Roadway Departure Safety

A Manual for Local Rural Road Owners

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16. Abstract

According to the Federal Highway Administration, over 6 million lane-miles are in rural areas, and more than two-thirds of these rural roads are owned and operated by local entities. Rural areas face a number of highway safety challenges due to the nature of their facilities. Roadway departure crashes are frequently severe and account for the majority of fatalities in rural areas.

This document provides information on effectively identifying roadway departure 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. This document offers information on the procedures and processes to improve the safety of local rural roadways and to reduce the potential for future roadway departure crashes.

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1 Introduction and Purpose

Why Has This Manual Been Developed?

Local rural roads vary from two-lane paved highways to gravel or dirt roads in mountainous, forest, or tribal areas. A portion of these roadways lack basic signing, pavement markings, and appropriate alignment and delineation features. In many cases local agencies have no plans for improvements due to factors such as funding, low traffic volumes, or topographical challenges.

This document provides local road practitioners with relevant information to reduce roadway departure crashes on the roadway network. It discusses identifying locations with historical or potential rural roadway departure issues and countermeasures that address them. It offers information on the procedures and processes to improve safety by reducing the potential for roadway departure crashes.

Local roads are managed by more than 38,000 counties, villages, towns, and tribal governments.[1] Local administrators, township managers, and public works officials maintain and operate a variety of road types; often roadway safety and infrastructure maintenance may be only a small part of their job. The information is geared toward local road managers and other practitioners with responsibility for operating and maintaining local roads, regardless of safety-specific highway training. This document is designed to provide the practitioner with targeted information on roadway departure safety.[2] It is not intended as a comprehensive guide for improving roadway departure crashes. It does, however, provide a framework that can be used to assess and improve the safety of the local road network and its potential for this type of crash.

1 McNinch, T.L. and Colling, T.K. "Traffic Safety Education for Nonengineers." *Public Roads*, May/June, 2009, pp 32-39.

2 The Federal Highway Administration (FHWA) defines roadway departure crashes as, "a non-intersection crash which occurs after a vehicle crosses an edge line or a center line, or otherwise leaves the traveled way."

1.1. The Roadway Departure Crash Problem

In 2008 the Fatality Analysis Reporting System (FARS) indicated that 56 percent of fatalities on U.S. roadways occurred in rural areas. This is out of proportion, since rural roadways account for just 40 percent of all vehicle miles traveled nationally.[3]

Roadway departure crashes are frequently severe and account for the majority of U.S. highway fatalities.

There were 17,818 fatal roadway departure crashes in the same year, which was 53 percent of the fatal crashes in the United States.[4] More than 28 percent of all fatal crashes were associated with horizontal curves. The average crash rate for horizontal curves is about three times that of other types of highway segments. About three-quarters of curve-related fatal crashes involve a single vehicle leaving the roadway and striking trees, utility poles, rocks or other fixed objects, or overturning.[5] Eleven percent are head-on crashes, which are the result of a vehicle entering the opposing lane.[6] This can occur when a driver enters the opposing lane to maintain speed around the curve, or when a driver overcorrects after running off the right side of the roadway.

To reduce the number and severity of roadway departure crashes, safety practitioners focus on a hierarchy of three objectives:

1. Keep vehicles on the roadway;
2. If a vehicle leaves the roadway, provide an opportunity to return to the road safely; and
3. Minimize the severity of a roadway departure crash if it occurs.

A data-based approach to identifying roadways with a history of roadway departure crashes and those with the potential for these crashes is discussed in this document. Potential locations are based on factors such as road geometry and the presence of fixed objects in the clear zone.

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3 University of California – Berkeley, Safe Transportation Research and Education Center, "SafeTrec – Rural Road Safety" web page, 2009. Available at http://www.tsc.berkeley.edu/research/ruralroads.html

4 Federal Highway Administration, "Roadway Departure Safety" website. Available at: http://safety.fhwa.dot.gov/roadway_dept/horicurves/

5 University of California – Berkeley, Safe Transportation Research and Education Center, "SafeTrec – Rural Road Safety" web page, 2009. Available at http://www.tsc.berkeley.edu/research/ruralroads.html

6 American Association of State Highway and Transportation Officials, *Driving Down Lane Departure Crashes: A National Priority*, (Washington, DC: April 2008). Available at: http://downloads.transportation.org/PLD-1.pdf

1.2. Implementation Approaches

When working to reduce roadway departure crashes on the local rural road network, the practitioner should consider the implementation approach. Typical approaches include:

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

Systematic Approach

For the systematic approach the primary basis is crash types and proven safety countermeasures with specific crash locations 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 chosen and treated systematically with low cost proven 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.

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, thereby 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 a 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.

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 will likely 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 those.

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.

Comprehensive Approach

The comprehensive approach introduces the concept of the "4 E's of Safety": Engineering, Enforcement, Education, and Emergency Medical Services (EMS). 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 rural safety.

Some roadway segments will be identified that have frequent driving violations for which targeted enforcement is an appropriate countermeasure. In general, the most common violations 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 segments and corridors to reduce the potential for future driving violations and related crashes. Education and outreach efforts should supplement enforcement to improve the effect of each.

1.3. State Safety Plans

State highway agencies have developed statewide plans to address roadway departure safety problems. As local agencies learn about their own roadway departure safety needs, the State highway agency and State Local Technical Assistance Program (LTAP) office could be of assistance.

Strategic Highway Safety Plans (SHSP)

Beginning in 2005, States were required by the transportation legislation to develop an SHSP to be eligible for Federal safety funding. An SHSP is a statewide-coordinated safety plan that provides a comprehensive framework for reducing highway fatalities and serious injuries on all public roads. It is developed by the State highway agency in a cooperative process with local, State, Federal, and private sector safety stakeholders. The SHSP is a data-driven, comprehensive plan that establishes statewide goals, objectives, and key emphasis areas and integrates the four E's of safety – engineering, education, enforcement and emergency medical services. In most SHSPs, roadway departure is listed as a key emphasis area.

The purpose of an SHSP is to identify the State's safety needs and guide investment decisions to achieve significant reductions in highway fatalities and serious injuries on all public roads. The SHSP allows all highway safety programs in the State to work together in an effort to align and leverage its resources. It also positions the State and its safety partners to address the State's safety challenges on all public roads collectively.

There are two Federally-funded safety programs related to the SHSP that are potentially available for local public agency use:

- The Highway Safety Improvement Program (HSIP) is a Federal aid program focused on improving traffic safety on all public roads with infrastructure solutions.
- The High Risk Rural Roads Program (HRRRP) is a set aside program from HSIP that focuses on addressing rural road safety needs on eligible rural major and minor collectors and local rural roads with construction and operational improvements.

For additional information about these safety programs and the SHSP requirements, see Appendix A for links to the Federal Highway Administration (FHWA) websites on each topic.

Roadway Departure Safety Implementation Plans

The Federal Highway Administration currently offers roadway departure technical assistance to State highway agencies in the form of crash data analysis and implementation plan development. Roadway Departure Implementation Plans have been developed for Kentucky, Louisiana, North Carolina, Oregon, South Carolina, and Tennessee, with additional State plans at various stages of development. Each plan is designed to address roadway departure safety issues on both State and local roadways.

In participating States, FHWA has developed a data analysis package focused on crash history and roadway attributes for each state, and a set of strategies that can be used to reduce roadway departure crashes. A set of cost-effective countermeasures, deployment levels, and funding needs is identified to reduce the number and severity of roadway departure crashes in the State by a certain amount. The final plan quantifies the costs and benefits of a roadway departure-focused initiative and provides a step-by-step process for implementation.[7]

1.4. Information in this Document

The purpose of this document is to provide information on effectively identifying roadway departure safety issues and countermeasures that address them, leading to the effective implementation of safety projects to improve safety on affected roadways. This includes pertinent information on conducting field reviews, identifying rural roadway segments with multiple crashes and/or high potential for future crashes, and selecting the appropriate low-cost improvement to implement on these roadways.

7 For additional information about this initiative, visit the FHWA Strategic Approach to Roadway Departure website at http://safety.fhwa.dot.gov/roadway_dept/strat_approach.

Step 1
Identify Roadway Departure 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 feed the countermeasure selection process.

- Warning signs and curve delineation
- Pavement markings and RPMs
- Rumble strips
- 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 roadway departure safety treatments after installation.

- Track countermeasure installations
- Monitor crash experience at treated locations

Figure 1 – Steps to Address Roadway Departure Safety

This document is geared toward local road managers and other practitioners with responsibility for operating and maintaining local roads regardless of training. In many cases, the person responsible for highway safety may have multiple responsibilities including public works functions such as water and wastewater treatment, trash collection, and snow removal. In these cases, roadway safety may be only a small part of the job. The document is intended to provide appropriate, focused roadway departure safety information in one report.

This report suggests a process for the planning and implementation of roadway departure safety improvements. The processes which are discussed in this document can be summarized in Figure 1.

Section 2 provides an overview of the types of data to collect for the identification of problem roadway segments. It describes the types of information available and how they can be used, and it defines and describes various approaches for implementing safety strategies.

Section 3 summarizes the types of analyses that can be conducted to determine if roadway departure countermeasures should be implemented. This discussion builds on the information 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 to address roadway departure crashes on local rural roads. They include basic countermeasures such as standard curve warning signing and curve delineation, and also systematic solutions like rumble strips and the safety edge. This section also provides an example of a recommended process to document the information and the decisions made about the countermeasure(s) to be installed.

The process to complete an evaluation of installed treatments is 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 roadways to make them safer as well.

Section 6 includes case studies of local jurisdictions around the country addressing roadway departure crashes. Examples include signing improvements, enforcement solutions, and road safety audits (RSAs).

Section 7 provides a summary of this manual.

A list of resources and references is presented in **Appendix A**. This list covers numerous topics from publications that focus on roadway departure countermeasures, research that supports their use, and various studies that document their effectiveness. The Appendix also includes references related to Federal safety funding programs that can potentially be used by local agencies.

Appendix B presents an overview of the Manual on Uniform Traffic Control Devices (MUTCD) minimum requirements for traffic control devices most likely to be used in response to roadway departure crashes. 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 travel.

Appendix C contains the formulas to calculate the crash rate of roadway segments. Additionally, examples are included for crash rates by traffic volume and crash rates by length of roadway.

2 Identifying Safety Issues

There are a number of information sources that can be accessed to get a picture of the roadway departure issues on the rural roadway network. These can be formal information sources or informal sources, including:

- Formal sources:
  - » State and local crash databases;
  - » Law enforcement crash reports, citations; and
  - » Field assessments.
- Informal sources:
  - » Observational information from road maintenance crews; and
  - » Citizen notification of safety concerns.

Examining the crash history will help practitioners identify locations with an existing roadway departure problem, and it will also provide information to identify locations that are susceptible to future roadway departure crashes. In addition to the location, the data can also provide information regarding crash causation. This will provide insights into identifying potentially effective countermeasures.

For the systematic treatment of roadway departure crashes based on proven low cost countermeasures, the available crash data is used to determine where specific crash types are predominant.

Emphasis on data-driven decisions is indicative of reliability and efficiency. The more reliable the data, the more likely the decisions regarding safety improvements will be effective. However, detailed, reliable crash data are not available in all areas. Under this circumstance the practitioner should use the best available information and engineering judgment to make the best decisions.

As a guideline, it is generally accepted that at least 3 years of historical data be used for crash history analysis, though additional years of data can provide more information. Due to the randomness of crashes in a given year, a multi-year average of safety data will smooth outlier years of relatively high or low roadway departure crash occurrences. If only severe crashes are analyzed (those that resulted in a fatality and/or serious injury), more years of data may be necessary for effective evaluation. In using data more than 5 years old, however, the practitioner should consider possible changes in traffic patterns and infrastructure when conducting the analysis.

2.1. State and Local Crash Databases

Each state has a central repository for storing crash data. This is generally the most comprehensive data for roadway safety analysis, particularly if all public roads are included in the database. Several states share this information with the local road agencies. Alternatively, many states that do not currently share the raw crash data often provide comprehensive data analysis to local agencies upon request.

If the data are available, the local road practitioner can use these data to identify locations with multiple roadway departure crashes, conduct an analysis that can produce predominant crash types, and identify associated roadway features that may have contributed. The local agency can work with the State to compare its crashes to those occurring in similar areas around the state.

This information can be used for both spot location treatments and systematic deployments, depending on the details of the collected data. For example, if a high number of crashes are occurring at a particular curve or along a segment of roadway, a spot treatment at that location may be appropriate. However, systematic treatment of multiple locations experiencing specific crash types or location with the potential for those crash types may be necessary.

Action: Obtain at least 3 years of data to identify local roads that have a history of roadway departure crashes. Identify predominant roadway departure crash sub-types and other common characteristics.

Begin a spreadsheet of crashes, law enforcement reports, and citizen notifications by starting with crash history data (see Table 1). This can serve as a database to help an agency identify common crash characteristics and identify the appropriate countermeasures.

2.2. Law Enforcement Crash Reports

Both State and local law enforcement officials can be an important source of roadway departure crash data. Law enforcement crash reports can be valuable in identifying the location and contributing circumstances to roadway departure crashes. For these crash types, 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;
- Light conditions;
- Sequence of events; and
- Contributing circumstances.

The local practitioner using multiple sources of law enforcement crash reports should be aware that they may differ by jurisdiction; however, the basic information is always included and should provide sufficient data to identify crashes on local roads.

Similar to the crash database, the information in the crash reports can be used to assist in the identification of potential treatments and deployment approach.

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 roadway segments.

2.3. Field Assessments

Many local jurisdictions do not have formal crash databases, and some State databases do not include local road crash data. Additionally, some local entities may not have a local police force, and in some cases State forces may not share their crash reporting with these local entities. In this case, the local road practitioner can still conduct field assessments to help determine the safety of the roadway network.

Regardless of data availability and quality or the implementation approach, a field assessment should be conducted at selected locations. Assessing locations in the field provides additional information to the local practitioner that will factor into issue identification and countermeasure selection.

An assessment can be as informal as driving or walking the road network looking for evidence of roadway departure crashes. An informal field assessment can be performed by an in-house multidisciplinary team with a traffic safety expert and law enforcement personnel. The team can visit several sites and document evidence of crashes or deficiencies on the roadway or roadside. Examples include damaged trees or fences, skid marks, ruts on the shoulder, car parts on the shoulder, and/or pavement drop-offs. This information can be used to develop recommendations for improvement.

Field reviews can also be more formalized in the form of a Road Safety Audit (RSA). An RSA is a formal safety performance examination of an existing or future road by an independent, multidisciplinary team. The team examines and reports on potential road safety issues and identifies opportunities for safety improvements for all road users.

As with other sources of information, evidence discovered in a field assessment can help support spot location treatments and/or systematic deployments, depending on the information found. For example, if evidence is found of multiple roadway departure crashes on a single curve (due to multiple ruts on the roadside, fence repairs, or vehicle parts found on the roadside from more than one vehicle), a spot treatment may be appropriate to address safety at the curve. If similar types of crashes are occurring on several curves on the roadway network, then systematic deployment of appropriate countermeasure(s) can a viable solution.

2.4. Observational Information

Law enforcement officers and local crews who maintain the roads can serve as valuable resources to identify problem areas. Since they travel extensively on the local roads, they can continuously monitor the roads for actual or potential problems (e.g., poor delineation, fixed objects near the roadway, missing signs, signs of vehicles leaving the road).

Law enforcement officers patrol the local jurisdiction at night and on weekends when most public agency employees are not in the field. Their observations of driver behavior and roadway elements at these times can provide valuable insight to the local road agency. Additionally, law enforcement officers are sometimes aware of problem areas based on citations written, even if crashes related to the violations have not yet occurred.

Road maintenance crews often keep logs of their work, including sign replacements and edge drop-off repairs. These logs can provide supplemental information about crashes that may have not been reported to law enforcement.

Very similar to field assessments, information obtained from road maintenance crews and law enforcement officers while they are completing their normal duties can help support all three methods of implementation - spot location treatments, systematic deployments, and the comprehensive approach. Often, offenses such as speeding and impaired driving lend themselves to education and enforcement solutions to address these behaviors and supplement infrastructure countermeasures.

Action: Add information received from law enforcement and road maintenance crew observations to the spreadsheet (see Table 1).

Add information received from law enforcement citations to the spreadsheet.

Develop a system for maintenance crews to report and record observed roadway departure safety issues and a mechanism to address them.

2.5. Public Notifications

Occasionally, when unsafe situations are observed, local citizens may notify the local government by email, letter, telephone call, or at a public meeting. While this is anecdotal information, these sources can serve as indicators that a safety issue may exist; the notifications potentially warrant further review and analysis to determine the extent of the issues.

Information identifying safety issues on local roads may also come from community or regional newspapers and newsletters or correspondence from local homeowner and neighborhood associations. This information can help pinpoint which segments are candidates for review, and it can support the local agency's relationships with the community that will benefit the safety program.

Action: Review and summarize the information, identifying segments or corridors with multiple notifications and recording the locations, dates, and nature of the problem that is cited.

Add information received from public notifications to the Table 1 spreadsheet.

2.6. 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 on roadway segments:

- Roadway surface (dirt, aggregate, asphalt, concrete);
- Lane information (number, width);
- Shoulder information (width, type);
- Median (type, width); and
- Traffic control devices present (signs, pavement marking).

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 segment is experiencing a high number of horizontal curve-related crashes, analysis of the inventory of roadway elements could reveal that the roadway does not have sufficient signing installed in advance of many of those curves.

2.7. 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 effective comparison of locations. Exposure data provide a common metric to the crash data so roadway segments and intersections can be compared more appropriately.

The most common type of exposure data used on roadway segments is traffic volume. A count of the number of vehicles can provide information to the practitioner for comparison. For example, if two roadway segments have the same number of crashes but different traffic volumes, the segment with fewer vehicles (i.e., less exposure) will have a higher crash rate, meaning that vehicles were more likely to have experienced a crash along that roadway segment.

In situations where traffic volume is not available, segment length can serve as an effective exposure element for comparison.

Table 1 – Spreadsheet to Monitor Roadway Departure Crashes

Location	Source of Information	Date	Type of Information	Problem	Nature of Crash
Rt. 123, 2 miles North of Fox Mill Road	Local Newspaper	12/1/2007	Citizen Observation	Speeding	N/A
Rt. 123 West / 1/2 mile south of intersetion with Fox Mill Road to intersection	Citizen Call	3/8/2008	Observation	Drivers losing control at curve	N/A
Miller's Curve on Rt. 430, 3 miles South of city limits	Local Police	2/1/2008	Police Report	Crash Report	Driver ran off road at curve
Rt. 657; 1/2 mile South of Glade Drive	Local Police	4/1/2008	Police Report	Crash	Driver hit tree on shoulder; single vehicle
Rt. 657; 1/4 mile South of Glade Drive	State Police	10/4/2008	Police Report	Crash Report	Driver ran off road; single vehicle
Clifton Road; South of Veirs Mill Road	State Police	11/11/2008	Police Report	Crash	Driver ran off road on curve; exceeding posted speed
Oakwood Road near Jones Elementary	Local Police	11/12/2009	Police Report	Speeding Sitation	N/A
Rt. 657; 1/4 mile South of Glade Drive	Local Police	11/24/2009	Police Report		
Oakwood Road just North of post office	Maintenance Crew	7/9/2009	Observation	Trees covering warning signs	N/A
Middlebrook Pike; 1 mile North of Running Cedar Road	Maintenance Crew	12/12/2009	Observation	Numerous tire tracks on curve approach	N/A

Table 1 (continued) – Spreadsheet to Monitor Roadway Departure Crashes

Time of Day	Weather Conditions	Other Con-tributors	Review Site?	Action?	Date of Action
			Y	Pending	
		Speeding	Y	Pending	
7:22	Clear		N		
23:03	Snow	Alcohol involved	N		
19:21	Rain		N		
12:23	Rain	Speeding	N		
10:06	Rain	Speeding	N		
23:04	Rain		N		
			Y	Trimmed trees	7/16/2009
			Y	Advanced Curved Warning Signs Added	1/8/2010

3 Safety Analysis

Safety analysis will assist with making informed decisions on the type, deployment levels, and locations for safety countermeasures. This builds on the previous discussions on information sources to identify roadway departure issues. Regardless of implementation approach selected, some level of data analysis will be relevant. These analyses are most relevant for the identification and prioritization of locations with safety issues and selection of appropriate countermeasures for the spot location approach, for the countermeasure-based systematic approach, the safety analysis discussed in this section would occur only after the selection of proven low cost countermeasures. In the crash type-based systematic approach, analysis will focus only on those roadway departure crash types identified as pertinent in the local jurisdiction.

3.1. Quantitative Analysis

Crash data analysis is used to determine the extent of the roadway departure safety issue, the priority for the application of scarce resources, and selection of appropriate countermeasures. The two main quantitative analysis methods for roadway departure crashes are crash frequency and crash rates.

Crash Frequency

Crash frequency is defined as the number of crashes occurring within a determined study area. A local practitioner can determine crash counts using information compiled from the State crash database or law enforcement crash reports. This will allow the practitioner to:

- Summarize the crashes by attributes such as type, severity and location;
- Spatially display the sites on a map using push pins or a GIS software package;
- Provide a report sorted by location and crash type to identify problem locations;
- Determine predominant roadway departure crash types and associated roadway physical characteristics; and
- Determine appropriate countermeasures.

Once this information is collected and displayed, the practitioner can complete a methodical analysis by county or route, and also a cluster analysis to determine those roadway locations that have experienced a high or moderate level of crashes.

Crash Rate

Crash rates can be an effective tool to measure the relative safety at a particular location. The calculation of crash frequency (crashes per year) divided by vehicle exposure (traffic volumes, or roadway length) results in a crash rate. Crash rate analysis can be a useful tool to determine how a specific roadway or segment compares to an average roadway on the network. A count of the number of crashes is often inadequate when comparing multiple roadways of varying lengths and/or traffic volume. Crash rate is often used to prioritize locations for safety improvements when working with limited budgets and trying to achieve the greatest safety benefits with limited resources.

For example, it is possible that two roadways in a jurisdiction (Route A and Route B) each have the same number of crashes. However, Route A could have more than double the number of vehicles on a typical day than does Route B. To effectively compare the relative safety of the two locations, the practitioner must factor in the level of exposure on each route. Exposure is often represented by number of vehicles using the route or by the length or roadway.

One limitation of crash rates for low volume roads is the sensitivity of the formula to low traffic volume. The crash rate calculation is not as beneficial at low volumes as it is with higher volume roads, as small changes in the number of vehicles results in a disproportionate change in the crash rate for the segments that in reality operate similarly.

Where traffic volume data is unavailable, other information can be used to provide exposure information. One often-used factor is the length of the roadway segment on each route studied. Comparing the number of roadway departure crashes per mile can help an agency identify potential opportunities to improve safety.

Appendix C includes formulas for calculating crash rates on roadway segments and examples of crash rate calculations by vehicle miles traveled and by roadway mileage.

3.2. Qualitative Analysis

Qualitative analysis considers the physical characteristics of the identified sites. This can take the form of examination of maps and photographs or field assessment.

Field Assessment

As discussed in Section 2, field assessments can be an informal review of the safety of the roadway, or be more formalized in a Road Safety Audit. The RSA will qualitatively estimate and report on existing and potential roadway departure safety issues and identify opportunities for improvements. In the case of the countermeasure-based systematic approach, the field assessment can be used to validate the countermeasures selected.

Ensuring Compliance with MUTCD Standards

During the field assessment, it is important to determine if identified locations comply with the minimum standards for signs and pavement markings included in the ***Manual on Uniform Traffic Control Devices*** (MUTCD). The MUTCD provides the minimum standard requirements for traffic control devices on all public streets, highways, bikeways, and private roads open to public travel.[8] Complying with these requirements can assist in improving safety on the transportation system. Local practitioners should also contact the State DOT for the State's minimum requirements, as often they are more stringent than the requirements in the MUTCD.

If the traffic control devices on the segment are not in compliance with MUTCD or the State minimum requirements, appropriate devices should be installed. Non-compliance is an important consideration that can affect road safety and might have liability implications for a jurisdiction.

Figure 2 shows some of the most common traffic control devices related to roadway departure treatments.

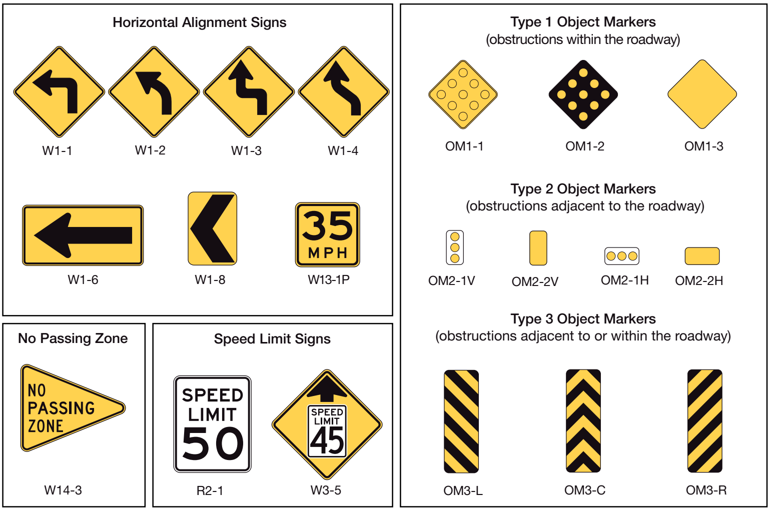

Figure 2 - MUTCD Traffic Control Devices

8 The MUTCD can be found at http://mutcd.fhwa.dot.gov. Local practitioners should be cognizant that many States adopt standards that are more stringent than the MUTCD. Where these exist, the local practitioner is required to comply with those State standards. This information can be obtained from the State Department of Transportation or their LTAP Center.

Signing

- **Speed Limit.** Speeding is often a contributing factor in roadway departure crashes. Posting appropriate speed limit signs along a roadway provides motorists with guidance for safe driving speeds.
- **Reduced Speed Ahead.** When the speed limit is reduced (for example, when entering the city limits of a city, town or village), the Reduced Speed Ahead sign can provide motorists warning of that change.
- **Curve Warning Signs**
  - » **Curve/Turn and Reverse Curve/Turn.** These horizontal alignment signs are the basic treatment for a horizontal alignment change. Care should be taken to choose the most appropriate sign and to place it at the optimum location for approaching motorists.
  - » **Advisory Speed Plaque.** The advisory speed plaque provides drivers with additional information regarding the relative sharpness of an approaching curve or turn.
  - » **Chevron Alignment Signs.** These signs are placed within the curve or turn to provide delineation and guidance to motorists as they drive through the curve. Chevron signs are particularly helpful with combination horizontal/vertical curves, as the vertical curvature can hide the horizontal alignment change from view of motorists. The delineation provided by chevrons can help guide drivers through this complex alignment.
  - » **One-direction Large Arrow.** The large arrow sign is used to supplement curve or turn signs to provide motorists additional warning within the curve or turn.
- **Object Markers (Type 1, 2, 3).** Object markers are used to warn drivers of obstructions within the roadway or adjacent to the roadway (e.g., culvert, other roadside obstacle).

No Passing Zones

- **Pavement Marking.** No Passing Zones are marked at locations where drivers do not have sufficient sight distance to safely overtake a slower moving vehicle. The solid yellow line on the motorist's side of the center line is an indication that the motorist should wait for a safe passing opportunity.
- **No Passing Zone Pennant Sign.** The No Passing Zone pennant sign supplements the pavement marking to further emphasize the sight distance restrictions.

4 Countermeasures

The decision regarding which countermeasures to install to address a safety issue can be challenging. When necessary, the local practitioner should seek engineering expertise from a county engineer, State DOT, or through the State Local Technical Assistance Program (LTAP). To make the most informed decision regarding roadway departure countermeasure selection, an agency should use all available data, both quantitative and qualitative. Through the work of several agencies (Federal, State and local) and universities, several proven, effective countermeasures have been identified to address roadway departure crashes. When using the countermeasure-based systematic approach, the practitioner should determine the appropriate conditions for which the countermeasure is most effective (crash type, geometric features, traffic conditions).

For a relatively small number of high crash locations with varying causes, the spot location implementation approach may be the most appropriate. Systematic implementation of proven low-cost safety countermeasures is often the most effective approach when there are several locations on the roadway network experiencing similar types of roadway departure crashes. For locations that have yet to experience crashes, but have identified features that contribute to roadway departure crashes, systematically applying safety treatments may be the best approach to prevent future crashes.

A high proportion of crashes tend to occur at locations that share common geometric or operational elements. Installing the same countermeasure at multiple locations (where appropriate) could, in many cases, increase the cost effectiveness of the safety improvement, allowing an increased number of treatments to be applied.

4.1. Select Roadway Departure Countermeasure

The countermeasures discussed in this section of the document are not all-inclusive of all those available to reduce the frequency and severity of roadway departure crashes on local, rural roads. Those discussed have shown to be effective for the appropriate roadway departure crashes.

The determination of sites to consider for countermeasure implementation is based on the analysis performed. Each countermeasure discussed in this section includes the following information:

- *Crash Type Addressed* – In order to effectively reduce the number and severity of roadway departure crashes, it is necessary to match countermeasures to the crash types they are intended to address. Depending on the type of problem, one or more of a wide range of treatments could be the most effective way to reduce the number and severity of future crashes.
- For example, if the most frequent crash type on a corridor involved vehicles running off the road around curves, the most effective countermeasures will likely be those that address curve crashes directly, which include curve warning signs, curve alignment signs, and pavement marking.
- *Where to use* – Roadway segments with specific common characteristics can be addressed with similar countermeasures that are most effective.
- *Why it works* – A discussion of the benefit of a countermeasure is important to determine its appropriateness in addressing certain roadway departure crash types at areas with specific issues as determined by the data and roadway features.
- *Timeline for Implementation* – This category refers to the approximate relative 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. Note that costs can vary considerably due to local conditions.
- *Crash Reduction Factor* – The crash reduction factor (CRF)[9] is an indication of the effectiveness of a particular treatment, measured by the percentage of crashes it is expected to reduce. The CRF for a given countermeasure is calculated based on research conducted on the pre- and post-crash frequencies at sites where the countermeasure has been installed. The higher the CRF, the greater the expected reduction in crashes. For instance, a CRF of 20 is interpreted as an expected reduction of 20 percent of previously-experienced crashes. 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.

9 Federal Highway Administration in conjunction with the University of North Carolina Highway Safety Research Center, "Crash Modification Factors Clearinghouse" website. Available at: http://www.cmfclearinghouse.org/

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Install Advanced Curve Warning Signs

Crash type addressed

Roadway departure crashes attributed to motorists running off the road while attempting to negotiate a curve or turn in the roadway. In some situations, the driver was not aware they were approaching a curve or turn.

Time:	● ○ ○
Cost:	*Low*
CRF:	*30%*

Where to use

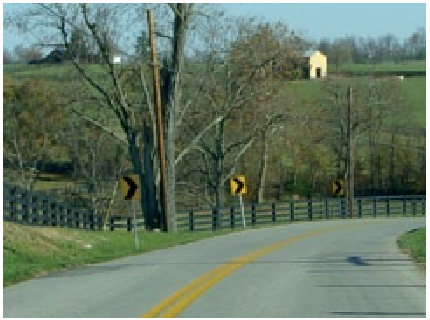
Any curve or turn with a history of roadway departure crashes, and curves or turns with similar geometry or traffic volume yet to experience crashes. According to the 2009 MUTCD (Table 2C-5), warning signs are required on curves or turns where the advisory speed is 10 mph less than the posted speed.

Why it works

Installing warning signs in advance of a curve or turn provides information to motorists before they enter the curve, giving them a chance to modify their approach speed as they enter the new horizontal alignment.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes," FHWA, 2008.

Provide Curve Delineation Signing (Chevrons)



Crash type addressed

Roadway departure crashes attributed to motorists running off the road while attempting to negotiate a curve or turn in the roadway. In some situations, the driver was not aware of the severity of the curve in relation to their operating speed.

Time:	● ○ ○
Cost:	*Low*
CRF:	*35%*

Where to use

Any curve or turn with a history of roadway departure crashes, and curves or turns with similar geometry or traffic volume yet to experience crashes. According to the 2009 MUTCD (Table 2C-5), alignment delineation (or a one direction large arrow) is required on curves or turns where the advisory speed is 15 mph less than the posted speed limit.

Why it works

Installing alignment delineation within a curve or turn provides information to motorists where they need it most – within the actual horizontal alignment. The signs show the shape and degree of curvature, and they guide drivers through the entire curve or turn.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes," FHWA, 2008.

Install Object Markers

Crash type addressed

Roadway departure crashes attributed to motorists hitting a fixed object along the side of the roadway. Contributing circumstances include speed and inattention.

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

Where to use

Any road with a history of fixed object crashes is a candidate for this treatment, as are roadways with similar fixed objects along the roadside that have yet to experience crashes. If a fixed object cannot be relocated or made break-away, placing an object marker can provide additional information to motorists.

Why it works

Object markers delineate the location of potentially hazardous fixed objects along the roadside. In a situation where a motorist departs the roadway, the marker can provide information to motorists so they can avoid the object.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes," FHWA, 2008.

Install Center Line and Edge Line Pavement Markings

Crash type addressed

Roadway departure crashes attributed to motorists running off the right side of the road, crossing the center line, or dropping off the roadway on an edge drop-off. Contributing circumstances include speed and inattention.

Time: ●●○

Cost: *Low–Moderate*

Center Line CRF: *33%*
Edge Line CRF: *38-44%*

Where to use

Any road with a history of run-off-road right, head-on, opposite-direction-sideswipe, or run-off-road-left crashes is a candidate for this treatment. Depending on the width of the roadway, various combinations of edge line and/or center line pavement markings may be the most appropriate.

Why it works

Pavement markings provide motorists important guidance information regarding the edge of the traveled way on the right and the location of the opposing lane on the left. When used around curves, pavement markings serve as curve delineation.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes," FHWA, 2008.

Install Raised Pavement Markers (RPMs)

Crash type addressed

Crashes attributed to roadway departure in wet and/or dark conditions, due to driver inability to see lane markings. This treatment is most applicable in situations where the crashes have occurred at night or on wet pavement.

Time:	●●○
Cost:	*Moderate*
CRF:	*Up to 24%*

Where to use

RPMs are designed to supplement the delineation provided by pavement markings. They should be installed on routes with sufficient pavement quality to hold the devices in place. The type of RPM to install is dependent on regional climate. For example, in areas that experience snowfall, snow plowable RPMs should be used.

Why it works

During certain conditions, particularly on wet roads in the dark, it is sometimes difficult for motorists to determine the location of the center line and edge line pavement markings. This increases the likelihood of the vehicle departing the roadway. By installing RPMs, the pavement markings are much more prominent in adverse weather conditions, providing important information to the driver.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes," FHWA, 2008.

Install Edge Line, Shoulder, or Center Line Rumble Strips/Stripes

Crash type addressed

Run-off-road-right, run-off-road-left, and head-on crashes attributed to a vehicle leaving its lane of travel. Contributing circumstances include speeding, impaired driving, and inattention.

Time: ●●○

Cost: *Low*

Center Line CRF: 15-25%
Edge Line CRF: *10-22%*

Removing fixed objects

Where to use

Center Line rumble strips/stripes can be used on virtually any roadway – especially those with a history of head-on crashes. Shoulder and edge line milled rumble strips/stripes should be used on roads with a history of roadway departure crashes. It is recommended that rumble strips/stripes be applied systematically along an entire route instead of only at spot locations. For all rumble strips/stripes, pavement condition should be sufficient to accept milled rumble strips.

Why it works

Rumble strips provide an auditory indication and tactile rumble when driven on, alerting drivers that they are drifting out of their travel lane, giving them time to recover before they depart the roadway or cross the center line. Additionally, rumble stripes (pavement marking in the rumble itself) provide an enhanced marking, especially in wet dark conditions.

Persaud, B. N., Retting, R. A., and Lyon, C., "Crash Reduction Following Installation of Center Line Rumble Strips on Rural Two-Lane Roads." Arlington, Va., Insurance Institute for Highway Safety, (2003)
Carrasco, O., McFadden, J., and Chandhok, P., "Evaluation of the Effectiveness of Shoulder Rumble Strips on Rural Multi-lane Divided Highways In Minnesota." Washington D.C., 83rd Transportation Research Board Annual Meeting, (2004)

Install Pavement Friction Treatments

Crash type addressed

Roadway departure crashes attributed to motorists sliding off the roadway. This treatment is most applicable in situations where the crashes have occurred on wet pavement.

Time:	●●○
Cost:	*Moderate-High*
CRF:	40-75%
Wet crashes	

Where to use

Epoxy-based, microsurface, or chip seal overlays can address spot locations (e.g., a single curve, interchange ramp, bridge, or short roadway section). It should be used at locations with severe slick conditions that could benefit from increased friction.

Why it works

Vehicles often leave the road due to lack of friction – especially in wet conditions when water gets between the tires and pavement causing hydroplaning. The epoxy overlay can reduce the number of wet crashes by improving friction at specific locations of need.

Lyon, C and B. Persaud. "Safety Effects of a Targeted Skid Resistance Improvement Program." 87th Annual Meeting of the Transportation Research Board, 2008 Annual Meeting CD-ROM.

Provide Safety Edge for Pavement Edge Drop-off

Crash type addressed

Roadway departure crashes attributed to motorists dropping off the roadway due to an edge drop-off. Contributing circumstances include speed, weather issues, and inattention.

Time:	●●○
Cost:	*Low*
CRF:	*Unknown**

Where to use

This treatment is designed to be a standard policy for any overlay project. Instead of an overlay project ending with a 90-degree asphalt or concrete face at the edge of pavement, the Safety Edge provides a 30-degree angle at the edge.

Why it works

As earth or gravel falls away from the edge of a typical pavement, a vertical edge drop-off is exposed. The Safety Edge eliminates the vertical edge by providing an angled edge to the side of the roadway, also providing a more durable pavement edge. A motorist can more safely re-enter the traveled way after the tires leave the pavement.

Research is currently being finalized to develop an official crash reduction factor for this countermeasure.

Removing, Moving, or Marking Fixed Objects

Crash type addressed

Roadway departure crashes attributed to vehicles striking a fixed object on the side of the roadway. Examples include trees, utility poles, and culverts.

Time:	*Varies*
Cost:	*Varies*
CRF:	*Up to 71%*

Removal is 71%, others are unknown

Where to use

Depending on the situation, fixed objects on any roadway should be addressed in the following prioritized order:

1. Remove the obstacle.
2. Redesign the obstacle so it can be safely traversed.
3. Relocate the obstacle to a point where it is less likely to be struck.
4. Reduce impact severity by using an appropriate breakaway device.
5. Use impact attenuation devices to shield the obstacle, reducing crash severity.
6. Protect the driver through redirection of the errant vehicle.
7. Mark the object to provide motorist information.

Why it works

Removing, redesigning, marking, or relocating the fixed object reduces the likelihood of a crash. If a crash occurs, adding breakaway features, crash cushions, or redirection devices reduces crash severity.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes," FHWA, 2008.

Create Clear Zones

Crash type addressed

Roadway departure crashes attributed to striking fixed objects, ditches, or other roadside obstacles.

Time:	●●○
Cost:	*Low–Moderate*
CRF:	13-44%

Where to use

A clear zone should be developed on every roadway, as space is available. In situations where public right-of-way is limited, steps should be taken to request assistance from property owners, as appropriate. For additional information about clear zones, visit the FHWA Office of Safety website at *http://safety.fhwa.dot.gov/roadway_dept/clear_zones*.

Why it works

A clear zone is an unobstructed, traversable roadside area that allows a driver to stop safely or regain control of a vehicle that has left the roadway. Removing or moving fixed objects, flattening slopes, or providing recovery areas reduces the likelihood of a crash.

Unless otherwise noted, all Crash Reduction Factors (CRFs) in this document are from "Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes," FHWA, 2008.

5 Evaluation

Evaluation of roadway departure treatments after they are installed to determine effectiveness can be used to guide future decisions regarding roadway departure countermeasures.

A record of crash history and countermeasure installation forms the foundation for assessing how well implemented strategies have performed. An important database to keep is a current list of installed 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 each countermeasure's success.

In order to perform the assessment, it is necessary to collect the required information for a certain period after strategies have been deployed at the locations. The time period varies, but should be no less than one full year (with 2-3 years preferred). The information required may consist of public input and complaints, police reports, observations from maintenance crews, and local and State crash data.

It is important to keep the list of strategy installations up to date since it will serve as a record of countermeasure deployment history (see Table 2 for an example). By using this type of system, assessment dates can be scheduled to review the crashes and other pertinent information on segments where roadway departure countermeasures have been installed.

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

Location	Type of Countermeasure Installed	Date Installed	Crashes Before	Crashes After	Comments
Middlebrook Pike, 1 mile north of Running Cedar Rd.	Advanced Curve Warning Sign	11/10/2009	3 in 3 years		Subdivision built in Summer 2010 near this location.
Route 657, ½ mile south of Glade Drive	Chevrons	12/19/2009	5 in 3 years		Traffic volume has increased 25% between the installation date and the "after" period.
Clifton Road, South of Veirs Mill Road	Speed Limit Signs	2/3/2010	2 in 1 year		

Table 2 - Example Table to Monitor Countermeasure Application History and Crash/Observational Data

6 Case Studies

This section contains descriptions of programs and projects implemented by select local jurisdictions to address roadway departure crashes. These programs illustrate how local practitioners have instituted processes or select countermeasures to address roadway departure crashes on their roadways.

6.1. Low-cost Local Safety Solutions: Douglas County, Georgia[10]

Douglas County, Georgia developed a *County Curve Action Plan* as part of the Georgia Department of Transportation's Safety Action Plan Program. This plan has been particularly helpful to the county as it supported funding opportunities through the Georgia Off-System Safety Program.

One of the principal components of their safety action plan, which aligns with the Georgia SHSP, is a focus on roadway departure crashes along curves. Horizontal curves on local and rural roadways represent a major concern in Douglas County, because many of their roads are former wagon trails that were paved over time without addressing the roadway alignment, shoulders, clear zones, and lighting to meet current standards. Consequently, the County experiences a significant number of roadway departure crashes associated with these types of curves.

With a lack of comprehensive data, the County depended on their County Road Department staff, historic knowledge from the sheriff department, and residents to supplement the available data to develop the *Curve Action Plan*. High-risk locations were identified. A consultant was hired to conduct a qualitative analysis of critical locations and identify countermeasure strategies where appropriate. Improvement strategies included signing and striping modifications as well as center line and edge line raised pavement markers.

There has been a significant reduction in roadway departure crashes since the county began implementing low cost strategies such as warning signs, chevron signs and raised pavement markers along the curves. After installing the double advance warning signs, chevrons alignment signs, and raised pavement markers, a number of crashes continued to occur along some curves. The County took another step by adding the "curve ahead" markings on the pavement, including arrows, developed by Pennsylvania Department of Transportation. The pavement markings have made a tremendous difference as there have been no crashes in the treated locations since the installation.

10 Federal Highway Administration, "Noteworthy Practices: Addressing Safety on Locally-Owned and Maintained Roads." (Washington, D.C.: 2010). Available at http://safety.fhwa.dot.gov/local_rural/training/fhwasa10027/

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6.2. Engineering and Enforcement Safety Solutions: Contra Costa County and Alameda County, California[11]

Winding curves, lack of guardrails, and short sight distance in certain areas were creating a difficult environment for motorists utilizing the heavily congested Vasco Road in both Contra Costa and Alameda Counties. The traffic volumes on Vasco Road had more than doubled from 10,000 vehicles per day in 1990 to over 22,000 in 2007, resulting in a high number of collisions. Between 2002 and 2004, 72 crashes occurred along the project corridor, many of them related to roadway departure.

To address the high incidence of roadway departure crashes, a comprehensive, cooperative, and multijurisdictional approach was taken to address speeding and aggressive driving on Vasco Road. As a result, in 2004, the Alameda County Public Works Agency, the Contra Costa County Public Works Agency, City of Brentwood, City of Livermore, the Alameda County Sheriff's Department, and the California Highway Patrol offices in both counties joined with community groups and elected officials in an attempt to reduce crashes along Vasco Road. They introduced a variety of safety measures, including the following:

- Speed display signs;
- Community safety signs;
- Daytime headlight signs;
- Center line rumble strips;
- Soft median barrier striping;
- Center line delineators;
- Double fine zone; and
- Coordinated speed enforcement

These measures have produced extraordinary results. The collaborative traffic engineering, speed enforcement, and funding efforts of both counties have significantly reduced head-on collisions and improved overall roadway departure safety along Vasco Road. The crash rate per million vehicle miles dropped from 0.58 to 0.42. Between 2005 and 2007, there have been just 46 collisions, a 36 percent reduction from previous years.

Contact:

11 2009 National Roadway Safety Awards Best Practices. Accessed at http://www.roadwaysafety.org/

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6.3. Signing and Marking Improvements: Mendocino County, California.[12,13,14]

The terrain of Mendocino County, a large rural county with more than 1,000 center line miles of county-maintained roads, is mountainous with a few small valleys. Traffic-related injuries and fatalities in the county are primarily the result of roadway departure crashes.

In the 1990s the Mendocino County Department of Transportation (MCDOT) developed a *Road System Traffic Safety Review* program to improve signing and markings on the arterial and collector roadways on their system. Each year the team completes a systematic review of one-third of the county roads, identifying potential signing and marking deficiencies, recommending changes based on the current California Department of Transportation (Caltrans) signing and marking guidelines, and implementing the results.

During recurring three-year cycles, all arterials, all collectors, and a number of selected local roadways are reviewed. These annual reviews are funded through the Mendocino Council of Governments (MCOG) with a combination of state and local monies. Early efforts in Mendocino County concentrated on improving signing for curves and eliminating nonstandard signing in order to conform to current Caltrans standards. Funding from the Caltrans *Hazard Elimination Safety* (HES) Program was used to upgrade approximately one-quarter of the county's signs the first year. Since then, funds to implement the recommendations of the annual reviews have been allocated in the MCDOT budget.

The effectiveness of the Traffic Safety Review project was measured by comparing roadway departure crash data for reviewed roads with data for roads not included in, or influenced by, the reviews. Over two consecutive, three-year cycles, the number of crashes on the reviewed roads fell dramatically by 42.1 percent while on those county-maintained roads not reviewed increased by 26.5 percent. Using cost data provided

12 The American Traffic Safety Services Association and the National Association of County Engineers, *Low-cost Local Road Safety Solutions* (Fredericksburg, VA: 2008). Accessed at: http://www.atssa.com/galleries/default-file/Low%20Cost%20Local%20Roadsrev10-09-08-reduced.pdf

13 Federal Highway Administration and the Roadway Safety Foundation, *2007 National Roadway Safety Awards Best Practices Guidebook* (Washington, DC: October 2007). Accessed at: http://www.roadwaysafety.org/wp-content/uploads/2007awards.pdf

14 Peaslee, G. "Signs Show the Way to Cost-Effective Rural Safety," Public Roads, January/February 2005. Accessed at: http://www.tfhrc.gov/pubrds/05jan/08.htm

by the California Department of Transportation, the County calculates that, for an expenditure of $79,300, the project prevented between $12.6 million and $23.7 million in traffic crash losses.

The results speak for themselves. Mendocino County has since expanded the *Road Traffic Safety Review* program to cover its entire county-maintained road system

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6.4. Local Road Safety Audits: Cape May County, New Jersey[15]

The South Jersey Transportation Planning Organization (SJTPO) instituted its Local Road Safety Audit program in 2004 in response to the disproportionate share of roadway departure crashes occurring on rural two-lane roads in the SJTPO region. SJTPO took a data-driven approach to the safety audit program. Audits were first conducted on two Cape May County roads with documented crash histories and significant roadway departure crash potential.

A consultant firm conducted the audits with the assistance of the Cape May County Engineer's office and SJTPO. Of special interest is the interdisciplinary nature of the audit teams, which consisted of county representatives, law enforcement, engineering and public works staff of the affected municipalities, the New Jersey Department of Transportation, the Division of Highway Traffic Safety and the Federal Highway Administration.

The audits have raised awareness among local decision makers by

15 Federal Highway Administration and the Roadway Safety Foundation, *2005 National Roadway Safety Awards Best Practices Guidebook* (Washington, DC: 2005). Accessed at: http://www.roadwaysafety.org/wp-content/uploads/2005awards.pdf

identifying low-cost, quick turn-around safety improvements that are expected to yield immediate safety benefits to address roadway departure crashes. It was one of the first local programs of its kind, utilizing Federal planning funds to systemically identify local road segments of concern, organize a team of independent specialists, engage a consultant team for the audits, and secure Federal funding for the resulting recommended improvements.

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Source: 2005 National Roadway Safety Awards Best Practices

http://www.roadwaysafety.org/

7 Summary

Roadway departure crashes account for 53 percent of national fatalities, many of which occur in rural, local areas. Local administrators, township managers, and public works officials who maintain and operate local rural roads need to be engaged in roadway safety by reviewing understandable literature to guide their identification of roadway segments with safety issues and the countermeasures to address them.

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

When seeking to address local rural road safety, the local practitioners should consider which implementation approach to institute. The three main approaches are – Systematic, Spot location, and Comprehensive. Availability and quality of crash and roadway data, number of locations to be addressed, and 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 roadway departure 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 the system. 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 the 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 – 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 roadway departure safety issues.

Regardless of the implementation approach chosen, a field review should be conducted at identified locations. Field reviews have the potential to identify safety issues and solutions that cannot be determined by data analysis alone. These reviews can be conducted as informal field reviews 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 conventional rural roadway segments, warning signs, curve delineation, rumble strips, and fixed object removal should be considered. In addition, a large 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 roadway departure 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, so they should be taken into account during assessment.

While the challenge to decrease the number of roadway crashes on local rural roads may seem overwhelming due to limited resources, there are a number of low cost proven countermeasures that can be installed; many can be installed relatively quickly.

Local highway agencies have unique responsibilities and challenges related to the safety of 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.

Appendix A – Additional Resources

This section contains additional references on the types of roadway departure countermeasures, studies and technical reports on local and rural roads, and guidelines used for countermeasure installation.

Federal Funding Opportunities

Federal Highway Administration, "Highway Safety Improvement Program (HSIP) website." Available at *http://safety.fhwa.dot.gov/hsip*

Federal Highway Administration, "High Risk Rural Roads Program (HRRRP) website." Available at *http://safety.fhwa.dot.gov/safetealu/memos/memo051906.cfm*

Selected Technical Resources

Federal Highway Administration, "Low Cost Treatments for Horizontal Curve Safety," FHWA-SA-07-002 (Washington, D.C.: 2006). Available at *http://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa07002*

Federal Highway Administration, "9 Proven Crash Countermeasures website." Available at *http://safety.fhwa.dot.gov/policy/memo071008*

This guidance memorandum highlights when and where certain processes, design techniques, or safety countermeasures should be used: "NCHRP Report 500: Guide and for Implementation of the AASHTO Strategic Highway Safety Plan" – a series in which relevant information is assembled into single concise volumes, each pertaining to specific types of highway crashes (e.g., run-off-road, head-on) or contributing factors (e.g., aggressive driving). Specific volumes include:

> *Volume 03: A Guide for Addressing Collisions with Trees in Hazardous Locations:*
> *http://safety.transportation.org/guides.aspx?cid=24*
>
> *Volume 06: A Guide for Addressing Run off Road Collisions:*
> *http://safety.transportation.org/guides.aspx?cid=27*
>
> *Volume 07: A Guide for Reducing Collisions on Horizontal Curves:*
> *http://safety.transportation.org/guides.aspx?cid=32*
>
> *Volume 08: A Guide for Reducing Collisions Involving Utility Poles:*
> *http://safety.transportation.org/guides.aspx?cid=31*

Road Safety Audits:
http://safety.fhwa.dot.gov/rsa/

U.S. Department of Transportation (2008). The U.S. Department of Transportation Rural Safety Initiative. Available at
http://www.dot.gov/affairs/ruralsafety/ruralsafetyinitiativeplan.htm

American Traffic Safety Services Association (ATSSA), "Low Cost Local Road Safety Solutions," 2006.

Federal Highway Administration, "Safety Evaluation of Improved Curve Delineation" (Washington, DC: 2009). Available at
http://www.tfhrc.gov/safety/pubs/09046/index.htm

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

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

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, 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

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

Resources Related to Program Development/Program Coordination

National Local Technical Assistance Program (LTAP) website. Available at
http://www.ltapt2.org/nltapa

This website summarizes the roles and function of the LTAP program and provides links, by state, for local points of contact who may help identify data, resources, and offer assistance.

Examples of State Programs/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*

Pennsylvania Department of Transportation (2008). District Highway Safety Guidance Manual. Federal Highway Administration, Wyoming Technical Transfer Center, Kansas LTAP, Field Guide for Unpaved Rural Roads. Available at *http://www.t2.unh.edu/pubs/field_guide.pdf*

Appendix B: 2009 MUTCD Standards for Traffic Control Devices

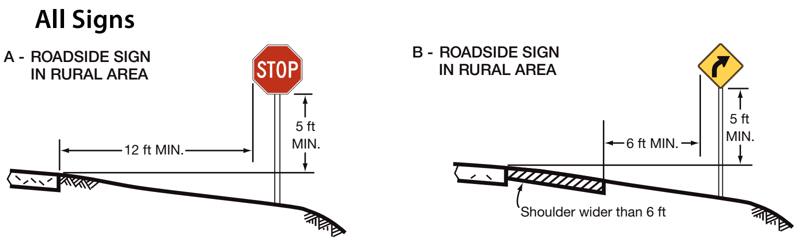

Figure 3 - MUTCD Roadside Placement (MUTCD Figure 2A-2)

For a typical rural road with no shoulder, the sign should be placed on the right-hand 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 at least 5 feet above the ground elevation at the edge of pavement. Enhancing Sign Conspicuity Cost Effectively (MUTCD, Figure 2A-2).

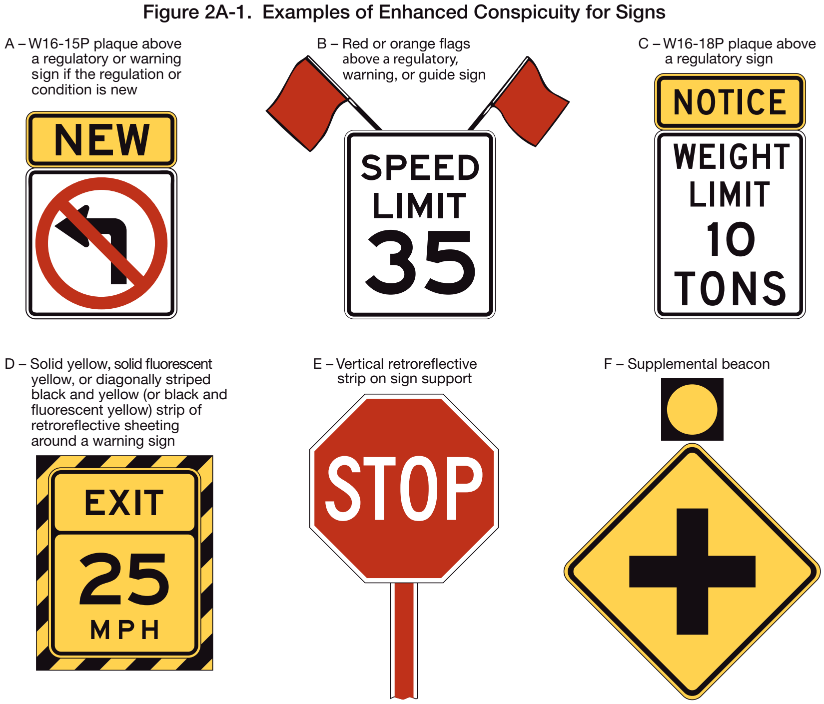

Figure 4 - MUTCD Examples of Enhanced Conspicuity for Signs (MUTCD, Section 2A.15)

- In a situation where it is desired to enhance a sign's conspicuity, the following are among the methods that 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.
  - » Adding a strip of retroreflective material to the sign support

Speed Limit Signs

Speed Limit (R2-1; MUTCD, Section 2B.13)

Minimum Sign Size: 24″ x 30″

When to use

- The Speed Limit sign shall display the limit established by law, ordinance, regulation, or as adopted by the authorized agency based on the engineering study.
- The speed limits displayed shall be in multiples of 5 mph.
- Speed Limit signs shall be located at the points of change from one speed limit to another.
- Additional Speed Limit signs shall be installed beyond major intersections and at other locations where it is necessary to remind road users of the speed limit that is applicable.
- Speed Limit signs indicating the statutory speed limits shall be installed at entrances to the State.

Reduced Speed Limit Ahead (W3-5, W3-5a; MUTCD, Section 2C.38)

Minimum Sign Size: 36″ x 36″

When to use

A Reduced Speed Limit Ahead (W3-5 or W3-5a) sign should be used to inform road users of a reduced speed zone where the speed limit is being reduced by more than 10 mph, or where engineering judgment indicates the need for advance notice to comply with the posted speed limit ahead.

Figure 2C-2. Example of Warning Signs for a Turn

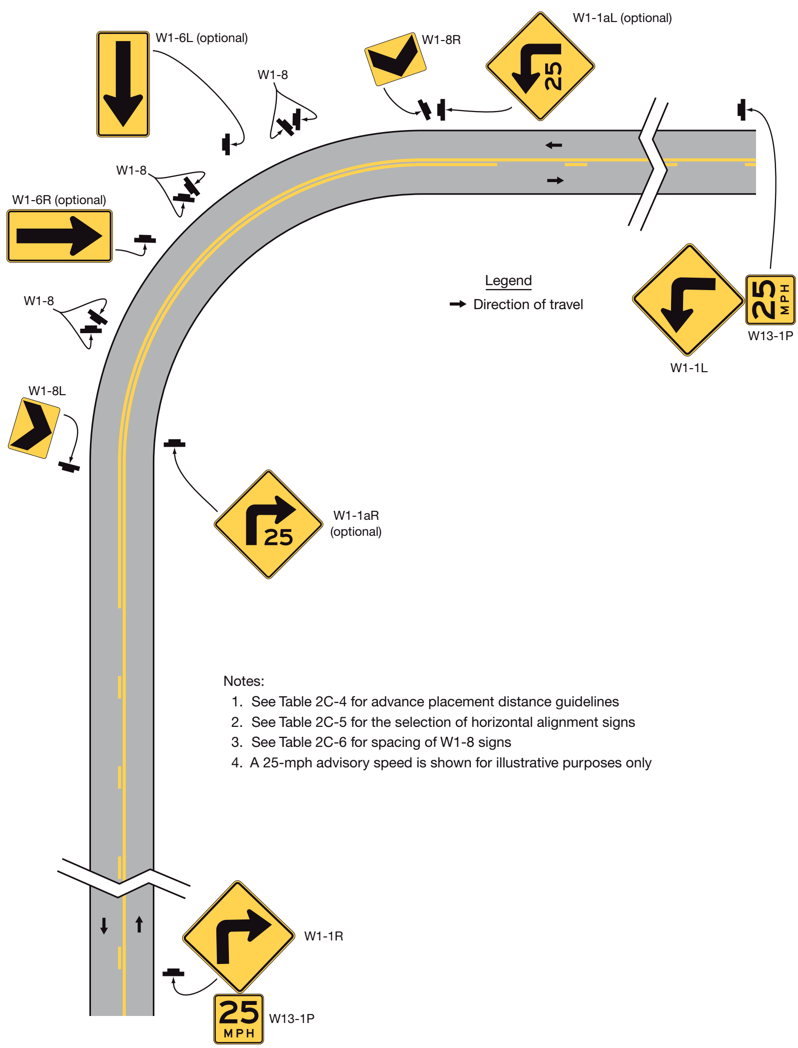

Figure 5 - MUTCD Example of Warning Signs for a Turn

Table 2C-5. Horizontal Alignment Sign Selection

Type of Horizontal Alignment Sign	Difference Between Speed Limit and Advisory Speed				
	5 mph	10 mph	15 mph	20 mph	25 mph or more
Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W10-1) (see Section 2C.07 to determine which sign to use)	Recommended	Required	Required	Required	Required
Advisory Speed Plaque (W13-1P)	Recommended	Required	Required	Required	Required
Chevrons (W1-8) and/or One Direction Large Arrow (W1-6)	Optional	Recommended	Required	Required	Required
Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp	Optional	Optional	Recommended	Required	Required

Note: Required means that the sign and/or plaque shall be used, recommended means that the sign and/or plaque should be used, and optional means that the sign and/or plaque may be used.

See Section 2C.06 for roadways with less than 1,000 ADT.

Horizontal Alignment Signs

All square/diamond warning signs have a minimum sign size of 30" x 30".

When to use

In advance of horizontal curves on freeways, on expressways, and on roadways with more than 1,000 AADT that are functionally classified as arterials or collectors, horizontal alignment warning signs shall be used in accordance with **Table 2C-5** based on the speed differential between the roadway's posted or statutory speed limit or 85th-percentile speed, whichever is higher, or the prevailing speed on the approach to the curve, and the horizontal curve's advisory speed.

Horizontal Alignment Warning signs may also be used on other roadways or on arterial and collector roadways with less than 1,000 AADT based on engineering judgment.

Curve signs (W2-1) vs. Turn signs (W1-1) (MUTCD, Section 2C.07)

When to use

A Turn sign shall be used instead of a Curve sign in advance of curves that have advisory speeds of 30 mph or less.

Reverse Curve (W1-4) and Reverse Turn (W1-3) (MUTCD, Section 2C.07)

When to use

Where there are two changes in roadway alignment in opposite directions that are separated by a tangent distance of less than 600 feet, the Reverse Turn sign should be used instead of multiple Turn signs and the Reverse Curve sign should be used instead of multiple Curve signs.

Combination Horizontal Alignment / Intersection Warning Signs (W1-10 Series; MUTCD, Section 2C.11)

When to use

The Turn sign or the Curve sign may be combined with the Cross Road sign or the Side Road sign to create a combination Horizontal Alignment/Intersection warning sign that depicts the condition where an intersection occurs within or immediately adjacent to a turn or curve.

Elements of the combination Horizontal Alignment/Intersection warning sign related to horizontal alignment should comply with the provisions of Section 2C.07, and elements related to intersection configuration should comply with the provisions of Section 2C.46.

The symbol design should approximate the configuration of the intersecting roadway(s). No more than one Cross Road or two Side Road symbols should be displayed on any one combination Horizontal Alignment/Intersection warning sign.

Advisory Speed Plaque (W13-1P; MUTCD, Section 2C.08)

Minimum Plaque Size: 18" x 18"

Roadside Placement: The sign height changes when a speed plaque is added.

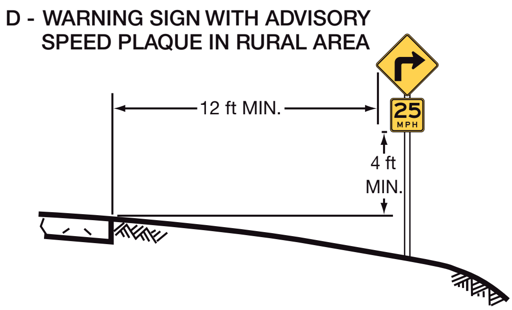

Figure 6 - MUTCD Roadside Placement with Plaque

When to use

The use of the Advisory Speed plaque for horizontal curves shall be in accordance with the information shown in Table 2C-5. The Advisory Speed plaque shall also be used where an engineering study indicates a need to advise road users of the advisory speed for other roadway conditions.

If used, the Advisory Speed plaque shall carry the message XX MPH. The speed displayed shall be a multiple of 5 mph.

Except in emergencies or when the condition is temporary, an Advisory Speed plaque shall not be installed until the advisory speed has been determined by an engineering study.

The Advisory Speed plaque shall only be used to supplement a warning sign and shall not be installed as a separate sign installation.

The advisory speed shall be determined by an engineering study that follows established engineering practices. Among the established engineering practices that are appropriate for the determination of the recommended advisory speed for a horizontal curve are the following:

- An accelerometer that provides a direct determination of side friction factors
- A design speed equation
- A traditional ball-bank indicator using the following criteria:
    - » 16 degrees of ball-bank for speeds of 20 mph or less
    - » 14 degrees of ball-bank for speeds of 25 to 30 mph
    - » 12 degrees of ball-bank for speeds of 35 mph and higher

Combination Horizontal Alignment/Advisory Speed Signs (W1-1a, W1-2a) (MUTCD, Section 2C.10)

When to use

The Turn sign or the Curve sign may be combined with the Advisory Speed plaque to create a combination Turn/Advisory Speed sign or combination Curve/Advisory Speed sign.

The combination Horizontal Alignment/Advisory Speed sign may be used to **supplement** the advance Horizontal Alignment warning sign and Advisory Speed plaque based upon an engineering study.

If used, the combination Horizontal Alignment/Advisory Speed sign **shall not be used alone** and **shall not be used as a substitute** for a Horizontal Alignment warning sign and Advisory Speed plaque at the advance warning location. The combination Horizontal Alignment/Advisory Speed sign shall only be used as a **supplement** to the advance Horizontal Alignment warning sign.

If used, the combination Horizontal Alignment/Advisory Speed sign shall be installed at the beginning of the turn or curve.

The advisory speed displayed on the combination Horizontal Alignment/Advisory Speed sign should be based on the advisory speed for the horizontal curve and match that speed.

Chevron Alignment Signs (W1-8; MUTCD, Section 2C.09)

Minimum Sign Size: 18" x 24"

Sign Design: The Chevron Alignment sign shall be a vertical rectangle. No border shall be used on the Chevron Alignment sign.

When to use

The use of the Chevron Alignment sign to provide additional emphasis and guidance for a change in horizontal alignment shall be in accordance with the information shown in Table 2C-5.

Sign Placement

If used, Chevron Alignment signs shall be installed on the outside of a turn or curve, in line with and approximately at a right angle to approaching traffic. Chevron Alignment signs shall be installed at a minimum height of 4 feet, measured vertically from the bottom of the sign to the elevation of the near edge of the traveled way.

Spacing Around Turns/Curves

The approximate spacing of Chevron Alignment signs on the turn or curve measured from the point of curvature (PC) should be as shown in Table 2C-6. Chevron Alignment signs should be visible for a sufficient distance to provide the road user with adequate time to react to the change in alignment.

One-Direction Large Arrow Sign (W1-6; MUTCD, Section 2C.12)

Minimum Sign Size: 48" x 24"

Sign Design: The One-Direction Large Arrow sign shall be a horizontal rectangle with an arrow pointing to the left or right.

When to use

A One-Direction Large Arrow sign may be used either as a supplement or alternative to Chevron Alignment signs in order to delineate a change in horizontal alignment (see Figure 2C-2). The use of the One-Direction Large Arrow sign shall be in accordance with the information shown in Table 2C-5.

A One-Direction Large Arrow sign may be used to supplement a Turn or Reverse Turn sign to emphasize the abrupt curvature.

Sign Placement

If used, the One-Direction Large Arrow sign shall be installed on the outside of a turn or curve in line with and at approximately a right angle to approaching traffic. The One-Direction Large Arrow sign should be visible for a sufficient distance to provide the road user with adequate time to react to the change in alignment.

Object Markers (MUTCD, Sections 2C.63 through 2C.65)

Minimum Sign Sizes

Type 1: 18″ x 18″

Type 2: 6″ x 12″

Type 3: 12″ x 36″

Sign Design: Object markers shall not have a border and shall consist of an arrangement of one or more of the following types shown in Figure 2C-13.

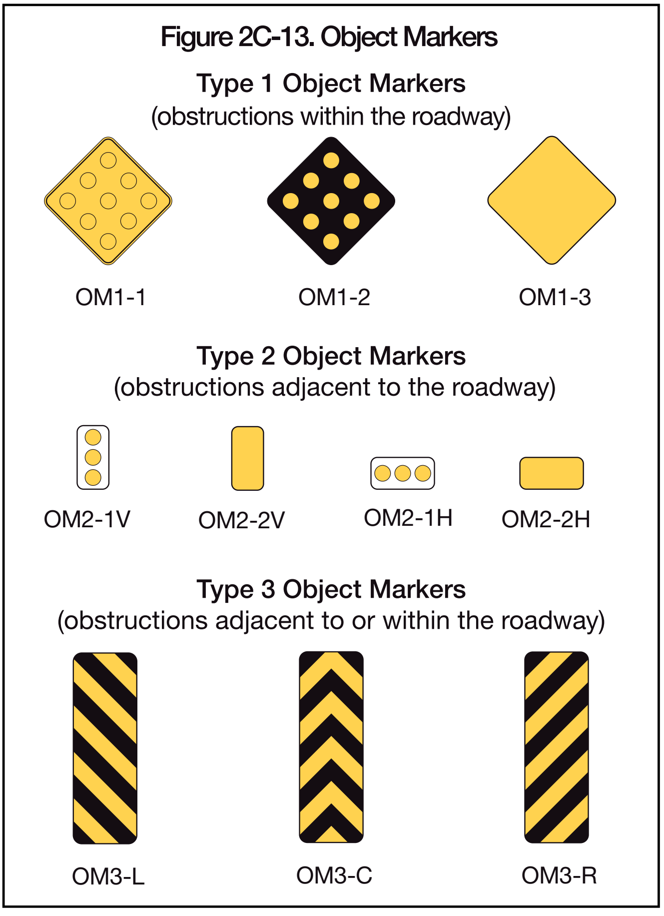

Figure 7 - MUTCD Object Markers

When to use

Type 1 object markers are used to mark obstructions within the roadway.

Type 2 and 3 object markers are used to mark obstructions adjacent to the roadway.

Obstructions not actually within the roadway are sometimes so close to the edge of the road that they need a marker. These include underpass piers, bridge abutments, handrails, ends of traffic barriers, utility poles, and culvert headwalls. In other cases there might not be a physical object involved, but other roadside conditions exist, such as narrow shoulders, drop-offs, gores, small islands, and abrupt changes in the roadway alignment, that might make it undesirable for a road user to leave the roadway, and therefore would create a need for a marker.

Object Marker Placement – Type 1, 2, 3

When used for marking obstructions within the roadway or obstructions that are 8 feet or less from the shoulder or curb, the minimum mounting height, measured from the bottom of the object marker to the elevation of the near **edge of the traveled way**, should be 4 feet.

When used to mark obstructions more than 8 feet from the shoulder or curb, the distance from the bottom of the object marker to the **ground** should be at least 4 feet.

When object markers or markings are applied to an obstruction that by its nature requires a lower or higher mounting, the vertical mounting height may vary according to need.

If a Type 2 or Type 3 object marker is used to mark an obstruction adjacent to the roadway, the edge of the object marker that is closest to the road user shall be installed in line with the closest edge of the obstruction.

No Passing Zones

Pavement Markings (MUTCD, Section 3B.02)

On roadways with center line markings, no-passing zone markings shall be used at horizontal or vertical curves where the passing sight distance is less than the minimum shown in Table 3B-1 for the 85th-percentile speed or the posted or statutory speed limit.

Figure 3B-4 details the measurements needed to determine No Passing Zones at curves.

Where the distance between successive no-passing zones is less than 400 feet, no-passing markings should connect the zones.

Sign Enhancement for No Passing Zones

No Passing Zone pavement marking can be enhanced with the following signs as desired.

Do Not Pass (R4-1) (MUTCD, Section 2B.28)

Minimum Sign Size: 24" x 30"

When to use

The DO NOT PASS sign may be used in addition to pavement markings to emphasize the restriction on passing. The DO NOT PASS sign may be used at the beginning of, and at intervals within, a zone through which sight distance is restricted or where other conditions make overtaking and passing inappropriate.

Pass With Care (R4-2) (MUTCD, Section 2B.29)

Minimum Sign Size: 24" x 30"

When to use

The PASS WITH CARE sign should be installed at the downstream end of a no-passing zone if a DO NOT PASS sign has been installed at the upstream end of the zone.

No Passing Zone pennant (W14-3) (MUTCD, Section 2C.45)

Minimum Sign Size: 48" x 48" x 36"

When to use

If signing is needed on the left-hand side of the roadway for additional emphasis, NO PASSING ZONE signs may be used.

When used, the NO PASSING ZONE sign shall be installed on the left-hand side of the roadway at the beginning of no-passing zones identified by pavement markings.

Retroreflectivity Requirements (MUTCD, Section 2A.08)

2009 MUTCD "Section 2A.08 Maintaining Minimum Retroreflectivity"

The MUTCD provides suggestions for methods to be used:

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 levels should be replaced.

Measured Sign Retroreflectivity

Sign retroreflectivity is measured using a retroreflectometer. Signs with retroreflectivity below the minimum levels should be replaced.

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 levels. Signs older than the expected life should be replaced.

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.

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 levels.

Other Methods

Other methods developed based on engineering studies can be used.

Additional guidance on retroreflectivity requirements for various signs is provided in Table 2A-3.

Table 2A-3. Minimum Maintained Retroreflectivity Levels[1]

Sign Color	Sheeting Type (ASTM D4956-04)				Additional Criteria
	Beaded Sheeting			Prismatic Sheeting	
	I	II	III	III, IV, VI, VII, VIII, IX, X	
White on Green	W*; G ≥ 7	W*; G ≥ 15	W*; G ≥ 25	W ≥ 250; G ≥ 25	Overhead
White on Green	W*; G ≥ 7	W ≥ 120; G ≥ 15			Post-mounted
Black on Yellow or Black on Orange	Y*; O*	Y ≥ 50; O ≥ 50			[2]
Black on Yellow or Black on Orange	Y*; O*	Y ≥ 75; O ≥ 75			[3]
White on Red	W ≥ 35; R ≥ 7				[4]
Black on White	W ≥ 50				–

[1] The minimum maintained retroreflectivity levels shown in this table are in units of cd/lx/m² measured at an observation angle of 0.2° and an entrance angle of -4.0°.
[2] For text and fine symbol signs measuring at least 48 inches and for all sizes of bold symbol signs
[3] For text and fine symbol signs measuring less than 48 inches
[4] Minimum sign contrast ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity)
* This sheeting type shall not be used for this color for this application.

Bold Symbol Signs

- W1-1,2 – Turn and Curve
- W1-3,4 – Reverse Turn and Curve
- W1-5 – Winding Road
- W1-6,7 – Large Arrow
- W1-8 – Chevron
- W1-10 – Intersection in Curve
- W1-11 – Hairpin Curve
- W1-15 – 270 Degree Loop
- W2-1 – Cross Road
- W2-2,3 – Side Road
- W2-4,5 – T and Y Intersection
- W2-6 – Circular Intersection
- W2-7,8 – Double Side Roads
- W3-1 – Stop Ahead
- W3-2 – Yield Ahead
- W3-3 – Signal Ahead
- W4-1 – Merge
- W4-2 – Lane Ends
- W4-3 – Added Lane
- W4-5 – Entering Roadway Merge
- W4-6 – Entering Roadway Added Lane
- W6-1,2 – Divided Highway Begins and Ends
- W6-3 – Two-Way Traffic
- W10-1,2,3,4,11,12 – Grade Crossing Advance Warning
- W11-2 – Pedestrian Crossing
- W11-3,4,16-22 – Large Animals
- W11-5 – Farm Equipment
- W11-6 – Snowmobile Crossing
- W11-7 – Equestrian Crossing
- W11-8 – Fire Station
- W11-10 – Truck Crossing
- W12-1 – Double Arrow
- W16-5P,6P,7P – Pointing Arrow Plaques
- W20-7 – Flagger
- W21-1 – Worker

Fine Symbol Signs (symbol signs not listed as bold symbol signs)

Special Cases

- W3-1 – Stop Ahead: Red retroreflectivity ≥ 7
- W3-2 – Yield Ahead: Red retroreflectivity ≥ 7; White retroreflectivity ≥ 35
- W3-3 – Signal Ahead: Red retroreflectivity ≥ 7; Green retroreflectivity ≥ 7
- W3-5 – Speed Reduction: White retroreflectivity ≥ 50
- For non-diamond shaped signs, such as W14-3 (No Passing Zone), W4-4P (Cross Traffic Does Not Stop), or W13-1P,2,3,6,7 (Speed Advisory Plaques), use the largest sign dimension to determine the proper minimum retroreflectivity level.

Appendix C: Crash Rate Calculations

The crash rate for roadway departure crashes on a roadway is calculated as:

$$R = \frac{C \times 100{,}000{,}000}{V \times 365 \times N \times L}$$

The variables in this equation are:

R = Roadway Departure crash rate for the road segment expressed as crashes per 100 million vehicle-miles of travel,

C = Total number of roadway departure crashes in the study period

V = Traffic volumes using Average Annual Daily Traffic (AADT) volumes

N = Number of years of data

L = Length of the roadway segment in miles

This equation relies on having traffic volume information To determine how to obtain actual and estimated traffic volumes for a particular roadway, a local agency can contact its State highway agency, LTAP representative, or other state agencies.

Example 1. Crash Rate by Vehicle Miles Traveled

In this example, two roadways have the same number of crashes but different traffic volumes. By factoring in exposure, the calculation indicates that Route B may be more susceptible to future crashes. However, before any decision is made, other factors such as roadway geometrics, cross section, and other potential differentiating factors should be considered. There could be other issues not related to traffic volume that affect crash rates.

Roadway	RD Crashes (C)	Traffic Volume (V)	Years of Data (N)	Length of Segment (L)	Crash Rate (R)
Route A	15	4,000	5	12 miles	0.98
Route B	15	2,500	5	12 miles	1.85

Table 3 - Example of Roadway Departure Crash Rate Calculation by Vehicle Miles Traveled

Route A has experienced 0.98 crashes per 100 million vehicle-miles traveled on that roadway. Route B has experienced 1.85 crashes per 100 million vehicle-miles traveled. This data can be used to compare the two roadways. In this case, even though both routes had the same number of crashes, Route B is more susceptible to crashes based on the level of exposure. The practitioner could consider Route B a more promising candidate for a safety treatment than Route A due to its higher crash rate.

Example 2. Crash Rate by Route Length

In this example, two roadways have the same number of crashes but different roadway lengths. Traffic volume data is not available.

A "crashes per mile" rate for road segments is calculated as:

$$R = \frac{C}{N \times L}$$

Where:

R = Crashes per mile for the road segment expressed as crashes per each 1 mile of roadway per year.

C = Total number of crashes in the study period.

N = Number of years of data.

L = Length of the roadway segment in miles.

Roadway	RD Crashes (C)	Years of Data (N)	Length of Segment (L)	Crashes per Mile (R)
Route A	12	5	17 miles	0.71
Route B	12	5	26 miles	0.46

Table 4 - Example of Roadway Departure Crash Rate Calculation by Route Length

In this example, Route A has experienced 0.71 crashes per roadway mile. Route B has experienced 0.46 crashes per mile of roadway. In this case, even though both routes have the same number of crashes, Route A may be more susceptible to future crashes. Therefore Route A may be a more promising candidate for safety treatments.

For More Information
Office of Safety
Federal Highway Administration
1200 New Jersey Ave, SE
Washington, DC 20590-9898
http://safety.fhwa.dot.gov

FHWA-SA-11-09