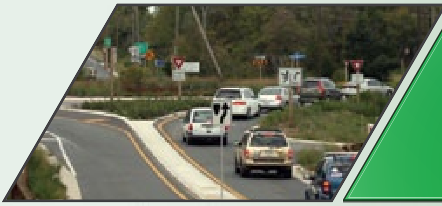

Intersection Safety

A Manual for Local Rural Road Owners

U.S. Department of Transportation
Federal Highway Administration
http://safety.fhwa.dot.gov
FHWA-SA-11-08

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16. Abstract

According to the Federal Highway Administration, over 6 million lane-miles of roadway are in rural areas, and more than two-thirds of these rural roads are owned and operated by local entities. In 2008 56 percent of the 37,261 fatalities on U.S. roadways occurred in rural areas. Rural areas face a number of highway safety challenges due to the nature of their facilities.

More than 20 percent of all traffic fatalities in the United States occur at intersections and over 80 percent of intersection-related fatalities in rural areas occur at unsignalized intersections. This document provides information on effectively identifying intersection safety issues in local areas, choosing the countermeasures that address them, and evaluating the benefits of those treatments. It is geared toward local road managers and other practitioners with responsibility for operating and maintaining their roads. It offers information on the procedures and processes to improve the safety of local rural unsignalized intersections and to reduce the potential for future crashes.

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1 Introduction and Purpose

Three million miles of local roads are maintained and operated by local administrators, township managers, and public works officials in more than 38,000 counties, cities, villages, towns, and tribal governments across the United States.[1] One issue common to all local agencies is traffic safety.

One of the most pressing traffic safety issues on local roads is intersection safety. Intersections can vary widely in terms of size, shape, number of entering legs, and number of turn lanes. According to the American Association of State Highway and Transportation Officials' (AASHTO) ***A Policy on Geometric Design of Highways and Streets***, an intersection is defined as the general area where two or more highways join or cross, including the roadway and roadside facilities for traffic movements within the area. Each highway radiating from an intersection and forming part of it is an intersection leg. The most common intersection where two highways cross has four legs. Intersections generally involve through- or cross-traffic movements and typically involve turning movements between the highways. There are three general types of highway crossings – at-grade intersections, grade separations without ramps, and interchanges. This document addresses safety issues related to at-grade intersections.

Local rural roads also encompass a wide range of surface types, including paved facilities, gravel roads, and dirt roads. Many local rural intersections lack suitable design standards, delineation, and signing that may be provided on higher volume roadways. Further, many were not officially designed, but rather "evolved" over time to their current geometric configuration.

1.1. The Intersection Crash Problem

In 2008 the National Highway Traffic Safety Administration (NHTSA) indicated that 56 percent of the 37,261 fatalities on U.S. roadways occurred in rural areas.[2] This figure is disproportionate since only 23 percent of Americans live in rural areas[3] and rural roadways account for just 40 percent all vehicle miles traveled nationally.[4]

1 McNinch, T.L. and Colling, T.K. "Traffic Safety Education for Nonengineers." *Public Roads*, May/June, 2009, pp. 32-39. Available at: http://www.fhwa.dot.gov/publications/publicroads/09june/05.cfm

2 National Highway Traffic Safety Administration, *Traffic Safety Facts: 2008 Data* (Washington, DC: 2009). Available at: http://www-nrd.nhtsa.dot.gov/Pubs/811164.pdf

3 U.S. Department of Transportation, "Rural Safety Initiative," web page, February 2008. Available at: http://www.dot.gov/affairs/ruralsafety/ruralsafetyinitiativeplan.htm

4 U.C. Berkeley, Safe Transportation Research & Education Center, "Rural Road Safety" web page. Available at: http://www.tsc.berkeley.edu/research/ruralroads.html

More than 20 percent of all traffic fatalities in the United States occur at intersections, both signalized and unsignalized. As shown in Figure 1, the number of intersection-related fatalities has been decreasing since 2005, yet the overall number is still very high.

More than 80 percent of rural intersection fatalities occur at unsignalized intersections. Due to this high proportion of crashes at these types of intersections, unsignalized intersections will be the focus of this report. For information on safety at signalized intersections, please refer to ***Signalized Intersections: Informational Guide***[5] and NCHRP Report 500, Volume 12, ***A Guide for Reducing Collisions at Signalized Intersections***.[6]

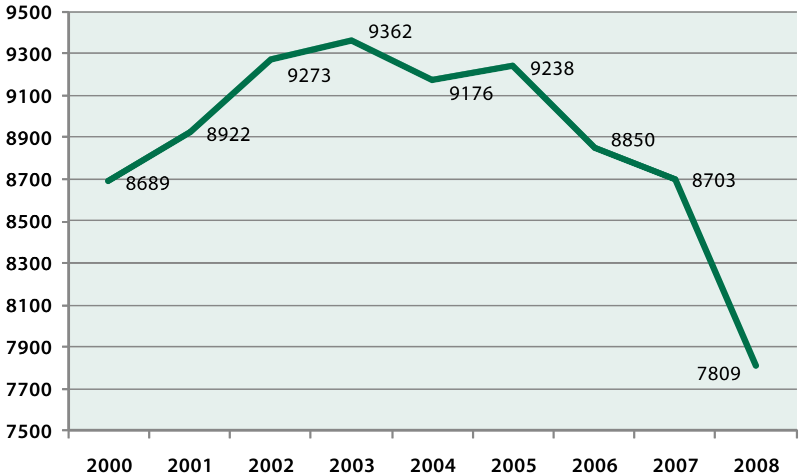


Figure 1 – Intersection Fatalities by Year

According to FHWA, the most severe crash type at unsignalized intersections is a right-angle crash. This crash type typically occurs when two vehicles approaching at a perpendicular angle collide due to one vehicle failing to stop or yield right of way from a Stop or Yield sign. In recent data analyses commissioned by the Federal Highway Administration (FHWA), every 100 reported angle crashes at unsignalized intersections resulted in approximately 1 to 3 fatalities and 5 to 15 serious injuries.[7]

5 U.C. Berkeley, Safe Transportation Research & Education Center, "Rural Road Safety" web page. Available at: http://www.tsc.berkeley.edu/research/ruralroads.html

6 Antonucci, N. et al., *A Guide for Reducing Collisions at Signalized Intersections*, TRB, National Research Council, NCHRP Report 500, Vol. 12, 2004. Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v12.pdf

7 Federal Highway Administration, "State Intersection Safety Implementation Plans," 2008-2010. (unpublished studies)

1.2. State Intersection Safety Implementation Plans

FHWA recognized that while a number of States had intersection safety as an emphasis area in their Strategic Highway Safety Plans (SHSP), they lacked an action plan to guide their intersection safety implementation activities on State and local roads. To date, FHWA has worked with 11 States to develop Intersection Safety Implementation Plans (Arizona, Florida, Georgia, Indiana, Louisiana, Mississippi, Missouri, Ohio, Pennsylvania, South Carolina, and Tennessee).[8] The plans include the activities, countermeasures, strategies, deployment levels, implementation steps, and estimate of funds necessary to achieve the intersection component of the State's SHSP goal. Local road practitioners should consult their State's Intersection Safety Implementation Plan, if available, before embarking on an improvement strategy.

1.3. Implementation Approaches

Local practitioners should consider implementation methodology when seeking to address intersection safety within their jurisdiction. Typical approaches include:

- Systematic approach;
- Spot location approach; and
- Comprehensive approach incorporating human behavior issues.

1.3.1. Systematic Approach

For the systematic approach, the analysis is based on crash types and proven safety countermeasures selected based on those types.

In one application of the systematic approach, common crash types are selected from analysis. Locations experiencing these crash types and locations with similar geometric features as those experiencing selected crash types are selected and treated systematically with low-cost safety countermeasures.

Another application of the systematic approach begins with identifying low-cost, effective countermeasures to common traffic safety issues. Once a basic set of countermeasures is identified, the crash data system is analyzed to choose locations where the countermeasures can be cost-effectively deployed. Estimates of the impacts of implementation can be made in terms of deployment cost and the benefits measured in traffic crash reduction.

8 An example Intersection Safety Implementation Plan is available at: http://safety.fhwa.dot.gov/intersection/resources/sfty_imp_pln0709/index.cfm#toc

Benefits of the systematic approach may include:

- **Widespread effect.** The systematic approach can impact safety issues at a large number of locations on an entire local roadway network.
- **Crash type prevention.** Using predominant crash types with a high or moderate level of crashes, an agency can address locations that have not yet experienced these crash types, but have similar characteristics to locations with such crash histories (e.g., geometric conditions, traffic volume).
- **Cost-effectiveness.** Implementing low-cost solutions across an entire system can be a more cost-effective approach to addressing system-wide safety.
- **Reduced data needs.** The systematic approach can be used without detailed crash history for specific locations, reducing data needs.

Drawbacks of the systematic approach may include:

- **Justifying improvements can be difficult.** Because this approach does not always address locations with a history of crashes with recommended treatments, it can be difficult to justify improvements at locations without crash history. The systematic approach will rarely include a recommendation for a large-scale safety improvement at a single location. Since these are the types of projects that garner attention from decision makers, the media, elected officials, and the general public, it can require additional effort from the safety practitioner to explain the systematic approach and its benefits to those groups.

1.3.2. Spot Location Approach

The spot location approach has typically been based exclusively on an analysis of crash history. Due to the fact that some locations in a jurisdiction may have a significantly higher number of crashes than most of the others, it is important to identify those locations and treat them accordingly.

The benefits to the spot location approach may include:

- **Focus on demonstrated needs.** The spot location approach focuses directly on locations with a history of crashes and addresses them.

Drawbacks of the spot location approach may include:

- **Assumption that the past equals the future.** This approach assumes locations with a history of crashes will continue to have the same number and type of crashes in the future.
- **Minimal overall benefit.** This approach often focuses on specific locations, and because of this, it is difficult to have a significant impact on the entire network.

The spot location approach to traffic safety can be implemented in parallel with the systematic approach to provide the best combination of safety treatments in a jurisdiction. In addition, the spot location approach could be applied to those locations that have had low-cost countermeasures installed systematically but, after an assessment, continue to show a higher than average crash rate.

1.3.3. Comprehensive Approach

The comprehensive approach introduces the concept of the 4 E's of Safety; Engineering, Enforcement, Education, and Emergency Medical Services. This approach recognizes that not all locations can be addressed solely by infrastructure improvements. Incorporating other elements is often required to achieve marked improvement in intersection safety.

Some intersections will be identified that have frequent driving violations for which targeted enforcement is an appropriate countermeasure. In general, the most common violations at intersections are speeding, failure-to-yield, aggressive driving, failure to wear safety belts, and driving while impaired. When locations are identified that have reports and observations of these violations, coordination with the appropriate law enforcement agencies is needed to deploy visible targeted enforcement at the identified intersections to reduce the potential for future driving violations and related crashes. Education and outreach efforts should supplement enforcement to improve the effect of each.

1.4. Information in this Document

The purpose of this document is to provide information on effectively identifying intersection safety issues and countermeasures that address them, leading to the effective implementation of safety projects. This includes pertinent information regarding the Manual on Uniform Traffic Control Devices (MUTCD) requirements, guidance on conducting field reviews, identification of unsignalized intersections with multiple crashes and/or high potential for future crashes, selection of the appropriate low-cost improvement at these intersections, and evaluation of safety projects and processes.

This document is intended to provide appropriate intersection safety information in one report. Some practitioners responsible for the safety of the local road network may not have formal safety-specific highway training; this can present a challenge in reducing the risk of crashes at rural unsignalized intersections on local roads. In addition, the person responsible for highway safety may have multiple responsibilities including public works functions, such as water and/or wastewater treatment, trash collection, and snow removal. In these cases, roadway safety and infrastructure maintenance may be only a small part of the job.

The report is not intended as a comprehensive guide for intersection design and improvement. It does, however, provide a framework that can be used to assess the safety of existing intersections and determine whether additional countermeasures should be installed.

This document suggests a process for the planning and implementation of intersection safety improvements. The processes discussed in this document are summarized in Figure 2.

Step 1
Identify Intersection Safety Issues
(Manual: Section 2)

Safety issues can be identified by collecting crash history, roadway, and exposure information from the following sources:

- State and local crash databases
- Law enforcement crash reports and citations
- Observations by law enforcement or road maintenance crews
- Public notifications
- Hospital records
- State and local roadway databases
- Traffic count records

Step 2
Record Information for Safety Analysis
(Manual: Table 1)

Compile information in a table that includes the source of the information, the type of problem, and other attributes of the crash, observation, or notification.

Steps 3 & 4
Data Analysis, Countermeasure Selection, and Installation

Depending on the approach, the order of data analysis, countermeasure selection, and countermeasure installation steps may vary.

- **Spot Location Approach and Systematic Approach (Crash Type Focus)**
- **Systematic Approach (Countermeasure Focus)**

Spot Location Approach and Systematic Approach (Crash Type Focus)

Step 3
Analyze Data
(Manual: Section 3)

Data can be analyzed in the following ways, based on available information:

- Crash frequency
- Crash rate calculations
- Qualitative analysis

Step 4
Select and Install Countermeasures
(Manual: Section 4)

Details from crash data and analysis feeds the counter-measure selection process.

- Enhanced signing
- Transverse rumble strips
- Clear sight triangles
- Other

Systematic Approach (Countermeasure Focus)

Step 3
Select Countermeasures
(Manual: Section 4)

Develop a list of countermeasures and thresholds for their application (e.g. crash frequency, crash type, traffic volumes).

Step 4
Analyze Data and Install Countermeasures
(Manual: Section 3 and 4)

- Search crash data for the criteria identified in Step 3.
- Determine cost-effective level of deployment for each countermeasure.

Step 5
Assessment and Follow-up
(Manual: Section 5)

Evaluate intersection safety treatments after installation.

- Track countermeasure installations
- Monitor crash experience at treated locations

Figure 2 – Steps to Address Intersection Safety

Section 2 of this manual provides an overview of the types of data to collect for the identification of intersection safety issues. It discusses the sources of crash data and how they can be used. Additionally, types of roadway data used in safety analyses are introduced.

Section 3 summarizes the types of analysis that can feed the issue identification and countermeasures selection process. This discussion builds on the types of information and data discussed in Section 2 and provides definitions and examples of the factors that should be considered.

Section 4 provides a description of selected countermeasures that have been shown to improve safety at unsignalized intersections on local rural roads. It includes a basic set of strategies – supplementary warning signs and pavement markings – to install at locations experiencing a history of crashes. The section also introduces additional safety strategies, including flashing beacons on Stop signs and turn lane modifications.

The steps to complete an evaluation are presented in **Section 5**. After the countermeasures are installed, assessing their effectiveness will provide valuable information and can help determine which countermeasures should continue to be installed on other intersections to make them safer as well.

In **Section 6** a summary of the overall content of the manual is presented.

A list of resources and references is presented in **Appendix A**. It includes publications that focus on intersection countermeasures, research that supports their use, and various studies that document their effectiveness. The appendix also includes references that focus on the use of data-driven processes for countermeasure selection, assessment procedures and strategies, descriptions of successful programs, and national programs that may help identify resources to support local efforts.

Appendix B addresses compliance with MUTCD minimum requirements for rural unsignalized intersections. The MUTCD provides 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.

2 Identifying Safety Issues

Determining what the problems are and where they are occurring will assist in making the most informed decisions regarding countermeasure selection and implementation to address intersection safety issues. When conducting a safety analysis, a minimum of 3 years of data is desired to obtain an accurate picture of the crash history within a jurisdiction, since crashes are relatively rare events and are not universally distributed across all intersections. A relatively large representative sample size for crashes in the jurisdiction will increase the chance that locations with the most severe safety issues will be identified. Due to the possibility of changes in traffic patterns and the roadway itself, data more than 5 years old are typically not desirable for assessing safety issues.

Analysis can range from simple "push pin" maps for identifying crash clusters to statistical analyses of crash rates, depending on the crash history and other data available.

There are a number of information sources used to identify crashes and risk factors at rural intersections. These include:

- State and local crash databases;
- Law enforcement crash reports and citations;
- Observational information from road maintenance crews and law enforcement; and
- Public notification of safety concerns.

In order to determine the intersections with a history of crashes (and those with a potential for future crashes), it is important to consider the types of data available and how those data can be used. In addition to the location of the crashes, the data can also provide information regarding crash causation to help identify potentially effective countermeasures.

The types of data available can range from anecdotal information, such as public input, to crash databases provided by State or local agencies. In some cases it may be beneficial to collect data from multiple sources to identify safety issues occurring at intersections.

The following discussion presents the most common information sources and recommendations for their use.

2.1. State and Local Crash Databases

Each State has a central repository for storing crash data that identifies locations with crash occurrences. Information found in a typical crash database includes; time and date of the crash, location, crash type, crash severity, and weather conditions. These data can be used to help compare a jurisdiction's intersections with others in the State. This comparison can help determine the level of need as it relates to similar locations in the region. Often States will provide or assist local agencies with their crash data analysis needs. Crash data is typically stored by the State Department of Transportation (DOT), Department of Public Safety (DPS), or Department of Revenue (DOR).

In addition, some local jurisdictions keep their own crash and roadway databases. If these exist, the information can be used as described above.

Action: Depending on your State's organizational structure, contact the county, regional, or State engineer or your State's Local Technical Assistance Program (LTAP) representative to determine if crash data within your jurisdiction is available for your use. If available, obtain 3 to 5 years of crash and roadway characteristic data. Develop a spreadsheet for intersections with a history of crashes (see Table 1). This can serve as a basic database to help identify common crash characteristics and identify appropriate countermeasures.

2.2. Law Enforcement Crash Reports and Citations

If an agency does not have access to State crash databases, law enforcement crash reports can be a valuable tool to identify the location and contributing circumstances to intersection crashes. The following variables (at a minimum) should be extracted and compiled from the crash reports:

- Location;
- Date and time;
- Crash type;
- Crash severity;
- Weather conditions;
- Sequence of events; and
- Contributing circumstances.

Review of law enforcement crash reports can support decisions regarding the locations to improve and the safety treatments to select. While the information collected by law enforcement personnel may differ by jurisdiction, the basic elements should provide sufficient data to identify intersections that need improvement.

Citation records by law enforcement can provide information regarding driver behavior issues within a jurisdiction. Though not correlated directly to crash locations, citation information can indicate overall issues in the region that can potentially be addressed with enforcement and education strategies.

Police reports should be reviewed periodically in order to compile the necessary information for conducting an analysis. This information can also be stored in the spreadsheet shown in Table 1.

Action: Develop a relationship with law enforcement officials responsible for enforcement and crash investigation on their roads. This could foster cooperation in sharing crash reports and safety information and collaboration on problem intersections.

2.3. Observational Information

The crews who maintain the roads and law enforcement officers can serve as valuable resources to identify problem areas. Since they travel extensively on the local roads, they are able to continuously monitor the region for actual or potential problems (e.g., reduced sight distance due to vegetation growth, missing signs). Road maintenance crews often keep logs of their work activities connected to traffic safety issues, including sign replacements and edge drop-off repairs. These logs can assist safety practitioners in identifying recurring safety issues.

Law enforcement personnel are sometimes aware of problem areas that may not show up in the crash database or be known by public works staff, especially issues occurring at night or on weekends. This supplemental information about intersection safety can be beneficial to the safety improvement process.

Action: Develop a system for maintenance crews to report and record observed intersection safety issues and a mechanism to address them.

Set up a regular meeting with local law enforcement to discuss their observations of traffic safety issues in the local jurisdiction.

Source of Information	Date (MM/DD/YYYY)	Type of Information	Problem	Crash?	Nature of Crash	Time of Day (24 hr time)	Weather Conditions	Traffic Conditions	Intersetion Reviewed?	Action?	Date of Action
Local Newspaper	3/8/2008	Citizen Complaint	Speeding	N					Y	Pending	
Local Police	4/8/2008	Police Report	Crash Report	Y	Vehicle traveling North on Route 657 hit while making left turn onto Glade Drive	11:39	Clear	Light Volume	N		
Local Police	11/12/2009	Police Report	Crash Report	Y	Vehicle traveling West on Glade collided with vehicle on Route 657	23:04	Rain	No Traffic	N		
Maintenance Crew	12/12/2009	Observation	Missing Stop Sign	N					Y	Replaced Stop Sign	12/19/2009
State Police	11/24/2008		Crash Report	Y	Vehicle traveling West on Clifton Road rear-ended at intersection	19:21	Rain	Light Volume	N		

Table 1. Sample Spreadsheet to Monitor Crashes/Observations at Local Intersections

2.4. Public Notifications

Information about observed near misses or other perceived problems can support identification of intersections with safety issues and the potential for severe crashes. Occasionally, when near misses occur or an unsafe situation is observed, a citizen may notify the local government through an email, letter, telephone call, or public meeting. While this is anecdotal information, these sources can serve as important indicators that a problem may exist and would warrant further review and analysis to determine its extent.

Public notification of intersection safety issues can come from community or regional newspapers and newsletters, or correspondence from local homeowner associations, neighborhood groups, or individuals. Receiving this information could help pinpoint which intersections are candidates for review and establish links and relationships with the community to foster communication on safety related issues.

Action: Acknowledge input and, depending on the nature of the problem, establish a plan to review the identified sites. Keep a record of notifications and periodically monitor them.

2.5. Roadway Data

It is also valuable to obtain information about the roadway infrastructure. The following roadway data are often used to assist practitioners in safety analyses at intersections:

- Roadway surface (dirt, aggregate, asphalt, concrete);
- Lane information for approaches (number, width);
- Median (type, width);
- Number of intersection legs;
- Configuration of intersection legs; and
- Traffic control devices present (signs, pavement marking, traffic signals).

This information can be combined with crash data to help local practitioners identify appropriate locations and treatments to improve safety. For example, if a local rural intersection is experiencing a high number of right angle crashes, analysis of the inventory of roadway elements could reveal that the roadway does not have Stop signs on any approaches. An appropriate countermeasure could be to install Stop signs to provide traffic control at that location.

2.6. Exposure Data

The raw number of crashes can sometimes provide misleading information about the most appropriate locations for treatment. Introducing exposure data helps to create a more accurate comparison of locations. Exposure data provide a common metric to the crash data so intersections can be compared more appropriately.

The most common type of exposure data used at intersections is entering traffic volume. A count of the number of vehicles entering an intersection can provide information to the practitioner for comparison. For example, if two intersections have the same number of crashes but different entering traffic volumes, the location with fewer vehicles (i.e., less exposure) will have a higher crash rate, meaning that vehicles were more likely to have experienced a crash at that location. This rate reflects the fact that an increase in the number of vehicles has an effect on the expected number of crashes.

3 Safety Analysis

Conducting safety analyses will assist the practitioner in identifying intersections with safety issues and selecting countermeasures to improve them. The types of analysis can be qualitative or quantitative. This section outlines steps to identifying intersections with safety issues and making data-supported decisions as to the type, deployment levels, and locations of countermeasures. These steps build on the previous discussion of overall safety implementation approaches and sources of information for identifying safety problems. Additional information on analysis procedures and data can be reviewed in "Road Safety Information Analysis: A Manual for Local Rural Road Owners."

3.1. Crash Frequency

Crash frequency represents the number of crashes that have occurred at a particular intersection over a period of time. It can be determined from the State or local crash database (or law enforcement crash reports).

This allows the practitioner to:

- Summarize the crashes by type and location;
- Spatially display crash locations on a map using push pins or a computer software package; and
- Provide a report identifying intersections with a history of crashes.

Once this information is collected and displayed, the local practitioner can compare intersections using cluster analysis to determine crash experience by frequency levels.

3.2. Crash Rate

Crash frequency alone is often inadequate when comparing multiple intersections or prioritizing locations for improvement. Crash rates can be an effective tool to measure the relative safety at a particular intersection. The ratio of crash frequency (crashes per year) to vehicle exposure (number of vehicles entering the intersection) results in a crash rate. Crash rate analysis can be a useful tool to determine how a specific intersection compares to the average intersection on the roadway network.

For example, it is possible that two intersections in a jurisdiction (Intersection A and Intersection B) each have a similar number of crashes. However, Intersection A may have many more vehicles entering the intersection on a typical day than Intersection B, as shown in Table 2. In order to effectively compare the safety of the two locations, the practitioner must factor in the level of exposure to crashes for each intersection. Exposure data here is represented by the number of vehicles entering the intersection. Population and number of licensed drivers within a jurisdiction are other types of exposure data that can be used depending on the circumstances and availability.

Crash rate is often used to prioritize locations for safety improvements when working with limited budgets to achieve the greatest safety benefits with available resources.

Crash rates can be calculated using the following widely accepted equation. This equation can be used for any crash type or severity. The intersection crash rate based on vehicles entering the intersection is calculated as:

$$R = \frac{1{,}000{,}000 \times C}{365 \times N \times V}$$

Where:

R = Crash rate for the intersection expressed as crashes per million entering vehicles (MEV)

C = Total number of intersection-related crashes in the study period

N = Number of years of data

V = Traffic volumes entering the intersection daily

This equation relies on traffic volume information. Actual and estimated traffic volumes are often compiled and kept by State highway agencies, local governments and property developers.

In the following example shown in Table 2, two intersections have approximately the same number of crashes but different entering traffic volumes. By factoring in traffic volume (exposure), the calculation indicates that Intersection B may be a more promising roadway for safety treatments due to its higher intersection crash rate (measured in number of crashes for every 1 million entering vehicles).

Location	Intersection Crashes (C)	Entering Traffic Volume	Years of Data (N)	Intersection Crash Rate (R)*
Intersection A	25	14,000	5	0.98
Intersection B	22	6,500	5	1.85

*Measured as the number of crashes per 1 million entering vehicles.

Table 2. Example of the Intersection Crash Rate Calculation

Intersection A

$$R = \frac{(1{,}000{,}000)\ (25)}{(365)\ (5)\ (14{,}000)} = 0.98 \text{ crashes per million entering vehicles}$$

Intersection B

$$R = \frac{(1{,}000{,}000)\ (22)}{(365)\ (5)\ (6{,}500)} = 1.85 \text{ crashes per million entering vehicles}$$

Action: Calculate the crash rates for intersections experiencing crashes in the jurisdiction, and then use that crash rate to prioritize locations for investigation and possible treatments.

Develop a database to record crash rate calculations over time for comparison with intersections that have potential safety issues in the future. This can provide practitioners with a jurisdiction-specific average intersection crash rate for varying situations.

3.3. Geometric Issues

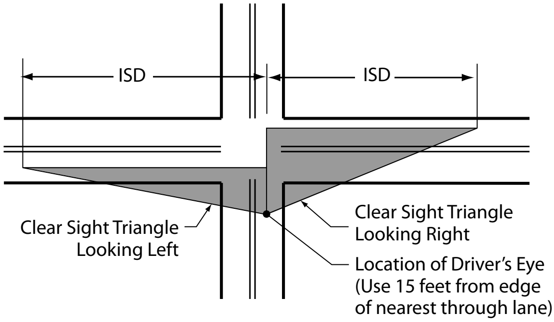
The geometric design of intersections can create navigational problems for motorists, potentially contributing to crashes at these locations. Among geometric design elements, two specific issues can cause safety concerns: sight distance limitations and skewed geometry.

3.3.1. Sight Distance

Insufficient sight distance can be a contributing factor in intersection traffic crashes. Intersection sight distance is typically defined as the distance a motorist can see approaching vehicles before their line of sight is blocked by an obstruction near the intersection. The driver of a vehicle approaching or departing from a stopped position at an intersection should have an unobstructed view of the intersection, including any traffic control devices, and sufficient lengths along the intersecting roadway to permit the driver to anticipate and avoid potential collisions. Examples of obstructions include crops, hedges, trees, parked vehicles, utility poles, or buildings. In addition, the horizontal and vertical alignment of the roadway approaching the intersection can reduce the sight triangle of vehicles navigating the intersection.

It is important for approaching motorists on the major road to see side street vehicles approaching the Stop sign, and for minor road motorists to see approaching major road vehicles before entering the intersection. Poor sight distance can lead to rear-end crashes on the approaches and to angle crashes within the intersection because motorists may be unable to see and react to traffic control devices or approaching vehicles.

The area needed for provision of this unobstructed view is called the Clear Sight Triangle (see Figure 3).



Source: Modified from *A Policy on Geometric Design of Highway and Streets*, 5th Edition, American Association of State Highway and Transportation Officials (AASHTO), 2004.

Figure 3 – Sight Distance Triangles for 4-Leg Stop-controlled Intersections

The Intersection Sight Distance (ISD) is measured along the major road beginning at a point that coincides with the location of the minor road vehicle. Table 3 provides the recommended values for ISD, based on the following assumptions:

- Stop control of the minor road approaches;
- Using driver eye and object heights associated with passenger cars;
- Both minor and major roads are considered at level grade;
- Considers a left-turn from the minor road as the worst-case scenario (i.e., requiring the most sight distance); and
- The major road is an undivided, two-way, two-lane roadway with no turn lanes.

If conditions at the intersection being evaluated differ from these assumptions, an experienced traffic engineer or highway designer should be consulted to determine whether different ISD values should be used.

Speed (mph)	Stopping Sight Distance (ft.)	Design Intersection Sight Distance (ft.)
25	155	280
30	200	335
35	250	390
40	305	445
45	360	500
50	425	555
55	495	610
60	570	665
65	645	720

Source: *A Policy on Geometric Design of Highway and Streets*, 5th Edition, American Association of State Highway and Transportation Officials (AASHTO), 2004.

Table 3 – Sight Distance at Intersections

Stopping Sight Distance (SSD) provides sufficient distance for drivers to anticipate and avoid collisions. However, in some cases this may require a major road vehicle to stop or slow to accommodate the maneuver by a minor road vehicle. To enhance traffic operations, sight distances that exceed the recommended SSD (as shown in Table 3) are desirable. Note that design intersection sight distance criteria for stop-controlled intersections are longer than stopping sight distance to ensure the intersection operates smoothly.

3.3.2. Skewed Geometry

Optimally, an intersection should be designed to have roadways cross at a 90-degree angle. In situations where the intersecting angles are 60 degrees or less, the intersections are considered skewed (see Figure 4).

Figure 4 – Skewed Intersection

Potential problems associated with skewed intersections include:

- Vehicles may have a longer distance to traverse while crossing or turning onto the intersecting roadway, resulting in an increased period of exposure to the cross-street traffic;
- Older drivers may find it more difficult to turn their heads, necks, or upper bodies for an adequate line of sight down an acute-angle approach;
- The driver's sight angle for convenient observation of opposing traffic and pedestrian crossings is decreased;
- Drivers may have more difficulty aligning their vehicles as they enter the cross street to make a right or left turn;
- Drivers making right turns around an acute-angle radius may encroach on lanes intended for oncoming traffic from the right;
- The larger intersection area may confuse drivers and cause them to deviate from the intended path;
- Motorists on the major road making left turns across an obtuse angle may attempt to maintain a higher than normal turning speed and cut across the oncoming traffic lane on the intersecting street; and
- The vehicle body may obstruct the line of sight for drivers with an acute-angle approach to their right.

When crashes are occurring at skewed intersections, it may be desirable to reduce or eliminate the skew angle of the approaches. Treatments include pavement marking, delineator islands, and roadway realignment.

3.4. Field Reviews

Regardless of implementation approach, a field review should be conducted at identified locations. Intersection field reviews have the potential to identify safety issues and solutions. Field reviews can be conducted as informal field assessments or formal Road Safety Audits (RSAs). An informal field assessment is generally performed by an in-house team with available personnel. The team will spend time at identified intersections and document safety issues to develop recommendations for improvement.

An RSA is a formal safety performance examination of an existing or future road or intersection by an independent, multidisciplinary team. The process includes a formal report on existing or potential road safety issues and identifies opportunities for safety improvements for all road users.[9]

9 More information on RSA's can be found in Appendix A: Resources and References.

When conducting field reviews at intersections, one source of information to reference is the MUTCD. It provides the minimum standards for the installation and maintenance of traffic control devices on all public streets, highways, bikeways, and private roads open to public traffic.[10] Complying with the MUTCD standards is an important step toward a safer transportation system. If the intersection is not in compliance with the MUTCD, it should be brought up to standard. Non-compliance is an important consideration that can affect road safety and may have liability implications.

There are several elements to consider for this review, as listed below. The appropriate MUTCD sections are noted in parentheses and summary information pertinent to intersections is found in Appendix B. These elements are:

- Signs
  - » Retroreflectivity requirements (Section 2A.07, Section 2A.08)
    - ◊ All regulatory, warning, and guide signs should display the same colors both day and night. Retroreflectivity (reflecting light back to its source) allows signs to do this.
  - » Stop and Yield sign placement (Section 2B.10)
    - ◊ Stop and Yield signs should be installed as close as practical to the intersection and on the right-hand side of the approach to which it applies.
  - » Sign types (regulatory, warning) (Section 2A.05)
    - ◊ The MUTCD defines specific functions for each category of sign.
  - » Sign sizes (Section 2A.11)
    - ◊ The MUTCD defines minimum dimensions for all signs.
  - » Number of signs and clutter (Section 2A.04)
    - ◊ The installation of signs should be a conservative process as unnecessary signs could cause a loss of effectiveness for all signs.
- Pavement Markings
  - » Retroreflectivity (Section 3A.03)

Action: Analyze crash data to determine crash frequency and crash clusters.

Calculate the crash rate of identified locations for comparison and prioritization.

Identify intersections with common safety-related characteristics for potential systematic treatment of safety strategies.

Conduct field reviews of selected locations to determine their compliance with the MUTCD and identify any other potential safety issues and countermeasures.

10 Federal Highway Administration, *Manual on Uniform Traffic Control Devices*, Washington, DC: December 2009. The MUTCD can be accessed at http://mutcd.fhwa.dot.gov

4 Countermeasures

To make the most informed decision regarding countermeasure selection, an agency should begin with the crash history data, observational information, and public notifications. After an analysis of that information, the local practitioner can choose appropriate safety treatments. The decision regarding which countermeasures to install to address a safety issue can be challenging. When appropriate, an agency should seek engineering expertise from a State or local engineer or through the State Local Technical Assistance Program (LTAP).

For isolated high crash locations, the spot location approach is most appropriate. For those areas with a number of intersections with varying levels of crashes, systematic implementation of safety countermeasures is often the most effective approach. For locations that have yet to experience crashes, systematically applying safety treatments based on other criteria such as geometric configuration can prevent future crashes.

For example, a high proportion of crashes may occur at intersections that share common geometric or operational elements.[11] Installing the same low-cost countermeasures at multiple intersections (where appropriate) could, in many cases, improve the cost effectiveness of the safety improvement.

The countermeasures presented here represent strategies that have been used by State and local jurisdictions to improve rural unsignalized intersection safety.

4.1. Enhanced Sign and Pavement Marking Improvements

For a conventional unsignalized intersection, a typical enhancement of sign and pavement markings as shown in Figure 5 should be considered. This installation is recommended for intersection locations that have experienced a high or moderate level of crashes. Depending on the crash type(s), crash frequency and roadway geometry at the location, one or more of the following treatments may be appropriate:

- For the minor road stop approach of the intersection, two Stop Ahead signs (mounted left and right) and a painted stop bar are recommended to warn the driver of a stop condition ahead. The first Stop sign is installed at the traditional right side location; a second is recommended in the median (if available) of the approach. To accommodate this left-mounted Stop sign, a small mountable curb is suggested. This curb and associated pavement markings provide the motorist with additional information that

11 Federal Highway Administration, *Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections*, FHWA-SA-09-020, (Washington, DC: May 2009).

he or she is entering an intersection. At a three-leg T-intersection, a Double Arrow Board is installed on the far side of the intersection facing the minor approach to warn drivers that the roadway does not continue straight past the intersecting roadway.

- For the major road approach, Intersection Ahead warning signs are recommended (mounted left and right). In addition, it is recommended that street name signs be placed underneath each intersection warning sign. These street name plaques provide the driver with additional information about the street the motorist is approaching so he or she can make an early decision regarding potential turning movements.
- The installation of edge line and centerline pavement markings are also recommended on the main line approach, with a gap in the centerline pavement marking to indicate the presence of an intersecting roadway.

Even if all signs cannot be feasibly installed at a given intersection, enhancement of traffic control devices with installation of part of this sign and pavement marking package can provide some level of improved safety.

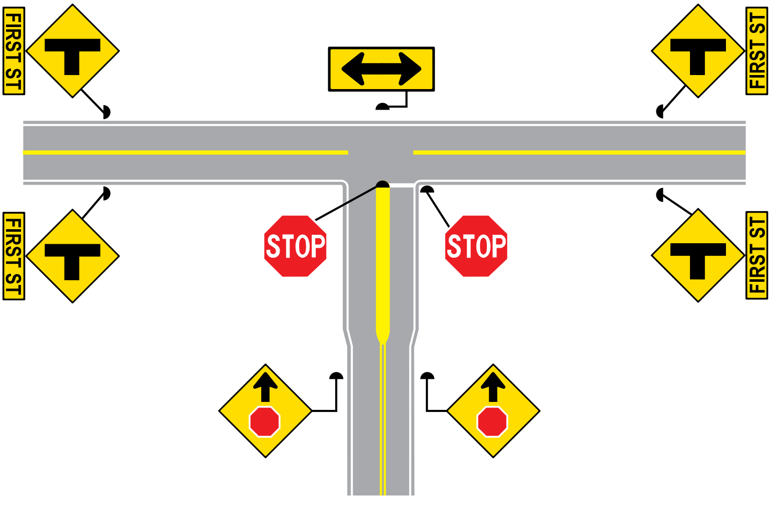


Figure 5 – Basic Package for Intersections Experiencing Crashes[12]

In addition to this basic package, supplemental enhancements can be installed as needed. For example, Stop signs can be oversized (typically 48 inches wide, but sometimes up to 60 inches is acceptable), with a reflective red strip on the post, or with a flashing red beacon installed above the sign to increase recognition of the intersection. Flashing

12 Federal Highway Administration, *Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections*, FHWA-SA-09-020, (Washington, DC: May 2009).

amber beacons and yellow reflective post strips can be added to warning signs.

Additional enhancements to pavement markings include raised pavement markers (RPMs) and pavement legends, including the word "STOP" painted on the roadway just before the stop bar.

For intersections identified for safety improvements, additional analysis may be needed to determine the most appropriate countermeasures to reduce future crashes. The information compiled from the database will help determine, for each intersection, the contributing crash and roadway attributes that will form the foundation for selecting appropriate countermeasures.

4.2. Select Intersection Countermeasures

This section contains specific information on a number of select countermeasures to prevent future crashes at unsignalized intersections. These individual treatments should be considered in addition to, or in lieu of, the basic package discussed previously to address specific safety issues. This does not represent an all-inclusive list of intersection countermeasures; for additional countermeasures see the following documents.

- NCHRP Report 500, Volume 5. "A Guide for Addressing Unsignalized Intersection Collisions."
- Federal Highway Administration, "Objectives and Strategies for Improving Safety at Unsignalized and Signalized Intersections."
- Federal Highway Administration, "Intersection Safety Strategies Brochure."

Each countermeasure discussed includes the following information:

- *Crash Type Addressed* – In order to effectively reduce the number and severity of intersection crashes, it is necessary to match countermeasures to the crash types they are intended to address. For example, if the most frequent crash types are angle crashes due to poor sight distance with an overgrowth of foliage, the most effective countermeasure would be to clear the intersection's sight triangles to improve sight distance.
- *Where to use* – Some countermeasures will have specific types of intersections where their benefit is greater than others. For example, the addition of a turn lane is most likely to benefit an intersection with a high number of turning vehicles.
- *Why it works* – A discussion of the benefit of a countermeasure is important

to determine its appropriateness to address certain intersection crash types.

- *Timeline for Implementation* – This category refers to the relative approximate time it can take to implement the countermeasure.

● ○ ○	Short Time Period
● ● ○	Moderate Time Period
● ● ●	Long Time Period

- *Estimated cost* – Most countermeasures included in this report are considered low-cost; low to moderate cost; or moderate cost. These categories represent relative costs of the countermeasures to each other. Costs can vary considerably due to local conditions.
- *Crash Reduction Factor* – The crash reduction factor (CRF) for a given countermeasure is an indication of how many crashes a treatment is expected to reduce if installed. It is calculated based on research conducted on the pre- and post-crash frequencies at sites where the countermeasure has been installed specifically to address a certain crash type. For example, an oversized Stop sign may be installed to improve recognition of the intersection. In this case, it is expected that right-angle crashes at the intersection will be reduced. The higher the CRF, the greater the expected reduction in crashes. For instance a CRF of 20 percent is interpreted as an expected reduction of 20 percent of crashes.[13, 14] The effect of a countermeasure on crashes can also be expressed as a Crash Modification Factor (CMF). It is defined mathematically as 1 – CRF. In the example above, a 20 percent reduction of crashes is represented by a CMF of 0.80. This effect of the countermeasure can be calculated by multiplying its value by the number of current crashes to determine an expected number of future crashes. For instance, if there are 50 current crashes, by multiplying the CMF of 0.80 times 50, one could expect 40 future crashes.

13 Unless otherwise noted, CRFs in this document were from "Issue Brief: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes." Available at: http://safety.fhwa.dot.gov/intersection/resources/fhwasa10005/brief_8.cfm

14 Additional CRFs can be found at the *Crash Modification Factors Clearinghouse*. Available at: http://www.cmfclearinghouse.org

Improve Visibility of Intersections by Providing Enhanced Signing and Delineation

Crash type addressed

Right-angle and rear-end crashes attributed to drivers unaware of the intersection.

Time:	● ○ ○
Cost:	*Low*
CRF:	*40%*

Where to use

Unsignalized intersections that are not clearly visible to approaching motorists, particularly approaching motorists on the major road. The strategy is particularly appropriate for intersections with patterns of rear-end, right-angle, or turning crashes related to lack of driver awareness of the presence of the intersection.

Why it works

Installation of signing in advance of and at intersections will provide approaching motorists with additional information at these locations. Drivers should be more aware that the intersection is coming up, and therefore make safer decisions as they approach the intersection.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Provide Improved Maintenance of Stop Signs

Crash type addressed

Right-angle crashes attributed to drivers unaware of the intersection or failing to stop at the Stop sign.

Time:	● ○ ○
Cost:	*Low*
CRF:	*Unknown*

Where to use

All stop-controlled intersections should be addressed with this treatment. Damaged signs should be replaced without undue delay, and a suitable schedule for inspection, cleaning, and replacement of Stop signs should be established.

Why it works

The Stop sign is often the only indication to drivers that conflicting traffic could be approaching at an intersection. Maintenance of Stop signs must be at a high standard to ensure that the effectiveness of the signs is retained.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Provide a Stop Bar on Minor Road Approaches

Crash type addressed

Right-angle crashes attributed to drivers unaware of the intersection or failing to stop at the Stop sign.

Time:	● ○ ○
Cost:	*Low*
CRF:	*19%*

Where to use

Minor road approaches where conditions allow the stop bar to be seen by an approaching driver at a significant distance from the intersection. Locations should be identified by patterns of crashes related to lack of driver recognition of the intersection.

Why it works

Providing visible stop bars on minor road approaches to unsignalized intersections can help direct the attention of drivers to the presence of the intersection.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Provide Supplementary Stop Signs Mounted Over the Roadway

Crash type addressed

Right-angle and rear-end crashes attributed to drivers unaware of the intersection or failing to stop.

Time:	● ○ ○
Cost:	*Low*
CRF:	*Unknown*

Where to use

Unsignalized intersections with patterns of right-angle crashes related to lack of driver awareness of the presence of the intersection. In particular, it might be appropriate to use this strategy at the first stop-controlled approach (possibly of a series) located on a long stretch of highway without any required stops, or at an intersection located after a sharp horizontal curve.

Why it works

Installation of an additional Stop sign above the roadway will provide approaching motorists a clear message that they must stop at the intersection. This reduces the opportunity for right-angle crashes attributed to a driver inadvertently running the Stop sign.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Install Flashing Beacons at Stop-Controlled Intersections

Crash type addressed

Right-angle and rear-end crashes attributed to drivers unaware of the intersection or failing to stop at the Stop sign.

Time:	● ○ ○
Cost:	*Low*
CRF: Angle crashes	*12–58%*

Where to use

Unsignalized intersections with patterns of right-angle crashes related to lack of driver awareness of the intersection on an uncontrolled approach and lack of driver awareness of the Stop sign on a stop-controlled approach.

Why it works

Flashing beacons provide a visible signal to the presence of an intersection and can be very effective in rural areas where there may be long stretches between intersections as well as locations where nighttime visibility of intersections is an issue.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Install Splitter Islands on the Minor Road Approach to an Intersection

Crash type addressed

Right-angle and rear-end crashes attributed to drivers unaware of the intersection.

Time:	● ● ○
Cost:	*Moderate*
CRF:	*35–45%*
Injury crashes	

Where to use

Minor road approaches to unsignalized intersections where the presence of the intersection or the stop sign is not readily visible to approaching motorists. The strategy is particularly appropriate for intersections where the speeds on the minor road are high.

Why it works

The installation of splitter islands allows for the addition of a stop sign in the median to make the intersection more conspicuous. Additionally, the splitter island on the minor-road provides for a positive separation between turning vehicles on the through road and vehicles stopped on the minor-road approach.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Install Transverse Rumble Strips

Crash type addressed

Right angle and roadway departure crashes attributed to motorists unaware of Stop or Yield signs as they approach an intersection.

Time:	● ○ ○
Cost:	*Moderate*
CRF:	*28–35%*

Where to use

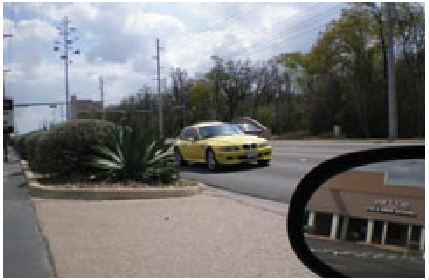
Transverse rumble strips are installed in the travel lane for the purposes of providing an auditory and tactile sensation for each motorist approaching the intersection. They can be used at any stop or yield approach intersection, often in combination with advance signing to warn of the intersection ahead. Due to the noise generated by vehicles driving over the rumble strips, care must be taken to minimize disruption to nearby residences and businesses.

Why it works

When motorists are traveling along the roadway, they are sometimes unaware they are approaching an intersection. This is especially true on rural roads, as there may be fewer cues indicating an intersection ahead. Transverse rumble strips warn motorists that something unexpected is ahead that they need to pay attention to.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Clear Sight Triangles on Stop- or Yield-Controlled Approaches to Intersections



Crash type addressed

Right-angle and left-turn crashes attributed to poor sight distance at the intersection. Minor road vehicles could be turning right, left, or going straight.

Time:	● ○ ○
Cost:	*Moderate*
CRF:	*14–26%*

Where to use

Unsignalized intersections with restricted sight distance and patterns of crashes related to lack of sight distance where sight distance can be improved by clearing roadside obstructions without major construction.

Why it works

By removing sight distance restrictions (e.g., vegetation, parked vehicles, signs, buildings) from the sight triangles at stop or yield-controlled intersection approaches, drivers will be able see approaching vehicles on the main line, without obstruction and therefore make better decisions about entering the intersection safely.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Provide Right-Turn Lanes at Intersections

Crash type addressed

Rear-end crashes attributed to right turning vehicles hit from behind.

Time:	● ● ○
Cost:	*Moderate*
CRF:	*14–26%*

Where to use

Unsignalized intersections with a high frequency of rear-end crashes resulting from conflicts between (1) vehicles turning right and following vehicles and (2) vehicles turning right and through vehicles coming from the left on the cross street.

Why it works

Providing right-turn lanes at intersections will allow vehicles that are traveling through the intersection to continue without stopping while turning vehicles will use the right-turn lanes. Assuming turn lanes are of adequate length, vehicles will not be stopped on the travel lanes which allows for through traffic to continue without stopping for vehicles turning at an intersection.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Provide Bypass Lanes on Shoulder at T-Intersections

Crash type addressed

Rear-end crashes attributed to left turning vehicles hit from behind.

Time:	● ○ ○
Cost:	*Low*
CRF:	*24%*

Right-angle injury crashes

Where to use

At three-legged unsignalized intersections on two-lane highways with moderate through and turning volumes, especially intersections that have a pattern of rear-end collisions involving vehicles waiting to turn left from the mainline.

Why it works

Providing bypass lanes on the shoulder will allow vehicles that are traveling through the intersection to continue without stopping, thus reducing the potential for stopped vehicles waiting to make the turn from being hit from behind.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Provide Left-Turn Lanes at Intersections

Crash type addressed

Rear-end crashes attributed to left-turning vehicles hit from behind.

Time:	●●○
Cost:	*Moderate*
CRF:	*28–48%*

Where to use

Unsignalized intersections with a high frequency of crashes resulting from the conflict between (1) vehicles turning left and following vehicles and (2) vehicles turning left and opposing through vehicles.

Why it works

Providing left-turn lanes at intersections will allow vehicles that are traveling through the intersection to continue without stopping while turning vehicles will use the left-turn lanes. Assuming turn lanes are of adequate length, vehicles will not be stopped on the travel lanes which allows for through traffic to continue without stopping for vehicles turning at an intersection.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Provide Offset Left-Turn Lanes at Intersections

Crash type addressed

Head-on and angle crashes due to left-turning motorists pulling out in front of opposing through traffic.

Time:	●●○
Cost:	*Moderate–High*
CRF:	*20–26%*

Urban locations

Where to use

Unsignalized 4-legged intersections with a high frequency of crashes between vehicles turning left and opposing through vehicles. This treatment can be applied at intersections on divided highways with medians wide enough to provide the appropriate positive offset, and also on approaches without medians if sufficient width exists.

Why it works

Positive offset turn lanes provide the left-turning motorist a line of sight to opposing through vehicles. Instead of attempting to look around opposing left-turning vehicles, the motorist can clearly see oncoming traffic.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Realign Skewed Intersection

Crash type addressed

Skew reduction or elimination is appropriate at unsignalized intersections with a high frequency of crashes resulting from insufficient sight distance caused by the skew.

Time:	●●○
Cost:	*Moderate – High*
CRF:	*Varies*

*The CRF varies by the degree of skew.

Where to use

Skew realignment is appropriate at unsignalized intersections with a high frequency of crashes resulting from insufficient intersection sight distance and awkward sight lines at a skewed intersection.

Why it works

Reducing or eliminating the skew at intersection approaches helps address problems like vehicle alignment, long exposure in the intersection, and potential driver confusion. Treatments include pavement markings, channelizing islands, and realignment.

* The CRF varies by the degree of skew. Details are available at http://safety.fhwa.dot.gov/intersection/resources/intsafestratbro/ub16_intersection_skew.pdf

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Improve Visibility of the Intersection by Providing Lighting

Crash type addressed

Right-angle, left-turn, and rear-end crashes attributed to dark conditions.

Time:	●●○
Cost:	*Moderate–High*
CRF: Injury crashes	*38%*

Where to use

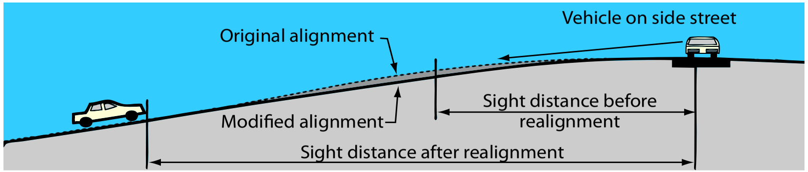
Unsignalized, unlit intersections with substantial patterns of nighttime crashes. In particular, patterns of rear-end, right-angle, or turning crashes on the major road approaches to an unsignalized intersection may indicate that approaching drivers are unaware of the presence of the intersection.

Why it works

At night in rural areas, the only source of lighting for roadways is generally provided by vehicle headlights. Roadway lighting allows for greater visibility of the intersection which makes the intersection more conspicuous to motorists and provides aid in helping drivers determine their paths through the intersection by making signs and markings more visible.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Change Horizontal and/or Vertical Alignment of Approaches to Provide More Sight Distance



Time:	● ● ●
Cost:	*High*
CRF:	*5–17%*

Crash type addressed

Right-angle and rear-end crashes attributed to poor sight distance.

Where to use

Unsignalized intersections with restricted sight distance due to horizontal and/or vertical geometry and with patterns of crashes related to that lack of sight distance that cannot be ameliorated by less expensive methods.

Why it works

Although changing alignment is a high cost treatment, in some cases sight distance is restricted by horizontal and vertical curvature. Straightening a roadway will increase sight distance and allow for better visibility of other vehicles and the intersection itself.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

Install Roundabout Intersection

Crash type addressed

Right-angle and left-turn crashes attributed to motorists unaware of Stop or Yield signs, unaware of conflicting traffic at the intersection, or misjudging gaps in the mainline traffic.

Time:	● ● ●
Cost:	*High*
CRF:	*71%*

Where to use

Roundabouts can be installed in a wide variety or rural locations. In particular, unsignalized intersections with a history of right angle crashes are good candidates for roundabout installation. Sufficient agency-owned right-of-way is necessary to install the roundabout, as its geometric footprint differs from a traditional intersection.

Why it works

Roundabouts are a proven safety treatment for intersection crashes due to a reduced number of conflict points and reduced intersection speeds. A motorist approaching the intersection looks in only one direction for conflicting traffic before entering the roundabout. The geometry of the approach legs and the inner circle keep speeds low, reducing the severity of any crash that might occur.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Issue Brief 8: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes," FHWA, 2009.

4.3. Funding Intersection Safety Countermeasures

Each State has a Strategic Highway Safety Plan (SHSP) as a requirement of the Federal funding legislation: the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). As part of that requirement, Federal funds are set aside for transportation safety projects. Some sources of Federal safety funding include the following:

- **Highway Safety Improvement Program (HSIP).** The HSIP is a Federal Aid program focused on improving traffic safety on all public roads with infrastructure solutions.
- **High Risk Rural Roads Program (HRRRP).** The HRRRP is a set aside from the HSIP funds. It focuses on addressing rural road safety needs on rural major and minor collectors and local rural roads with construction and operational improvements.
- **Safe Routes to School (SRTS) Program.** The SRTS Program empowers communities to make walking and bicycling to school a safe and routine activity. The program makes funding available for a wide variety of programs and projects, from building safer street crossings to establishing programs that encourage children and their parents to walk and bicycle safely to school.

Human behavior-related funding sources for traffic safety include the following:

- **NHTSA Programs.** The National Highway Traffic Safety Administration (NHTSA) provides a number of funding sources focused on human behavior aspects of traffic safety with emphases on speeding, safety belt use, child passenger safety, and impaired and distracted driving.[15]
- **GHSA Programs.** Programs promoted by the Governors Highway Safety Association (GHSA) target unsafe driving practices at the State level.[16]

In addition, potential access to other transportation funding sources (not directly focused on safety) for safety projects may also be available. Further information about Federal funding sources can be accessed at the FHWA Office of Safety website: http://safety.fhwa.dot.gov.

Outside the Federal funding sources, State safety funds may be available to a jurisdiction for intersection safety projects.

Action: Contact the State DOT or LTAP Center to find out more information about how Federal and State safety funds are used and could potentially be used to support safety projects at local intersections.

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15 For details on NHTSA funding sources, see National Highway Traffic Safety Administration, "SAFETEA-LU Information and Facts Sheets" available at: http://www.nhtsa.gov/About+NHTSA/Programs+&+Grants/SAFETEA-LU+Information+and+Facts+Sheets

16 For details on GHSA Program funding sources, visit http://www.ghsa.org.

5 Evaluation

It is important to evaluate intersection safety treatments after installation to determine their effectiveness. The effort that goes into conducting the assessment will help guide future decisions regarding intersection countermeasures.

A record of crash histories, if available, and countermeasure installations forms the foundation for assessing how well implemented strategies have performed. It is important to keep a current list of installed intersection countermeasures with documented "when/where/why" information. Periodic assessments will provide the necessary information to make informed decisions on whether each countermeasure contributed to an increase in safety, whether the countermeasure could or should be installed at other locations, and which factors may have contributed to the strategy's success.

To perform the assessment it is necessary to collect the required information for a period of time after strategies were deployed at the intersection. The time period varies, but should be no less than one full year (with 3 years preferred). The information required may consist of public input and complaints, police reports, and observations from maintenance crews. The most important information is crash data before and after implementation.

It is important to keep the list of strategy installations up to date since it will serve as a record of countermeasure history. By using this type of system, assessment dates can be scheduled to review the crashes and other pertinent information at intersections where treatments have been installed (see Table 4).

Action: Develop a spreadsheet to track future safety project installations and record 3 years of "before" crash information at those locations.

Intersection	Specific Location	Type of Countermeasures Installed	Date Installed	Date Removed (If Appl.)	Comments	3 Years Prior to Installation			1 Year After Installation		
						Number of Public Comments	Number of Crashes	Number of Near Misses	Number of Public Comments	Number of Crashes	Number of Near Misses
Middlebrook Pike and Waples Mill Road	Waples Mill – West Approach	Stop Sign	12/19/2009		Sign was old and faded	0	0	0			
Rt. 123 and Fox Mill Road	Fox Mill Road – South Approach	Stop Bars	7/9/2008			5	0	1	2	0	0
Route 657 and Glade Drive	Route 657 – East Approach	Traffic Island at Stop Approach	6/4/2008			2	2	3	0	0	2
Route 657 and Clifton Road	Clifton Run – North Approach	Added Left-turn Lane	8/8/2007			4	1	3	1	0	0

Table 4. Example Spreadsheet to Monitor Countermeasure Application History and Crash/Observational Data

6 Summary

Fatalities at rural road intersections account for approximately 40 percent of the national intersection related fatalities; more than 80 percent of these fatalities occur at unsignalized intersections. Local administrators, township managers, and public works officials who maintain and operate local rural roads should be engaged in intersection safety to identify intersections with safety issues and choose countermeasures to reduce the number and severity of intersection crashes.

To date, several States have completed Intersection Safety Implementation Plans with assistance from FHWA. These plans were developed to guide intersection safety implementation activities on State and local roads arising from the State Strategic Highway Safety Plans. The plans include the activities, countermeasures, strategies, deployment levels, implementation steps, and estimate of funds necessary to achieve intersection safety goals. The local road practitioners should consult their State's Intersection Safety Implementation Plan, if available, before embarking on an improvement strategy.

When seeking to address local rural road intersection safety, the local practitioners should consider which implementation approach to use. The three main approaches are systematic, spot location, and comprehensive. Availability and quality of intersection crash and roadway data, the number of locations to be addressed, and available funding are factors that may play a role in the selection of an implementation approach.

Determining the nature of the problems and their locations will assist in making the most informed decisions for countermeasure selection and implementation in addressing intersection safety issues. When conducting a safety analysis, a minimum of 3 years of crash data is desired to obtain an accurate picture of the intersection safety issues within a jurisdiction, since crashes are relatively rare events and are not universally distributed across all intersections. Due to the possibility of changes in traffic patterns and the roadway itself, data more than 5 years old are typically not desirable for assessing safety issues.

Analysis can range from simple "push pin" maps for identifying crash clusters to statistical analyses of crash rates, depending on the crash history and other available data. There are a number of information sources that can be used to identify crashes that are occurring at rural intersections; State and local crash databases, law enforcement crash reports and citations, observational information from road maintenance crews and law enforcement, and public notification of safety concerns.

Other variables to be considered when conducting analysis include crash location, date and time, crash type, crash severity, weather conditions, sequence of events, and contributing circumstances. In addition, roadway data and traffic volumes are factors to be considered when determining the intersection safety issues.

Regardless of the implementation approach chosen, a field review should be conducted at identified locations. Intersection field reviews have the potential to identify safety issues and solutions that cannot be determined by data analysis alone. Field reviews can be conducted as informal field assessments or as formal Road Safety Audits (RSAs).

Decisions regarding which countermeasures to install to address a safety issue can be challenging. When appropriate, the local practitioner should seek engineering expertise from a State or local engineer or through the State Local Technical Assistance Program (LTAP). For a conventional unsignalized intersection, a typical enhancement of sign and pavement markings including double Stop signs, Stop Ahead signs and stop bars on the minor leg(s) of the intersection and intersection warning signs and appropriate pavement markings for the major leg(s) of the intersection should be considered. This installation is recommended for intersection locations that have experienced a high or moderate level of crashes. In addition, a high number of supplemental countermeasures are available for deployment based on crash history, location, and level of effectiveness.

Countermeasure assessment after implementation is important to the intersection safety program. This will inform the practitioner of the effectiveness of the strategy and if it should be applied to other locations. The most common methodology for the evaluation of a given countermeasure is the analysis of crash data before and after its installation. Three years of data after the installation is ideal for evaluation, however, changes in traffic volume and roadway information can also affect the outcome and should be taken into account during assessment.

Local highway agencies have unique responsibilities and challenges related to the safety of the intersections on their roadway system. By beginning any traffic safety effort using a data-supported approach, those agencies will be in a better position to address their highway safety needs. While the challenge to decrease the number of intersection crashes on local rural roads can be challenging due to limited resources, there are a number of low-cost proven countermeasures that can be installed to improve intersection safety on local roads and many can be installed within a short timeframe.

Appendix A – Resources and References

This section contains references to further information on the types of countermeasures available, studies and technical reports on local rural roads and intersections, and guidelines used for countermeasure installation.

Selected Technical Resources

Federal Highway Administration, *Intersection Safety website*. Available at *http://safety.fhwa.dot.gov/intersection/*

Federal Highway Administration, *Rural Intersection Safety website*. Available at *http://safety.fhwa.dot.gov/intersection/rural*

Federal Highway Administration, Unsignalized Intersection Safety website. Available at *http://safety.fhwa.dot.gov/intersection/unsignalized/*

Federal Highway Administration, "Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections," FHWA-SA-09-020. (Washington, DC: 2009). Available at *http://safety.fhwa.dot.gov/intersection/resources/fhwasa09020/*

Federal Highway Administration, "Objectives and Strategies for Improving Safety at Unsignalized and Signalized Intersections," (Washington, DC: 2008). Available at *http://safety.fhwa.dot.gov/intersection/resources/intsafestratbro/inter_guide_key.cfm*

Federal Highway Administration, "Intersection Safety Strategies Brochure," FHWA-SA-08-008 (Washington, DC: 2008). Available at *http://safety.fhwa.dot.gov/intersection/resources/intsafestratbro/#ue*

American Traffic Safety Services Association, National Association of County Engineers, "Low Cost Local Road Safety Solutions," 2006. Available at *http://safety.fhwa.dot.gov/intersection/resources/fhwasa09027/resources/Low%20Cost%20Local%20Road%20Safety%20Solutions.pdf*

Federal Highway Administration, "Guidance Memorandum on Consideration and Implementation of Proven Safety Countermeasures." Available at *http://safety.fhwa.dot.gov/policy/memo071008/*

Neuman, T.R., et al. *A Guide for Addressing Unsignalized Intersection Collisions*, NCHRP Report 500, Vol. 5. TRB, National Research Council, Washington, DC. 2003. Available at: *http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v5.pdf*

Federal Highway Administration, *Road Safety Audits website*. Available at *http://safety.fhwa.dot.gov/rsa/*

Federal Highway Administration, Manual on Uniform Traffic Control Devices (Washington, DC: 2009). Available at *http://mutcd.fhwa.dot.gov/*

Federal Highway Administration, "Vegetation Control for Safety: A Guide for Local Highway and Street Maintenance Personnel" FHWA-SA-07-018 *http://safety.fhwa.dot.gov/local_rural/training/fhwasa07018/*

McNinch, T.L. and Colling, T.K., "Traffic Safety Education for Nonengineers." U.S. Department of Transportation, Federal Highway Administration, pp. 32-38, *Public Roads*, May/June 2009. Available at *http://www.fhwa.dot.gov/publications/publicroads/09june/05.cfm*

Resources Related to Program Development and Coordination

Local Technical Assistance Program (LTAP)

The web page below summarizes the roles and functions of the LTAP program and provides links, by State, for local points of contact who may help identify data, resources, and offer assistance.
http://www.ltapt2.org/nltapa

Strategic Highway Safety Plans (SHSP)

Each State is required to develop an SHSP to promote best practices and strategies that are designed to have a substantial impact on reducing fatal and injury crashes. There is no central site for all State plans; to review your State's plan, you will need to search using your State and "strategic highway safety plan" as search terms in order to access and review your State's plan. The FHWA has resources available to help States' in their development and implementation efforts.
http://safety.fhwa.dot.gov/hsip/shsp/

Resources Related to Data Analysis and Evaluation

Federal Highway Administration, *Highway Safety Facts and Statistics* website. Available at *http://safety.fhwa.dot.gov/facts_stats/*

National Highway Traffic Safety Administration, Center for Statistics and Analysis, *Fatality Analysis Reporting System (FARS)*. Available at *http://www-fars.nhtsa.dot.gov/Main/index.aspx*

Green, E.R. and Agent, K.R., *Crash Rates at Intersections*, University of Kentucky College of Engineering, Kentucky Transportation Center. Research Report KTC-03-21/SPR258-03-2I (2003). Available at *http://www.ktc.uky.edu/Reports/KTC_03_21_SPR258_03_2I.pdf*

Gross, F. and Yunk, K. U.S. "Using CRFs to Improve Highway Safety." Department of Transportation, Federal Highway Administration, *Public Roads*, May/June 2009, pp. 26-31. Available at *http://www.fhwa.dot.gov/publications/publicroads/09june/04.cfm*

Federal Highway Administration, "Issue Brief: Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes." (Washington, DC: 2009). Available at *http://safety.fhwa.dot.gov/intersection/resources/fhwasa10005/brief_8.cfm*

Federal Highway Administration, "Desktop Reference for Crash Reduction Factors." (Washington, DC: 2007). Available at *http://www.ite.org/safety/issuebriefs/Desktop%20Reference%20Complete.pdf*

Federal Highway Administration, *Crash Reduction Factors website*. Available at *http://safety.fhwa.dot.gov/tools/crf/*

Federal Highway Administration, Crash Modifications Factors Clearinghouse website. Available at *http://www.cmfclearinghouse.org/*

Examples of State Programs and Initiatives

Federal Highway Administration, "Making the Case for Transportation Safety – Ideas for Decision Makers" (Washington, DC: 2008) Available at *http://tsp.trb.org/assets/briefing%20book%20hi-res.pdf*

Iowa Department of Transportation, "Crash Analysis." Available at *http://www.intrans.iastate.edu/pubs/traffichandbook/5CrashAnalysis.pdf*

Minnesota Department of Transportation and Minnesota Local Road Research Board, *Safety Impacts of Street Lighting at Isolated Rural Intersections*, 2004. Available at *http://www.ctre.iastate.edu/reports/rural_lighting.pdf*

Federal Highway Administration, Wyoming Technical Transfer Center, Kansas LTAP, "Field Guide for Unpaved Rural Roads." (2004) *http://www.t2.unh.edu/pubs/field_guide.pdf*

Appendix B – MUTCD Compliance Issues at Rural, Two-Way Stop-Controlled Intersections

All Signs

Retroreflectivity (MUTCD Table 2A-3)

The MUTCD provides suggestions for methods to be used:

A. **Visual Nighttime Inspection**—The retroreflectivity of an existing sign is assessed by a trained sign inspector conducting a visual inspection from a moving vehicle during nighttime conditions. Signs that are visually identified by the inspector to have retroreflectivity below the minimum acceptable level should be replaced.

B. **Measured Sign Retroreflectivity**—Sign retroreflectivity is measured using a retroreflectometer. Signs with retroreflectivity below the minimum acceptable level should be replaced.

C. **Expected Sign Life**—When signs are installed, the installation date is labeled or recorded so that the age of a sign is known. The age of the sign is compared to the expected sign life. The expected sign life is based on the experience of sign retroreflectivity degradation in a geographic area compared to the minimum acceptable level. Signs older than the expected life should be replaced.

D. **Blanket Replacement**—All signs in an area/corridor, or of a given type, should be replaced at specified intervals. This eliminates the need to assess retroreflectivity or track the life of individual signs. The replacement interval is based on the expected sign life compared to the minimum levels for the shortest-life material used on the affected signs.

E. **Control Signs**—Replacement of signs in the field is based on the performance of a sample of control signs. The control signs might be a small sample located in a maintenance yard or a sample of signs in the field. The control signs are monitored to determine the end of retroreflective life for the associated signs. All field signs represented by the control sample should be replaced before the retroreflectivity levels of the control sample reach the minimum acceptable level.

F. **Other Methods**—Other methods developed based on engineering studies can be used.

Roadside Placement (MUTCD, Figure 2A-2)

For a typical rural road with no shoulder, the sign should be placed on the right side of the roadway, 12 feet laterally from the edge of the traveled way. In terms of vertical height, the bottom of the sign should be installed 5 feet above the ground elevation at the edge of pavement.

Enhancing Sign Conspicuity Cost Effectively (MUTCD Figure 2A-1)

In a situation where it is desirable to enhance a sign's conspicuity, any of the following methods may be used:

- Increasing the size of the sign;
- Doubling-up by adding a second identical sign on the left hand side of the roadway; or
- Adding a strip of retroreflective material to the sign support.

Regulatory Signs and Markings

Stop Sign (R1-1)

Sign Size
The minimum size for a STOP sign shall be 30″ x 30″ for a typical rural, two-lane facility.

Stop Bars

Design
Stop bars shall be a solid white line.

Stop bars should be 12-24″ wide.

Placement
The stop line should be placed at the desired stopping or yielding point, but should not be placed more than 30 feet or less than 4 feet from the nearest edge of the intersecting traveled way.

Pavement Markings

Design
Markings should be visible at night by use of retroreflectivity or ambient illumination (Section 3A.03).

The MUTCD specifies allowable colors for pavement markings and the function of each color. (Section 3A.05).

Placement
To avoid confusion to the road user, pavement markings should be placed according to the MUTCD, and pavement markings which are no longer applicable should be removed (Section 3A.02)

Warning Signs

All Signs

When to use
The use of warning signs shall be based on an engineering study or on engineering judgment.

Placement
Warning signs should be installed in advanced of the intersection in accordance with Table 2C-4, which provides placement distances based on speed.

Stop Ahead (W3-1)

Sign Size: 30″ x 30″ minimum

These signs shall be installed on an approach to a STOP sign that is not visible for a sufficient distance to permit the road user to respond to the device.

To be used only on the "side road" that must come to a stop.

Intersection Ahead (W2-1, W2-2, W2-3, W2-4)

Sign Size: 30″ x 30″ minimum

The Intersection Warning sign should illustrate and depict the general configuration of the intersecting roadway, such as cross road, side road, T-intersection, or Y-intersection.

Advisory Speed Plaque (W13-1P)

Sign Size: 18″ x 18″

Roadside Placement
The sign height changes when a speed plaque is added. See Figure 2A-2, Page 38, for details.

Two-Direction Large Arrow (W1-7)

Sign Size: 48″ x 24″

The two-direction large arrow shall be installed on the far side of a T-Intersection in line with, and at approximately a right angle to, traffic approaching from the stem of the T-intersection.

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For More Information

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Washington, DC 20590-9898
http://safety.fhwa.dot.gov

FHWA-SA-11-08