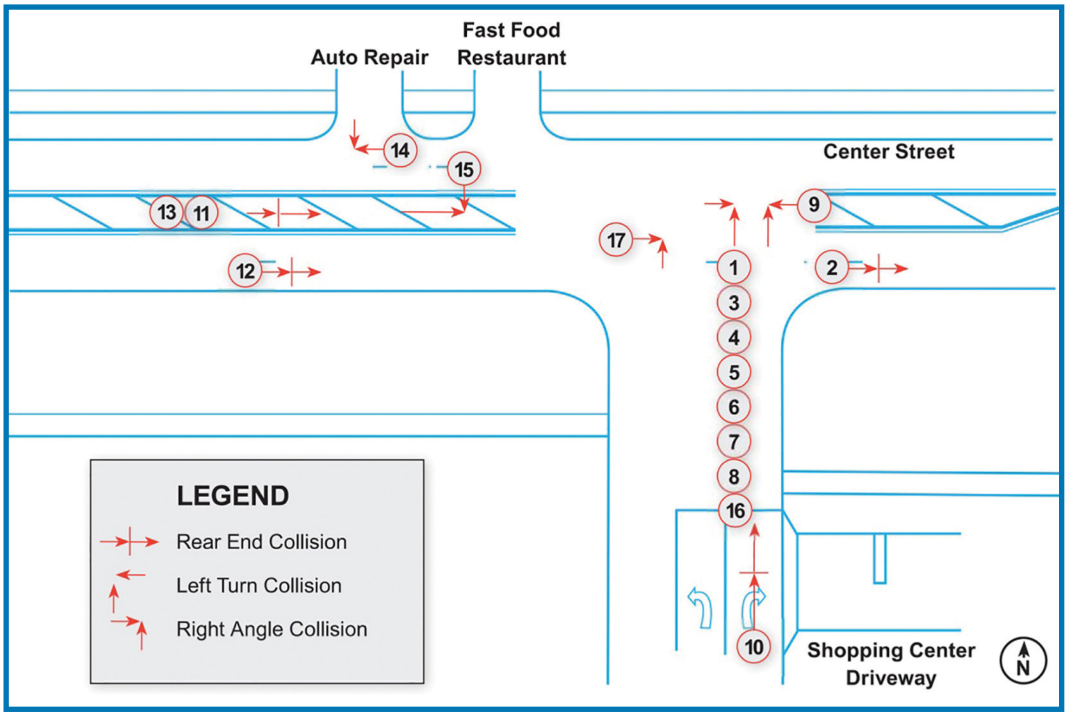
Time of Events	Human	Vehicle/Equipment	Physical Environment
Pre-Crash	Poor vision, distraction, age, cell phone use	Worn brakes, malfunctioning headlight	Wet pavement, poorly lit intersection
Crash	Failure to use a seat belt, driving under the influence of alcohol	Bumper heights and energy absorption, seat belt malfunction	Grade, potholes, low friction pavement surface
Post-Crash	Age of driver, alcohol	Ease of removal of injured passengers	Poor emergency response system

Crash Diagrams and Conditions Diagrams. Crash diagrams are a technique to graphically illustrate crash data associated with a given site. Each crash is plotted on a schematic of the site at the approximate location where the crash occurred. Icons are used to represent crash types so that patterns are identifiable. Crash diagrams are sometimes cross referenced with a tabular listing of the associated crash data so that key information can be accessed easily.

Figure 14 is a crash diagram for the data in Table 5 above. The table provides a summary of crashes, while the crash diagram provides information about the number of crashes in the context of the site being studied. Together, they provide a more complete understanding of site crash conditions than either one does separately. Note the pattern of right angle crashes on the south leg of the intersection near the shopping center.

Condition diagrams are sketches showing the physical layout of the site under investigation such as surrounding land uses, roadway lane configurations, driveways, and other physical features of the site. Crash and condition diagrams can be either sketched by hand or created using software.

Figure 14. Example Collision Diagram

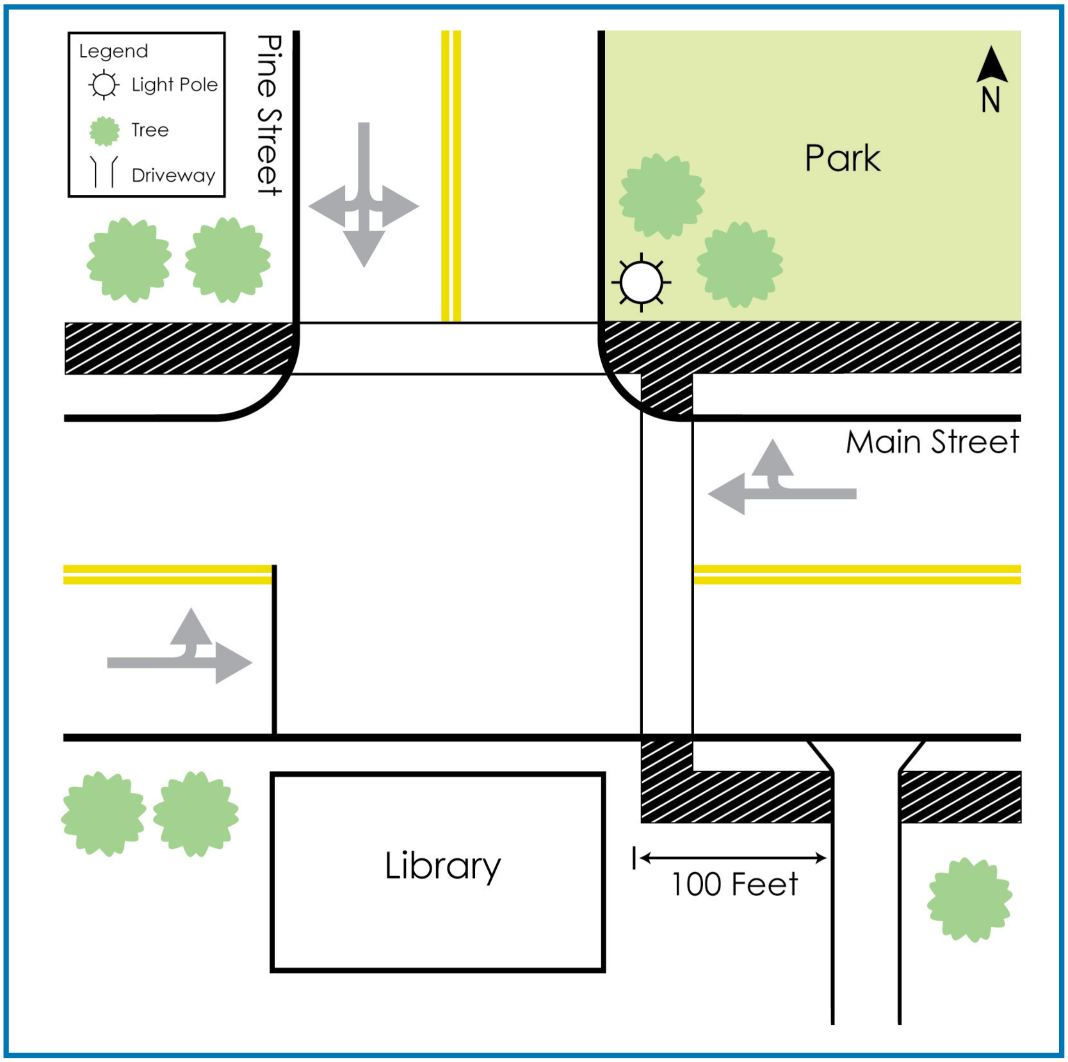


Source: FHWA.

Step 4

Figure 15 shows an example condition diagram that has been created based on site visit information. Details of the intersection such as lane configuration and the locations of obstructing trees were collected during a site visit. For example, overgrown shrubs close to the intersection could explain a pattern of crashes where lack of sight distance was identified as a crash factor.

Figure 15. Condition Diagram



Application

Graphical and tabular analysis of crash data are useful when there are many crashes associated with a site. In rural areas, especially on low volume roads, intersections may not have enough crash history to reveal crash patterns. In these cases, a systemic analysis would be a good alternative to pursue (see Step 2). A systemic analysis identifies low-cost and widely applicable treatments that can be applied across the road network[2] to reduce crash frequency and/or severity.

[2] Not only at "high crash" locations.

Identify Countermeasures

After crash and field conditions have been studied, the next step is to identify potential countermeasures to address the identified safety concerns. A countermeasure is a strategy or action implemented to reduce the frequency or severity of crashes at a site. Countermeasures can be implemented at the specific site or implemented at multiple locations based on needs, budgets, and local priorities. Note that often (and in this Toolkit) the terms countermeasures and treatments are used interchangeably.

Example of a Countermeasure: Installation of chevrons along a horizontal curve is a **countermeasure** that is proven to reduce the likelihood of road departure crashes.

To identify countermeasures, the practitioner must understand the factors that contribute to crashes at the site (see the previous section) and link them to countermeasures designed to address the factors. Collaboration among road owners, stakeholders, and other safety partners in the countermeasure identification process can result in more comprehensive and effective multidisciplinary safety solutions and lessen the likelihood of "second guessing" after countermeasures are implemented.

Countermeasures can be identified by:

1. Addressing a specific crash type of concern;
2. Considering conditions at a specific location; or
3. Implementing known best practices.

Identifying Countermeasures Based on Addressing a Crash Type of Concern

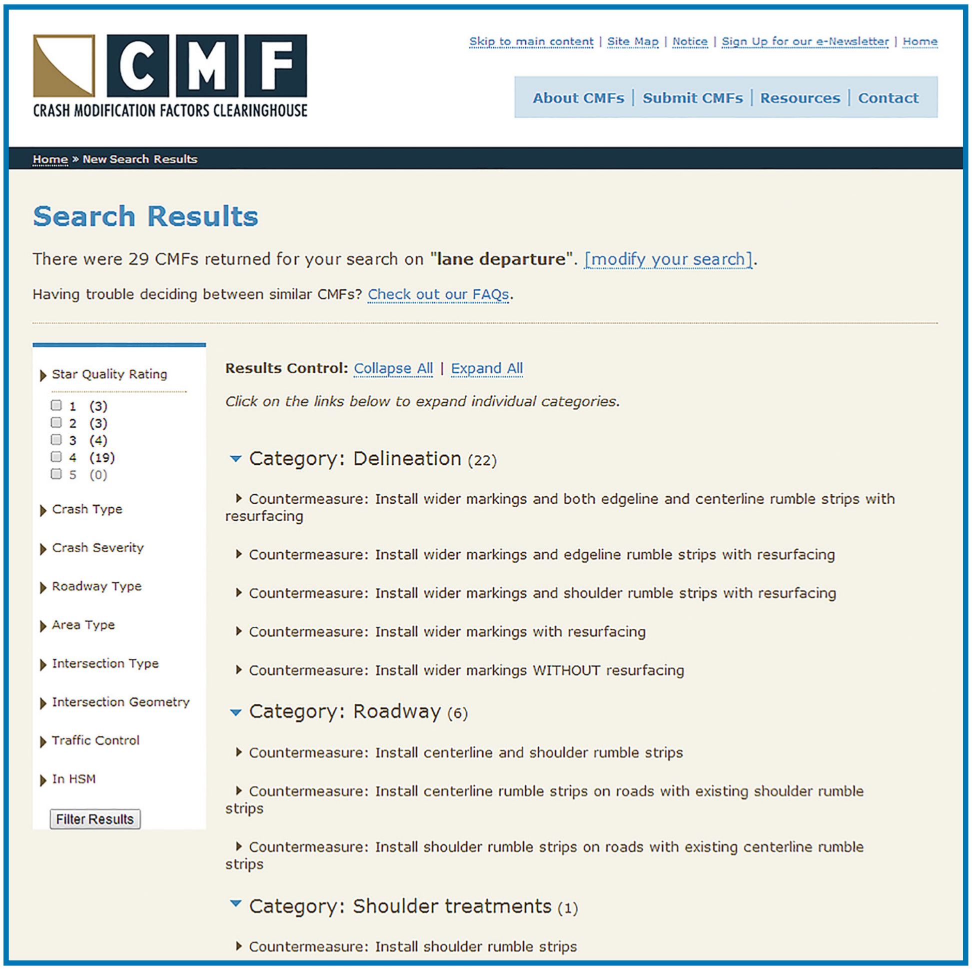
The FHWA Crash Modification Factor (CMF) Clearinghouse is one of the most current tools available for identifying, selecting, and prioritizing countermeasures. The Crash Modification Factors (CMF) Clearinghouse serves as a central on-line repository of CMFs. The CMF Clearinghouse defines a crash modification factor as: "a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site."

Users are able to query the Clearinghouse' database to identify treatments and the associated CMF. For each CMF, the database provides users with published information, such as how it was developed, the research quality behind the CMF, and a link to the publication from which the CMF was extracted. Based on this, users are able to determine the most applicable CMF for their condition.

The clearinghouse is updated regularly to incorporate the latest safety research. The CMF Clearinghouse also reports which CMFs are included in the Highway Safety Manual; these CMFs typically have a higher quality rating given the strict HSM inclusion criteria.

Figure 16 shows an example of a CMF look-up from the clearinghouse for lane departure crashes.

Figure 16. Example of CMF Look-up



Source: http://www.cmfclearinghouse.org/.

Step 4

Crash Modification Factors: What Are They?

A CMF is a factor used to compute the number of crashes expected after implementing a given countermeasure. The CMF is multiplied by the expected crash frequency without treatment. A CMF greater than 1.0 indicates an expected increase in crashes, while a value less than 1.0 indicates an expected reduction in crashes.

For example: a CMF of 0.8 indicates an expected safety benefit; specifically, a 20 percent reduction in crashes. A CMF of 1.2 indicates an expected degradation in safety; specifically, a 20 percent expected increase in crashes.

Multiple countermeasures: CMFs for several countermeasures can be multiplied to reflect the application of multiple safety countermeasures applied at the same location.

Crash Reduction Factors (CRF) are equal to 100% x (1-CMF).

Where do I find CMFs – see the FHWA CMF clearinghouse web site.

When selecting treatments and applying the CMFs from the Clearinghouse or from any other resource, be aware that a single countermeasure may have more than one CMF associated with it. Practitioners should look for treatments that have similar characteristics as their location(s).

When a safety countermeasure is applied at a given site, consider the potential interactions of the treatment with other site conditions to limit the likelihood of unintended consequences. For example, if a lane is widened, drivers may feel they can drive faster due to the perception of improved safety of a wider roadway.

The Oregon Department of Transportation provides a useful set of instructions on how to query and interpret the information in the CMF Clearinghouse. The link to this information is http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/pages/crash_mod_factors.aspx.

Identifying Countermeasures Based on Location

Overview

Countermeasures can sometimes be determined based only on the location characteristics of the crashes of concern. For example, common crash countermeasures have been determined for roadway features such as intersections and curves. FHWA, the National Cooperative Highway Research Program (NCHRP), and others, have developed guidebooks practitioners can use to identify appropriate countermeasures for specific location types. This approach to selecting countermeasures is useful because it can provide guidance when little data are available. A few example resources are:

- Intersection Safety: A Manual for Local Rural Road Owners;[3]
- Guidelines for Selection of Speed Reduction Treatments at High-Speed Intersections;[4]
- Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes;[5]
- NCHRP 500 Reports;[6]
- Low-Cost Safety Enhancements for Stop-Controlled Intersections;[7] and
- Low-Cost Treatments for Horizontal Curve Safety.[8]

The resources section for this step describes these in more detail.

Application

Using location characteristics to identify potential countermeasures is appropriate when limited data are available. For example, to improve the safety of a horizontal curve with no formal data, the practitioner should consider application of rumble strips and additional signage as these countermeasures typically reduce crashes on horizontal curves.

3 http://safety.fhwa.dot.gov/local_rural/training/fhwasa1108/fhwasa1108.pdf.
4 http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_613.pdf.
5 http://safety.fhwa.dot.gov/intersection/resources/fhwasa10005/docs/brief_8.pdf.
6 http://www.trb.org/Main/Blurbs/152868.aspx.
7 http://safety.fhwa.dot.gov/intersection/resources/fhwasa09020/fhwasa09020.pdf.
8 http://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa07002/fhwasa07002.pdf.

Identifying Countermeasures Based on Best Practices

Overview

Practitioners also can take advantage of "best practices" which are known to be widely applicable to many situations and to provide increased safety when installed properly. For example, if safety analysis shows that a particular site has experienced a series of road departure crashes, the agency may consider installing rumble strips or stripes which are known to reduce road departure crashes on two-lane roadways. Countermeasures can be applied to a single location, multiple locations, or across en entire network depending on need, budget, and local priorities.

Example

In January 2012, the FHWA advanced a list of nine countermeasures that have been proven to improve safety but are not yet widely implemented. This set of proven countermeasures includes:

- Roundabouts;
- Corridor Access Management;
- Backplates with Retroreflective Borders;
- Longitudinal Rumble Strips and Stripes on Two-Lane Roads;
- Enhanced Delineation and Friction for Horizontal Curves;
- Safety Edge;
- Medians and Pedestrian Crossing Islands in Urban and Suburban Areas;
- Pedestrian Hybrid Beacon; and
- Road Diet.

Source: http://safety.fhwa.dot.gov/provencountermeasures/.

Resources For Step 4: Diagnose Site Crash Conditions and Identify Countermeasures

Resources for Diagnosis without Crash Data

Road Safety 365: A Workshop for Local Government. This one-day workshop was developed by the FHWA. The workshop promotes the development of a safety culture by showing participants how construction and maintenance activities impact safety. Module 4 of the workshop is the "reading the road" section which provides information for site diagnosis. The workshop is offered through state LTAP and Regional TTAP Centers.

Highway Safety Manual Part B Chapter 5: Diagnosis. The AASHTO Highway Safety Manual was published in 2010. The HSM's Volume 1, Chapter 5 describes field assessments and provides examples of considerations during a site review. Appendix 5D provides a field review checklist for segments, signalized intersections, and unsignalized intersections. Volume 2, Part C presents the predictive method.

Additional information on the HSM: http://www.highwaysafetymanual.org/.

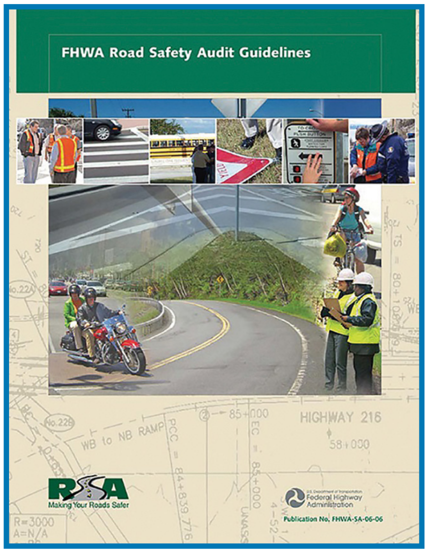
Resources for Road Safety Audits

FHWA Office of Safety Web site. The FHWA provides information about RSAs on their web site at: http://safety.fhwa.dot.gov/rsa/. The site provides information about:

- The benefits of an RSA;
- The legal topics related to implementing an RSA; and
- Steps to conduct an RSA.

The site also provides comments on the effectiveness of the RSA as a tool by traffic safety professionals, and directs viewers to additional RSA training and resources. The FHWA compiles a periodic RSA newsletter that provides practitioners with the most current information on RSAs.

FHWA Road Safety Audit Guidelines. This publication presents background information on RSAs, the steps in the RSA process, and the RSA tools. The background chapters introduce the RSA concept to beginning practitioners, and describe issues that should be considered prior to RSA implementation, such as project selection, and costs and benefits. The publication details an eight-step process to conducting an RSA.



Source: FHWA.

The document also includes several tools to assist in the data collection process for RSAs, including various "Prompt Lists" to identify all of the elements that should be examined on a set of road plans or in the field.

The guidelines are available at the following link: http://safety.fhwa.dot.gov/rsa/guidelines/documents/fhwa_sa_06_06.pdf.

The document can be ordered in hard copy at the FHWA report center: http://www.fhwa.dot.gov/research/library/reportsources.cfm.

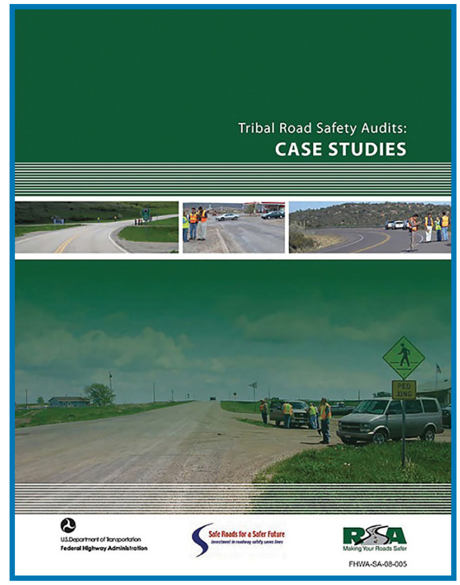
Report Number: FHWA-SA-06-06.

FHWA Tribal Road Safety Audit Case Studies. This document was published in 2008 and provides background information on the RSA process and the implementation of this process specifically on Tribal lands. Based on four case studies, the document summarizes key factors and lessons learned in conducting a successful RSA on Tribal lands. Detailed cases study background information, safety issues, and findings are provided in the document's appendix.

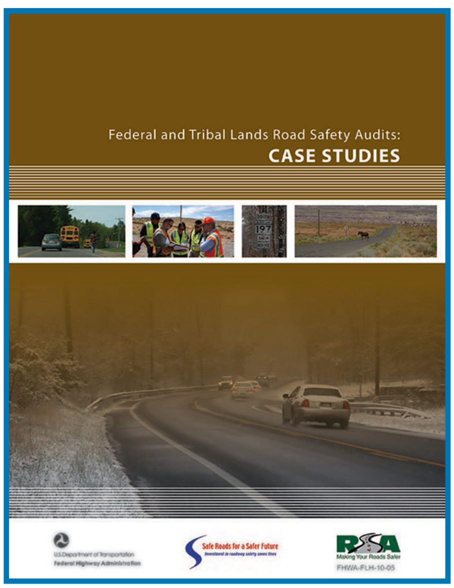
The document is available at the following link: http://safety.fhwa.dot.gov/rsa/tribal_rsa_studies/tribal_rsa_studies.pdf.

The document can be ordered in hard copy at the FHWA report center: http://www.fhwa.dot.gov/research/library/reportsources.cfm.

Report Number: FHWA-SA-08-005.



Source: FHWA.



Source: FHWA.

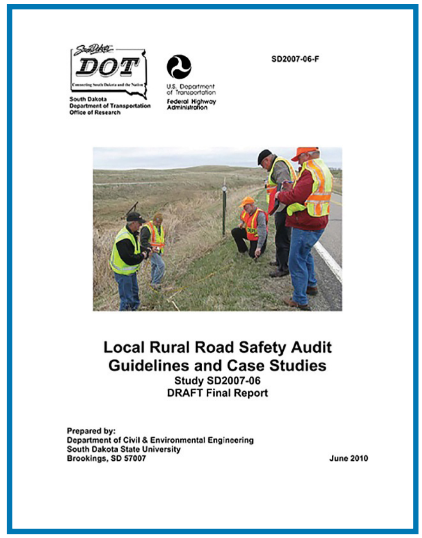
FHWA Federal and Tribal Lands Road Safety Audits, Case Studies. The FHWA published this document in 2009, targeting Federal Land Management Agencies (FLMA) and Tribal agencies that want to implement RSAs. The document provides background on the RSA process and conducting RSAs on Federal and Tribal lands. It provides six Federal and Tribal lands RSA case studies and two additional RSAs on Federal lands conducted by the Western and Eastern Federal Lands Division Offices. Each case study includes photographs, a project description, a summary of key findings, and lessons learned.

The document is available at the following link: http://safety.fhwa.dot.gov/rsa/resources/casestudiesflh/casestudiesflh.pdf. The document can be ordered in hard copy at the FHWA report center: http://www.fhwa.dot.gov/research/library/reportsources.cfm.

Report Number: FHWA-FLH-10-05.

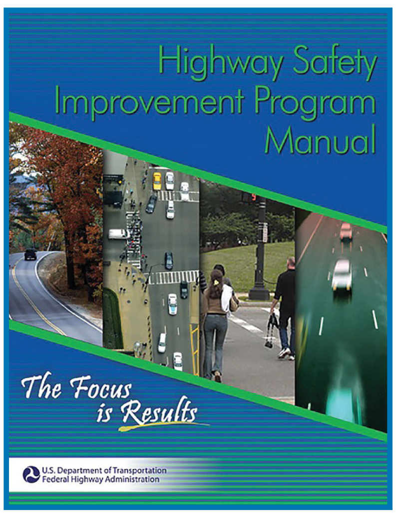
FHWA Local Rural Road Safety Audit Guidelines and Case Studies. This document demonstrates how RSAs can be used to improve the safety performance of local rural roads. It includes 12 RSA case studies focused on county roads, township roads, intersections, and railroad crossings. For each case study, the document includes photographs, project descriptions, summary of key findings, lessons learned, and the follow-up actions that were taken to improve safety. The document's appendices provide detailed case study information and a safety issues review list for practitioners to consider when doing a road safety field review.

The document is available at the following link: http://www.ltap.org/conference/2010/downloads/2010_SDPoster.pdf.



Source: FHWA.

Resources for Diagnosis with Crash Data



Source: FHWA.

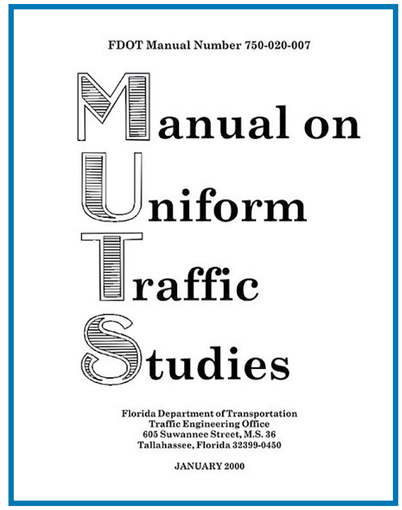
FHWA Highway Safety Improvement Program Manual. The manual, published in 2010, describes the overall Highway Safety Improvement Program (HSIP) and provides a roadway safety management process that emphasizes a data-driven, strategic approach to safety infrastructure decisions. Chapter 3 of the manual provides a discussion on countermeasure identification using crash data.

The document is available at the following link: http://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/fhwasa09029.pdf. The document can be ordered in hard copy at the FHWA report center: http://www.fhwa.dot.gov/research/library/reportsources.cfm.

Report Number: FHWA-SA-09-029.

Florida Manual On Uniform Traffic Studies. The Florida Manual on Uniform Traffic Studies (MUTS) is designed to establish minimum standards for conducting traffic engineering studies on roads under the jurisdiction of the Florida Department of Transportation. The electronic version of this manual provides a series of PDF files which address the various steps of completing safety studies. It also includes blank forms for the collection of field data, and instructions on how to develop a collision diagram, condition diagram, and other studies. Chapter 6 of the manual provides an example of a collision diagram and a crash summary that represent the different types of crashes at a particular intersection.

The document is at the following link: http://www.dot.state.fl.us/trafficoperations/Operations/Studies/MUTS/muts.shtm.


FDOT Manual Number 750-020-007

Manual on Uniform Traffic Studies

Florida Department of Transportation
Traffic Engineering Office
605 Suwannee Street, M.S. 36
Tallahassee, Florida 32399-0450

JANUARY 2000

Source: Florida Department of Transportation.

Highway Safety Manual Part B Chapter 5: Diagnosis provides information reviewing safety data to identify patterns in crash types, severities, environmental conditions, and crash locations.

Step 4

The HSM is available to order at the AASHTO bookstore at: https://bookstore.transportation.org/search.aspx?Text=hsm-1. ISBN Number: 1-56051-477-0.

Resources for Identifying Countermeasures Based on Addressing a Crash Type of Concern

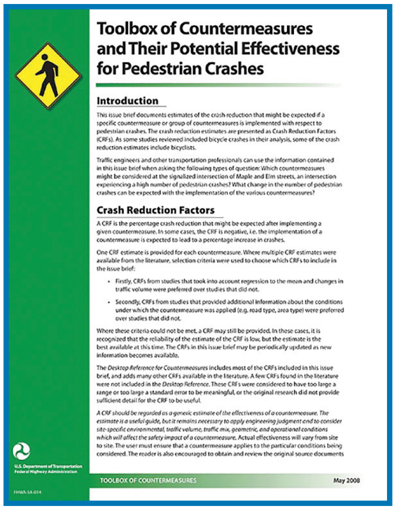
CMF Clearinghouse. The Crash Modification Factors (CMF) Clearinghouse serves as a central on-line repository of CMFs. Users are able to query the Clearinghouse' database to identify treatments and the associated CMF. For each CMF, the database provides users with published information, such as how it was developed, the research quality behind the CMF, and a link to the publication from which the CMF was extracted. Based on this, users are able to determine the most applicable CMF for their condition.

The clearinghouse is updated regularly to incorporate the latest safety research. The CMF Clearinghouse also reports which CMFs are included in the Highway Safety Manual; these CMFs typically have a higher quality rating given the strict HSM inclusion criteria.

Source: http://www.cmfclearinghouse.org/.

The site is at the following link: http://www.cmfclearinghouse.org/.

Related to the clearinghouse, the Oregon Department has a useful additional discussion of how to query and interpret the information in the CMF Clearinghouse. The link to this information is http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/pages/crash_mod_factors.aspx.



Source: FHWA.

Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes. This toolbox provides users with crash reduction effectiveness information for three types of pedestrian safety countermeasures – signalization (i.e., pedestrian signal phasing), geometric (i.e., pedestrian overpass or raised median), and operational (i.e., signs and markings). For each countermeasure, the toolbox provides Crash Reduction Factors (CRF). Note that a CMF is equal to 1-CRF. For example, if the CRF is equal to 35 percent, the CMF is equal to (1-0.35) or 0.65.

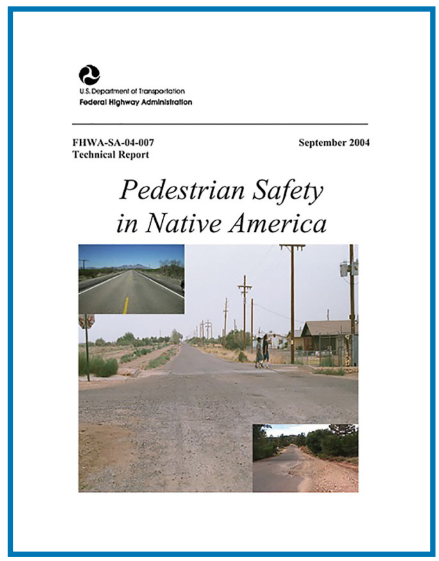
The toolbox is at the following link: http://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_tctpepc/ped_tctpepc.pdf. The document can be ordered in hard copy at the FHWA report center: http://www.fhwa.dot.gov/research/library/reportsources.cfm.

Report Number: FHWA-SA-014.

Pedestrian Safety in Native America. This FHWA report analyzed data from multiple national sources to typify crash patterns among Native American communities. The report provides countermeasures, including education-based, media-based, and law enforcement-based interventions as well as child education and pedestrian facility improvements. The report also provides four successful Tribal safety intervention programs and their crash reductions after implementation.

The document is at the following link: http://katana.hsrc.unc.edu/cms/downloads/Peds_Safety_in_Native_America.pdf. The document can be ordered in hard copy at the FHWA report center: http://www.fhwa.dot.gov/research/library/reportsources.cfm.

Report Number: FHWA-SA-04-007.



Source: FHWA.

NCHRP 500 Reports. The NCHRP 500 Reports are publications that help local practitioners reduce injuries and fatalities in targeted areas. Each publication addresses a specific type of crash or contributing factor:

- Volume 01. A Guide for Addressing Aggressive-Driving Collisions;
- Volume 02. A Guide for Addressing Collisions Involving Unlicensed Drivers and Drivers with Suspended or Revoked Licenses;
- Volume 03. A Guide for Addressing Collisions with Trees in Hazardous Locations;
- Volume 05. A Guide for Addressing Unsignalized Intersection Collisions
- Volume 04. A Guide for Addressing Head-On Collisions;
- Volume 06. A Guide for Addressing Run-Off-Road Collisions;

- Volume 07. A Guide for Reducing Collisions on Horizontal Curves;
- Volume 08. A Guide for Reducing Collisions Involving Utility Poles;
- Volume 09. A Guide for Reducing Collisions Involving Older Drivers;
- Volume 10. A Guide for Reducing Collisions Involving Pedestrians;
- Volume 11. A Guide for Increasing Seat Belt Use;
- Volume 12. A Guide for Reducing Collisions at Signalized Intersections
- Volume 13. A Guide for Reducing Collisions Involving Heavy Trucks;
- Volume 14. Reducing Crashes Involving Drowsy and Distracted Drivers;
- Volume 15. A Guide for Enhancing Rural Emergency Medical Services;
- Volume 16. A Guide for Reducing Crashes Involving Alcohol;
- Volume 17. A Guide for Reducing Work Zone Collisions;
- Volume 18. A Guide for Reducing Collisions Involving Bicycles;
- Volume 19. A Guide for Reducing Collisions Involving Young Drivers;
- Volume 20. A Guide for Reducing Collisions Head-on Crashes on Freeways;
- Volume 21. Safety Data and Analysis in Developing Emphasis Area Plans;
- Volume 22. A Guide for Addressing Collisions Involving Motorcycles; and
- Volume 23. A Guide for Reducing Speed-Related Crashes

The publications classify each strategy as proven, tried, or experimental based on: 1) whether the strategy has been applied in multiple locations; and 2) whether the evaluations proving the strategy's effectiveness are properly designed. The publications also provide links to information on agencies or organizations currently implementing the strategy. Note that since publication of this document, the classification of some countermeasures may have changed from "experimental" to "tried," or from "tried" to "proven" based on research that has been completed.

The NCHRP 500 Reports can be accessed with this site: http://www.trb.org/Main/Blurbs/152868.aspx. The reports can be ordered in hard copy at the TRB Book Store: http://books.trbbookstore.org/. Book Code: NR500A (for Volume 01) to NR500Y (for Volume 23).

FHWA Maintenance of Signs and Supports. The FHWA produced this guide to aid local agency practitioners and maintenance staff in ensuring that their agency's signs are maintained to meet road user needs. Section 8 of the guide can be useful for maintenance staff conducting routine investigations. It discusses inspection methods and offers maintenance staff a sign inspection checklist.

An electronic copy of the Manual is available here: http://safety.fhwa.dot.gov/local_rural/training/fhwasa09025/fhwasa09025.pdf. The manual is FHWA Report Number: FHWA-SA-09-025.

Vegetation Control for Safety. The FHWA produced this guide in 2008 to assist local agency maintenance staff with identifying locations where vegetation control can be improved to enhance traffic and pedestrian safety. This document provides staff with specific items to check, and safe ways to mow, cut brush, and control roadside vegetation.

An electronic copy of the Manual is available here: http://safety.fhwa.dot.gov/local_rural/training/fhwasa07018/vegetationfv1108.pdf. The manual is FHWA Report Number: FHWA-SA-07-018.

Maintenance of Drainage Features for Safety. The FHWA produced this guide in 2009 to help local maintenance staff understand the importance of maintaining and upgrading drainage features on their road system and the potential impacts to road safety. The document guides staff to recognize drainage problems and how to correct drainage features. An electronic copy of the manual is available here: http://safety.fhwa.dot.gov/local_rural/training/fhwasa09024/. The manual is FHWA Report Number: FHWA-SA-09-024.

Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD defines the standards used by road managers nationwide to install and maintain traffic control devices on all public streets, highways, bikeways, and private roads open to public traffic. The MUTCD has been administered since 1971, and updated periodically to address changing transportation needs and new safety technologies and management techniques. The most current edition of the MUTCD is from 2009, with additional revisions made in 2012.

An electronic copy of the MUTCD is available here: http://mutcd.fhwa.dot.gov/. The manual also can be purchased from the AASHTO Bookstore: https://bookstore.transportation.org/item_details.aspx?ID=1550.

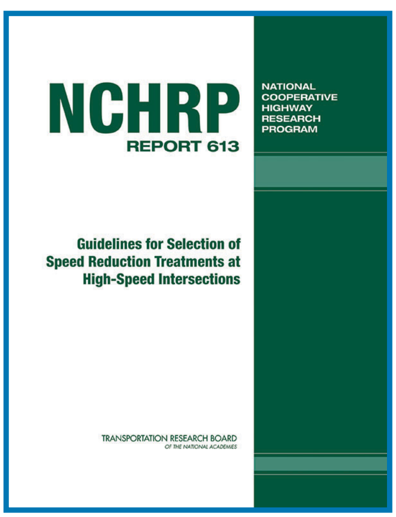
Guardrail Repair. The FHWA produced this guide in 2008 to provide practitioners with up-to-date information on how to repair W-Beam guardrails. Chapter 2 of the manual offers guidance on identifying the extent of guardrail damage to assess its continued safety performance.

An electronic copy of the manual is available here: http://safety.fhwa.dot.gov/local_rural/training/fhwasa08002/. The manual is FHWA Report Number: FHWA-SA-08-002.

Resources for Identifying Countermeasures Based on Location

Intersection Safety: A Manual for Local Rural Road Owners. Chapter 4 of this manual provides countermeasures and specifies the intersection types where each countermeasure is effective.

This manual can be downloaded from the following link: http://safety.fhwa.dot.gov/local_rural/training/fhwasa1108/fhwasa1108.pdf. The manual is FHWA Report Number: FHWA-SA-11-08.



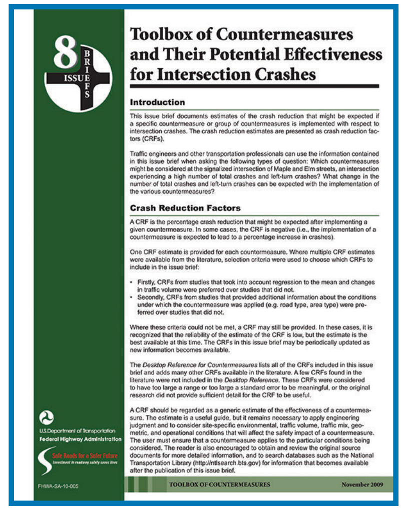
Source: National Cooperative Highway Research Program.

Guidelines for Selection of Speed Reduction Treatments at High-Speed Intersections. This report details how practitioners could evaluate and select speed reduction treatments for intersections with approach speeds of 45 miles per hour or greater. Section 2.2 of the report presents a summary of various speed reduction treatments, and Section 3.6 walks users through a step-by-step process of using intersection information (i.e., roadway features and speed data) to select the appropriate treatments to achieve speed reduction objectives.

This manual can be downloaded from the following link: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w124.pdf. The reports can be ordered in hard copy at the TRB Book Store: http://books.trbbookstore.org/. Book Code: NR613.

Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes. This FHWA brief provides practitioners with information for considering the most effective countermeasures for a particular intersection. The document presents the estimated crash reduction factors (CRF) with countermeasure implementation. This information is organized by three categories of countermeasures – signalization, left turn, and operational.

This toolbox can be downloaded at no expense from the following link: http://safety.fhwa.dot.gov/intersection/resources/fhwasa10005/docs/brief_8.pdf. The toolbox is FHWA Report Number: FHWA-SA-10-005.



8 ISSUE BRIEFS

Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes

Introduction

This issue brief documents estimates of the crash reduction that might be expected if a specific countermeasure or group of countermeasures is implemented with respect to intersection crashes. The crash reduction estimates are presented as crash reduction factors (CRFs).

Traffic engineers and other transportation professionals can use the information contained in this issue brief when asking the following types of question: Which countermeasures might be considered at the signalized intersection of Maple and Elm streets, an intersection experiencing a high number of total crashes and left-turn crashes? What change in the number of total crashes and left-turn crashes can be expected with the implementation of the various countermeasures?

Crash Reduction Factors

A CRF is the percentage crash reduction that might be expected after implementing a given countermeasure. In some cases, the CRF is negative (i.e., the implementation of a countermeasure is expected to lead to a percentage increase in crashes).

One CRF estimate is provided for each countermeasure. Where multiple CRF estimates were available from the literature, selection criteria were used to choose which CRFs to include in the issue brief:

- Firstly, CRFs from studies that took into account regression to the mean and changes in traffic volume were preferred over studies that did not.
- Secondly, CRFs from studies that provided additional information about the conditions under which the countermeasure was applied (e.g. road type, area type) were preferred over studies that did not.

Where these criteria could not be met, a CRF may still be provided. In these cases, it is recognized that the reliability of the estimate of the CRF is low, but the estimate is the best available at this time. The CRFs in this issue brief may be periodically updated as new information becomes available.

The *Desktop Reference for Countermeasures* lists all of the CRFs included in this issue brief and adds many other CRFs available in the literature. A few CRFs found in the literature were not included in the *Desktop Reference*. These CRFs were considered to have too large a range or too large a standard error to be meaningful, or the original research did not provide sufficient detail for the CRF to be useful.

A CRF should be regarded as a generic estimate of the effectiveness of a countermeasure. The estimate is a useful guide, but it remains necessary to apply engineering judgment and to consider site-specific environmental, traffic volume, traffic mix, geometric, and operational conditions that will affect the safety impact of a countermeasure. The user must ensure that a countermeasure applies to the particular conditions being considered. The reader is also encouraged to obtain and review the original source documents for more detailed information, and to search databases such as the National Transportation Library (http://ntlsearch.bts.gov) for information that becomes available after the publication of this issue brief.

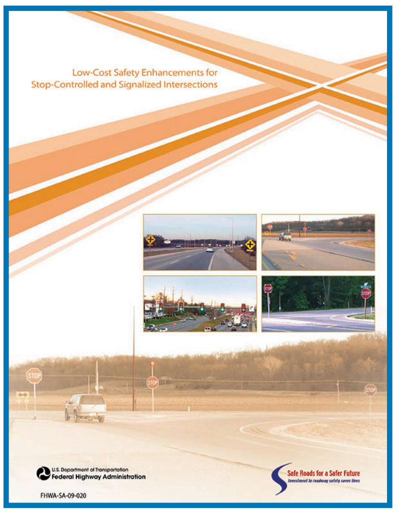
U.S. Department of Transportation Federal Highway Administration

Safe Roads for a Safer Future

FHWA-SA-10-005

TOOLBOX OF COUNTERMEASURES November 2009

Source: FHWA.



Source: FHWA.

Step 4

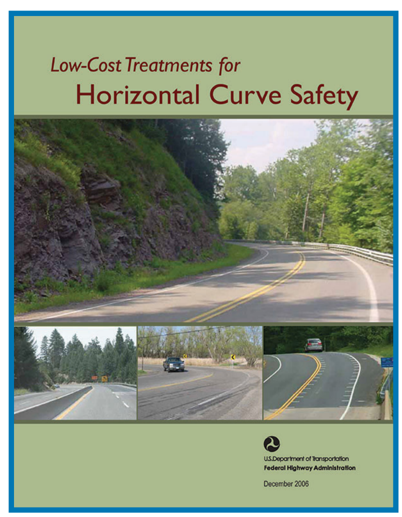
Low-Cost Safety Enhancements for Stop-Controlled Intersections. This report provides information about low-cost countermeasures for crash problems at various intersection types such as stop-controlled, signalized, and poorly lit intersections. For each countermeasure, the document provides an estimated crash reduction factor, the typical crash threshold for using the countermeasure, any additional implementation factors, and the typical range of implementation cost.

This report can be downloaded at no expense from the following link: http://safety.fhwa.dot.gov/intersection/resources/fhwasa09020/fhwasa09020.pdf. The toolbox can be ordered in hard copy at the FHWA report center: http://www.fhwa.dot.gov/research/library/reportsources.cfm.

Report Number: FHWA-SA-09-020.

Low-Cost Treatments for Horizontal Curve Safety. Published in 2006, this guide provides practical information on low-cost treatments for safety issues in horizontal curves. The publication describes each treatment; shows examples; suggests when the treatment might be applicable; provides design features; and where available, provides information on the potential safety effectiveness and costs.

The document is available on-line at: http://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa07002/fhwasa07002.pdf.

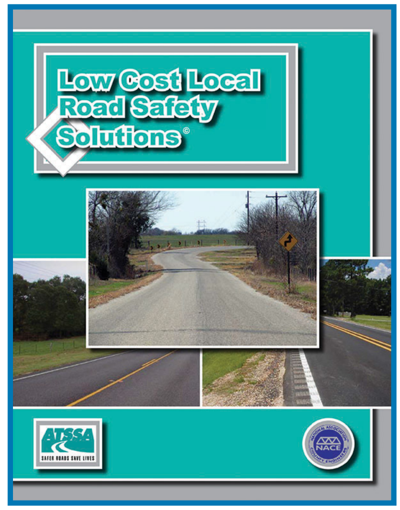


Source: FHWA.

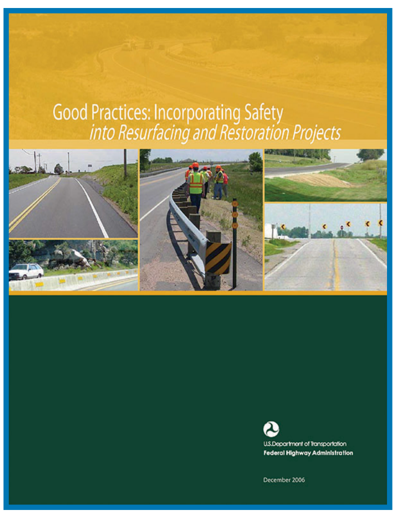
Resources for Identifying Countermeasures Based on Best Practices

Low Cost Local Road Safety Solutions. This ATSSA publication provides users with information on 16 proven low-cost countermeasures, focusing on traffic control devices such as signing and pavement marking. For each countermeasure, the publication gives users an overview of the countermeasure, its crash reduction effectiveness, and the relevant reference and countermeasure applications that prove the countermeasure's effectiveness.

This report can be downloaded at no expense from the following link: http://safety.fhwa.dot.gov/intersection/resources/fhwasa09027/resources/Low%20Cost%20Local%20Road%20Safety%20Solutions.pdf. To order hard copies of Low Cost Local Road Safety Solutions, email TrishH@atssa.com, or call (877) 642-4637, ext. 135.



Source: FHWA.



Source: FHWA.

Good Practices: Incorporating Safety into Resurfacing and Restoration Projects. This FHWA reports provides users guidance on how to make sure safety improvements are included in resurfacing and restoration projects. The document identifies a set of common issues and common success factors in agencies across six states.

This report can be downloaded at no expense from the following link: http://safety.fhwa.dot.gov/roadway_dept/strat_approach/fhwasa07001/fhwasa07001.pdf. The report can be ordered in hard copy at the FHWA report center: http://www.fhwa.dot.gov/research/library/reportsources.cfm. Report Number: FHWA-SA-07-001.

Roadway Departure Safety – A Manual for Local Road Owners. This manual was developed by the FHWA to provide local practitioners with information to identify locations with historical or potential rural roadway departure crashes, and countermeasures to address these locations. Chapter 4 of the manual provides effective countermeasures on different roadway types based on best practice.

This manual can be downloaded at no expense from the following link: http://safety.fhwa.dot.gov/local_rural/training/fhwasa1109/fhwasa1109.pdf. The manual can be ordered in hard copy at the FHWA report center: http://www.fhwa.dot.gov/research/library/reportsources.cfm. Report Number: FHWA-SA-11-09.

Step 5. Prioritize Countermeasures for Implementation

If a single site was studied and only one countermeasure was selected, then the agency is ready to begin implementation (go to Step 6). If, on the other hand, more than one site was studied or multiple countermeasures were identified at one or more sites, the agency will need to choose which countermeasures to implement. In these cases, the countermeasures must be prioritized to determine which should be implemented given agency resources. The appropriate prioritization method to use depends on the resources and data available.

Technical Definition – Countermeasure: an action taken to counteract a danger or threat. In the context of safety – a *safety* countermeasure is an action designed to counteract a threat to safety.

Example: after examining traffic crash history, roadway geometry, and other factors, the construction of a modern roundabout was selected as the appropriate countermeasure to address identified safety issues.

Related Terms: several terms are used to characterize actions to address a safety concern, including: countermeasure, treatment, "fix," improvement, or mitigation.

Prioritizing Countermeasures Using Qualitative Rating

Overview

One method for prioritizing among several countermeasures is to qualitatively evaluate each potential countermeasure against a set of criteria important to the community. In addition to project cost, there are many other criteria that may influence the suitability of a countermeasure to a given site. Some of these are:

- Public demand for improvements;
- Available right of way;
- Environmental considerations;
- Potential positive or negative community response to the countermeasure;
- The presence of community endorsed plans for mobility or accessibility in the corridor;
- Road user needs;
- The community's transportation vision;
- Anticipated safety benefits;
- Design concerns; and
- Funding limitations.

To perform a qualitative evaluation, staff members select the appropriate evaluation criteria for their community or situation and rate the potential impacts and/or benefits of each countermeasure relative to the selected criteria. The rating can be "good, fair, or poor" or "high, medium, or low" based on staff members' judgment. For criteria that *can* be quantified (criteria, including cost, safety effectiveness, acres of right of way needed for the treatment, and wetland impacts), the quantitative value should also be included in the evaluation.

Examples

Table 7 illustrates a hypothetical application of a "high, medium, low" qualitative rating applied to two countermeasures. The criteria selected for evaluating the countermeasures are in the left hand column. The information in the table is hypothetical. In application, the criteria and rating would be developed based on the judgment of the practitioners rating the countermeasures and the basis of the rating in the table:

- **Environmental Impacts.** The environmental impacts of Countermeasure 1 are less than those of Countermeasure 2.
- **Anticipated Safety Benefits.** In this example, CMFs are not available so the practitioners have used their experience and professional judgment to determine that the benefits of Countermeasure 2 are higher and better than those of Countermeasure 1.[1]
- **Consistency with Community Plans.** In this example, the practitioners believe that both countermeasures are consistent with relevant plans for the community such as agency capital improvement plans, long-range transportation plans, maintenance programs, and road resurfacing programs.
- **Public Acceptance.** The practitioners believe the public is not likely to support Countermeasure 2 and will reasonably support Countermeasure 1.
- **Right-of-Way Impacts.** This criterion can be quantified. However, if it has not been quantified at this stage, the practitioners can judge the order of magnitude impacts based on knowledge of the site and familiarity with construction methods.
- **Construction Costs.** This criterion can be quantified. However, if it has not been quantified at this stage, the practitioners with relevant expertise can estimate the order of magnitude costs of constructing and maintaining each countermeasure.
- **Future Maintenance Costs.** This criterion can be quantified or at this stage maintenance staff from the agency could provide input on the order of magnitude costs of annual maintenance for both countermeasures. In this example, agency staff believe that the cost to maintain each countermeasure would be approximately equal over the years, and that there is some degree of maintenance involved for each countermeasure.

It is valuable to include (to the extent possible) the public/residents/community-advocates in the process of evaluating, planning for, and implementing improvements. If they cannot be included to such an extent, they should at least know that their concerns are recognized. This is important because projects with community support are more likely to be successful. Without community support a potentially good project can fail and have limited opportunities for a second chance.

[1] If a CMF is available it could be directly used in this table. If a CMF is not available, the practitioners could comparatively judge the benefits of one countermeasure versus another based on experience in the community or experience drawn from peers.

Based on this qualitative assessment, each countermeasure was assigned a low, medium, or high rating for each criterion. The countermeasures were then compared and prioritized based on the assessment (see Table 7 below). In this hypothetical example, countermeasure A would be selected.

Table 7. Hypothetical Application of a "High," "Medium," and "Low" Rating

	Site A Countermeasure 1	Site A Countermeasure 2
Environmental Impacts	Low	Medium
Anticipated Safety Benefits	Medium	High
Consistency with Community Plans	High	High
Public Acceptance	Medium	Low
Right-of-Way Impacts	Low	High
Order of Magnitude Costs	Low	High
Future Maintenance Obligations	**Medium**	**Medium**
Countermeasure Selected?	**Yes**	**No**

Application

Qualitative evaluation is a relatively quick and easy to use "order of magnitude" tool for prioritizing countermeasures. It is applicable in situations where available data are limited and preliminary design activities have not been conducted.

Prioritizing Countermeasures Based on Economic Evaluation

Overview

Countermeasures also can be evaluated by converting the benefits and costs of the countermeasure to monetary value and conducting either a benefit/cost analysis, or a cost effectiveness analysis.

In a benefit/cost analysis, safety benefits are converted to the estimated dollar value of fatalities, injuries, and property damage avoided over the service life of the treatment. This is calculated as the net present dollar value of benefits. The dollar value of these benefits is then compared to the dollar value of constructing and maintaining the countermeasure over the service life of the countermeasure. Costs include construction costs, environmental costs, planning and design costs, and ongoing maintenance costs. Consideration also is given to service life of the countermeasure. In more complex applications of benefit/cost analysis, societal costs (including health care costs, pain and suffering, and insurance costs) and benefits also are considered and quantified.

Cost effectiveness analysis is similar to benefit/cost analysis except that instead of quantifying safety benefits in terms of dollar values, safety benefits are quantified in terms of expected crash reductions. Cost effectiveness analysis is used when it is not possible or practical to estimate the dollar value of the safety benefits of a treatment.

Examples

Net Present Value. The net present value (NPV) or net present worth (NPW) benefit/cost analysis method expresses the difference between the discounted costs and discounted benefits of a safety improvement project. The costs and benefits have been "discounted" meaning they have been converted to a present value using a discount rate.

The NPV has two functions. It can be used to determine which countermeasures are most favorable based on the countermeasure(s) with the highest NPV. It also can be used to determine if a project is economically justified when the NPV is greater than zero, meaning the benefits are greater than the costs.

The NPV = PVB – PVC

Where PVB = Present value of benefits, and
PVC = Present value of costs

This method identifies the most desirable countermeasure(s) for a specific site, or it can be used to evaluate multiple projects across multiple sites.

Table 8 is a hypothetical example using the NPV to rank four alternatives.

Table 8. Example Using Net Present Value

Alternative Countermeasure	Present Value of Benefits	Present Value of Costs	Net Present Value	Alternate Rank
A	$1,800,268	$500,000	$1,300,268	3
B	$3,255,892	$1,200,000	$2,055,892	1
C	$3,985,768	$2,100,000	$1,858,768	2
D	$2,566,476	$1,270,000	$1,296,476	4

Source: FHWA.

Note: Alternative B has the greatest Net Present Value. All of the alternatives are economically justified, as their net present value is greater than zero.

For alternative A the NPV is calculated:

NPV = $1,800,268 – $500,000 = $1,300,268

The same step is repeated for the other three countermeasures. All are economically justified with NPV greater than zero. Alternative B has the greatest NPV, and is ranked number 1, based on this method.

Benefit/Cost Ratio. A benefit/cost ratio divides the sum of all of the benefits associated with implementing a countermeasure, expressed in monetary terms, by the sum of all the costs associated with implementing and maintaining the countermeasure. The benefit/cost ratio (B/C Ratio) of the project is the ratio of the present dollar value of the benefits to the present dollar value of the costs.

B/C Ratio = PVB/PVC

Where:

PVB = Present value of benefits, the dollar value of injuries reduced; and

PVC = Present value of costs, the dollar value of costs to implement the countermeasure.

A project with a B/C Ratio greater than 1.0 is considered economically justified. The B/C Ratio can be used to prioritize optional countermeasures at one site or to prioritize among sites, by estimating the B/C Ratio for selected countermeasures at each site, and ranking the sites from highest to lowest B/C Ratio. The sites at the top of the list should be selected for countermeasure implementation. Table 9 shows an example using benefit cost ratios.

Table 9. Example Using Benefit/Cost Ratio

Alternative Countermeasure	Present Value of Benefits	Present Value of Costs	Benefit/Cost Ratio
A	$1,800,268	$500,000	3.6
B	$3,255,892	$1,200,000	2.71
D	$2,566,476	$1,270,000	2.02
C	$3,985,768	$2,100,000	1.89

Source: FHWA.

Note: Alternative A has the highest benefit/cost ratio. All of the alternatives are economically justified, as their benefit/cost ratios are greater than zero.

Step 5

For alternative A, the B/C is calculated:

B/C = $1,800,268 / $500,000 = 3.6

The same step is repeated for the other three countermeasures. All are economically justified with B/C greater than one. Alternative A has the greatest B/C ratio, and is ranked number 1, based on this method.

Some state departments of transportation have publicly available cost benefit spreadsheets. It can be worthwhile to check on the state DOT web site for availability.

Cost-Effectiveness Index. In situations where it is not possible or practical to determine dollar values of countermeasure benefits, a “cost-effectiveness” metric can be used in lieu of the net present value or benefit/cost ratio. Cost-effectiveness is the amount of money required to avoid a single crash, or the total amount spent on the countermeasure(s) divided by the expected number of crashes reduced. In this case, the countermeasure with the lowest cost-effectiveness index is ranked highest.

The Cost-Effectiveness Index is calculated as follows:

$$\text{Cost-Effectiveness Index} = PVC/AR$$

Where:

PVC = Present value of project cost; and

AR = Total crash reduction.

In this analysis, the present value of the project cost is calculated in the same manner as in benefit/cost analysis. The value of crash reduction is estimated by multiplying the relevant crash modification factor by the number of existing crashes to yield the number of crashes expected after countermeasure implementation. This method provides a general sense of a project's value, and can be used to compare many safety improvement projects relative to each other. This method also avoids the sensitivities of placing a dollar value on lives and injuries. In this method, a smaller cost-effectiveness index is better.

Table 10 provides an example of evaluating four alternatives at a given site using a cost-effectiveness index as the measure for prioritizing countermeasures.

Table 10. Example Using Cost-Effectiveness Index

Alternative Countermeasure	Present Value of Cost	Total Accident Reduction	Cost-Effectiveness Index	Alternative Rank
A	$500,000	43	11,628	1
B	$1,200,000	63	19,048	3
C	$2,100,000	70	30,000	4
D	$1,270,000	73	17,397	2

Source: FHWA.

Note: Alternative A is ranked first as it has the lowest cost associated with each crash reduction.

For alternative A, the cost-effectiveness index is calculated as:

$$\text{Cost-Effectiveness Index} = 500{,}000/43 = 11{,}628$$

The cost-effectiveness index is calculated for each alternative as shown in the table. Alternative A is ranked first since it has the lowest cost associated with each crash reduced.

Step 5

Application

Agency preferences and available resources influence which countermeasure prioritization method is applied. Funding agencies often suggest and sometimes require agencies use a particular method in their applications for funding. In these cases, technical guidance outlining the specific requirements of the analysis is typically provided by the funding agency.

Other prioritization and optimization methods are sometimes used as well, including:

- Incremental benefit/cost analysis;
- Linear programming;
- Integer programming; and
- Dynamic programming.

These methods are not typically used for selecting or programming projects at the local level because of the technical expertise required and generally the number of project is limited. They are described in some detail in Chapter 8 of the Highway Safety Manual.

Resources For Step 5: Prioritize Countermeasures For Implementation

Resources for Economic Evaluation

Highway Safety Improvements Program Manual. Section 4.4 of the Highway Safety Improvement Program (HSIP) manual discusses methods of prioritizing countermeasures for implementation. These methods include: project cost, monetary value of benefits, total number of crashes reduced, net present value, and cost-effectiveness. The manual also provides information about incremental benefit/cost analysis and optimization methods.

An electronic copy of the HSIP Manual is available here: http://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/fhwasa09029.pdf.

Highway Safety Manual Part B. The HSM's Volume 1, Chapter 7 presents methods for prioritizing countermeasures at one site or prioritizing sites for implementation. The Manual's Table 8-1: Summary of Project Prioritization Methods provides users with a comparison of the input needs, outcomes, and considerations for the different methods.

Step 6. Implement Countermeasures

Overview

Obtaining the necessary human and financial resources is a major consideration in implementing any safety project or program. Harnessing local funding sources and staff resources is often the quickest way to implement projects. For example, maintenance or public works staff can implement low-cost projects such as maintenance or replacement of signs, maintenance of striping, and/or vegetation control as part of their regular duties.

Some safety project can be 100 percent Federally funded while others may be eligible for an increased Federal share. Agencies also can use locally generated funds as a match to leverage State or Federal dollars. The FHWA, Bureau of Indian Affairs (BIA), National Highway Traffic Safety Administration (NHTSA), and other Federal agencies distribute Federal transportation funding to states and other jurisdictions. State DOTs, state police agencies, and various other state institutions typically administer the disbursement of Federal transportation funding to smaller jurisdictions.

Procedures and requirements governing grant application processes vary by state. For instance, some states dedicate funds for local *safety* projects while others emphasize local *roadway* projects. Also, some state departments of transportation (DOT) use a centralized office or department to prioritize and program funds for local safety (or local roadway) projects, others allocate these responsibilities to the various DOT regions or districts, yet other States use a hybrid approach combining elements from each of these approaches. The FHWA "Assessment of Local Road Safety" Report provides additional information and insight on this topic (see the Resources section at the end of this chapter).

The Local Technical Assistance Program (LTAP) web site describes the various types of local agency support provided by state DOTs – a useful first stop for identifying the resources available by state. The LTAP web site is http://www.ltap.org/resources/lpa/state.php.

Agencies should look beyond safety focused funding programs for access to a broader set of funding pools. By incorporating safety treatments into maintenance or capital improvement projects, agencies may be able to secure more funding than they would if they limited their applications strictly to safety programs. The evidence that safety improvements will occur if the "non-safety focused" project is implemented (because of the inclusion of safety treatments) could give the project a higher score, thereby improving its chances of being funded. This is because many state and Federal programs include application scoring criteria that give projects with a safety benefit higher scores. Likewise, safety is often a component of scoring systems some regional and metropolitan planning agencies use to select projects for inclusion in the Transportation Improvement Program (TIP). The FHWA publication: *Good Practices: Incorporating Safety into Resurfacing and Restoration Projects* provides helpful guidance on incorporating safety features into non-safety focused projects. Please see the Resources section for more information. Finally, in some cases safety improvements can be included as part of the conditions of approval for a private development if there sufficient evidence connecting the proposed land use to the safety issue.

Examples

Major Safety Funding Programs of MAP-21. The current transportation bill, MAP-21, outlines Federal priorities for the transportation system. It includes several provisions which allocate funds to states for safety improvements. The Highway Safety Improvement Program (HSIP) and the Tribal Transportation Program (TTP) are two elements of MAP-21.

- Highway Safety Improvement Program (HSIP). The HSIP is a Federally funded safety program administered by state departments of transportation. The HSIP requires states to set safety performance targets within their Strategic Highway Safety Plans (SHSP), and HSIP funds can be used on all public roads. The HSIP identifies the projects that will be implemented to achieve the goals of the SHSP. Typically HSIP funds are distributed through an annual project application and award cycle. Some states have separate set-asides for local programs.
- **Tribal Transportation Program (TTP).** This is a new program under MAP-21 and replaces the Indian Reservation Roads (IRR) program. The TTP outlines most of the Federal transportation funding opportunities for Tribal governments. MAP-21 requires that up to two percent of TTP funds be set aside for safety projects based on identification and analysis of highway safety issues and opportunities on Tribal lands. Eligible project types include safety studies and roadside safety audits.

Technical Definition: MAP-21 – Moving Ahead for Progress in the 21st Century Act

The name of a two-year transportation bill that took effect October 1, 2012 and will last through September 30, 2014 (FY 13 and FY 14).

Why is MAP-21 important?

This transportation bill funds all highway activities, including the Highway Safety Improvement Program (HSIP).

Application

Many state- and Federal-level programs require local agencies to submit funding applications that describe projects in some detail and characterize their anticipated benefits. These applications help agencies decide which projects to fund given their limited resources. Scoring criteria are used to help rank the applications based on their ability to meet pre-defined program goals. It is good practice for agencies to obtain the funding application scoring criteria before identifying projects and developing applications to better determine how well various projects support the goals of the funding program.

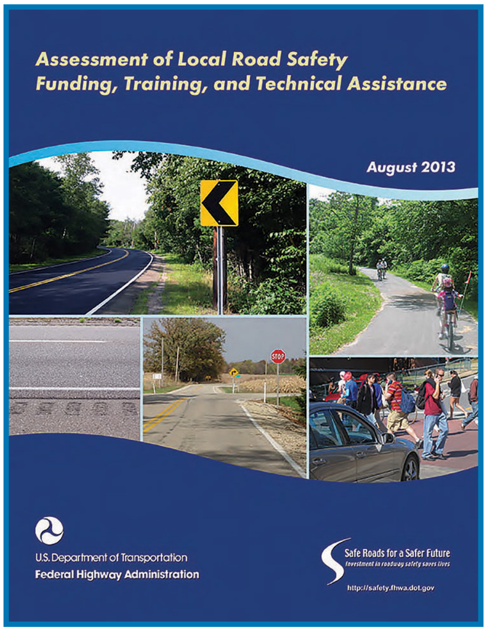
Understanding the goals of the safety program providing the funding helps agencies identify projects that better match the program criteria and tailor their applications to better meet the needs of the funding program. Participating in the state's SHSP development process can provide insight on the goals of the various safety funding programs (including HSIP). Safety programs also typically require evidence that the project is cost-effective and that serious and fatal crash incidents will be reduced if the project is implemented.

Resources For Step 6: Implement Countermeasures

Good Practices: Incorporating Safety into Resurfacing and Restoration Projects. This document was originally produced in 2006 as the result of a domestic scan on best practices. The scan included local agency representatives on the team and identified several local agency-friendly practices.

The report includes several case studies of best practices that agencies are using to incorporate traffic safety activities into everyday practice.

An electronic copy of the report is available on the National Association of County Engineer's web site at: http://www.countyengineers.org/ResourcesEdu/Safety/Documents/good%20practices.pdf.



Source: FHWA.

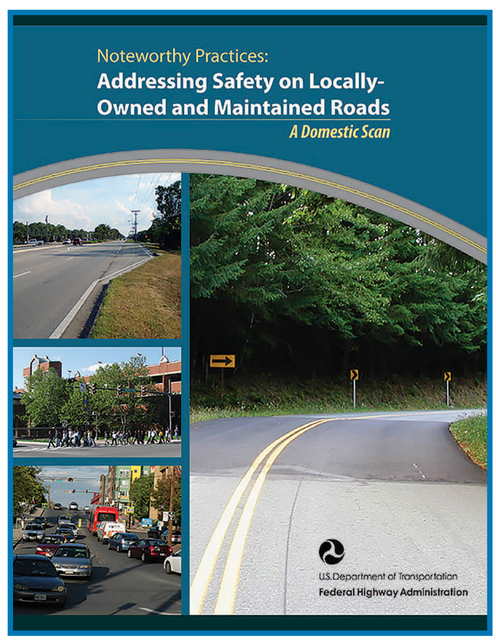
Assessment of Local Road Safety Funding, Training, and Technical Assistance. The purpose of this report is to summarize state DOT practices for delivering safety funding and resources to local entities for road safety improvement projects. This report identifies model local road safety practices that can be implemented by state DOTs, local practitioners (i.e., public works directors, transportation directors, county engineers, transportation planners, and elected officials), Local Technical Assistance Programs (LTAP), and metropolitan planning organizations (MPO) in any state.

The report is available at:

http://safety.fhwa.dot.gov/local_rural/training/fhwasa13029/lclrdsfy.pdf.

Noteworthy Practices: Addressing Safety on Locally-Owned and Maintained Roads, a Domestic Scan. Published in 2010, the Domestic Scan report identifies and documents practices in the planning, programming, and implementation of efforts to improve local road safety. Practices are presented in data collection and analysis; local project identification; local project administration; funding; and training and technical assistance. Chapter 7 discusses outreach and partnerships between state DOTs and local agencies.

The report is available at: http://safety.fhwa.dot.gov/local_rural/training/fhwasa10027/fhwasa10027.pdf.



Source: FHWA.

Step 7. Evaluate Effectiveness

Overview

The purpose of this step is to describe how to evaluate the impact of the treatments that have been implemented in terms of crash frequency or severity. A reliable assessment of the effectiveness of safety countermeasures cannot be made immediately after implementation. Some time needs to pass, often two to three years, before enough data can be collected to determine how many crashes, serious injuries, and fatalities have occurred since implementation of the countermeasure and then compare it with the same types of data from before implementation.

This step should not be overlooked. Evaluation provides information that can help agencies decide whether or not the investment has reduced crash frequency or severity. Evaluation also can help agency staff demonstrate the value of the program to community leaders and the general public.

The level of effort required to conduct an evaluation depends on the resources available and the method chosen. Some methods are:

- Collect public feedback data; such as:
  - The number of complaints received about the location of interest;
  - The number of compliments received on the installed countermeasure(s);
  - The number and type of police citations issued; and
  - The number and type of maintenance issues at the site.
- Conduct a comparative assessment of before and after crash frequency, severity, and traffic volumes.
- Conduct a simple before/after study.
- Conduct a rigorous before/after analysis.

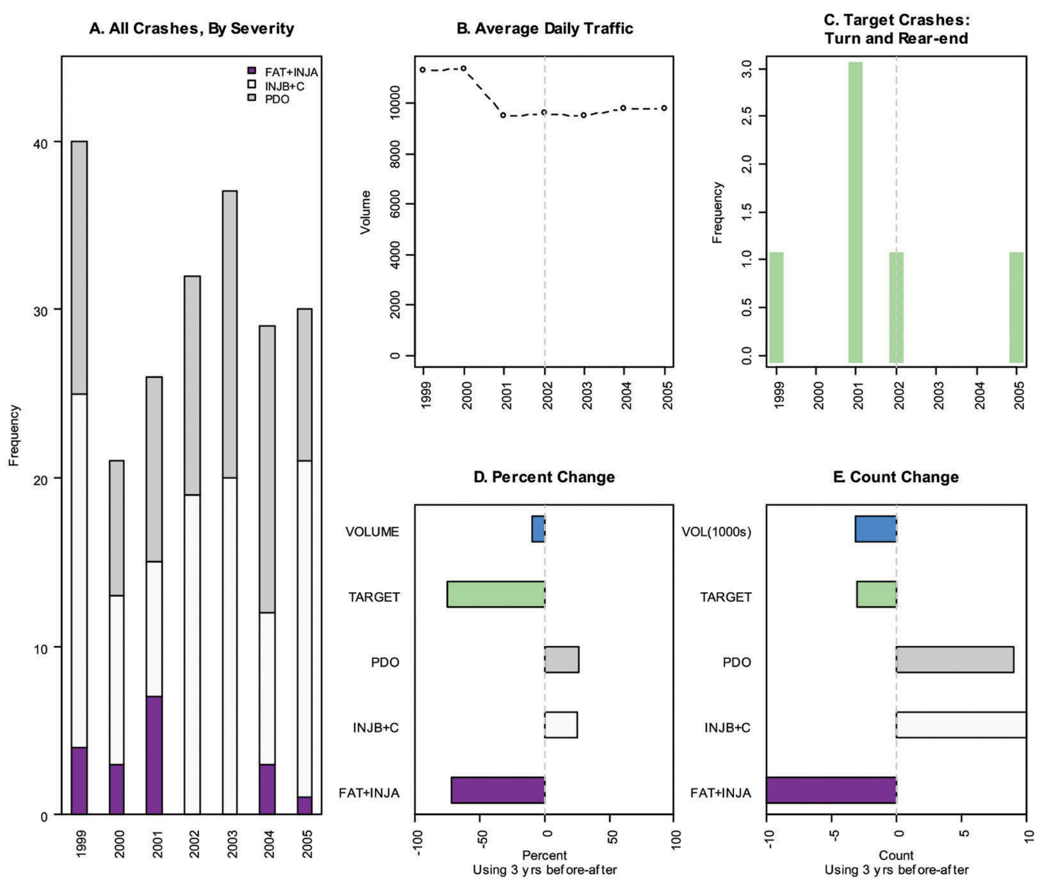
At the most basic level, evaluation is a "before and after" comparison. This means that some sort of "before" or "baseline" data must be available against which the "after" data can be compared. This baseline data is often available as part of the information used to select the site in the first place. To demonstrate the benefits of safety investments, the agency should track before and after performance measures, analyze trends, and conduct selective benefit/cost analysis. The Highway Safety Improvement Program manual provides detailed information about how to do this. Please see the Resources at the end of this section.

Example

Comparative Assessment – Treatment at One Site. Figure 17 illustrates a comparative analysis of before and after conditions conducted after a treatment has been implemented at a single site.

Charts A, B, and C summarize crash counts, average daily traffic, and target crash type crash counts for the three years before and after implementing the project. Charts D and E show the relative (percent) and absolute (number) changes in traffic volumes and crashes after implementation. Visually comparing these characteristics side by side allows a qualitative assessment of the treatment's effectiveness. A comparative assessment considers crash counts, crash type and severity and traffic volume to develop a qualitative assessment of the changes from before to after deploying a treatment.

Figure 17. Example of Comparative Analysis of Before and After Conditions



Source: *Oregon Department of Transportation, Evaluating the Effectiveness of the Safety Investment Program (SIP) Policies for Oregon. http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/2009/SIP_Evaluation_FR.pdf.*

Simple Before/After Crash Analysis. A simple before/after crash analysis compares the number of crashes that occurred during the three-year period before a treatment is installed to the number of crashes that occurred in the three-year period after the treatment is installed (see Table 11). A simple before/after crash analysis is focused only on crash counts for the purposes of estimating the quantitative benefits of deploying a treatment.

Table 11. Example Simple Before/After Analysis

	2006-2008	2009-2011	Percent Reduction
Total Crashes at Site	22	16	27%

This type of analysis is an appealing way to estimate the quantitative safety benefits of a treatment because it is easy to complete, requires little data, and is easy to explain. But there are some important limitations to it. The main problem with it stems from the underlying assumption that the number of crashes experienced before implementing the countermeasure is a good estimate of the number of crashes that would be expected in the future assuming the countermeasure had not been implemented. However, this is not always the case because traffic volumes or surrounding land uses may change or levels of enforcement may change. Due to this and other limitations, it cannot be relied upon solely to evaluate effectiveness.

Rigorous Before/After Crash Analysis. To address the weaknesses inherent in simple before/after crash analysis, methods that utilize more sophisticated statistical tools are used. These include before/after analysis with comparison groups, empirical Bayes (EB) analysis, full Bayes studies, and cross-sectional studies. These methods should be used whenever an agency wants to develop a reliable quantitative estimate the effectiveness of a treatment.[1] The Highway Safety Manual and "Recommended Protocols for Developing Crash Modification Factors" available on the Crash Modification Factor Clearinghouse web site provide information and guidance on using these methodologies. Please see the Resources at the end of this section.

Empirical Bayes Analysis – What is it?

The Empirical Bayes (EB) method is a statistical method that combines the observed crash frequency with the predicted crash frequency using SPFs (see below) to calculate expected crash frequency. By combining crash history and predicted crash frequency, a better estimate of expected crash frequency can be made.

SPF – safety performance function – represents the change in mean crash frequency as ADT (or other exposure measure) increases or decreases.

The EB method overcomes regression-to-the-mean.

Application

Effectiveness evaluations are typically conducted two to three years after the treatment has been in place. There are three primary reasons for this:

1. It takes time for enough data to accumulate so that meaningful results can be obtained.
2. Road users, who may be quite familiar with the roadway environment "pre-treatment," will often modify their driving behavior "post-treatment" until they become familiar with the new environment. Because this

[1] To develop a Crash Modification Factor (CMF) for example.

interim period does not reflect the long-term impact of the treatment, it is important to wait until drivers are used to the new roadway environment before evaluating effectiveness.

3. In contrast, if the evaluation is conducted too many years after the treatment is implemented, conditions such as traffic volumes and land uses around the site may have changed to such a degree that any observed change in crash frequency or crash severity may not be attributable *only* to the treatment.

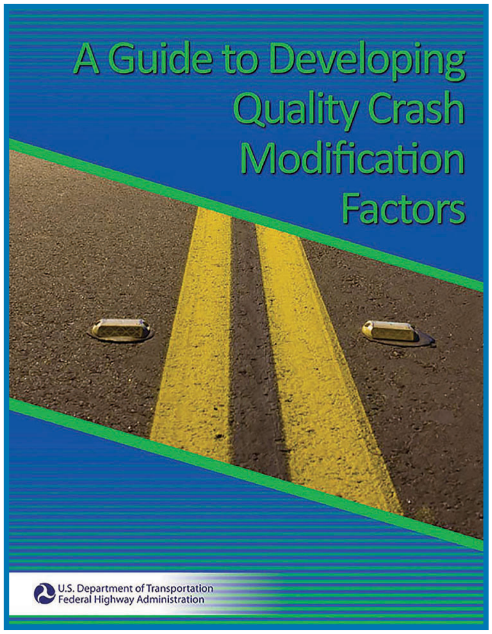
Resources For Step 7: Evaluate Effectiveness

Highway Safety Improvements Program Manual. Chapter 6 of the Highway Safety Improvement Program (HSIP) manual discusses various safety evaluation methods and provides calculation example for each method. The manual's Table 6.1 compares data and inputs required for these methods.

An electronic copy of the guide is available here: http://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/fhwasa09029.pdf.

A Guide to Developing Quality Crash Modification Factors. This FHWA guide provides guidance for users to develop crash modification factors (CMF). Table 12 in the guide provides users with a comparison of evaluation study designs. The guide's Chapter 4 provides a flowchart for users to select preferred evaluation design based on data availability and project.

An electronic copy of the guide is available here: http://safety.fhwa.dot.gov/tools/crf/resources/fhwasa10032/fhwasa10032.pdf.



Source: FHWA.

Highway Safety Manual. Volume 1, Chapter 9 of the HSM documents and discusses the various methods for evaluating the effectiveness of a treatment, a set of treatments, an individual project, or a group of similar projects after safety improvements have been implemented. The chapter also highlights which methods are appropriate for assessing safety effectiveness in specific situations, and provides step-by-step procedures for conducting safety effectiveness evaluations.

National Highway Institute (NHI) Highway Safety Improvement Program (HSIP) Project Evaluation. This is a NHI course that presents users with a description of safety effectiveness evaluation, an overview of fundamentals for performing safety effectiveness evaluation, and information about the importance of safety effectiveness evaluation in the context of the HSIP. Users are provided example before and after studies, and learn about the data needs for each methodology. The course lasts five hours and is partially instructor led and partially web based.

More course information is available here: http://www.nhi.fhwa.dot.gov/training/course_search.aspx?tab=0&key=380112&course_no=380112&res=1.

Conclusion

This Safety Toolkit developed for Rural Local and Tribal Road Practitioners provides a step-by-step process and identifies resources for conducting road safety analysis. The Toolkit should be considered a starting point for safety analysis and is designed to provide a number of resources and techniques that are flexible in their application. The Toolkit can help practitioners:

- Study and improve safety at one intersection or road segment; and/or
- Study and improve safety for a whole category of roadway types or intersections (e.g., all two-way stop-controlled intersections in town, or all two-lane rural highways in a community).

The Toolkit is designed for local and Tribal agency staff responsible for roadway safety. These staff typically have a wide range of expertise and experience, along with broad responsibilities, but may not have a formal background in traffic safety. The Toolkit provides plain language guidance to help them enhance roadway safety in their community.

The road safety analysis process shown in Figure 1 can be used as a step-by-step process starting with Step 1 and moving progressively through Step 7 or as a guide to applying one or more individual steps as deemed necessary. For each step of the process, the Toolkit provides an overview of:

- What the step is;
- How or when the step might be accomplished; and
- Resources for learning more about how to conduct analyses within each step.

There also are two User Guides available. Each User Guide demonstrates the Toolkit in practice by walking through a typical local or Tribal road safety analysis scenario:

- **User Guide #1 – Improving Safety on Rural Local and Tribal Roads – Site Safety Analysis** describes how to conduct a site-specific safety analysis. This scenario assumes community stakeholders have complained about safety conditions at one site and the agency has decided to evaluate the site. It is assumed the agency has crash data but does not have a lot of data about roadway configurations and characteristics or traffic volume data.
- **User Guide #2 – Improving Safety on Rural Local and Tribal Roads – Network Safety Analysis** describes how to conduct a proactive analysis of a component of the transportation network such as all two-lane road segments, or all stop-controlled intersections. In this scenario, the agency has decided to study safety conditions at all of the two-way stop-controlled intersections in the community. The agency has decided to develop a prioritized list of sites with potential for safety improvement. In this scenario, the community has crash data and some information about roadway conditions and traffic volume.

Overall the purpose of the FHWA Toolkit and User Guides is to assist local and Tribal road practitioners in conducting analyses to identify and diagnose safety issues; identify and implement countermeasures to address them in order to save lives on their roadways. Also included is information about the many resources available for conducting the analyses and step-by-step examples of how to do so.

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