

ROADSIDE

Horizontal Curve Delineation (1 of 2)

DESCRIPTION AND DEFINITION

To improve successful navigation of horizontal curves, provide enhanced delineation of the road through chevrons, advisory speed plaques, arrow boards, shoulder rumble strips, and expanded road cross sections such as paved shoulders.



ROADWAY OPERATIONS

Improves drivers' ability to navigate through horizontal curves.

TYPICAL COSTS

- Implementation Costs
- Chevrons = \$3,000 per curve
 - Narrow paved shoulder = \$40,000 per curve
 - Dynamic signs = \$50,000

SAFETY CHARACTERISTICS

In greater Minnesota, over 50 percent of severe road departure crashes on county roads occur on curves, but 75 percent of curves have had no crashes in a 5-year period. How do you identify the at-risk locations?

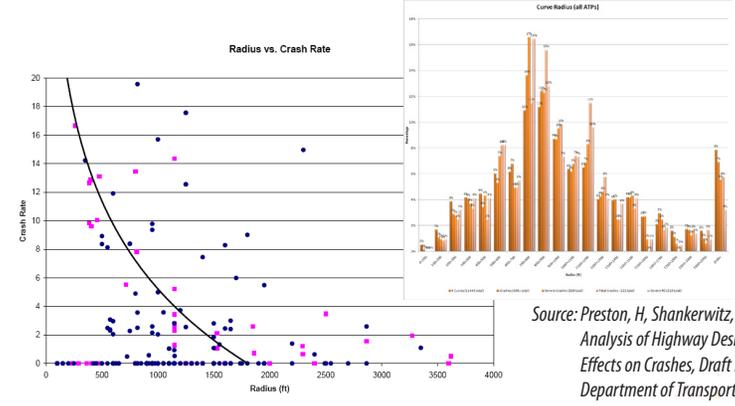
The county road safety plan efforts resulted in the review of over 10,000 curves on both the state and county systems. Reviewing the curves has provided information on the geometric and traffic-related characteristics of curves that pertain to crash risk.

- The majority of severe curve-related crashes occur on curves with:
- Radii between 500 and 1,200 feet
 - Average Daily Traffic (ADT) volumes between 500 and 1,500 vehicles per day

- A crest vertical curve present before the beginning of the horizontal curve, or when a minor road, tree line, or line of utility poles continues on a tangent creating a visual trap
- Intersections on the curve

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- NCHRP 500 series considers horizontal curve delineations a **TRIED** strategy, but MnDOT considers them **PROVEN** based on recent installation and studies. Installing shoulder rumble strips on horizontal curves and widening the roadway are considered **PROVEN** strategies.
- The FHWA Crash Reduction Clearinghouse studies found that adding chevrons at horizontal curves resulted in crash reduction rates between 10 and 50 percent.



TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

Candidate curve locations for implementation of enhanced curve delineation strategies are those with curve radii and ADT volumes ranges considered at higher risk for crashes as identified in the Safety Characteristics section: radii between 500 and 1,200 feet and ADT volumes between 500 and 1,500 vehicles per day. It should be noted that the 2009 MUTCD now requires horizontal alignment signing for all roadways with ADT volumes over 1,000 per day and speed differentials greater than 15 mph.



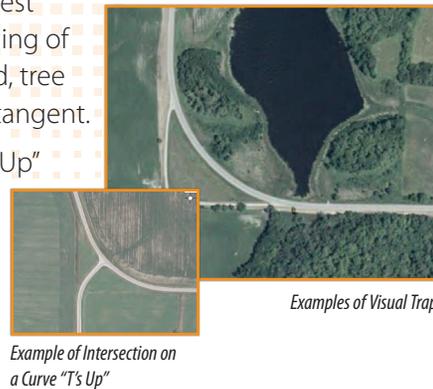
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Horizontal Curve Delineation (2 of 2)

Some other curve characteristics that may increase the risk of crashes at curves but have not been proven are:

- **Intersections on the curve**—An intersection on the curve creates conflicting movements, with both vehicles turning at the intersections and vehicles maneuvering through the curve.
- **Visual Trap**—A visual trap exists when a crest vertical curve is present before the beginning of the horizontal curve, or when a minor road, tree line, or line of utility poles continues on a tangent.

The current best practice is to attempt to “T-Up” intersections. An example is shown in the pictures to the right. By removing the two access points at one T-intersection, one visual trap is removed and there is a reduction in access along the roadway.



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.

Source: 2009 Manual on Uniform Traffic Control Devices

Best Practice

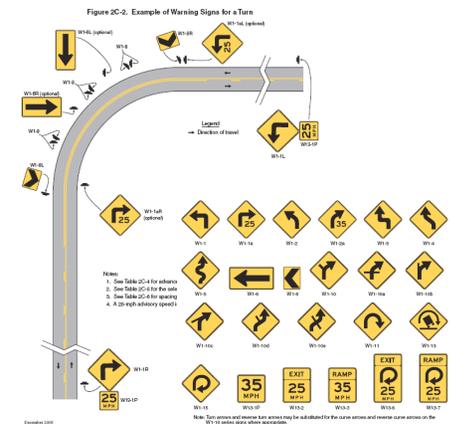
The 2009 MN MUTCD now requires horizontal alignment signing for all roadways with ADT volumes over 1,000 per day and speed differentials greater than 15 mph. Curves that do not meet this requirement should be prioritized based on risk factors determined from current crash research. Safety strategies include: chevrons, 2-foot paved shoulders, and edge line rumble stripes.

DESIGN FEATURES

Design features of the proposed curve delineation and roadway widening strategies include:

1. **Horizontal alignment signing**—The MN MUTCD provides signing types and locations.
2. **Rumble strips**—Rumble strips encourage vehicles to stay on the road.
3. **Shoulder paving**—The paved shoulder for curves is typically 2 feet wide.

Some agencies have also developed standard installation practice ensuring that a chevron gets placed in the middle of the approach lane tangent.



SOURCES

In-Vehicle Technologies and Infrastructure Modifications to Prevent Crashes Along Curves and Shoulders, Minnesota Local Road Research Board, Report 200939TS.
Benefit: Cost Analysis of In-Vehicle Technologies and Infrastructure Modifications as a Means to Prevent Crashes Along Curves and Shoulders, Minnesota Local Road Research Board, Report 200939.
Simplifying Delineator and Chevron Applications for Horizontal Curves, Federal Highway Administration, Report TX-04/0-4052-1.
Horizontal Curve Signing Handbook, Federal Highway Administration, Report TX-07/0-5439-P1.



Horizontal Curves Delineation Policy

POLICY PURPOSE/INTRODUCTION

The purpose of this policy is to establish uniformity and consistency in the application, installation, and maintenance of implementation of safety strategies on horizontal curves on **<Insert Agency>**'s roadway system.

DEFINITIONS

Chevron—The chevron is a V-shaped roadway sign that indicates a sharp bend to the left or right.



POLICY

It is **<Insert Agency>**'s policy to provide enhanced horizontal curve delineation on prioritized curves within **<Insert Agency>**'s roadways. For roadways with average daily traffic (ADT) volumes greater than 1,000 vehicles per day, **<Insert Agency>** will follow the latest 2009 MN MUTCD requirements for signing of horizontal curves for all roadways. Roadways with ADT volumes less than 1,000 vehicles per day, curves will be prioritized based on risk factors and additional delineation will be provided for the highest priority locations. **<Insert Agency>** will also maintain an inventory of all horizontal curve signs within its jurisdiction and regularly review the inventory to align with available maintenance funding. (NOTE: See Traffic Signs for more information on inventory and sign maintenance.)

POLICY CRITERIA

Roadways with ADT volumes greater than 1,000 vehicles per day will meet MN MUTCD requirements as shown in the table below.

Type of Signs	Difference between Speed Limit and Advisory Speed				
	5 mph	10 mph	15 mph	20 mph	25 mph or more
Advance Warning Sign	Recommended	Required	Required	Required	Required
Advisory Speed Plaque	Recommended	Required	Required	Required	Required
Chevrons	Optional	Recommended	Required	Required	Required

Source: 2009 MUTCD.



Roadways with fewer than 1,000 vehicles per day will be prioritized based on five roadway features that have been found to increase the level of risk at individual curves. The risk factors are:

- **Curve Radius**—Shorter curve radii results in higher overall crash density; however, a majority of rural Minnesota severe crashes occurred on curves with 500- to 1,200-foot radii. This relationship is similar to that found in MnDOT and other national research. Another factor in support of establishing a 1,200-foot radius as the upper limit for the range of at-risk curves is the fact that this radii approximates a 55-mph design speed based on Table 3-3.02A in MnDOT's *Road Design Manual*.
- **Traffic Volumes**—A range of volumes in each system is overrepresented relative to the frequency of curve-related crashes. In rural Minnesota, in the volume range between 400 and 1,400 vehicles per day, curves accounted for the majority of severe crashes.
- **Intersection in the Curve**—The presence of an intersection in the curve increased crash risk.
- **Visual Trap**—The presence of a visual trap increases the level of crash risk. A visual trap exists when a crest vertical curve occurs before the beginning of the horizontal curve or when a minor road, tree line, or line of utility poles continues on a tangent.
- **Crash Experience**—A curve had experienced a severe crash over the 5-year study period.

NOTE: Counties that have had a county road safety plan completed will already have their curves prioritized based on the risk factors.

Strategies for enhanced delineation of prioritized curves with fewer than 1,000 vehicles per day include:

- Chevrons
- 2-foot paved shoulders
- Edge line rumble stripes

FINANCIAL CONSIDERATIONS

Highway Safety Improvement Program (HSIP) funding is available for curve delineation enhancement projects. The typical cost of chevrons is \$3,000 per curve, and the typical cost of 2-foot shoulders is \$40,000 per curve.