Improving Safety on Rural Local and Tribal Roads

Network Safety Analysis – User Guide #2

August 2014

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16. Abstract

Rural roadway safety is an important issue for communities throughout the country and presents a challenge for local and Tribal agencies. The FHWA created a Toolkit and two User Guides to help rural local and Tribal roadway safety practitioners address these challenges. The Toolkit provides a step-by-step process to assist local agency and Tribal practitioners in completing traffic safety analyses. Each Toolkit step contains a set of tools, examples, and links to resources appropriate to the needs of safety practitioners. The User Guides accompanying the Toolkit provide hypothetical yet typical local or Tribal agency safety analysis scenarios and step-by-step solutions to the scenarios using materials from the Toolkit.

This report is *Improving Safety on Rural Local and Tribal Roads, Network Safety Analysis – User Guide #2*. This report presents an example scenario and step-by-step solution for studying safety conditions and identifying potential treatments at unsignalized intersections on a network. This User Guide demonstrates how to conduct network screening, select sites for further investigation, conduct safety diagnosis, select countermeasures, and prioritize and implement improvements. The User Guide provides example applications of all seven steps in the *Improving Safety on Rural Local and Tribal Roads – Safety Toolkit* (FHWA-SA-14-072): 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.

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1.0 Introduction

The Federal Highway Administration (FHWA) Office of Safety created a Safety Toolkit for Improving Rural Tribal and Local Roads (referred to hereafter as the Toolkit) to provide a step-by-step process to assist local agency and Tribal practitioners in completing traffic safety processes. Figure 1 shows the safety process outlined in the Toolkit. For each step in the process, the Toolkit includes an explanation of the step and tools, examples, guidance, and resources for learning more about each step. The process and tools presented in the Toolkit are flexible and can be applied to assist in solving any number of safety situations.

The Toolkit has been developed to provide information about how to study road safety on rural roads under the jurisdiction of local or Tribal agencies. There are many different types of staff that could be responsible for safety on local and Tribal roads, including maintenance staff, landscapers, planners, engineers, and politicians. Throughout the Toolkit and User Guides, these people are referred to 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 agency.

Figure 1. Toolkit Safety Analysis Process

What are the User Guides?

The FHWA has developed two User Guides (this document and its counterpart) to provide practitioners with examples applying the tools presented in the Toolkit. Each User Guide presents an example scenario that is typical on rural roads and example solutions to the scenario using methods presented in the Toolkit.

The User Guides' example scenarios show intended use and application of the tools for each toolkit process step. The User Guides' example solutions presented provide step-by-step procedures for practitioners to apply the methods to comparable situations in any community.

There are two User Guides:

1. **User Guide #1 – Improving Safety on Rural Local and Tribal Roads – Site Safety Analysis** describes a step-by-step analysis for conducting a site-specific safety analysis. This scenario is typical of a situation where a site of concern is identified by staff at the agency, an elected official or someone outside the agency based on crash history. *User Guide #1* demonstrates Step 1 and Steps 4 through 7 in Figure 1.
2. **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. *User Guide #2* demonstrates how to identify sites for safety improvement, diagnose conditions, implement selected countermeasures, and evaluate countermeasure effectiveness. *User Guide #2* demonstrates all of the steps in Figure 1.

This is *User Guide #2 – Network Safety Analysis*. The hypothetical scenario that follows presents a situation where the agency has decided to study safety at many locations.

User Guide #2 demonstrates how to screen and select sites for safety investigation given a large pool of sites, identify specific sites for investigation, diagnose site conditions, implement selected countermeasures, and evaluate countermeasure effectiveness. *User Guide #2* demonstrates all steps in the Toolkit process shown in Figure 1.

- Step 1 – Compile Data;
- Step 2 – Conduct Network Screening;
- Step 3 – Select Sites for Investigation;
- Step 4 – Diagnose Site Conditions and Identify Countermeasures;
- Step 5 – Prioritize Countermeasures for Implementation;
- Step 6 – Implement Countermeasures; and
- Step 7 – Evaluate Effectiveness of Implemented Countermeasures.

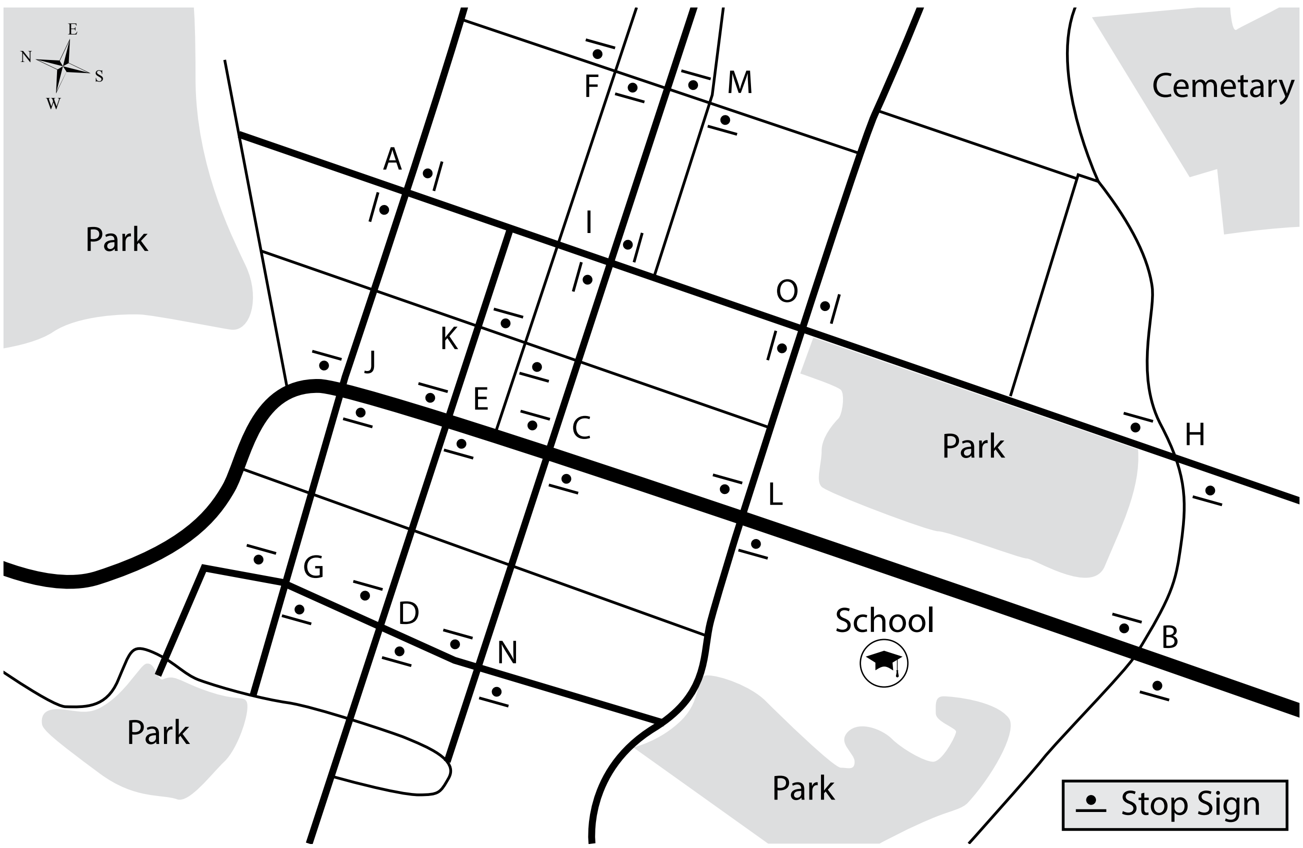
See *User Guide #1* to review an example application of tools to study safety at a preselected location.

2.0 User Guide #2 Scenario

This scenario is set in a small, rural town. The Roadway Manager in this community is responsible for approximately 50 miles of roads. About six months ago, a teenager died in a fatal car crash at an intersection in town. During the annual public works briefing regarding future road projects, one of the town commissioners asked if there are projects on the list that will improve intersection safety, or if there is a process for identifying sites that may need safety improvements. As an outcome of the discussion, the Roadway Manager was asked to develop an intersection safety plan to identify and prioritize safety improvements.

The intersection safety plan will document the evaluation of all 15 two-way stop-controlled intersections in town, identify intersections for detailed evaluation, diagnose conditions at these locations, and identify and prioritize countermeasures for implementation. Figure 2 is a schematic of the town roadway system and identifies all of the two-way stop-controlled intersections that will be evaluated.

Figure 2. Schematic of Town Roadway System



The Roadway Manager and staff have ample experience managing and maintaining the road system in their community. For studying this situation, they will:

1. Compile crash reports from the police department;
2. Conduct network screening;
3. Select sites for investigation;
4. Diagnose conditions and identify countermeasures using resources identified in the Toolkit;
5. Conduct a benefit/cost analysis to prioritize countermeasures;
6. Implement the selected treatment using guidance from national safety manuals presented in the Toolkit; and
7. Evaluate the effectiveness of the implemented treatment.

3.0 Solution

In this scenario, the Roadways Manager will be studying road safety at the two-way stop-controlled intersections in town, and identifying if anything should be implemented to address safety concerns. As such, this scenario will conduct all of the steps in Figure 1.

Step 1. Compile Data

The first step in studying the two-way stop-controlled intersections is compiling and evaluating the available data. The data available influences the type of analyses that can be conducted. Typically, the information available can be divided into anecdotal information and quantitative information.

In this scenario, the *anecdotal* information is gathered from the town commissioners and concerned residents. For many years, residents and commissioners alike have expressed concerns about vehicles making left turns onto and off of the main roads at intersections in town. While different intersections have different issues, in summary residents have expressed concerns about:

- Higher-speed vehicle through-movements making it difficult to turn left from both the minor and major street;
- Sight distance constraints making it difficult to make a turn from the minor street onto the major street; and
- Difficulty seeing intersections at nighttime.

Is Anecdotal Data Valuable?

Anecdotal data may provide information that is not shown in the crash reports. This information can be valuable in providing clues on where to start a data-driven investigation. The challenge with anecdotal data is sorting out what issues are the perceptions of safety issues versus actual addressable safety issues.

These concerns can be a good source of information and provide useful clues as to what should be studied at sites; however, this type of information should be supported with quantitative data when possible to separate perception from fact.

Table 1 shows the types of quantitative data that can be used for this type of safety analysis, and shows the data types that this scenario assumes are available. More information about sources for and how to work with each data type follows in this section.

Crash Data

Background

The crash summary data and printed crash records can be acquired from the local law enforcement agency or from the state department managing the crash data.

Local law enforcement agencies typically only hold crash records created by their officers, so crash records may be missing if there are other police agencies that have jurisdiction in the area. Only reported crashes will be in the official records. Also, most states require crashes to be reported when the dollar value of damages exceeds a minimum threshold or if there is an injury. Crashes that result in limited vehicle property damage may not be reported to police. Usually, the more severe the crash, the more likely the crash gets reported to the police.

Table 1. Quantitative Data for Safety Analysis

Type of Quantitative Data	Data Source and Format	Available in this Scenario
Crash Data	• Paper crash records from police/sheriff • Electronic crash reports from local database or state Department of Transportation (DOT)	• Spreadsheet of crash data
Average Daily Traffic Volume	• Historic traffic counts available at the agency (actual or estimated through periodic process) • Historic traffic counts available from the DOT (actual or estimated through periodic process) • New traffic counts conducted specifically for this analysis	• If needed, staff can conduct traffic counts
Roadway Characteristics	• Characteristics information from field evaluations • Aerial views from Internet-based mapping providers • As-built documents on file at the agency or state DOT	• Field evaluations and aerial views from Internet are available
Other Documents	• State Strategic Highway Safety Plan (SHSP) and/or Focus/Emphasis Area Team Plans	• The state has an SHSP in which rural intersection crashes have been identified as an emphasis area • The Roadway Manager recently attended a Highway Safety Manual Training session provided by the Local Technical Assistance Program (LTAP)

Depending on what data sources are available, compiling data may be a step that is completed before or with the network screening activity. Agencies that have data in electronic formats, such as GIS databases, can compile and report on data with little effort. As such, compiling crash summaries for every intersection in the road network is quick and easy; however, agencies that have to manually compile data may only create summary tables for locations identified in the screening step due to the effort involved.

What is a GIS Layer?

Geographic Information Systems (GIS) can be thought of as a map combined with a database. All the information contained in the database is related to a physical location contained in a map. GIS users can apply a legend or a theme to present specific data on the map as a data layer. Various layers of data items can be overlaid to visualize relationships.

Examples: A road layer can be overlaid with a land use layer, or a bridge location layer (or both), and then crash locations can be also added.

This Scenario

In this example, the Roadway Manager and staff have been maintaining a crash data spreadsheet for the town's intersections for many years. Each year, they acquire the intersection crash data from local law enforcement, and record each intersection's crash data in a spreadsheet. The type of information they record for each crash includes:

- **Type.** Angle, rear-end, sideswipe, or fixed object;
- **Severity.** Fatality, incapacitating injury, nonincapacitating injury, possible injury, or property damage only;
- **Environmental Conditions.** Day, night, dry, snowy/icy, or wet road; and
- **Driver Conditions.** Impaired or not impaired.

Crash data can be summarized from individual crash records and then all of the crash records for a given location can be summarized. Table 2 shows an example of summary details from individual crash records at one of the intersections – First Street and Main Street. Table 3 shows how all crash data for all of the locations can be summarized.

Although crash record forms vary from state to state, Table 2 shows an example of the common information that might be compiled from a crash record form. This information can provide clues to crash contributing factors in later diagnosis steps in the process.

Crash Severity KABCO System

The KABCO Scale 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 2. Subset of 2010-2012 Crash Records for Intersection of First Street/Main Street (Intersection L in Table 3)

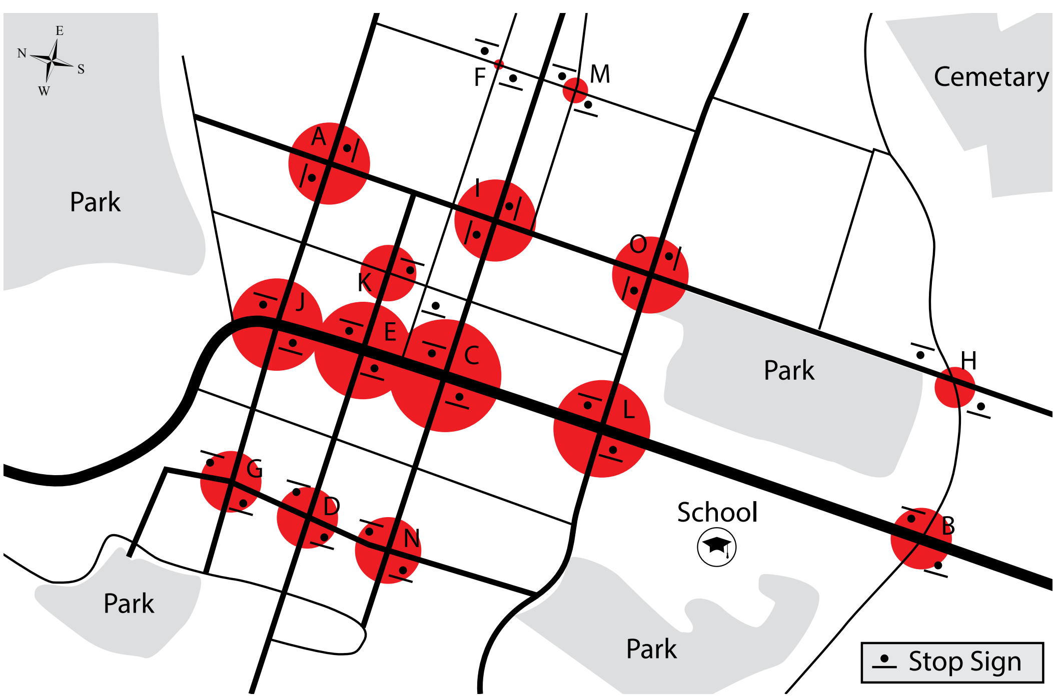
Crash ID	Year	Collision Type		Crash Severity	Collision Type	Surface Condition	Light Condition	Description
1	2010	Angle	NB Main Street to WB First Street colliding with EB First Street Vehicle	Injury – C	Angle	Dry	Daylight	Did not yield right-of-way
2	2011	Rear-end	WB First Street Approach	PDO	Rear-end	Wet	Daylight	Driving too fast for conditions
3	2012	Head-on	NB/SB Main Street through movements	Fatal	Head-on	Dry	Night	Opposing direction vehicles collided in the center of the intersection
4	2012	Angle	SB Main Street traveling to EB First Street struck by vehicle traveling NB on First Street	PDO	Angle	Dry	Daylight	Left turn from First did not see oncoming vehicles

Table 3. Intersection Crash Data Summary – 2010 to 2012

		Severity			Type						
Int	Total	Fatal	Injury	PDO	Run-Off	Single Vehicle	Angle	Head-On	Rear-End	Sideswipe	Other
A	**16**	0	6	10	2	0	7	1	4	2	0
B	**12**	1	4	7	0	1	5	1	3	1	1
C	**22**	0	9	13	3	1	9	1	5	2	1
D	**12**	0	3	9	2	0	5	1	3	1	0
E	**19**	1	6	12	2	0	8	1	5	2	1
F	**2**	0	1	1	0	0	1	0	1	0	0
G	**12**	0	5	7	1	0	5	1	3	1	1
H	**8**	0	3	5	1	0	3	1	2	1	0
I	**16**	0	7	9	2	0	7	1	4	1	1
J	**18**	1	7	10	2	0	8	1	4	2	1
K	**11**	0	5	6	1	0	5	0	3	1	1
L	**19**	1	7	11	2	0	8	1	5	2	1
M	**5**	0	2	3	1	0	2	0	1	0	1
N	**13**	0	4	9	2	0	6	1	3	1	0
O	**15**	1	7	7	2	0	6	1	4	2	0

In this scenario, a mapping tool is available; therefore, the crash data also can be summarized as demonstrated in Figure 3. This map shows total number of crashes at the two-way stop-controlled intersections in this analysis. The size of the dot is scaled to the total number of crashes at each intersection for the study period. However, as discussed in the Toolkit, a map like this could alternatively show the summary of crashes by type or severity at the study intersections, or distribution of crashes by year.

Figure 3. Map of Intersection Crashes – 2010 to 2012



Traffic Volume Data

Background

The availability of major and minor street average daily traffic (ADT) volume data allows the practitioner to conduct network screening analyses using crash rate or critical crash rate methods. Chapter 4 of the Highway Safety Manual presents these methods. However, Annual Average Daily Traffic (AADT) volumes are not always available because of the expense of a regular traffic counting program. For most studies, ADT collected at the study sites on any day is used to estimate AADT.

Often, the ADT at intersections is converted to Total Entering Volume (TEV). The TEV is the sum of all traffic entering an intersection. TEV of the study intersections can be mapped using a GIS database or can be summarized in a table.

This Scenario

For this network screening scenario traffic volume data will not be used.

Consideration When Applying Crash Rate Network Screening Method

Crash rate network screening is useful because:

- It is based on data that is relatively easy to acquire – traffic volume and crash data;
- It is easy to calculate – crashes divided by traffic volume; and
- It makes it possible to compare safety performance of locations.

However, if multiple sites have the same number of crashes, the lower volume locations will always show higher crash rates. So, crash rates should only be used to compare sites with traffic volumes in the same range.

Roadway Characteristics

Background

As described in the Toolkit, roadway characteristics data may be available in-house from the engineering team, or externally from the state DOT roadway databases or as-built drawings, on-line mapping tools such as Google Street View™ mapping service and/or site field visits. To the greatest extent possible, a site visit should always be part of the safety analysis process.

The types of roadway characteristics that can be collected in the field site visit are:

- Number of and type of vehicle lanes;
- Adjacent land use and driveways;
- Presence of bike lanes;
- Presence of sidewalks;
- Type of intersection control;
- Sight distance; and
- Posted speed limits.

More information about the type of roadway characteristics data to collect is included in Step 1 of the Toolkit.

This Scenario

Intersection characteristics information will be used in this scenario as part of the site investigation and diagnosis. The type of information that will be used includes:

- **Lanes.** Number of lanes approaching each leg of the intersection and number of turning lanes at the intersection (e.g., number of left-turn lanes, number of through-lanes, and number of right-turn lanes).
- **Traffic Control.** All study intersections have stop-control on the lower volume (i.e., minor) approach to the intersection. Traffic on the higher volume (i.e., major) approach to the intersection does not stop when traveling through the intersection.
- **Speed Limits** on both streets.
- **Crosswalks.** Availability of crosswalks at the intersection.
- **Driveways and Access Control** in the vicinity of the intersection.

Table 4 demonstrates how this type of information might be summarized in a table and what this data set might look like for a subset of intersections from Table 3.

Table 4. Roadway Characteristics

	Approach Lanes		Lane Configurations		Crosswalks (North, South/East, West)	Driveways within 250 Feet of Intersection	
Intersection	Major Street	Minor Street	Major Street – Lane Configuration (Lt/Th/Rt)	Minor Street – Lane Configuration (Lt/Th/Rt)	Yes (Y)/ No (N)	Major Street	Minor Street
A	1	1	Lt-Th-Rt	Lt-Th-Rt[b]	(Y, Y/N, N)	1	1
B	2	1	Lt/Th-Rt[a]	Lt-Th-Rt	(Y,Y/Y, Y)	3	2
C	2	1	Lt/Th-Rt	Lt-Th-Rt	(N, N/N, N)	0	1
D	1	1	Lt-Th-Rt	Lt-Th-Rt	(Y, Y/Y, Y)	2	1
E	2	1	Lt/Th-Rt	Lt-Th-Rt	(Y, Y/N, N)	3	1

[a] *Lt/Th-Rt – Both directions of the approach to the intersection are striped with one left-turn lane and one combined through and right-turn lane.*

[b] *Lt-Th-Rt – Both directions of the approach to the intersection are striped with one lane to accommodate left turns, through movements, and right turns.*

Table 4 includes information about the number of driveways within 250 feet of the intersection. Depending on traffic volume and pedestrian and bicycle traffic, often as the number of driveways increases, rear-end crashes will increase with the amount of activity along and across the roadway. So, the number of driveways can be useful in understanding crash contributing factors near intersections. This information is not often collected and maintained in a database, but it can be collected using recent aerial photos, an on-line tool like Google Street View™ mapping service or during the field visits.

Other Documents

Background

Finally, there may be other agency-specific or statewide documents that contain information useful for the analysis. For example, the state SHSP may contain information about the characteristics of intersection crashes in state and preferred actions to address these strategies. Additionally, if the state is an intersection focus state, the state DOT may have an intersection plan that can be useful in providing information on identifying and addressing intersection safety issues.

This Scenario

The state's SHSP has identified that intersection crashes are a focus area. As such, there are strategies and actions available to assist with addressing intersection crashes. The following are some of these strategies and actions:

- Implement geometric improvements;
- Increase awareness of safety issues at intersections;
- Improve operating characteristics of intersections to reduce conflicts – possibly through signing and pavement marking modifications;
- Follow the principles of access management at intersections; and
- Conduct intersection enforcement.

The state also recently provided Highway Safety Manual training that included information about network screening. This information was drawn largely from the FHWA Highway Safety Manual training available on-line (http://safety.fhwa.dot.gov/hsm/training/).

Step 2

Step 2. Conduct Network Screening

When applying any network screening program, it is often useful to apply more than one network screening method to compare and contrast the results and draw yet more conclusions from the findings. Based on the data and resources available, this example scenario applied frequency-based and equivalent property damage-only (EPDO) network screening methods. Step 2 of the Toolkit provides more information about this and other network screening methods.

Threshold of Performance

A challenge with frequency-based network screening is that there are no specific indications as to whether the observed crash frequencies should be considered high, typical, or low for the particular study intersection group. There is no threshold or performance measure that says if the frequency is greater than *x*, the site has potential for safety improvement.

Network Screening Using Crash Frequency

Background

Crash frequency is one of the most basic network screening methods. In this method, the intersections are grouped, evaluated, and compared according to categories of traffic control; number of approach legs; and traffic volume range (e.g., higher-volume intersections separated from lower-volume intersections). For example, a network screening program could consider all three-legged signalized intersections in one group, and all four-legged two-way stop-controlled intersections in another group (as in this scenario).

The crash frequency measure is the total number of crashes over the analysis period or average number of crashes per year for the study intersections. The intersections are ranked from highest to lowest total crash frequency over the analysis period or average crash frequency per year. The crash frequency measure can be applied to total crashes, fatal and serious injury only crash severities, or by a particular crash type.

This Scenario

Table 5 illustrates how intersections could be ranked according to crash frequency. The sites are ordered by total crash frequency; the severity data is provided for reference.

Crash Rate Analysis

If traffic volumes at the intersections were available, a crash rate analysis could also be conducted. Crash rate (crashes divided by traffic volume) could be conducted on total crashes, fatal and serious injury only crashes, or a particular crash type.

If using crash rates, be sure to subdivide the sites into categories with comparable traffic volumes. For example:

- Category 1 – less than 1,000 ADT;
- Category 2 – 1,000 to 5,000 ADT; and
- Category 3 – greater than 5,000 ADT.

Table 5. Two-Way Stop-Controlled Intersections Ranked by Crash Frequency and Severity – 2010 to 2012

Intersection	Total	Severity		
		Fatal	Injury	PDO
C	**22**	0	9	13
L	**19**	1	7	11
E	**19**	1	6	12
J	**18**	1	7	10
A	**16**	0	6	10
I	**16**	0	7	9
O	**15**	1	7	7
N	**13**	0	4	9
D	**12**	0	3	9
G	**12**	0	5	7
B	**12**	1	4	7
K	**11**	0	5	6
H	**8**	0	3	5
M	**5**	0	2	3
F	**2**	0	1	1

Network Screening Using Equivalent Property Damage-Only Method

Background

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 to develop an equivalent 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 can be selected for investigation.

The major steps in this method are:

- **Compile crash severity cost data.** The Highway Safety Manual provides the following crash costs by crash severity:

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

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

Step 2

- **Calculate the severity weighting factors:**

  The crash severity weighting factors are calculated as a function of the PDO crash cost. The fatal EPDO weighting factor is:

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

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

$$Fatal\ Crash\ Weighting\ Factor = 541.7$$

  The injury EPDO weighting factor is:

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

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

$$Injury\ Crash\ Weighting\ Factor = 11.2$$

  The property damage only (PDO) weighting factor is:

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

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

$$PDO\ Crash\ Weighting\ Factor = 1.0$$

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

$$= (\text{Fatal Weighting Factor} \times \text{Fatal Crashes}) + (\text{Injury Weighting Factor} \times \text{Injury Crashes}) + (\text{PDO Weighting Factor} \times \text{PDO Crashes})$$

  For example, the EPDO score at Intersection A is:

$$EPDO = (541.7 \times 0) + (11.2 \times 6) + (1 \times 10)$$

$$EPDO = 0 + 67.2 + 10$$

$$EPDO = 77.2$$

This Scenario

Table 6 shows the EPDO score for each intersection. Ranked by EPDO, the top three intersections are Intersections L, J, and O; however, ranked by frequency the top three intersections are C, L, and E (see again Table 5).

Table 6. Two-Way Stop-Controlled Intersections Crashes Ranked by EPDO – 2010 to 2012

	Severity				
Intersection	Fatal	Injury (A-C)	PDO	Total	EPDO
L	1	7	11	19	631
J	1	7	10	18	630
O	1	7	7	15	627
E	1	6	12	19	621
B	1	4	7	12	593
C	0	9	13	22	113
I	0	7	9	16	87
A	0	6	10	16	77
G	0	5	7	12	63
K	0	5	6	11	62
N	0	4	9	13	54
D	0	3	9	12	42
H	0	3	5	8	38
M	0	2	3	5	25
F	0	1	1	2	12

Network Screening Using Systemic Analysis

Background

Systemic Analysis is another approach for network screening that is useful in the rural local and Tribal context. In the scenario presented here, the practitioner is evaluating safety conditions at spot-specific locations. The systemic approach analyzes crash history on an aggregate basis to identify:

- Facility types that have similar high-risk roadway characteristics;
- Countermeasures to address the roadway characteristics; and
- A prioritized implementation plan.

A systemic safety approach works by identifying which roadway characteristics (such as road width, shoulder width, posted speed, intersection control, urban or rural environment, or number of intersection approaches) are included at a large proportion of the road network's crash sites. 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.

The major steps 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.

Step 2

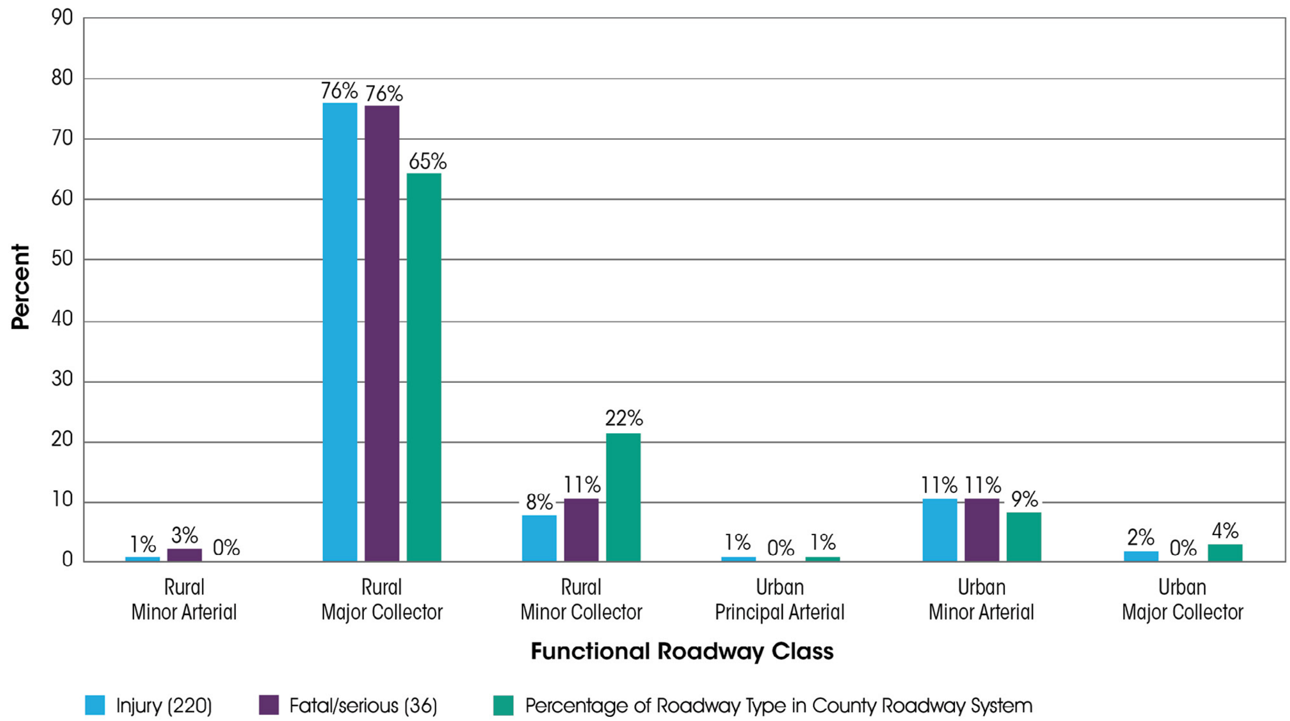
- **Screen and prioritize candidate locations:**
  - Identify network characteristics to analyze;
  - Conduct risk assessment; and
  - Prioritize focus characteristics.
- **Select countermeasures:**
  - Assemble comprehensive list of countermeasures;
  - Evaluate and screen countermeasures; and
  - Select countermeasures for deployment.
- **Prioritize projects:**
  - Create a decision process for countermeasure selection;
  - Develop safety projects; and
  - Prioritize project implementation.

The FHWA Systemic Safety Project Selection Tool, published in 2013, thoroughly describes these steps. See the resources section for more information.

As an outcome of a systemic analysis the agency will be able to understand roadway and roadside features that show higher risk than other features, have a list of treatment types that can potentially address risk, and have a list of sites for potential treatment.

For example, Figure 4 is taken from the FHWA Systemic Safety Project Selection Tool. In this case study, Thurston County Public Works in Washington State compared the proportion of severe curve-related roadway departure crashes on various functional classifications of roadways to the proportion those functional classifications represent of the entire County roadway system. The data show that the focus crash type – roadway departure crashes – occurs on roadways with a Rural Major Collector functional classification in a greater proportion than this roadway type represents for the County system. Based on this descriptive statistics analysis, Thurston County chose Rural Major Collector functional classification as a risk factor.

Figure 4. Evaluation of Roadway Functional Class as a Potential Risk Factor



Source: FHWA.

At the conclusion of this step, it would be useful to start the process of documenting the project analysis. An example document outline through this stage of the analysis is shown below.

Introduction

- Description of concerns; and
- Description of approach to analyzing conditions.

Data Collection and Evaluation

- Description of the data collected and summary of the data:
  - Crash data tables;
  - Traffic volume data;
  - Roadway characteristics summary or sketches; and
  - Other agency-specific or statewide documents.

Network Screening Results

- Summary of crash frequency network screening method and site ranking results; and
- Summary of EPDO network screening method and site ranking results.

Step 3. Select Sites For Investigation

Background

In this step, a subset of the sites evaluated in the network screening process is selected for detailed investigation. Step 3 of the Toolkit provides more information about the process and reasons for selecting or not selecting sites for more detailed investigation.

Sites can be eliminated from the remainder of the analysis for a variety of reasons, including:

- Recent construction at the site has modified conditions that may make the crash record nonrepresentative of current conditions;
- The screening results do not indicate a need to study the site in more detail;
- The issues and potential solutions for the site already are known, and documented elsewhere, and/or there already are plans to address the issues; and
- The issues at the site are known and potential solutions are cost prohibitive. No improvements can be implemented until funding is acquired and programmed.

Alternatively, sites can be selected for analysis if future development or construction is anticipated that could substantively change conditions. In this case, the site could be investigated for enhancements to implement with other upcoming changes.

This Scenario

Table 7 shows crash severity, total crash frequency, and the EPDO score for each intersection. The table also shows which intersections were selected for more detailed investigation and why. As shown, of the 15 sites included in the stop-controlled intersection safety plan, three have been selected for more detailed site investigation:

- Intersection L, because it has the highest EPDO score, a high crash frequency, and one of the fatal crashes;
- Intersection O, because it has a high EPDO score, high crash frequency, and one of the fatal crashes; and
- Intersection E, because it has a high EPDO score, high crash frequency, and one of the fatal crashes.

Note that even though Intersection J has a high EPDO score, high crash frequency, and one of the fatal crashes, it was **not** selected for investigation because there already are plans to signalize the intersection – this should address the issues at this location.

Intersection B was **not** selected for analysis either. It has a relatively high EPDO, and one of the fatalities occurred here. However, the issues at the location are known and have been previously studied.

In the next phase of the analysis, each of the selected sites will be studied in more detail to understand crash characteristics, potential contributing factors, and to identify possible countermeasures.

Table 7. Network Screening Results and Site Selection for Further Investigation

Int	Severity			Total	EPDO	Selected for Detailed Investigation?
	Fatal	Injury	PDO			
L	**1**	**7**	**11**	**19**	**631**	**Yes – High frequency and high EPDO score.**
J	1	7	10	18	630	No – Community already has plans to signalize this intersection in next fiscal year. No need for further investigation at this time.
O	**1**	**7**	**7**	**15**	**627**	**Yes – High frequency, severity, and high EPDO score.**
E	**1**	**6**	**12**	**19**	**621**	**Yes – High frequency, severity, and high EPDO score.**
B	1	4	7	12	593	No – Issues at the site are known and solutions have been identified previously; however, funding is not available for the preferred solution. No action until funding can be programmed.
C	0	9	13	22	113	No – Although frequency is high, severity is low, and the EPDO score is low.
I	0	7	9	16	87	No – Low severity and low EPDO.
A	0	6	10	16	77	No – Issues have been previously identified and sight distance maintenance is planned beginning next fiscal year.
G	0	5	7	12	63	No – Frequency and severity are low.
K	0	5	6	11	62	No – Frequency and severity are low.
N	0	4	9	13	54	No – Frequency and severity are low.
D	0	3	9	12	42	No – Frequency and severity are low.
H	0	3	5	8	38	No – Frequency and severity are low.
M	0	2	3	5	25	No – Frequency and severity are low.
F	0	1	1	2	12	No – Frequency and severity are low.

Step 3

At the conclusion of this step, the practitioner should continue documenting the analysis results and the reasons for selecting sites for detailed investigation. At this stage, there is an additional step to the document outline – Site Selection for Detailed Investigation.

Introduction

- Description of concerns; and
- Description of approach to analyzing conditions.

Data Collection and Evaluation

- Description of the data collected and summary of the data:
  - Crash data tables;
  - Traffic volume data;
  - Roadway characteristics summary or sketches; and
  - Other agency-specific or statewide documents.

Network Screening Results

- Summary of crash frequency network screening method and site ranking results; and
- Summary of EPDO network screening method and site ranking results.

Site Selection for Detailed Investigation

- Summary of method of identifying sites for detailed investigation and documentation of sites selected for investigation.

Step 4. Diagnose Site Crash Conditions and Identify Countermeasures

Diagnosis

Background

In this step, the sites identified for further evaluation are studied in more detail. The purpose of the detailed analysis at this stage is to identify potential crash contributing factors and identify potential treatments to address the identified safety concerns. The diagnosis steps and methods for identifying countermeasures are the same for each site under investigation. The issues and results of the analysis differ by site; however, the process for conducting this analysis does not change. Therefore, in this example, the process of diagnosis and selecting countermeasures is shown for one intersection only: Intersection L – First Street and Main Street. In practice, this process would be repeated for each site selected for detailed analysis identifying specific solutions for each site.

The Toolkit provides many different resources and tools for site diagnosis and countermeasures selection. A field visit is a very important step in conducting a site diagnosis. As described in the Toolkit, the field visit should be conducted in daylight and, if possible, under dark conditions. The field visit also could be conducted in the context of a Road Safety Audit (RSA), as described in the Toolkit.

Three tools that are integrated into field visits and RSAs and are useful in identifying potential crash contributing factors and countermeasures are collision diagrams, condition diagrams, and the Haddon Matrix. These tools are described below.

This Scenario

In this scenario, collision diagram, site condition diagram, and Haddon Matrix are developed for Intersection L (Main Street and First Street). These tools can be similarly applied for all intersections selected for detailed site investigation.

Table 8 shows the crash type summary table for Intersection L. Figure 5 shows the collision diagram for Intersection L.

Field Visit

It is important for the analyst to make a field visit if possible. They should view the site first hand and observe traffic and other features that data or photos alone cannot convey.

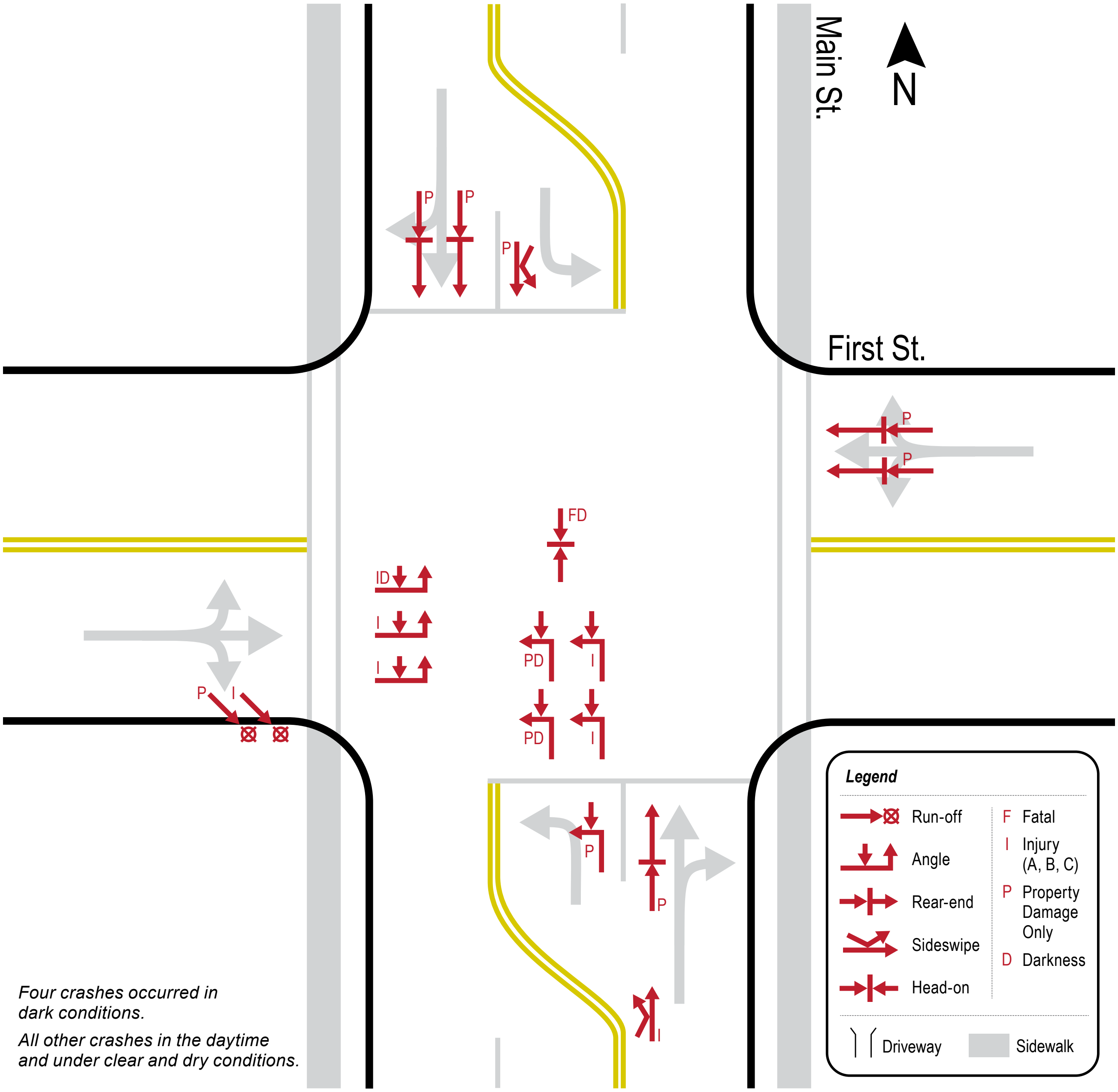
The type of data collected during a site visit should include number of lanes, lane width, shoulder width and shoulder type, sight distance where it appears limited, posted speed limit, and other signage. Videotape or photographs are also very helpful in documenting conditions.

A nighttime field visit is very important to evaluate the signing and pavement marking in dark conditions. The RSA Guidebook and Highway Safety Manuals have prompt lists that can assist in field visit data collection. See the Toolkit for more information on these resources.

Table 8. Intersection L: Crash Type Summary – 2010 to 2012

	Total (2010-2012) Crashes	Crash Type						
		Run-Off	Single Vehicle	Angle	Head-On	Rear-End	Sideswipe	Other
Int. L	19	2	0	8	1	5	2	1

Figure 5. Collision Diagram for Intersection L (First Street and Main Street) – 2010 to 2012



Reviewing the table and the diagram shows:

- Angle crashes are the most common crashes. Three occurred at the eastbound approach to the intersection and five occurred at the northbound approach to the intersection.
- Rear-end crashes are the next most common crashes. In the three-year period, there were five rear-end crashes. The rear-end crashes occurred at the northbound, southbound, and westbound approach to the intersection.

- The most severe crash was the head-on collision which resulted in a fatality. This crash also occurred at nighttime (without illumination).
- Both run-off-road crashes occurred at the eastbound approach to the intersection.

Figure 6 shows the site condition diagram. As shown, during the field review, staff noted that the intersection approaches have thick vegetation on the northwest and southeast corners of the intersections and there is no illumination on all four intersection corners. Furthermore, the intersection is at the crest of the vertical curve along the Main Street alignment. There also are two driveways off First Street – a residential driveway off westbound First Street located 50 feet east of the intersection, and a school driveway off eastbound First Street located 100 feet west of the intersection.

Figure 6. Condition Diagram for Intersection L (First Street and Main Street)

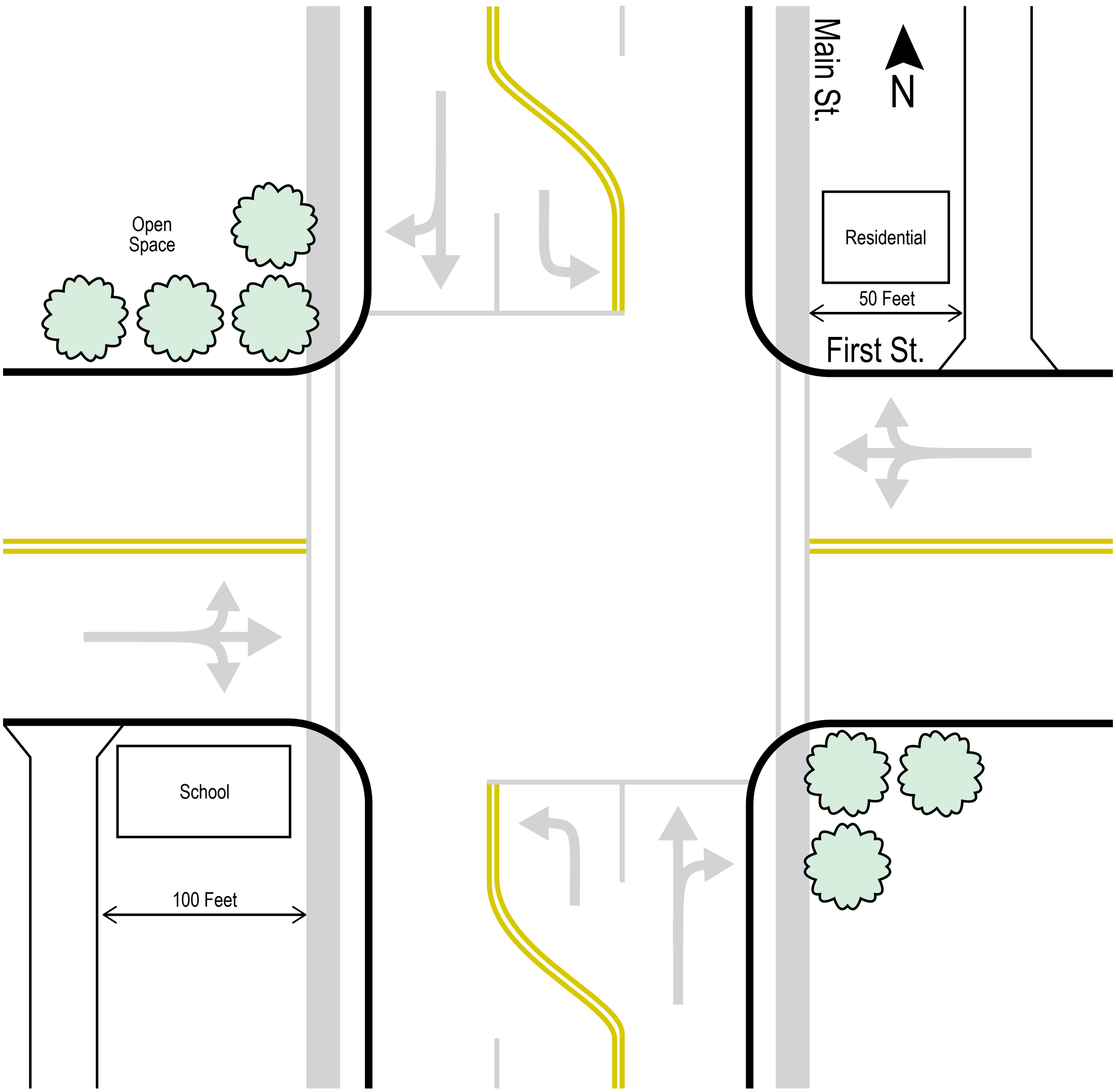


Table 9 shows the Haddon Matrix developed from the study intersection's crash records. As described in the Toolkit, the Haddon Matrix provides a framework for reviewing crash records and understanding potential contributing factors in the context of the time of events: before the crash, during the crash, and after the crash. The time of events is divided into the three major categories of contributing factors: the human, the vehicle, or the environment. For the most part, information and clues for the type of engineering solutions that might be useful can be drawn from the physical environment column.

Table 9. Haddon Matrix for Intersection L (First Street and Main Street)

Time of Events	Human	Vehicle/Equipment	Physical Environment
Precrash	• Poor vision, speeding • Risk-taking, follow too closely • Cell phone use • Failure to stop completely at stop sign	• Failed brakes • Malfunctioning headlight	• Vegetation/trees blocking sight distance as drivers approach the intersection • No streetlights at the intersection • High left-turn volumes from Main Street onto First Street
Crash	• Failure to use seat belt • Poor reaction time • Driving under the influence of alcohol	• Seat belt and airbag malfunction	• Low-friction pavement surface
Postcrash	• Crash victim had previous medical condition		NA

This Scenario

The field visit, crash data summary, and evaluation, collision diagram, condition diagram, and Haddon Matrix show:

- In the three-year period from 2010 to 2012, there have been 19 crashes at the intersection of First Street and Main Street, 8 of these are angle crashes. There has been 1 fatal collision at the intersection.
- Of the 19 crashes, 3 occurred at night with no streetlights.
- The collision diagram indicates that angle crashes are occurring between motorists turning from eastbound First Street onto Main Street, and motorists turning from northbound Main Street onto First Street.
- The angle crashes occurring from northbound Main Street onto westbound First Street may be caused by difficulty in judging gaps in southbound Main Street traffic flow – possibly due to the crest vertical curve.
- The condition diagram shows trees and shrubs within close proximity of the intersection's northwest and the southeast corners. This is possibly creating a sight distance constraint for motorists turning from eastbound First Street onto northbound Main Street.

Based on this summary, the left turn crashes from eastbound First Street onto Main Street and northbound Main Street onto First Street are the most critical and concerning; therefore, safety treatments will focus on reducing frequency and severity of these angle crashes.

Identify Countermeasures

Background

The resources available to identify countermeasures are summarized in Step 4 of the Toolkit. These resources are the same whether one site or many sites are being investigated: the web-based CMF Clearinghouse, Part D of the Highway Safety Manual, the NCHRP 500 Reports, and the FHWA Office of Safety Proven Countermeasures web page. Step 4 of the Toolkit provides detailed information about each of these resources. This scenario uses the CMF Clearinghouse and the Highway Safety Manual as resources for identifying possible countermeasures to address angle crashes at the intersection.

This Scenario

Table 10 shows countermeasures identified as possible treatments to address the scenario's turning movement and nighttime crashes. The potential countermeasures address sight distance constraints, lighting concerns, and angle crashes. The table also shows the CMF values and construction costs estimates[1] for the countermeasures.

Summary of Crash Modification Factors (CMF)

A CMF is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site. The CMF is multiplied by the expected crash frequency without treatment to show the expected crash frequency with the 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 after implementation of a given countermeasure. For example, a CMF of 0.8 indicates an expected safety benefit; specifically, a 20 percent expected reduction in crashes. A CMF of 1.2 indicates an expected degradation in safety; specifically, a 20 percent expected increase in crashes.

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

[1] Construction costs for these countermeasures are based on 2013 average unit price for Michigan Department of Transportation.

Table 10. Countermeasures Identified for Intersection L (First Street and Main Street)

Contributing Factor	Countermeasure	CMF	Cost[a]	Source
Vegetation/ trees limiting sight distance as drivers approach the intersection	Clear sight triangles at the northwest corner of intersection	• 0.44 – Fatal Crashes • 0.53 – Serious and Minor Injury Crashes • 0.89 – PDO Crashes	• $3,800 to $4,500 per acre	CMF Clearinghouse
Dark intersection with no street lights	Provide intersection illumination	• 0.62 – Nighttime Serious and Minor Injury Crashes • 0.23 – All Crash Types – Fatal Crashes • 0.5 – All Crash Types – Serious and Minor Injury Crashes • 0.52 – All Crash Types – PDO Crashes	• 30-foot light with 15-foot arm and concrete foundation: $2,900 each • $50 per month of operating cost	CMF Clearinghouse
High left-turn volumes from northbound Main Street and eastbound First Street	Convert intersection from stop-controlled to signal-controlled[b]	• 0.56 – All Crash Types – All severities	• Box span, pedestrian timer, and update crosswalk markings: $115,000 • $50 per month operating cost	Highway Safety Manual

[a] *Costs are for illustrative purposes only and should not be used for any jurisdiction-specific calculations.*

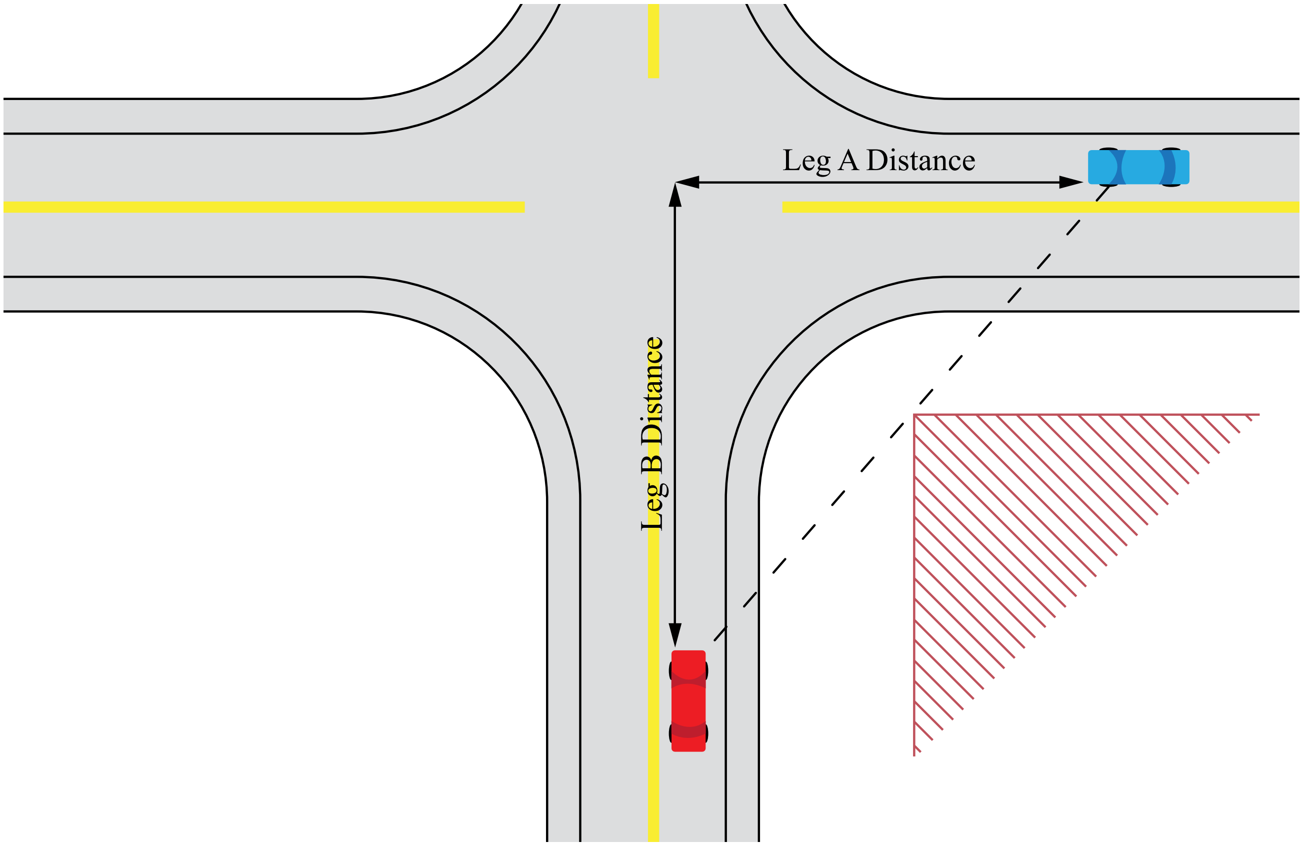
[b] *Subject to meeting MUTCD warrants.*

Vegetation Control. Through vegetation control, maintenance staff can remove plants, clear tree branches, and trim brushes that block a driver's line of sight at an intersection. Drivers approaching an intersection need a clear line of sight to the intersection and along the crossing roadway to perceive and react to potential conflicting vehicles, bicyclists, and/or pedestrians. The sight lines required for drivers to see approaching traffic form a sight triangle over an intersection corner, as shown in Figure 7.

Intersection Illumination. Intersection illumination can provide lighting for drivers, pedestrians, bicyclists, and other road users to see each other approaching the intersection. Streetlights also can illuminate intersection characteristics for users such as signage, striping, and shoulder. In rural situations, intersection illumination can act as a point of reference or landmark for drivers so they can see the intersection that they are approaching well in advance of their arrival. This helps in navigation.

Signalization. A traffic signal warrant is an analysis used to determine whether conditions warrant traffic signal installation at an intersection. If traffic signal warrants are met, converting an intersection from stop-controlled to signal-controlled provides specific signal phases for turning and through vehicles at the intersection, thereby reducing the number of possible collisions. The Manual on Uniform Traffic Control Devices (MUTCD) should be used to conduct the traffic signal warrant analysis.

Figure 7. Intersection Sight Distance Triangle



Source: Vegetation Control for Safety, A Guide for Local Highway and Street Maintenance Personnel, FHWA Office of Safety.

When choosing a CMF for a particular countermeasure, it is common to have to select one value among many. To select a CMF, the practitioner should consider:

- The quality of the research in calculating the CMF;
- Consistency between the site under investigation and site/research conditions provided in the research description of the CMF; and
- Crash severity or crash type under investigation.

For example, as shown in Figure 8 the CMF Clearinghouse provides six different CMFs for the countermeasure "Increase Triangle Sight Distance." Differences in these CMFs include:

- Variation in star quality ratings (quality of research);
- Application to specific crash severities (i.e., fatal, severe injury, or PDO); and
- Application to specific area types (e.g., roundabouts or stop-controlled intersections).

The practitioner will have to review the Clearinghouse's detailed information to select conditions most applicable to the site under investigation. In this example, Table 10 also shows the three sight distance triangle CMFs with the highest star rating and most applicable to our site conditions.

Figure 8. Increase Sight Distance Triangle From CMF Clearinghouse

Countermeasure: Increase triangle sight distance

CMF	CRF(%)	Quality	Crash Type	Crash Severity	Area Type	Reference	Comments
0.53	48	★★★☆☆	All	Serious injury,Minor injury	Not specified	Elvik, R. and Vaa, T., 2004	
0.89	11	★★★☆☆	All	Property damage only (PDO)	Not specified	Elvik, R. and Vaa, T., 2004	
0.44	56	★★★☆☆	All	Fatal		Rodegerdts et al., 2004	
0.63	37	★★★☆☆	All	Serious injury,Minor injury		Rodegerdts et al., 2004	
1.3	-30	★☆☆☆☆	All	Serious injury,Minor injury	Not specified	Elvik, R. and Vaa, T., 2004	
1.29	-29	★☆☆☆☆	All	Property damage only (PDO)	Not specified	Elvik, R. and Vaa, T., 2004	

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

At the conclusion of this step, the agency will have identified potential countermeasures for each site selected for investigation in Step 3. At this stage, the project documentation could be updated to include the diagnosis results and selection of potential countermeasures. An example of the documentation outline is shown below.

Introduction

- Description of concerns; and
- Description of approach to analyzing conditions.

Data Collection and Evaluation

- Description of the data collected and summary of the data:
  - Crash data tables;
  - Traffic volume data;
  - Roadway characteristics summary or sketches; and
  - Other agency-specific or statewide documents.

Network Screening Results

- Summary of crash frequency network screening method and site ranking results; and
- Summary of EPDO network screening method and site ranking results.

Site Selection for Detailed Investigation

- Documentation of sites selected for detailed investigation.

Diagnose Results and Selection of Countermeasures

- Summary of existing site conditions, crash, and roadway characteristics; and
- Summary of analysis and countermeasures selected for possible implementation.

Step 5. Prioritize Countermeasures for Implementation

Background

The purpose of the countermeasure evaluation and prioritization step is to review the potential countermeasures and select the most feasible countermeasure for the site under investigation. The process for prioritizing and selecting countermeasures among a number of optional countermeasures for one site can range from a quantitative benefit/cost analysis to a qualitative rating process using high, medium, and low (or good, fair, poor ratings), or a hybrid of both.

The criteria that influence the quantitative or qualitative analysis will vary from agency to agency. Some typical criteria are:

- Environmental impacts;
- Construction costs;
- Stakeholder input and community preferences;
- Maintenance costs;
- Anticipated safety effectiveness;
- Right-of-way availability; and
- Consistency with other community plans and goals.

Step 5 of the Toolkit and *User Guide #1* provide an example of a countermeasure selection process applying a qualitative ranking process.

This User Guide uses a quantitative benefit/cost analysis to identify the most feasible treatment at the site. Conceptually, in a benefit/cost analysis, the benefits and costs of implementing a countermeasure are converted to a present-year dollar value. The total present dollar value of the benefits is divided by the total present dollar value of the costs. If the ratio exceeds 1.0, the treatment is considered economically feasible. The higher the benefit/cost ratio, the greater the value of the project under consideration. Step 5 of the Toolkit presents more information about benefit/cost analysis.

This Scenario

The calculation steps for benefit/cost ratio are the same for all countermeasures; although actual benefits and costs of each countermeasure vary. As such the benefit/cost ratio calculations for only one of the three possible countermeasures identified for Intersection L – Main Street and First Street – vegetation control is shown. Table 11 summarizes the results of the all three B/C calculations.

The major steps in this benefit/cost analysis are:

1. **Estimate the potential annual savings in crashes by severity that can be attributed to clearing vegetation and maintaining sight distance.**
    a. Calculate existing annual crashes per year by crash severity.
        i. The crash diagram in Figure 5 showed three angle crashes from 2010 to 2012, which are likely to respond to vegetation control in the northeast corner of the intersection.

ii. Crashes per year that may respond to the treatment:

- $Crashes\ per\ year = \frac{3\ Angle\ Crashes}{3\ Years}$
- $Crashes\ per\ year = 1$

b. Calculate possible annual crashes per year by severity after clearing sight triangles.

i. All three angle crashes were injury crashes. There were no fatal or property damage-only crashes.

ii. The number of injury crashes per year that may respond to the improvements:

- $Injury\ crashes\ per\ year = \frac{3\ Injury\ Crashes}{3\ Years}$
- $Potential\ injury\ crashes\ per\ year\ saved = 1$

2. **Estimate the savings in crashes per year by severity.**

Vegetation Control CMF by Severity	CMF
Fatal Crash	0.44
Injury Crash	0.53
PDO Crash	0.89

a. The number of crashes per year by severity that can be potentially saved by clearing and maintaining sight distance at the intersection is equal to:

$$\begin{aligned} &Potential\ change\ in\ the\ number\ of\ injury\ crashes\ per\ year \\ &\quad = The\ number\ of\ existing\ injury\ crashes\ per\ year \\ &\quad - CMF\ for\ injury\ crashes \\ &\quad \times The\ number\ of\ existing\ injury\ crashes\ per\ year \end{aligned}$$

$$Potential\ change\ in\ the\ number\ of\ injury\ crashes\ per\ year = 1 - 0.53 \times 1$$

$$Potential\ change\ in\ the\ number\ of\ injury\ crashes = 0.47$$

b. There are no fatal or property damage-only crashes at the intersection that may be avoided with clearing and maintenance of sight distance.

3. **Calculate the net present value of the crash benefits of clearing and maintaining sight distance triangles.**

a. Convert the estimated savings in crashes per year by severity from crash frequency to a dollar value per year. From the Highway Safety Manual, Chapter 7 the societal cost of crashes is as follows:

i. Fatal (K) = $4,008,900;

ii. Injury (A, B, and C) = $82,600; and

iii. PDO (O) = $7,400.

Societal Cost

There are costs to society of a death or injury occurring in a crash. Costs include (defined by National Safety Council): wage and productivity losses, medical expenses, administrative expenses, motor vehicle damage, and employers' uninsured costs.

Step 5

$$Potential\ change\ in\ the\ number\ of\ injury\ crashes = 0.47$$

$$Cost\ of\ an\ injury\ crash = \$82{,}600$$

$$\begin{aligned} &Potential\ crash\ cost\ savings\ per\ year \\ &\quad = cost\ of\ injury\ crash \\ &\quad \times change\ in\ the\ number\ of\ injury\ crashes\ per\ year \end{aligned}$$

$$Potential\ crash\ cost\ savings\ per\ year = \$82{,}600 \times 0.47$$

$$Potential\ crash\ cost\ savings\ per\ year = \$38{,}822\ per\ year$$

If there were crashes with other severity types, the potential savings per year would be calculated in a similar fashion: the dollar value of the crash severity type multiplied by the potential savings in crash severity type per year.

b. Estimate the duration of effectiveness of the improvement.

   i. In this scenario, assume the sight distance triangle would be cleared and maintained for 20 years.

c. Calculate the net present value of the benefits of clearing the sight triangle. Net present value is the value of benefits or costs in a "future" year recalculated to a "present" value in the current year. So in this scenario, there are 20 years of potential benefits and 20 years of costs. The "net present value" is the sum of each present value of the benefits over 20 years or the sum of each of the present value of costs over 20 years.

This step calculates the net present value factor for calculating the potential benefits in every year. The equation for net present value factor is:

$$Present\ value\ in\ year\ Y = \frac{(1.0 + i)^{(y)} - 1.0}{i \times (1.0 + i)^{(y)}}$$

i = Minimum attractive rate of return or discount rate (this scenario assumes a return rate of 4 percent or *i* = 0.04)

y = Year in the service life of the countermeasure, one calculation for each year of life.

For example, in Year 10, the present value factor is:

$$Present\ value\ in\ year\ 10 = \frac{(1.0 + 0.04)^{(10)} - 1.0}{0.04 \times (1.0 + 0.04)^{(10)}}$$

Table 11 shows the present value of the benefits and costs for each year of effectiveness of the vegetation control. As shown, saving $38,822 (today's dollars) in injury crashes per year in Year 10 has a present value of $314,881.

4. **Calculate the net present value of the costs of clearing and maintaining sight distance at the intersection for 20 years.**

a. Calculate the annual costs of maintaining sight distance at the northwest corner of the intersection for 20 years.

Step 5

b. Calculate the net present value of the costs of clearing and maintaining the sight distance at the intersection for 20 years.

This scenario assumes it costs $4,500 per acre to clear sight triangles plus $500 per year to maintain conditions. This scenario further assumes that every third year, the more expensive sight distance maintenance will be required. These costs are for this example only and should not be applied to any jurisdiction-specific analyses. In this scenario it is necessary to clear one-half acre of vegetation from the northwest corner of the intersection.

Table 11 also shows the net present value of the costs to maintain sight distance at the intersection for 20 years. As shown, the present value of spending $2,750 in Year 10 is $22,305; and the total net present value for all 20 years to maintain sight distance is $200,548.

Table 11. Summary of Benefit/Cost Analysis for Vegetation Control for Intersection L (First Street and Main Street)

Year	Fatal	Injury A-C	PDO	Total Benefits ($)	Net Present Value Benefits	Cost Per Year[a]	Net Present Value Cost
1	$ –	$38,822	$ –	$38,822	$38,822	$2,750	$2,750
2	$ –	$38,822	$ –	$38,822	$73,222	$500	$943
3	$ –	$38,822	$ –	$38,822	$107,735	$500	$1,388
4	$ –	$38,822	$ –	$38,822	$140,920	$2,750	$9,982
5	$ –	$38,822	$ –	$38,822	$172,829	$500	$2,226
6	$ –	$38,822	$ –	$38,822	$203,510	$500	$2,621
7	$ –	$38,822	$ –	$38,822	$233,012	$2,750	$16,506
8	$ –	$38,822	$ –	$38,822	$261,379	$500	$3,366
9	$ –	$38,822	$ –	$38,822	$288,655	$500	$3,718
10	**$ –**	**$38,822**	**$ –**	**$38,822**	**$314,881**	**$2,750**	**$22,305**
11	$ –	$38,822	$ –	$38,822	$340,099	$500	$4,380
12	$ –	$38,822	$ –	$38,822	$364,347	$500	$4,693
13	$ –	$38,822	$ –	$38,822	$387,663	$2,750	$27,461
14	$ –	$38,822	$ –	$38,822	$410,082	$500	$5,282
15	$ –	$38,822	$ –	$38,822	$431,638	$500	$5,559
16	$ –	$38,822	$ –	$38,822	$452,365	$2,750	$32,044
17	$ –	$38,822	$ –	$38,822	$472,296	$500	$6,083
18	$ –	$38,822	$ –	$38,822	$491,459	$500	$6,330
19	$ –	$38,822	$ –	$38,822	$509,886	$2,750	$36,118
20	$ –	$38,822	$ –	$38,822	$527,604	$500	$6,795
Net Present Value					**$6,222,404**		**$200,548**

[a] *Costs are for illustrative purposes only.*

5. **Calculate the benefit/cost ratio.**

In practice, Steps 1 through 4 would be conducted for each countermeasure being considered for implementation.

Table 12 shows summary-level results of this calculation for each countermeasure. The benefit/cost ratio is the net present value of the benefits divided by the net present value of the costs. As shown, the benefit/cost ratio (B/C) for vegetation control is:

$$Benefit\ Cost\ Ratio = \frac{Net\ Present\ Value\ of\ Benefits}{Net\ Present\ Value\ of\ Costs}$$

$$Benefit\ Cost\ Ratio = \frac{\$6{,}222{,}404}{\$200{,}548}$$

$$Benefit\ Cost\ Ratio = 31.03$$

Table 12. Summary of Benefit/Cost Analysis

	Crash Savings Per Year					
Treatment	Fatal	Injury A, B, and C	PDO	NPV Benefits	NPV Costs	B/C Ratio
Vegetation Control	0.00	0.47	0.00	$6,222,404	$200,548	31.03
Illumination	0.00	0.13	0.21	$2,545,358	$167,080	15.23
Signalize	0.00	0.73	0.44	$13,865,663	$565,560	24.52

Step 5

The results of this analysis show that implementing vegetation control has the highest benefit/cost analysis, assuming the sight distance clearance is maintained at all times for 20 years. Therefore, this treatment is selected to be implemented and maintained at the intersection.

There also is a relatively high benefit/cost ratio associated with signalizing the intersection. If traffic signal warrants are met at the intersection and initial construction costs are available, this also could be considered a beneficial modification to the intersection.

At the end of this stage, it is appropriate to expand the project documentation again to include an explanation of the analysis, prioritization, and recommended treatments. This information also could be presented to agency leadership for review, input and approval if necessary. At this stage, the project documentation outline could be:

Introduction

- Description of concerns; and
- Description of approach to analyzing conditions.

Data Collection and Evaluation

- Description of the data collected and summary of the data:
  - Crash data tables;
  - Traffic volume data;
  - Roadway characteristics summary or sketches; and
  - Other agency-specific or statewide documents.

Network Screening Results

- Summary of crash frequency network screening method and site ranking results; and
- Summary of EPDO network screening method and site ranking results.

Site Selection for Detailed Investigation

- Documentation of sites selected for detailed investigation.

Diagnose Results and Selection of Countermeasures

- Summary of existing site conditions, crash, and roadway characteristics; and
- Summary of analysis and countermeasures selected for possible implementation.

Countermeasure Prioritization

- Summary of prioritization process and results based on the benefit-cost ratio method.

Recommendations

- Brief summary of the memorandum explaining fundamental conclusions of the analysis and the recommended action.

Step 6. Implement The Countermeasures

Background

At this stage of the process, diagnosis, countermeasure selection, and prioritization would be complete for all intersections selected for additional analysis in Step 3. Next, the agency works on implementing the countermeasures.

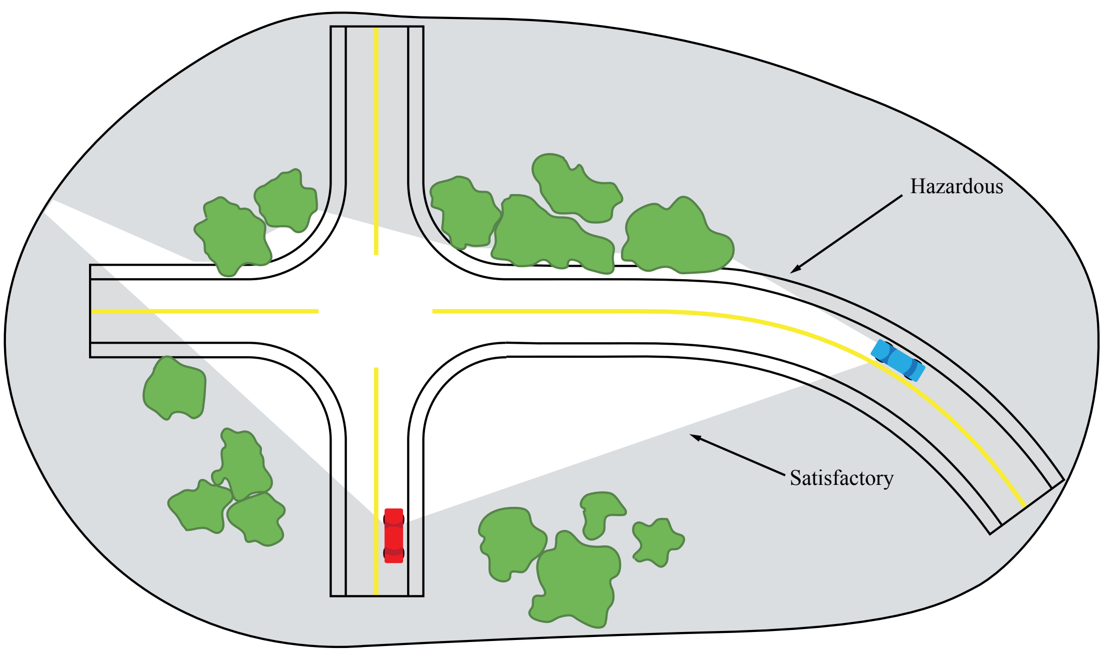
Obtaining the necessary human and financial resources is a major consideration in implementing any safety project or program. Harnessing local funding sources and staff resources is often the quickest way to implement projects. For example, maintenance or public works staff can implement low-cost projects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

In addition to local funds, 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. The Toolkit also provides more information about funding opportunities.

This Scenario

The FHWA's Vegetation Control for Safety Guide[2] provides guidance on checking and improving intersection sight distance. Drivers approaching an intersection need a clear line of sight to the intersection and along the intersection to react to potential conflicting vehicles, bicyclists and pedestrians to avoid a collision. Figure 9 from the FHWA's guide shows the sight triangles formed by the sightlines of two vehicles approaching an intersection.

Figure 9. FHWA's Vegetation Control for Safety Guide – Sight Triangle Diagram



Source: Vegetation Control for Safety, A Guide for Local Highway and Street Maintenance Personnel, FHWA Office of Safety.

2 http://safety.fhwa.dot.gov/local_rural/training/fhwasa07018/.

Step 6

In this scenario, vehicles stopped at the intersection on First Street need sight distance to see vehicles approaching from either direction of Main Street, so that the stopped driver can safely turn left, turn right, or proceed across the intersection. Of the three options, the sight distance needed for a left turn is the longest and can be used to establish the corner sight triangle for both legs of the minor road.

Vegetation at the northwest corner of the intersection is cleared and maintained for 20 years. No shrubs or plants within the corner sight triangle should be allowed to grow more than three feet high. Trees over three feet high are removed. In cases where sight distance is limited by vegetation on private property, staff can work with the private property owner to identify opportunities for controlling and managing vegetation.

Finally, if other aspects of the project have been documented, it would be useful to add the results of this step as well. At this stage, the project documentation outline could be:

Introduction

- Description of concerns; and
- Description of approach to analyzing conditions.

Data Collection and Evaluation

- Description of the data collected and summary of the data:
  - Crash data tables;
  - Traffic volume data;
  - Roadway characteristics summary or sketches; and
  - Other agency-specific or statewide documents.

Network Screening Results

- Summary of crash frequency network screening method and site ranking results; and
- Summary of EPDO network screening method and site ranking results.

Site Selection for Detailed Investigation

- Documentation of sites selected for detailed investigation.

Diagnose Results and Selection of Countermeasures

- Summary of existing site conditions, crash, and roadway characteristics; and
- Summary of analysis and countermeasures selected for possible implementation.

Countermeasure Prioritization

- Summary of prioritization process and results based on the benefit-cost ratio method.

Recommendations

- Brief summary of the memorandum explaining fundamental conclusions of the analysis and the recommended action.

Final Comments

- Potential for applying the treatment elsewhere in the community, and
- Lessons learned for future application of identifying sites for detailed investigation.

Step 7. Evaluate Effectiveness

Background

Three to five years after implementing and maintaining the treatment, agency staff should measure the effectiveness of the treatment. This can be completed by tabulating the number and type of crashes at the site since implementing the improvement – essentially repeating Step 1 and recreating Table 3 in this scenario and/or conducting more rigorous before-and-after study evaluations. Step 7 of the Toolkit provides more information about optional methods for evaluation.

Use Caution with Simple Before-and-After Analysis Results

A simple before-and-after analysis does not provide a quantitative result. Because of statistical limitations of crash data, a simple analysis is not sufficient to make an accurate quantitative assessment.

This Scenario

In this scenario, assuming traffic volume does not change dramatically, crash records for the three-year period after implementing the treatment are collected and compared to the three-year period before treatment implementation.

Table 13 shows how the before-and-after crash data can be tabulated. In this scenario, three years after clearing and maintaining the sight distance triangles, angle crashes at the intersection decreased from eight in the three-year period before the treatment to two in the three-year period after, or a 75 percent reduction in angle crashes. Because of statistical issues associated with crash data (explained in the Toolkit) – it should not be concluded that there was a 75 percent reduction in angle crashes. It can be concluded that angle crashes have decreased, but this analysis is not statistically rigorous enough to quantify the change in crash frequency.

Table 13 also shows that there has been a slight increase in rear-end crashes from the before to the after period. This could be due to the natural variation in crash frequency or it could reflect a new crash pattern emerging. It would be valuable to continue monitoring the intersection to ensure there are no additional modifications necessary.

Table 13. Example of Comparison of Before-and-After Period Crash Data

Crash Type	Before (2010-2012)	After (2014-2016)
Angle	8	2
Run-Off	2	1
Single Vehicle	0	0
Head-On	1	0
Rear-End	5	7
Sideswipe	2	2
Other	1	1
Total	**19**	**12**

It also is important to note that if traffic volume changes substantially after implementing the treatment at the site, this type of simple before-and-after crash analysis will be less valid because the change in traffic volume may be influencing the change in crash frequency or severity.

Documenting the results of the effectiveness analysis in a memo to file or for presentation to governing board would be useful. This could demonstrate the value of the project in the specific jurisdiction and serve as a resource if similar projects are being considered in the future.

4.0 Options for Additional Activities

Completing the analysis in this scenario results in an identified list of sites with potential for safety improvement and countermeasures selected for each location. If possible, the improvements can be implemented immediately, or the agency can develop a longer-term plan for implementing the countermeasures over time as funding and/or other resources become available.

Looking forward from implementing the treatments identified at each of the sites investigated in this safety analysis, there are other activities the agency could undertake to complement the work done this far and continue to build community interest in road safety. The agency manager could:

- Contact the stakeholders that were concerned about intersection safety in the community and gauge their interest in developing and participating in a community traffic safety committee. This committee could study traffic safety on other facilities in the community, or study and develop action plans for behavioral safety issues, if appropriate.
- If there is sufficient interest, this committee also could include staff members from the sheriff's department and the community hospital or clinic.
- Collaborate with police enforcement in the community to enhance enforcement throughout the community.
- Conduct a network screening analysis on another type of intersection or roadway in the community.

Resources about these activities can be found in the Toolkit.

5.0 Conclusions

User Guide #2 focuses on studying safety conditions at many sites. The need for the network screening analysis was derived from community concern for enhanced roadway safety at intersections. The agency manager chose to study all of the community's two-way stop-controlled intersections first because most of the community intersections operate this way. After conducting the network screening analysis, the agency manager identified a number of sites with potential for safety improvement. This list of potential study sites was whittled down to a smaller number of sites for detailed investigation based on staff and funding resources available to conduct the analysis. The detailed study at each site includes evaluating crash conditions (diagnosis) and identifying countermeasures, prioritizing and selecting countermeasures, implementing the countermeasure, and over time evaluating the effectiveness of the countermeasures that have been implemented.

At the conclusion of these activities, the practitioner also should evaluate whether there are other safety-related activities that could be undertaken as part of ongoing work in the agency. This can be especially successful while the community is interested and focused on road safety.

The information herein has been presented as a "go-by" to help a practitioner get through the process. The Toolkit associated with this *User Guide* provides many resources for conducting each of the steps.

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