Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads

REPORT NO. 2011-21








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16. Abstract (Limit: 250 words) The information in this Best Practices and Policies Guide is provided as a resource to assist local agencies in their efforts to better design, operate and maintain their systems of roads and highways. This information is provided to agencies in an effort to reduce the number of severe crashes on their highway system and it is understood that the final decision to implement any of these strategies resides with the agency. The practices and policies in this guide are consistent with guidance prepared by FHWA, AASHTO and NCHRP and is primarily intended to apply to new construction, except as noted. In addition, these practices and policies provide an overview of the current state of practice in Minnesota relating to the design, operation and maintenance of road systems. Agencies are encouraged to modify information in this material as necessary to reflect their own culture and practices. Each Best Practice provides the following information: Description & Definition, Safety Characteristics, Safety Effectiveness, Typical Characteristics of Candidate Locations, Effect on Roadway Operations, Typical Costs, Design Features, Best Practice, Sources (of additional information) and Sample Policy.			
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Document Information and Disclaimer (1 of 2)

The information in this Best Practices and Policies Guide is provided as a resource to assist agencies in their efforts to better design, operate, and maintain their systems of roads and highways. The information in this handbook is consistent with best practices in safety planning as presented in guidance prepared by the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the National Cooperative Highway Research Program (NCHRP). This information is provided to agencies in an effort to reduce the number of severe crashes on their highway system and it is understood that the final decision to implement any of the strategies resides with the agency. There is no expectation or requirement that agencies implement these safety strategies, and it is understood that actual implementation decisions will be made by agency staff based on consideration of economic, social, and political issues, and location-specific considerations.

In an effort to help reduce the potential exposure to claims of negligence associated with motor vehicle crashes on an agency's roadway system, two key points should be considered:

1. Minnesota tort law provides for discretionary immunity for decisions made by agency officials when there is documentation of the decision and evidence of consideration of social, economic, and political issues.
2. Minnesota tort law provides for official immunity for decisions made by agency staff when there is written documentation of the thought process supporting project development and implementation.

Following any implementation or application of these best practices and policies, agencies are encouraged to look back, evaluate, and, if necessary, modify practices to make it more consistent with their actual usage and system needs.

- This Best Practices and Policies Guide does not set requirements or mandates.
- This Best Practices and Policies Guide contains no warrants or standards and does not supersede other publications that do.
- This Best Practices and Policies Guide is not a standard and is neither intended to be, nor does it establish, a legal standard of care for users or professionals.
- This Best Practices and Policies Guide does not supersede publications such as the following:
  - Minnesota's ***Manual on Uniform Traffic Control Devices*** (MN MUTCD)
  - Association of American State Highway Transportation Officials' (AASHTO's) Green Book, ***A Policy on Geometric Design of Highways and Streets***
  - Other AASHTO and agency guidelines, manuals, and policies
- The practices and policies in this guide are primarily intended to apply to new construction, except as noted. As a result, from a risk management perspective, agencies should consider whether there is a clear enough distinction in their capital improvement programs between construction projects and ongoing maintenance activities.
- The practices and policies in this guide provide an overview of the current general state of the practice in Minnesota relating to the design, operation, and maintenance of road systems. Agencies are encouraged to modify information in this material as necessary to reflect their own culture and practices.

Each Best Practice provides the following information:

- ***Description and Definition***—Information on the purpose and description of the strategy
- ***Safety Characteristics***—A summary of the safety benefits of the strategy and any related research or data
- ***Proven, Tried, Ineffective or Experimental***—Summary of the strategy's crash reductions based on Federal Highway Administration Crash Reduction Clearinghouse and the National Cooperative Highway Research Programs (NCHRP) Report 500, or other relevant studies. Strategies are classified as one of the following:
  - Proven Strategies that have been widely deployed and that have been subject to properly designed evaluations that show them to be consistently effective.
  - Tried Strategies that have been implemented in a number of locations but have not been fully evaluated.

Document Information and Disclaimer (2 of 2)

  - Ineffective Strategies have been subject to evaluation and have been shown to not improve safety.
  - Experimental Strategies that are ideas that have been suggested and at least one agency has considered sufficiently promising to try on a small scale in at least one location.
- *Typical Characteristics of Candidate Locations*—The appropriate use of the strategy based on roadway characteristics
- *Roadway Operations*—A summary of potential impacts of the safety strategy on roadway traffic operations
- *Typical Costs*—A summary of the typical costs for installation of the safety strategies and any applicable maintenance costs based on available past projects based on available past projects
- *Design Features*—Information on the latest design of the safety strategy and the appropriate design criteria to be used during implementation; may also include expected service life of the strategy
- *Best Practice*—A short summary of the current best practice relating to the safety strategy
- *Sources*—Related resources and cited materials
- *Sample Policy*—Sample language that may be used in the development of individual agencies' policies

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Best Practices and Policies – Strategies Summary

TABLE SUMMARY

Strategy for Maintenance or New/Reconstruction—Maintenance includes overlays and routine operations of the roadway agency. New construction or reconstruction would apply to all new roadways or complete reconstruction of the roadway. The letter "M" refers to strategies that could be implemented during maintenance and other routine operations, and "NR" refers to strategies that are likely to be implemented during new construction or roadway reconstruction.

Operational Effects—Measures mobility based on the through put of the roadway with the following guide:

\+ Improves Mobility

0 No Effect on Mobility

– Decreases Mobility

		Page	Strategy for Maintenance (M) or New/ Reconstruction (NR)	Crash Reduction	Proven/Tried/ Experimental	Operational Effects	Candidate Locations	Construction Costs	Expected Service Life
General	Access Management	4-8	NR	20-40%	Proven	+	All Roads	$20K to >$1M	20 years
	Traffic Signs	9-13	M and NR	Varies by Sign	Varies by Sign	Varies	All Roads	Varies	10-13 years
Intersections	Intersection Treatments	14-16	NR	Varies by Type	Varies by Type	+	All Roads	Varies	20 years
	Rural Lighting	17-20	M and NR	20-50%	Proven	0	Rural	$5k-15k	15 years
	Traffic Signal Confirmation Lights	21-23	NR	10-50%	Proven	0	Urban	$1k /intersection	10 years
	Pedestrian Treatments	24-27	NR	Varies by Treatment	Varies by Treatment	Varies	Urban	Varies	20 years
	Turn Lanes	28-31	NR	10-50%	Proven	+	All Roads	$50k-$300k	10 years
	Rural Through/STOP Intersections	32-35	M and NR	-30-30%	Varies	0	Rural	Varies	8-10 years
Roadside	Pavement Markings	36-40	M and NR	10-60%	Tried	0	All Roads	$650-$8k/mile	1-4 years
	Edge Line Rumbles	41-44	M and NR	10-70%	Proven	0	Rural	$3,000/mile	8-10 years
	Horizontal Curve Delineation	45-47	M and NR	10-50%	Proven	0	Rural	Varies	10-15 years
	Safety Edge	48-50	M and NR	5-10%	Tried	0	Rural Primary & Secondary	$500-$2k/mile	8-10 years
	Clear Zones	51-53	NR	20-40%	Proven	+	All Roads	$100k-$500k/mile	20 years
	Mailboxes	54-57	M and NR	NA	Tried	0	All Roads	$100-200	8-10 years
	Guardrail and End Treatments	58-60	NR	10-45%	Tried	0	All Roads	$1k – 3K	10 years

(Sources of table information documented in individual Best Practices)

Access Management (1 of 3)

GENERAL

DESCRIPTION AND DEFINITION

Access management is a process that provides reasonable access to land development while simultaneously preserving the mobility of traffic and safety on the roadway system.

A comprehensive access management program typically consists of two components:

1. A traffic engineering component to control how, when, and where vehicles turn on and off the road.
2. A land planning component to encourage or require agencies to include access management in planning developments and building the roadway network.

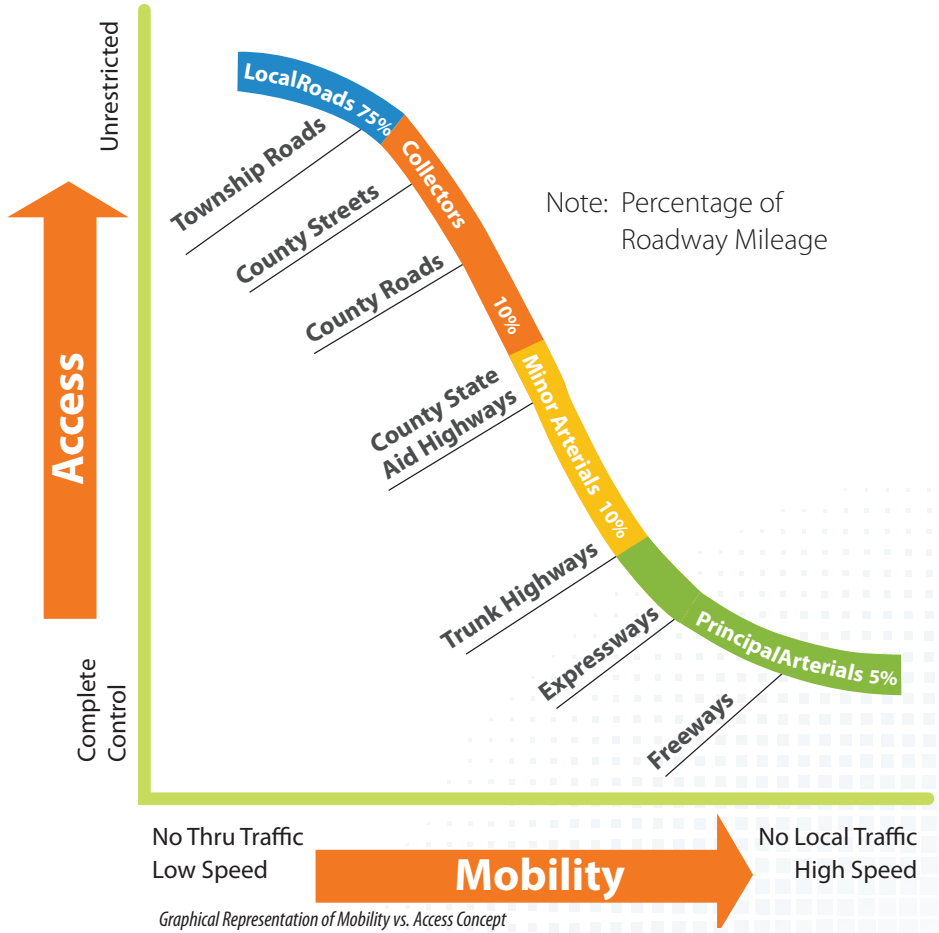
The basic principles of access management include the following:

- Consider access management strategies early in the land planning process
- Incorporate access management strategies in all major highway development projects
- Limit the total number of access points along a segment of roadway based on roadway type
- Interconnect local streets as appropriate to support the proper balance of access to the major highway
- Limit the number of conflicts at intersections, when applicable (see Intersection Treatments Practice Summary)
- Separate conflict points so that the influence areas of adjacent intersections do not overlap
- Separate turning volumes from through movements
- Maintain a hierarchy of access based on functional classification with major arterials having highly managed access, minor arterials and collectors providing a moderate level of access, and local streets being the primary provider of access
- Provide sufficient spacing between at-grade signalized intersections

ROADWAY OPERATIONS

Mobility vs. Access

- Major arterials are primarily intended to move traffic and access should be closely managed to optimize efficiency and safety.
- Local streets are primarily intended to provide access to abutting property and the roadways should be designed to minimize speeds, volumes, and through traffic with only minor access-related restrictions.



Graphical Representation of Mobility vs. Access Concept

Access Management (2 of 3)

GENERAL

- Minor arterials and collectors have to serve the dual functions of moving traffic and providing land access. A moderate level of access management, including features such as turning lanes, medians, and minimum driveway separations, is appropriate to mitigate the adverse effects associated with closely spaced driveways and high levels of turning traffic.

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

Most agencies have spacing guidelines for roadways based on functional classification and rural or urban location as part of their transportation plans.

SAFETY CHARACTERISTICS

Research has demonstrated that on state highways in Minnesota, there is a statistically significant relationship between access density and crash rates: the greater the number of access points, the higher the crash rate.

Phase II of the County Roadway Safety Plans has produced information that proves that the same access effect is present along the county highway system—as the access density increases, the crash and severity rates also increase.

County roadways in Minnesota with lower than average access density (8 to 10 access points per mile or less) have crash rates 20 percent below the average crash rate (0.9 crashes per 1 million vehicle miles) and 40 percent less than roadways with higher-than-average access density.

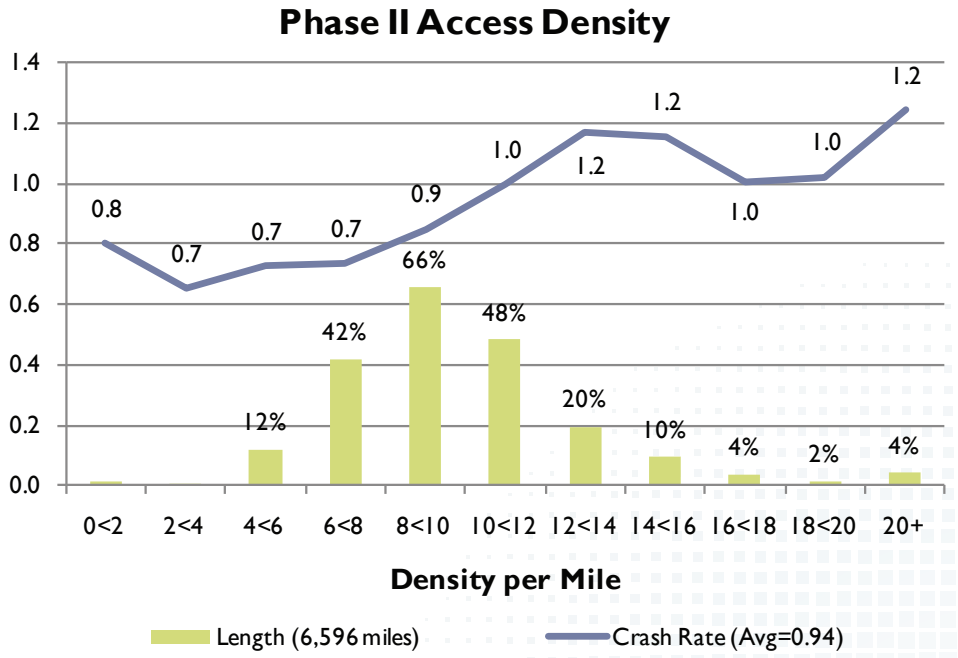
TYPICAL COSTS

Typical implementation costs range from $20,000 to greater than $1 million. The wide range in implementation costs is associated with the different types of access management strategies. The strategies can range from a low-cost median closure on a divided roadway to multiple access closures along a corridor on which frontage roads are necessary.

Access Spacing Guidelines

Type of Access	Major Arterial	Minor Arterial		Collector	Local
		More than 7,500 ADT[a]	Less than 7,500 ADT[a]		
Private Driveways	No direct access	No direct access	Variable [b]	Variable [b]	Variable [b]
Commercial Driveways	No direct access	Allow for Combined Commercial Access with Integrated Street Network	⅛ mile	⅛ mile	Variable [b]
Local Street and Collector Streets	½ mile full, ¼ mile partial	¼ mile	¼ mile, ⅛ mile partial	⅛ mile	⅛ mile

(a) Average Daily Traffic (ADT) is the 20-year forecast. *(b) Spacing is based on criteria such as sight distance, speed, traffic volumes, etc.*



Source: Phase II, MnDOT County Road Safety Plans, 2011.

Access Management (3 of 3)

GENERAL

DESIGN FEATURES

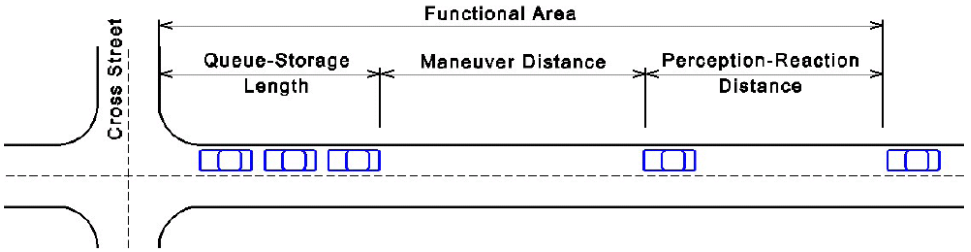
The location and design of a local street connection or driveway should consider the following access-related elements of the roadway (see MnDOT's *Access Management Manual*, Chapter 3):

- Number of existing driveways
- Sight distance
- Spacing between driveways
- Corner clearance and access within the functional area of an intersection
- Offset driveways and streets
- Restricted movements and median openings
- Shared driveways
- Interim access
- Auxiliary or turn lanes

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- Research completed by MnDOT and Iowa DOT concluded that access management is a **PROVEN** safety strategy with an average crash reduction rate of 30 to 40 percent.
- NCHRP 500 series considers access management a **TRIED** strategy.

The one 5-star rated study in the FHWA Crash Reduction Clearinghouse had a 25 to 30 percent reduction in all crashes with modification of access, including access removal and reconfiguration.



Example of Intersection Functional Area

Statutory Authority

In Minnesota, access to a roadway from an abutting property is considered a property right. Road authorities have the following rights:

- Usually have to allow a reasonable access unless the control of access is purchased
- Do have the right to regulate the number, location, and the design of accesses
- Have the right to close medians because reasonable access has been defined as to only one direction of travel

SOURCES

Access Management Manual, MnDOT.
Access Management Manual, Transportation Research Board, 2003.
MnDOT's County Road Safety Plans, Phase II Analysis, 2011.
Technical Guidelines for the Control of Direct Access to Arterial Highways, Volume II: Detailed Description of Access Control Techniques, Report No. FHWA-RD-76-87, Glennon, J. C., et al., Federal Highway Administration, 1975.
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Statistical Relationship between Vehicular Crashes and Access, LRRB Report 1998-27, Preston, H., 1998.
Access Management Awareness Program Phase II Summary Report, Iowa DOT, Center for Transportation Research and Education, Iowa State University, Maze, T and Plazak, D, 1997.
Iowa's Statewide Urban Design Standards Promote Improved Access Management Iowa DOT, Center for Transportation Research and Education, Iowa State University, Plazak, D and Harrington, D, 2003.

Access Management Policy (1 of 2)

GENERAL

POLICY PURPOSE/INTRODUCTION

The purpose of this policy is to establish uniformity and consistency in the application of access management on the ***<Insert Agency>***'s roadway system. A comprehensive access management program typically consists of two components: (1) a traffic engineering component to control how, when, and where vehicles turn on and off the road, and (2) a land planning component to require or encourage inclusion of access management in the projects.

DEFINITIONS

Major Arterials—Roadways primarily intended to move traffic and access to the roadways; should be highly managed to optimize efficiency and safety.

Local Street—Roadways primarily intended to provide access to abutting property; should be designed to minimize speeds, volumes, and through traffic with only minor access-related restrictions.

Minor Arterial or Collector—Roadways that have to serve the dual functions of moving traffic and providing land access. A moderate level of access management, including features such as turning lanes, medians, and minimum driveway separations, is appropriate to mitigate the adverse effects associated with closely spaced driveways and high levels of turning traffic.

POLICY

It is the policy of ***<Insert Agency>*** to manage access on its roadways by maintaining a hierarchy of access based on functional classification. Major arterials will have highly managed access, with minor arterials and collectors providing a moderate level of access and local streets being the primary provider of access within ***<Insert Agency>***.

POLICY CRITERIA

Access guidelines are separated into rural roadways and urban roadways (roadways located within a municipality).

Rural Roadways

<Insert Agency> will have ¼-mile spacing of residential, farm, field, and commercial entrances. Closer spacing requires investigation and approval of ***<Insert Agency>*** engineer. Upgrade or reconstruction roadway projects will consolidate driveways whenever possible to achieve the desired spacing of ¼ mile.

Urban Roadways

<Insert Agency> will follow the access spacing guidelines shown in Table 1. Distances shown are minimums. ***<Insert Agency>*** reserves the right to increase the minimum distances based on other criteria. The guidelines help inform decisions about the proper location and type of access to the roadway system as development or redevelopment occurs adjacent to ***<Insert Agency>*** roadways or when roadways are widened or reconstructed.

Table 1—Access Spacing Guidelines

Type of Access	Major Arterial	Minor Arterial		Collector	Local
		More than 7,500 ADT[a]	Less than 7,500 ADT[a]		
Private Driveways	No direct access	No direct access	Variable [b]	Variable [b]	Variable [b]
Commercial Driveways	No direct access	Allow for Combined Commercial Access with Integrated Street Network	⅛ mile	⅛ mile	Variable [b]
Local Street and Collector Streets	½ mile full, ¼ mile partial	¼ mile	¼ mile, ⅛ mile partial	⅛ mile	⅛ mile

(a) Average Daily Traffic (ADT) is the 20-year forecast. *(b) Spacing is based on criteria such as sight distance, speed, traffic volumes, etc.*

Access Management Policy (2 of 2)

GENERAL

Land Planning Component

<Insert Agency> will not allow urban land uses to be located in the agricultural districts of the county. Rezoning of land for commercial, industrial, or platted residential subdivisions anywhere in the county except immediately adjacent to municipal boundaries where they can receive municipal services will not be accepted. This restriction will allow our cities to grow in an orderly manner, and will also allow farms to continue farming without the encroachment of large developments of non-farmhouses adjacent to farming operations. ***<Insert Agency>*** will allow one new dwelling per quarter in all the districts outside of the cities, provided that the building lot has access to a public road. This type of development will also assist in the management of access provided that the residence would have one access, which would equal eight access points per mile.

Other items to consider when planning for the location of access along a *<Insert Agency>* roadway include:

- All accesses onto county right-of-way should be aligned to be straight and perpendicular to the centerline of the adjacent county roadway.
- All facilities, such as signs, entrances, medians, fencing, etc., should be placed or constructed outside the county right-of-way.
- Culverts constructed or placed within county right-of-way, or as part of an access, should be a minimum of 15 inches or a size determined by the ***<Insert Agency>*** Department of Public Works, whichever is greater
- Plastic pipe will not be used on accesses within the county right-of-way.
- Whenever possible, the location of new access points should be aligned with street accesses or entrances on the opposing side of the roadway to create four-way intersections. Offset intersections within the spacing criteria are to be avoided.
- Wherever possible, access points to commercial areas should be combined through service roads or common access points.
- Wherever possible, access locations should be directed onto roadways with a lower functional classification or lower traffic volume.
- The stacking distance back from an intersection on an arterial or collector will be considered when determining if a new access point will be allowed. A new full access will not be allowed within a fully developed left turn lane, right turn lane, or bypass lane.
- A right-in/out access may be required for safety and traffic flow purposes if other access options are not consistent with public safety and traffic flow.

Access Design Criteria

Table 2 provides design criteria for private access onto ***<Insert Agency>***'s roadway, including width, grade, landing size, and side slopes.

Table 2—Design Details for Access onto <Insert Agency> Roadways

Design Criteria	Residential			Commercial - Industrial - Farm			Field Approaches		
	Min	Max	Desired	Min	Max	Desired	Min	Max	Desired
Entrance Angle / skew (degrees)	70	110	90	70	110	90	70	110	90
Width [a] (feet)	16	24	24	24	32	32	20	32	20
Corner Clearance [b] (feet)	60	See Note b	See Table 1	60	See Note b	See Access Spacing	60	See Note b	See Table 1
Radius (feet) [c]	5 to 15	35	25	5 to 25	40	25	5 to 10	40	20
Entrance Grade (percent) [d]	0	± 14	-2.5	0	± 8	-2.5	0	± 14	-2.5
Landing (feet) (at 0.5 percent)	25		50	25		50	15		50
Side Slope [e] (feet:feet)	1:4 (6)	1:10	1:4 (6)	1:4 (6)	1:10	1:4 (6)	1:4 (6)	1:10	1:4 (6)

See MnDOT's Road Design Manual and Standard Plate 9000D for additional information

Notes:

(a) Urban residential widths are restricted to 24 feet wide. 32-foot double-wide field approaches are allowed at property lines when the access is shared between the two landowners.

(b) The closest access point to an intersection may need to be outside the functional area of that intersection depending on the local geometric and traffic characteristics of the county roadways. Functional areas of an intersection may be up to 820 feet.

(c) Minimum radius dependant on angle of driveway approach; see MnDOT's Road Design Manual.

(d) Entrance surface out to culvert or ditch line shall have a minimum drop of 6 inches at 20 feet from the edge of the driving lane. Maximum elevation drop is 15 inches at 20 feet from the edge of the driving lane.

(e) New side slopes of 1:6 are required when other approaches on the roadway are 1:6.

Traffic Signs (1 of 3)

GENERAL

DESCRIPTION AND DEFINITION

New language adopted in the MN MUTCD requires all agencies that maintain roadways open to the public to adopt a program designed to maintain traffic sign retroreflectivity at specific levels.

An informal survey of practice of local agencies was conducted as part of a Minnesota Local Technical Assistance Program (LTAP) workshop on Traffic Signing Best Practices. The survey found that most agencies attending the workshop did not have a large enough annual budget to maintain their existing inventory of traffic signs.

As agencies review their sign inventories and determine the appropriate maintenance policy, it is becoming clear that the suggested levels of investments necessary to maintain their inventory may not be possible. Proactive sign management requires agencies to follow these five steps when developing a sign maintenance program:

1. *Conduct/update sign inventory*—Review current inventory and document signs.
2. *Prepare annual budget*—Create a budget that accounts for knockdowns, vandalism, and the periodic replacement of signs as they wear out.
3. *Understand engineering study processes*—Create a written record of the engineering judgment regarding signs to remain and signs to be removed; this step supports establishing official immunity for agencies.
4. *Develop policy*—Develop a policy that implements sign placement based on MN MUTCD's effective safety requirements and that documents the planned maintenance method. The policy can also identify types of signs that the agency will not install.
5. *Initiate Projects*—Implement sign upgrade projects and consider sign removal. In the analytical process to determine an agency's annual sign maintenance budget, the only variable that the agency can control is the size of its inventory. Removal of unnecessary signs should be considered, especially ineffective or non-required signs.

SAFETY CHARACTERISTICS

A review of traffic safety literature found that, at this time, the only types of warning signs that have been proven effective are the Horizontal Alignment Series (but only in a narrow range of curve radii).

Bottom line—If an agency's decision to install a sign is based on an expectation of proven effectiveness—through either reducing crashes or changing driver behavior—supporting literature is virtually nonexistent.

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- The use of chevrons is considered to be **PROVEN** effective at reducing road departure crashes. The Federal Highway Administrations Crash Modification Factors (CMF) Clearinghouse documents 12 studies with crash reductions ranging from 5 to 50 percent.
- There is no documented evaluation of other signs, and they are considered **TRIED**.
- Application of new technologies to create dynamic signs has shown some promise but they have not been widely deployed or evaluated and are considered **EXPERIMENTAL**.
- A number of traffic signs have been proven to be **INEFFECTIVE**, such as pedestrian crossing signs, deer crossing signs, and warning signs for infrequent occurrences (falling rocks, slippery pavement, and pedestrian signs in rural areas).

Traffic Signs (2 of 3)

GENERAL

ROADWAY OPERATIONS

- *Effectiveness of Speed Limit Signs*—Drivers select a speed they perceive as safe based on their reaction to actual conditions (presence of pedestrians, road width, parked vehicles, etc.) along a roadway. Majority of drivers only comply with speed limits (and the signs) if the posted limits are consistent with their perception and selection of a safe speed.
- *Effectiveness of STOP Signs*—Research shows that increasing the level of intersection control does NOT improve safety for lower-volume rural county and state intersections (fewer than 500 vehicles per day on approach), and that only about 20 percent of drivers actually stop. STOP signs on high volume or speed roads might be considered as a safety feature, but only if indicated by a traffic study.

Study Location	Before	After	Sign Change +/- mph	85% Before After	Change mph
T.H. 65	SPEED LIMIT 40	SPEED LIMIT 30	-10	34 34	0
T.H. 65	SPEED LIMIT 50	SPEED LIMIT 40	-10	44 45	+1
Anoka CSAH 1	SPEED LIMIT 45	SPEED LIMIT 40	-5	48 50	+2
Anoka CSAH 24	SPEED LIMIT 30	SPEED LIMIT 45	+15	49 50	+1
Anoka CR 51	SPEED LIMIT 40	SPEED LIMIT 45	+5	45 46	+1
Henn. CSAH 4	SPEED LIMIT 50	SPEED LIMIT 40	-10	52 51	-1
Nobles Ave.	SPEED LIMIT 30	SPEED LIMIT 35	+5	37 40	+3
62nd Ave. N	SPEED LIMIT 35	SPEED LIMIT 30	-5	37 37	0
Miss. St.	SPEED LIMIT 30	SPEED LIMIT 35	+5	39 40	+1

Sample Data from Study of Effectiveness of Speed Limit Signs

DESIGN FEATURES

Out of the hundreds of signs contained in the MN MUTCD, 14 types of signs are actually required. This number suggests that if an agency decides to put up a sign, most of the time that action will be based on exercising the agency's judgement and NOT on the requirements of the MN MUTCD. The following signs are required:

- *Regulatory Sign Usage*
  - Speed limits (if in an established speed zone)
  - ONE WAY/DO NOT ENTER
  - Turn prohibitions
  - ALL-WAY STOP supplementary plaque
- *Warning Sign Usage*
  - Railroad Crossing
  - Low Clearance
  - Advance traffic control (if sight distance to the device is limited or impaired)
  - No Train Horn
  - Horizontal alignment (for roadways with volumes greater than 1,000 vehicles per day)
- *Guide Sign Usage*
  - Route numbers (on all numbered highways)
  - Junction assembly (such as Jct US 63)
  - Advance route turn assembly
- *Low-Volume Roads*
  - Four warning signs—STOP AHEAD (if sight distance is limited), Vertical Clearance, Railroad Crossing, and minimum maintenance roads; no regulatory or guide signs are required

TYPICAL COSTS

The cost of the maintenance of signs required to meet the MN MUTCD's retroreflectivity standards depends on the following factors:

- The number of signs in the agency's inventory
- Selected replacement schedule and method
- Estimated annual cost to address vandalism and knockdowns

MnDOT's *Traffic Sign Maintenance/Management Handbook* provides an estimated cost for the next 5 years to upgrade all the signs in an agency's inventory. Using an average $150 replacement cost per sign, costs range from $5,400 per year for townships to over $400,000 per year for counties for the first 5 years, depending on the number of signs in an agency's inventory.

Once all signs are up to standard, and if agencies use a 12-year blanket replacement approach (replacing 1 out of 12 signs each year, based on the 12-year warranty period), the annual costs range from $3,600 to $267,000 per

Traffic Signs (3 of 3)

GENERAL

year, including a 4 percent replacement rate for damage or vandalism.

The levels of investment are likely 10 to 20 times more than most agencies spend on their inventory of signs.

BEST PRACTICE

Agencies should develop and maintain an inventory of all signs on their roadway systems. Based on the inventory and policy considerations, signs that are not consistent with policy and signs that are not required or are determined by an engineering study to be unnecessary should be removed.

TORT LIABILITY

A number of agencies have expressed a concern for possible liability if they choose to take signs down. The tort law in Minnesota for highway agencies is very good, and its practice over time has identified two proven effective risk management techniques for activities associated with traffic signs: ***official immunity*** and ***discretionary immunity***. In official immunity, agency officials should document decisions about installing (or removing) signs. For discretionary immunity, an agency's action relative to signing should be consistent with written policy. The suggested steps listed in the practice description incorporate these risk management techniques.

SOURCES

Minnesota Manual on Uniform Traffic Control Devices. MnDOT.
Speed Limit vs. Actual Speed. MnDOT (unpublished data).
Best Practices for Traffic Sign Maintenance/Management Handbook. 2010. MnDOT.
Effectiveness of Traffic Signs on Local Roads, Minnesota Local Road Research Board, Report TRS-1002.
Putting Research into Practice: Establishing a Sign Retroreflectivity Maintenance Program, Minnesota Local Road Research Board, Report 2010-RIC02TS, 2010.

YOUR AGENCY IS NOW "ON THE CLOCK"

The following deadline applies to your agency's sign inventories:

- *January 2014*—Document the maintenance method your agency will use to maintain retroreflectivity on its signs.

The compliance dates for the following regulations regarding the minimum level of retroreflectivity are still under review:

- *Regulatory, warning, and ground-mounted guide signs*—The 2009 Federal MUTCD had a compliance date of January 2015 for regulatory, warning, and ground-mounted guide signs to meet the designated minimum level of retroreflectivity. The Federal Highway Administration announced on August 30, 2011, that it proposes to eliminate the deadline.
- *Overhead guide and street name signs*—The 2009 Federal MUTCD had a compliance date of January 2018 for all overhead guide and street name signs to meet the designated minimum level of retroreflectivity. The Federal Highway Administration announced on August 30, 2011, that it proposes to eliminate the deadline.

The Federal Highway Administration stated in the August announcement that "it is important to understand that elimination of a compliance date for a given Standard contained in the MUTCD does not eliminate the regulatory requirement to comply with the Standard. The Standard itself remains in the MUTCD and applies to any new installations, but the firm fixed date for replacing noncompliant devices that exist in the field is eliminated."

It is also important to understand that the elimination of the compliance dates has no effect on whether an agency's annual maintenance budget is sufficient to address ***all*** signs in its system. Experience has shown that there may be more risk in having signs installed that do ***not*** meet the retroreflectivity thresholds than not having signs up (or taking them down) that are not required.

Traffic Signs Policy (1 of 2)

GENERAL

POLICY PURPOSE/INTRODUCTION

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

This policy recognizes that the MN MUTCD is the standard for all traffic control devices on all public roads in Minnesota, and therefore all traffic control devices on ***<Insert City>***'s highway system must conform to its standards and specifications as specified in Minnesota Statute 169.06.

This policy officially recognizes the rule in the MN MUTCD that establishes minimum retroreflectivity levels for traffic signs and describes how ***<Insert Agency>*** achieves compliance.

It is in the interest of ***<Insert Agency>*** and the public to prevent the excessive use of traffic signs on the county/city roadway system. A conservative use of traffic signs reduces maintenance costs and improves the effectiveness of the remaining signs. Limiting the excessive use of traffic signs achieves the following:

- Fulfills demonstrated needs
- Champions a command of attention
- Reduces clutter that impedes the conveyance of a clear and simple meaning
- Fosters respect by road users, and reduces conflicts that may restrict time for a proper response that cumulatively improves traffic safety for all users
- Pursues the goals of the Minnesota Toward Zero Deaths partnership in ***<Insert Agency>***.

POLICY

All traffic signs on ***<Insert Agency>***'s highway system must conform to the MN MUTCD. Traffic signs not explicitly required to be installed by the MN MUTCD should not be installed on ***<Insert Agency>***'s highway system unless otherwise specified in this policy, or authorized by the traffic engineer or county or city engineer.

POLICY CRITERIA

Installation of Signs

The ***<Insert Agency>*** will develop and maintain a sign inventory of all signs on the roadway system. Based on the inventory and level of funding available for sign maintenance, ***<Insert Agency>*** will determine the amount of inventory that can be supported by the current funding structure.

<Insert Agency> will maintain the determined amount of traffic control devices (signs, traffic signals, and pavement markings) to ensure safe and efficient operations. Based on the inventory and policy considerations, signs that are not consistent with policy, and signs that are not required or are determined by an engineering study to be unnecessary will be removed. The following best practices will be implemented to assist in determining the need for all traffic signs:

- Signs that are required will be installed. Signs that require engineering judgment will undergo an engineering study, the results of which will be on file documenting reason for installation.
- No warning (curve, pedestrian crossing, deer signs) or regulatory (speed limit, STOP) signs on roads classified as local or residential.
- No STOP signs on low volume intersections (fewer than 200 vehicles per day).
- Traffic signs will not be used as a reactive response to traffic crashes.
- The application of warning signs will be based on system considerations; locations with similar characteristics will be proactively signed.
- Application of curve warning signs will be consistent with MN MUTCD requirements along roadways with ADT volumes greater than 1,000 vehicles per day and with the following guidelines for ADT volumes less than 1,000 vehicles per day:

Radius	Horizontal Curve Signing
Greater than 2,000 feet	No Sign
1,500 to 2,000 feet	Curve Ahead Warning Sign
1,200 to 1,500 feet	Curve Ahead Warning Sign + Speed Advisory Plaque
500 to 1,200 feet	Curve Ahead Warning Sign + Speed Advisory Plaque + Chevrons

Traffic Signs Policy (2 of 2)

Maintenance Method

It shall be the ***<Insert Agency>*** engineer's responsibility to decide which signs should be replaced by maintenance personnel or by contract. Compliance with MN MUTCD retroreflectivity requirements will be achieved using a management method using the expected sign life. ***<Insert Agency>*** adopts 15 years for the life of signs with ASTM Type XI sheeting material. Applicable sign life may be revisited to determine appropriate length based on the latest research.

Maintenance personnel should replace signs according to the following guidelines:

1. All signs are inspected annually for normal daytime visibility and legibility. Nighttime surveys may also be completed every few years to discover locations of vandalism or other issues. All signs not performing their function shall be repaired or scheduled for replacement.
2. Before each year's replacement program, the sign crew should review all signs. Additional signing, relocation of signing, or removal of needless signing can be incorporated into the program at this time. The available sign budget and the current inventory will be reviewed to determine feasibility of maintaining the current inventory.
3. The replacement program includes the use of the latest standards for sign design, dimensioning, mounting, and roadway location.
4. As each new sign is installed, the mounting should be checked for deterioration. Bent or excessively rusted posts should be replaced. All posts will comply with the AASHTO *Manual for Assessing Safety Hardware* for crashworthiness.

Intersection Treatments (1 of 2)

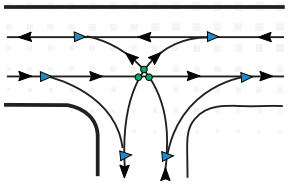
INTERSECTIONS

DESCRIPTION AND DEFINITION

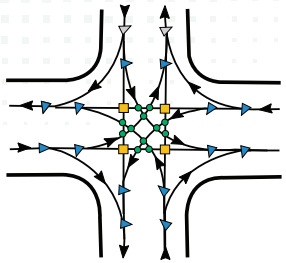
Safety research suggests that intersection crash rates are related to the number of conflicts at the intersection. Conflict points are locations in or on the approaches to an intersection where vehicles paths merge, diverge, or cross.

Some vehicle movements are more hazardous than others. The data indicates that minor street crossing movements and left turns on a major street are the most hazardous (possibly because of the need to select a gap from two directions of oncoming traffic). Left turns from the major street are less hazardous than the minor street movements, and right turn movements are the least hazardous.

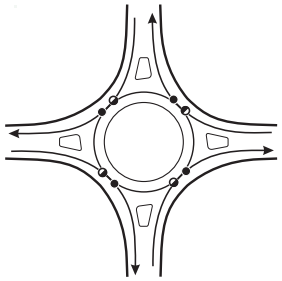
Full Access



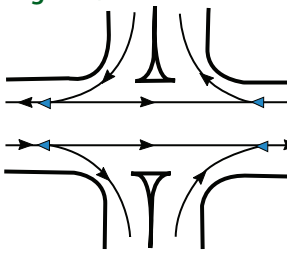
Full Access



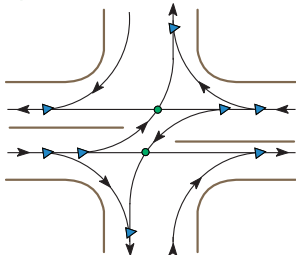
Roundabout Access



Right In/Out Access

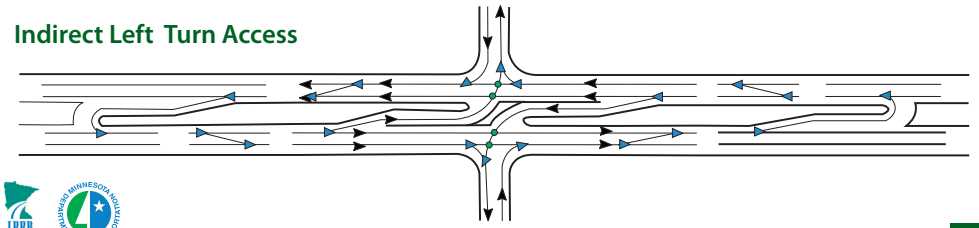


3/4 Access



CONFLICT TYPE
- Crossing
- Turning
- Merge/ Diverge

Indirect Left Turn Access



Analysis of crash data has proven that the most frequent type of severe intersection crash is the right-angle crash. In response, agencies are implementing intersection designs that reduce or eliminate the at-risk crossing maneuvers by substituting lower-risk turning, merging, and diverging maneuvers. Two designs being implemented are roundabouts and indirect turn treatments.

SAFETY CHARACTERISTICS

Crash rates at restricted access intersections (¾ access design and right-in/out) are typically lower than at similar four-legged intersections. Prohibiting or preventing movements at an intersection will likely reduce the crash rate.

Number Of Conflict Points By Intersection Type

	Crossing	Turning	Merge/ Diverge	Total	Typical Crash Rate (crashes per million entering vehicles)
Full Access (+)	4	12	16	32	0.3
Full Access (T)	0	3	6	9	0.3
¾ Access	0	2	8	10	0.2
Right-in/out Access	0	0	4	4	0.1
Roundabout	0	0	8	8	0.2
Indirect Left Turn	0	4	20	24	0.1

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- Eliminating or restricting turning maneuvers by providing channelization or closing median openings is considered a **PROVEN** strategy. NCHRP Report 420 found the crash rate for a roadway with a non-traversable median to be about 30 percent less than a two-way left turn lane configuration.
- The one study in the FHWA Crash Reduction Clearinghouse that looked at converting an intersection to a roundabout found a crash reduction of 40 to 70 percent.

Intersection Treatments (2 of 2)

INTERSECTIONS

- The one study in the FHWA Crash Reduction Clearinghouse that looked at converting an intersection to an indirect left turn access had a crash reduction of 30 to 60 percent for serious injury crashes, but an increase of 20 to 30 percent of sideswipe crashes.

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

- Divided roadways on urban and suburban arterials provide the most opportunity for access modification with the ability to use the median for restricted and channelization strategies.
- Coordination with access management guides—restricted and channelized medians reinforce partial access for minor roadways.

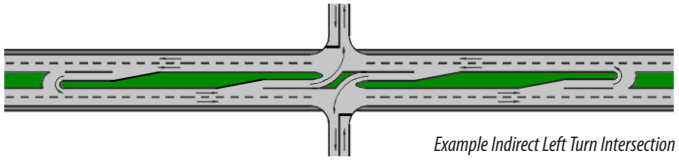
ROADWAY OPERATIONS

Restricting access as a safety treatment strategy does not reduce the capacity of the roadway. The treatments may slow vehicles (as they maneuver through a roundabout, for example), but provide improved safety.

TYPICAL COSTS

- Access modification = $10,000 to $100,000
- Roundabout = $800,000 to $1,000,000
- Indirect left turn = $500,000 to $750,000

Example Roundabout



Example Indirect Left Turn Intersection

SOURCES

How About a Roundabout? The Minnesota Experience – DVD (www.dot.state.mn.us/research/videos.html)
How About a Roundabout? A Minnesota Guide – Brochure (www.lrrb.org/pdf/FinalRoundaboutBrochure.pdf)
What is a J-Turn? Missouri DOT video (www.youtube.com/watch?v=Kfu6yx9kgCY)
Unconventional Arterial Intersection Design Interactive Website, University of Maryland Applied Technology and Traffic Analysis Program (http://attap.umd.edu/uaid_agus.php?UAIDType=25&Submit=Submit&iFeature=1)
Access Management Manual, Transportation Research Board, 2003.

Intersection Treatments Policy

INTERSECTIONS

POLICY PURPOSE/INTRODUCTION

The purpose of this policy is to establish uniformity and consistency in the application and installation of intersection configurations and traffic control on ***<Insert Agency>***'s roadway system.

DEFINITIONS

Functional Classification: The classification of a roadway that defines the purpose, use, and attributes necessary for it to provide safe and efficient movement of vehicles. Typical classifications include arterial, collector, and local streets.

POLICY

It is the policy of ***<Insert Agency>*** to provide a balance between operations, safety, access, and multimodal accessibility in the design of intersections on its roadways.

POLICY CRITERIA

<Insert Agency> will provide the lowest level of traffic control that provides a balance between operations and safety. With the understanding that some vehicle movements are more hazardous than others, and the fact that increasing the level of control increases overall delay and the number of crashes, the design of intersections will consider both the type of movements allowed and the type of traffic control used to permit movements. Various research indicates that:

- Minor street crossing movements and left turns on the major street are the most hazardous (possibly because of the need to select a gap from two directions of oncoming traffic)
- Left turns from the major street are less hazardous than the minor street movements
- Right turn movements are the least hazardous

Based on this information, the type of intersection geometry that is implemented at any given location will be based on the expected crash rate, depending on the type of traffic control, along with the level of access it provides.

Based on functional classification, a hierarchy will be used to determine traffic control on roadways; the same type of process is used in development of access management guidelines. The intersections of functionally classified roadways will have the following types of traffic control, unless otherwise recommended based on engineering judgment:

- *Local Street/Local Street*—No control unless engineering study documents need for STOP control
- *Local/Collector*—Through/STOP with local street stopping
- *Collector/Arterial*—Through/STOP with collector stopping
- *Arterial/Arterial*—Traffic signal/roundabout based on engineering study

Consideration for Roundabouts

When a project includes reconstructing or constructing new intersections that require signals, a roundabout alternative must be analyzed to determine if it is a feasible solution based on site constraints, including right-of-way, environmental factors, and other design constraints.

Exceptions to this requirement are locations where the intersection:

- Has no current or anticipated safety, capacity, or other operational problems
- Is within a well-working, coordinated signal system in a low-speed urban environment with acceptable crash characteristics
- Is where signals will be installed solely for emergency vehicle preemption
- Has steep terrain, graded at 5 percent or more for the circulating roadways
- Has been deemed unsuitable for a roundabout by a previous study

Rural Lighting (1 of 2)

INTERSECTIONS

DESCRIPTION AND DEFINITION

Install destination-style street lighting at rural intersections. Utility companies typically provide one or two lights.

ROADWAY OPERATIONS

The installation of street lighting does not have an effect on the roadway traffic operations.

TYPICAL COSTS

Implementation Costs

- $8,000 for a single light, $14,000 for two lights
- $500 for installation with existing utility pole

Maintenance and Power Costs

- $25 to $50/month

SAFETY CHARACTERISTICS

The installation of street lights at rural intersections has been found to reduce single-vehicle, multiple-vehicle, and nighttime crashes.

A benefit-to-cost analysis found that the crash reduction benefits of street lighting at rural intersections outweigh the costs by a wide margin. The average benefit-to-cost ratio was about 15:1.

Case study research suggests that the use of street lighting is more effective at reducing nighttime crashes than either transverse rumble strips or overhead flashers.

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- All FHWA Crash Reduction Clearinghouse studies documented reductions in nighttime crashes associated with providing intersection lighting.
- Documented crash reductions are in the range of 20 to 50 percent.
- Providing rural intersection lighting is considered a **PROVEN** effective safety strategy.

System-wide Comparative Analysis

Item	Intersections without Street Lights	Intersections with Street Lights	Reduction	Statistical Significance
Intersections	3,236	259		
Night Crashes	34%	26%	26%	Yes
Night Crash Rate	0.63	0.47	25%	Yes
Night Single-Vehicle Crashes	23%	15%	34%	Yes
Night Single-Vehicle Crash Rate	0.15	0.07	53%	Yes

Before vs. After Crash Analysis

Item	Before	After	Reduction	Statistical Significance
Intersections	12	12		
Number of Night Crashes	47	28	40%	Yes
Night Crashes/Intersection/Year	1.31	0.78	40%	
Total Crashes/Intersection/Year	2.44	2.08	15%	
Night Crash Rate	6.06	3.61	40%	Yes
Total Crash Rate	2.63	2.24	15%	Yes
Severity Index	43%	32%	26%	Yes
Night Single-Vehicle Crash Rate	4.0	2.84	29%	Yes
Night Multiple-Vehicle Crash Rate	2.06	0.77	63%	Yes

Source : Safety Impacts of Street Lighting at Isolated Rural Intersections, LRRB 1999-17.

Rural Lighting (2 of 2)

INTERSECTIONS

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

Typical intersection characteristics that determine if a location is a good candidate for rural intersection street lighting installation are:

- *Rural Through and STOP intersections*—County road and county road intersections, or county road and state highway intersections.
- *Typical Volumes*—Agencies can develop their own volume criteria based on their roadway system characteristics. An example is Dakota County's lighting criteria, which ranks intersections with the major roadway volumes greater than 1,000 vehicles per day and intersections with a minor roadway volume of greater than 250 vehicles per day as minimum criteria for rural intersection lighting.
- *Crash History*—Crashes experienced at an intersection during a 5-year period. Additional weight may be given to locations with nighttime crashes versus locations with only daytime crashes.

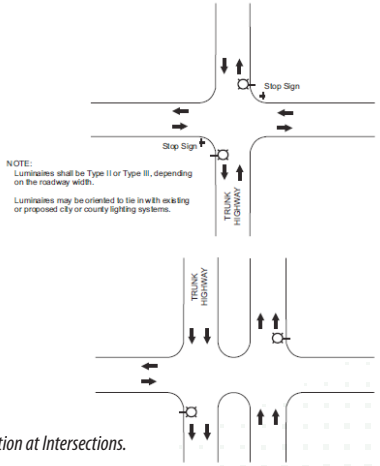
Other characteristics that can be used to determine at-risk locations include:

- *Geometry of Intersection*—Research has shown that skewed intersections have a higher risk of crashes.
- *Geometry of Roadway*—Research has shown that intersections located on or near a horizontal or vertical curve are subject to a higher level of risk.
- *Commercial Development in Quadrants*—Research has shown that intersections with commercial development located in one or more of the intersection quadrants have a higher level of risk. Private residences or farms are not considered locations with a high risk.
- *Distance from Previous STOP Sign*—Research has shown that driver attention decreases when travelling for longer distances between STOP signs.
- *Railroad Crossing on Minor Approach*—Intersections on or near a railroad line are subject to an increased level of risk. Drivers must navigate the railroad tracks while approaching the intersection.

DESIGN FEATURES

Many agencies are currently installing rural intersection lighting by mounting a davit arm and luminaries on existing utility poles. MnDOT's *Traffic Engineering Manual* also provides additional guidance if existing poles are not available.

Example of Using Luminaire Mast Arm on Existing Utility Pole
Source: MnDOT Traffic Engineering Manual.



Standard Location at Intersections.
Source: MnDOT Traffic Engineering Manual.

SOURCES

Safety Impacts of Street Lighting at Isolated Rural Intersections—Part II, Minnesota Local Road Research Board, Report 2006-35, 2006.
Safety Impacts of Street Lighting at Isolated Rural Intersections, Minnesota Local Road Research Board, Report 1999-17, 1999.
Strategies to Address Nighttime Crashes at Rural, Unsignalized Intersections, Iowa Highway Research Board (TR-540), 2008.
Statistical Models of At-Grade Intersection Accidents, FHWA-RD-96-125, March 2000.
Reducing Late-Night/Early Morning Intersection Crashes by Providing Lighting, FHWA-SA-09-017, 2009.

Rural Lighting Policy (1 of 2)

INTERSECTIONS

POLICY PURPOSE/INTRODUCTION

The purpose of this policy is to establish uniformity and consistency in the application, installation, and maintenance of rural street lighting on the ***<Insert Agency>***'s roadway system.

Research by the Minnesota Local Road Research Board (Report No. MN/RC-1999-17) has concluded that the installation of streetlights at rural intersection offers a low-cost and effective strategy for mitigation of nighttime vehicle crashes. Published reports have found that the installation of lighting at rural intersections resulted in a 20 to 50 percent reduction in the nighttime crash frequency. A benefit-cost analysis indicated the crash reduction benefits associated with the installation of street lighting at rural intersections outweigh the costs by a 15:1 ratio.

DEFINITIONS

Rural Intersection—Any intersection that is located outside of an Urban District, is not within the development area of a community, and has a speed limit of 45 mph or greater.

Urban District—The territory contiguous to and including any street that is built up with structures devoted to business, industry, or dwelling houses situated at intervals of less than 100 feet for a distance of ¼ mile or more.

POLICY

It is in the public's interest that ***<Insert Agency>*** should use the strategy of installing streetlights at rural intersections in order to reduce crashes and improve motorist guidance. The provisions are provided for use by the ***<Insert Agency>*** engineer in regulating the locations, design, and method of installation in a uniform manner of street lighting at rural intersections. It also provides detail cost responsibilities between local road authorities or governmental units and ***<Insert Agency>***.

POLICY CRITERIA

Installation of rural streetlights should be completed based on a comprehensive evaluation of the ***<Insert Agency>*** roadway system. Recognizing that rural street lighting cannot be implemented at all locations, two potential prioritization processes are included as references: the systemic intersection risk factors method, and the functional classification and traffic volumes method.

Systemic Intersection Risk Factors Method

The objective of the systemic method is the same as for the typically reactive black spot approach—to identify candidates for the deployment of safety improvement projects. However, the method makes one fundamental change in the approach. The black spot method assumes that the presence of (or large numbers of) crashes equals risk and that the absence of crashes indicates that there is no risk. The systemic method is based on the assumption that the absence of crashes does not equate to no risk. In order to support the development of a new approach that defines risk based on crashes plus a variety of surrogate measures, research was conducted that identified rural intersections with crashes and then documented the geometric and traffic features that were common among the various locations.

The risk factors, or surrogate measures, along with crash history include:

- Geometry of intersection (skew)
- Geometry of roadway (on/near curve—both vertical and horizontal)
- Commercial development in quadrants
- Distance to previous STOP sign (more than 5 miles from the previous stop)
- Average Daily Traffic (ADT) ratio (a ratio of 0.4 to 0.8)
- Railroad crossing on minor approach
- Crash history

If the necessary information to complete a Systemic Intersection Risk Factors method, which would incorporate the latest safety research, is not available, then the Functional Classification and Traffic Volumes method can be used to prioritize rural intersections for implementation of street lighting.

Rural Lighting Policy (2 of 2)

INTERSECTIONS

Functional Classification and Traffic Volume Method

Prioritization of the intersections will be based on the functional classification of the intersecting roadways. The following matrix will be used in determining the volume warrant for street lighting. The lower volume of a multiple classification intersection will take precedence in determining the priority. The functional classifications are based on the most current ***<Insert Agency>*** functional classifications map located in ***<Insert Agency>*** engineer's office, and volumes will be determined by placing traffic counters on all legs of the intersections.

Table 1—Ranking of Roadways based on Functional Class and Traffic Volume

Priority	Minor Arterial	Major Collector	Minor Collector	Local
Low	0 to 999	0 to 749	0 to 499	0 to 249
Moderate	1,000 to 2,000	750 to 1,000	500 to 750	250 to 500
High	More than 2,000	More than 1,000	More than 750	More than 500

Note: Use the appropriate classification above for the Major Street and Cross Street; the lower volume shall take precedence for priority.

Example: The Major Street is CSAH 35 and is classified as a Minor Arterial; the Cross Street is CR 117 and is classified as a Minor Collector. The ADT on CSAH 35 = 4,520 (rated High) and the ADT on CR 117= 520 (rated Moderate). The Moderate Priority would apply.

Financial Considerations

The ***<Insert Agency>*** Highway Department can authorize placement of street lighting at rural intersection and participate in the costs, based on the following criteria, provided that there are sufficient funds in the road and bridge budget:

1. ***<Insert Agency>*** will be responsible for all costs associated with the installation and maintenance of street lighting at warranted intersections under the county and city's jurisdiction, including electrical costs. If using volume warrants to meet this criterion, a "High Priority" in the volume matrix must be met. For those intersections that are under MnDOT's jurisdiction, a formal agreement, outlining the cost participation between the two agencies, or a MnDOT permit will be required.
2. Any local road authority or local unit of government that requests street lighting at an unwarranted intersection (if using volume warrants, this would mean a "Moderate" or "Low" priority in the volume matrix), will be responsible for all costs associated with the installation and maintenance of street lighting, including electrical costs. Under this provision, the local road authority or local unit of government will be required to apply for a utility permit for the installation of street lighting.

Design Details

For detail specification requirements on the standards of streetlight systems, refer to the MnDOT ***Traffic Engineering Manual***, Chapter 10—Lighting of Traffic Facilities.

Traffic Signal Confirmation Lights (1 of 2)

INTERSECTIONS

DESCRIPTION AND DEFINITION

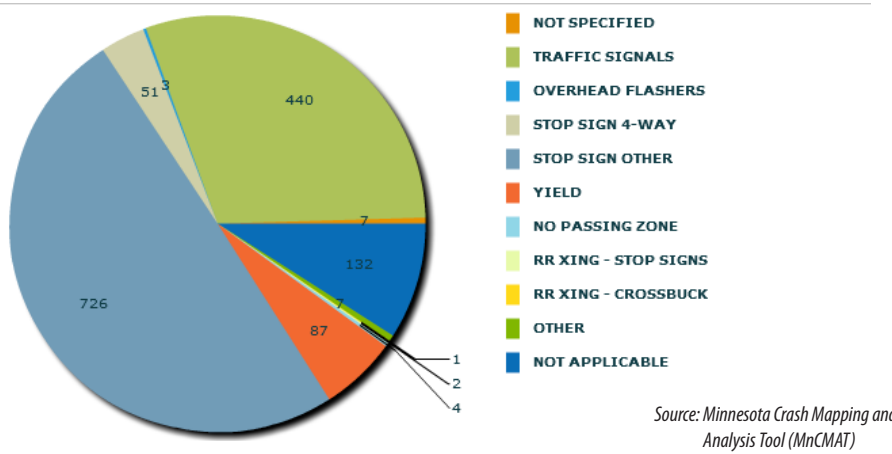
A confirmation light is a blue light that can be located on the back of the traffic signal mast arm or super pole, and used by law enforcement agencies to identify vehicles that run red lights. The confirmation light is wired into the red light circuits of the signal and comes on simultaneously with the red indication. It allows one officer to safely observe and pursue red light violators. Minnesota has only recently begun to deploy confirmation lights to help increase efficiency of enforcing red lights.

ROADWAY OPERATIONS

The combination of confirmation lights and extra enforcement efforts has reduced the number of red light violators.

SAFETY CHARACTERISTICS

Angle crashes at signalized intersections are the most common type of severe crash in urban areas in Minnesota and accounted for 30 percent of the 1,461 severe right-angle, intersection-related crashes in Minnesota between 2006 and 2010.



Source: Minnesota Crash Mapping and Analysis Tool (MnCMAT)

There is concern in the literature about confirmation lights possibly increasing the number of rear end crashes as a result of drivers making a greater effort to stop. The literature on the subject indicates that some of the tradeoff is associated with red light cameras, but there is no indication, yet, of it being the case with confirmation lights. Also, trading right-angle crashes for rear end crashes may actually be a good outcome given that right-angle crashes are typically more severe.

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- National Cooperative Highway Research Program 500 Series considers confirmation lights a **PROVEN** strategy along with optimizing clearance intervals. Upgrading of hardware to provide better visibility is considered **TRIED**.
- The Federal Highway Administration estimates a 15 percent reduction in crashes.
- At an intersection in Florida, a 3-month evaluation found a 50 percent decrease in red light violations and an 11 percent decrease in crashes, with 519 citations issued.

Traffic Signal Confirmation Lights (2 of 2)

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

Before implementation of confirmation lights, a typical candidate intersection would have already addressed unintentional red light running by:

1. *Checking clearance intervals*—Most agencies already have sufficient clearance intervals at their signalized intersections. A signed confirmation from the traffic engineer that the clearance intervals were reviewed should be obtained to assist in any attempted appeal process (violators claiming clearance intervals purposely adjusted by enforcement agencies to encourage more violations).
2. *Updating hardware*—To improve visibility of the signal, signals should be overhead with 12-inch lenses and background shields. (Most agencies have this hardware in place. A review found that of 100 signals in Hennepin County, 90 signals were overhead. Most that were not overhead signals were on one-way streets.)

After the clearance intervals and hardware are addressed, you are left with intentional red light running. Confirmation lights are more effective if the following criteria are met:

- They can be deployed along a corridor at multiple signals so officers have flexibility in location of enforcement.
- They are publicized. Through public announcements, let the public know about the lights and the consequences of running red lights.

Also, before confirmation lights are employed, acceptance from the local traffic court must be confirmed to assure that the citations will be accepted and that enforcement agencies are willing to use the device. Agencies are encouraged to meet with law enforcement officers in the field to discuss where they will be parked so the light can be placed at a location with clear sight views for a parked enforcement vehicle.

BEST PRACTICE

It is recommended that confirmation lights be deployed on multiple traffic signals along a corridor to provide enforcement agencies with the ability to change the time and location of enforcement for a broader safety effect on the travelling public.

TYPICAL COSTS

Implementation Costs = $1,000 per intersection ($500 per light for mainline approaches)

DESIGN FEATURES

The confirmation light is wired directly into the circuit of the red signal indicator. The red signal and blue confirmation light are powered by the same source.

SOURCES

www.stopredlightrunning.com
Red-Signal Enforcement Lights, FHWA-SA-09-005, May 2009.
Evaluation of Innovative Safety Strategies, Florida DOT, January 2008.

Traffic Signal Confirmation Lights Policy

POLICY PURPOSE/INTRODUCTION

The purpose of this policy is to establish uniformity and consistency in the application and installation of red light confirmation lights at signalized intersections on the ***<Insert Agency>***'s roadway system.

Red light running is a common safety concern on urban signalized arterials. The safety literature identifies a number of potential strategies to reduce red light running. Most of the strategies deal with signal design features such as 12-inch lenses, background shields, and overhead indications, all of which agencies in Minnesota routinely incorporate into their signal systems. Other strategies include enhancements to enforcement, cameras (which are not allowed in Minnesota), and a relatively new device: red light confirmation lights.

Installation of red light confirmation lights at intersections would allow one law enforcement officer to monitor an intersection for red light running. It should be noted that Minnesota is using a blue light instead of a white light in order to not confuse drivers accustomed to seeing white confirmation at locations with emergency vehicle preemption systems. Increased enforcement should drive down the number of occurrences of red light running.

DEFINITIONS

A confirmation light is a blue light located on the back of the traffic signal mast arm and is used by law enforcement to identify red light-running vehicles. The confirmation light is wired into the red light circuits of the signal and comes on simultaneously with the red indication. The confirmation light allows one officer to safely observe and pursue red light violators instead of the usual two officers needed without the light.

POLICY

It is the policy of ***<Insert Agency>*** that red light confirmation lights will be installed in the following situations:

- Installation of new signals
- Rehabilitated signals
- Crash history corridor
- Results of a safety study indicate angle crashes at signals are overrepresented.

POLICY CRITERIA

As part of installation of confirmation lights, the following activities will be completed to assist in the effectiveness of the lights:

- ***<Insert Agency>*** will coordinate with local law enforcement to reach an agreement on the level of enforcement that can be provided for corridors with installed confirmation lights.
- Before enforcing the confirmation lights, coordination will be completed between ***<Insert Agency>*** and local law enforcement, ***<Insert Agency>*** attorneys, and judges to develop understanding of the planned enforcement of the confirmation lights and to foster support for their implementation.
- ***<Insert Agency>***'s traffic engineer will review clearance intervals and confirm correct (consistent with Institute of Transportation Engineer's [ITE] guidelines) or adjust. The engineer will provide a signed note in the controller cabinet that provides the confirmed clearance interval information for use if enforcement results are challenged.

FINANCIAL CONSIDERATIONS

Confirmation lights are eligible for Highway Safety Improvement Program (HSIP) funding and typically cost $1,000 for two approaches of an intersection.

Pedestrian Treatments (1 of 2)

INTERSECTIONS

DESCRIPTION AND DEFINITION

The purpose of pedestrian safety strategies is to:

- Reduce potential vehicle conflicts by reducing pedestrian crossing distance and time
- Improve lines of sight
- Reduce vehicle/pedestrian conflicts at crosswalks

Some of the **PROVEN** effective strategies include:

- Medians
- Curb extensions
- Sidewalks
- High-intensity activated crosswalks (HAWKS)

TRIED (but promising) strategies include:

- Leading pedestrian intervals—the pedestrian walk is up 2 to 3 seconds ahead of the vehicle green, allowing pedestrians a head start and the ability to enter the crosswalk before right-turning vehicles can turn into the crosswalk
- Countdown pedestrian timers

Median Refuge Near Intersection

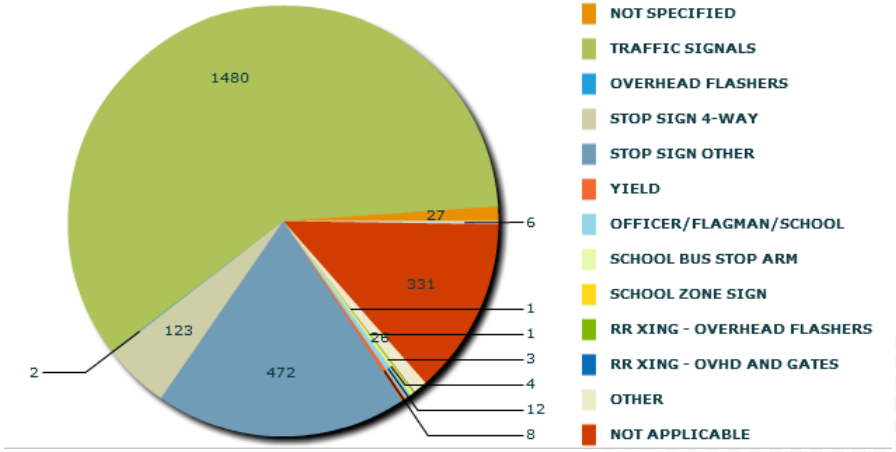
Only pedestrian signs and markings have been found to be **INEFFECTIVE**.

SAFETY CHARACTERISTICS

Review of the over 4,000 pedestrian/vehicle crashes in Minnesota between 2006 and 2010 found that over half of the crashes occurred at intersections. Of the intersection crashes, 59 percent occurred at signalized intersections. The Leading Pedestrian-Vehicle Interval (LPI) is the latest strategy for reducing crashes at signalized intersections. A 2010 study in the *Journal of the Transportation Research Board* found an up to 60 percent reduction in pedestrian/vehicle crashes at intersections that use the LPI strategy.

Multiple studies have reviewed the use of crosswalks at uncontrolled intersections and found that they are not always a safety strategy. In some areas, there are more pedestrian crashes at marked crosswalks than in unmarked crosswalks (even when adjusted for exposure). It appears that the least effective crosswalks are at uncontrolled intersections along multi-lane arterials.

A Federal Highway Administration 2005 study of unmarked crosswalks provides guidance on when an uncontrolled intersection may be a candidate for a crosswalk based on roadway speed, roadway geometry, and traffic volumes. Locations with higher speeds (greater than 40 mph) and high volumes (greater than 15,000 vehicles per day) are not candidates for crosswalks. Also, multi-lane roadways without a median are not candidates for crosswalks. Locations with low speed (35 mph or less) with two or three lanes of traffic are candidates, but other treatments such as curb extensions, medians, street lighting, and roadway narrowing should also be considered before a crosswalk is installed.



Minnesota Crash Data – 2006-2010, Pedestrian/Vehicle Crashes – Type of Intersection Control

Source: Minnesota Crash Mapping and Analysis Tool (MnCMAT)

Pedestrian Treatments (2 of 2)

INTERSECTIONS

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- **PROVEN:** Medians, curb extensions, and sidewalks
- **TRIED:** LPIs and countdown timers
- **INEFFECTIVE:** Pedestrian signs and markings only

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

Median Refuge Near Intersection

Consideration of maintenance issues, such as snow removal, and operational issues, such as transit usage and large vehicle manuevering, should be considered before implementing curb extensions and medians.

Curb Extensions and Sidewalks

TYPICAL COSTS

Implementation Costs:

- Install median = $10,000 to $15,000
- Curb extensions = $15,000 per corner
- Pedestrian countdown = $10,000 per intersection
- Install LPIs = No cost

DESIGN FEATURES

Strategies for signalized intersections:

- Signal cycles should be kept short (ideally, 90 seconds maximum) to reduce pedestrian delay, considering traffic volume needs
- Countdown timers should be added
- LPIs should be implemented
- Pedestrian phases should come up automatically if pedestrian traffic is frequent
- Signals should be visible to pedestrians

BEST PRACTICE

Crosswalks should be considered at all signalized intersections where an engineering study finds the presence of pedestrian activity because of the benefits, which include making it clear to vehicles where they should stop and delineating a path for pedestrians. Crosswalks at uncontrolled intersections should be limited and include other features, such as medians and curb extensions, when possible.

SOURCES

Safety Effectiveness of Leading Pedestrian Intervals Evaluated by a Before-After Study, Transportation Research Board of the National Academies, ISSN 0361-1981, Volume 2198, 2010.

Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations Final Report and Recommended Guidelines, FHWA, FHWA-HRT-04-100, September 2005.

Association Between Roadway Intersection Characteristics and Pedestrian Crash Risk in Alameda County, California, Transportation Research Board of the National Academies, ISSN 0361-1981, Volume 2198, 2010.

Best Practices for Traffic Control at Regional Trail Crossings, Collaborative Effort of Twin Cities Road and Trail Managing Agencies, July 26, 2011.

Bicycle and Pedestrian Toolbox, Minnesota Local Road Research Board, Report 200602, 2006.

How To More Safely Accommodate Pedestrians Through An Intersection With Free Flow Legs, Minnesota Local Road Research Board, Report 200424, 2004.

Evaluating Active and Passive Crosswalk Warnings at Unsignalized Intersections and Mid-Block Sites, Minnesota Local Road Research Board, Report 200903TS, 2009.

Warning Efficacy of Active Versus Passive Warnings for Unsignalized Intersection and Mid-Block Pedestrian Crosswalks, Minnesota Local Road Research Board, Report 200903, 2009.

Pedestrian Treatments Policy (1 of 2)

INTERSECTIONS

POLICY PURPOSE/INTRODUCTION

The purpose of this policy is to establish uniformity and consistency in the application and installation of pedestrian crosswalks on ***<Insert Agency>***'s roadway system.

One of the common strategies requested by the public as a mitigation measure for pedestrian crashes is the installation of a marked crosswalk. However, a research study involving thousands of intersections in dozens of cities across the nation found that marked crosswalks at unsignalized intersections are NOT safety devices.

A separate study found that pedestrian crash rates were actually higher at marked crosswalks and this effect is greatest for multi-lane arterials with volumes greater than 15,000 vehicles per day. This study also identified three strategies that were proven to improve pedestrian safety: sidewalks, median islands, and curb extensions. Sidewalks provide pedestrians with opportunities to separate themselves from vehicular traffic. The median islands and curb extensions provide pedestrians with safe places to wait for gaps in traffic, improve lines of sight for both pedestrians and drivers, and reduce walking distances—and therefore the amount of time pedestrians are exposed to traffic.

The implementation of countdown timers at traffic signals along urban arterials is also considered a proven safety strategy, and a recent study found that the use of a leading pedestrian indication resulted in a reduction in conflicts and pedestrian crashes.

DEFINITIONS

Median Island—A raised island in the center of the roadway provides a safe place for pedestrians to stop before crossing the second half of the roadway.

Curb Extensions—An extension of the sidewalk at an intersection that reduces the width of the roadway and adds space to the sidewalk so pedestrians are more visible in the crosswalk and also encourage vehicles to slow down when turning the corner or passing through the intersection.

Countdown Timers—A countdown timer is displayed at the same time as the flashing "Don't Walk" or upraised hand to inform pedestrians of the amount of time remaining for them to cross the street.

Leading Pedestrian Indication—A leading pedestrian indication brings up the WALK indication 2 to 5 seconds prior to the GREEN ball for vehicles. This technique does require a longer ALL RED interval and will cause a slight increase overall intersection delay.

High-Intensity Activated Crosswalk (HAWK)—A traffic signal used to stop road traffic and allow pedestrians to cross safely. It is also known as a "pedestrian hybrid beacon." The purpose of a HAWK beacon is to allow protected pedestrian crossings by stopping road traffic only as needed.

Pedestrian Treatments Policy (2 of 2)

INTERSECTIONS

POLICY

<Insert Agency> will continue to provide painted crosswalks at signalized intersections because they are an integral part of the intersection design and provide important guidance for both pedestrians and drivers.

At existing locations with marked crosswalks, an evaluation will be conducted at each location prior to refurbishing any of the markings. At specific locations, the evaluation process will determine if there is a need for pedestrian amenities based on identifying safety deficiencies. MnDOT's ***Guidance for Installation of Pedestrian Crosswalks on Minnesota State Highways*** or the Federal Highway Administration's ***Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations Final Report and Recommended Guidelines*** will be referred to for information on criteria for crosswalks at uncontrolled locations, such as traffic volumes, roadway speed, and number of pedestrians. Some of the criteria for uncontrolled locations include:

- Location must meet basic criteria such as adequate stopping sight distance, local roadways and collectors where there are lower levels of truck and turning traffic, and minimal driver distractions.
- No crosswalks for speeds greater than 40 mph, traffic volumes greater than 15,000 vehicles a day, roadways with more than 4 lanes of traffic, and crosswalks with fewer than 20 pedestrians per day.
- Crosswalks along with other improvements may be installed at locations with speeds between 35 and 40 mph, roadways with 2 to 3 lanes of traffic, and crosswalks with more than 20 pedestrians per day.

If a need is established, consideration will be given to refurbishing the crosswalk markings in conjunction with adding a center median, curb extensions, or both. If it is determined that a center median and curb extensions are not feasible, consideration will be given to not refurbishing the crosswalk.

In response to new requests to provide marked crosswalks, an evaluation of the specific location will be conducted. If a need to provide additional pedestrian safety measures is established, a marked crosswalk will only be considered if it is part of a response that also includes a center median, curb extensions, or both.

Sidewalks should be considered as well as crosswalks to assist in facilitating safe pedestrian movements along the roadway.

Turn Lanes (1 of 2)

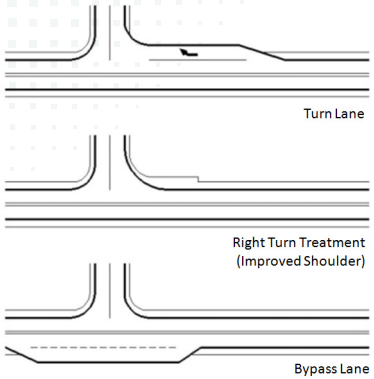
DESCRIPTION AND DEFINITION

A turn lane is an auxiliary lane designed to separate turning vehicles from through vehicles. Turn lanes serve two purposes: provide for deceleration of vehicles making turning movements, and provide storage for turning vehicles.

Bypass lanes on the right side are provided at unsignalized intersections on two-lane roadways to allow through moving vehicles to go around a stopped or turning vehicle. They are often considered for implementation instead of a left turn lane because of the reduced cost.

Turn Lane Types

Example of Right Turn Lane



TYPICAL COSTS

Implementation Costs:

- Left turn lane = $100,000 to $300,000
- Right turn lane = $50,000 to $70,000
- Bypass lane = $65,000 to $75,000

SAFETY CHARACTERISTICS

Turn Lanes

Turn lanes are mitigation for rear end crashes. Left turn lanes, which provide shelter for turning vehicles, may encourage drivers to be more selective and wait for a gap in opposing traffic at unsignalized intersections.

As discussed in the Intersection Treatments Practice Summary, the most severe type of crash is the right-angle crash at intersections. Because the turn lane does not address the most severe type of crashes, it should be considered a minor safety improvement or as only a mitigation for rear end crashes.

Bypass Lanes

A 1999 study of bypass lanes in Minnesota could not conclude that the use of the turn lane provided any greater degree of safety when compared to intersections without a bypass lane or left turn lane. However, studies completed in other states have found a decrease in rear end and left turn injury crashes with the implementation of bypass lanes.

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- All studies in the FHWA Crash Reduction Clearinghouse documented crash reductions of 10 to 50 percent after installation of left and right turn lanes.
- NCHRP considers providing left and right turn lanes **PROVEN** safety strategies for reducing the frequency and severity of conflicts at unsignalized intersections.
- Bypass lanes are considered a **TRIED** strategy.

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

Turn Lanes

Turn lanes are usually not appropriate on rural roadways with low volumes unless at an access to a high traffic generator site such as a commercial development.

Turn lanes are mostly appropriate on urban or suburban city/county roadways.

Bypass Lanes

The difference in cost between the implementation of a left turn lane and a bypass lane makes the bypass lane more likely to be implemented on rural roadways with lower volumes. The1999 study of bypass lanes in Minnesota cautioned the use of bypass lanes at four-legged intersections, citing the following findings:

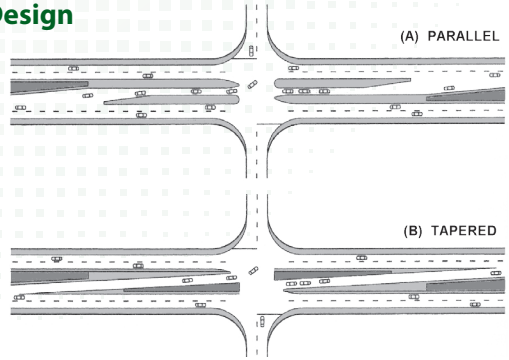
- No overall crash frequency reduction (did not address rear end crashes)
- Use of the bypass lane impairs the visibility of left-turning vehicles to opposing through traffic

Turn Lanes (2 of 2)

INTERSECTIONS

Vehicles approaching on the cross street may be confused by use of the bypass lane for someone using it as a turn lane. MnDOT's ***Access Management Manual*** now recommends that bypass lanes be used only on T-intersections. For bypass lane implementation purposes, intersections that have a private access as one approach are considered four-legged intersections.

Example of an Off-Set Left Turn Design



Example of Off-Set Left Turn Lane

DESIGN FEATURES

The basic objective of a turn lane is to reasonably accommodate decelerating vehicles while providing storage. The design process involves first computing the expected demand, which is based on vehicle speeds and volume, and then determining the design side of the equation—how to distribute the available space in the corridor between the tapered and full-width parts of the turn lane.

A new type of turn lane design on divided roadways is the Off-Set Left and Right Turn Lane. Advantages of this innovative design include the following:

- Improves left turn leaving gap acceptance
- Improves opposing traffic's ability to observe left turn traffic
- Buffers left-turning traffic from through traffic, thus reducing conflicts

Left-Turning Volume	Storage Length (feet)		
	0 – 5% Heavy Commercial	>5 – 10% Heavy Commercial	>10 – 15% Heavy Commercial
50	50	50	60
60	55	60	70
70	65	70	80
80	75	80	90
90	85	90	100
100	95	100	115
110	105	110	125
120	110	120	
130	120	130	
140	130	140	
150	145	150	
160	150	160	
170	160	170	
180	165	180	
190	175	190	215
200	185	200	225

Facility Type	Taper	Length
Unconstrained Conventional/Expressway	1:15	180 feet
Constrained Expressway Roadway	1:8	100 feet
Constrained Conventional Roadway	1:5	60 feet

Example of Design Tools found in Mn/DOT's Design of Turn Lane Guidelines

BEST PRACTICE

Turn lanes should be provided at all major intersections. Bypass lanes, if used, should be limited to T-intersections.

SOURCES

Bypass Lane Safety, Operations and Design Study. 2000. Preston, H. LRRB Research 2000-22.
MnDOT *Access Management Manual*.
MnDOT *Road Design Manual*.
Design of Turn Lane Guidelines, Minnesota Local Road Research Board, Report 2010-25, 2010.
Traffic Volume Thresholds for Requiring Right Turn Lanes and Treatments on Two-Lane Roads, Minnesota Local Road Research Board, Report 2008-25ts, 2008.
Turn Lane Lengths for Various Speed Roads and Evaluation of Determining Criteria, Minnesota Local Road Research Board, Report 2008-14, 2008.
Warrants for Right-Turn Lanes/Treatments on Two-Lane Roads, Minnesota Local Road Research Board, Report 2008-25, 2008.

Turn Lanes Policy (1 of 2)

POLICY PURPOSE/INTRODUCTION

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

DEFINITIONS

Turn Lane: A lane designated for slowing down and making a turn on a roadway so as to reduce disruption to through traffic.

POLICY

It is the policy of ***<Insert Agency>*** to provide turn lanes at all major traffic generators on two-lane, two-way roadways and divided highways when warranted under the terms in this policy. Turn lanes will be implemented as part of reconstruction projects and as part of traffic impact mitigation for commercial developments. Bypass lanes will only be considered at T-intersections when cost or right-of-way constraints limit the ability to implement turn lanes.

POLICY CRITERIA

Turn lane implementation will be determined based on two approaches: functional classification and operations analysis.

Functional Classification—One way to determine the need for turn lanes is based on the functional classification of the major street and the cross street or access. Higher functional classification connections (such as principal arterial to minor arterial) should have turn lanes with lower functional classification connections (for instance, local streets with private driveways) and would use a paved shoulder.

The table below provides guidance for turn lane needs based on the functional classification of the intersecting roadways.

Major Street Functional Classification	Cross Street Functional Classification				
	Principal Arterial	Minor Arterial	Collector	Local Street	Private Driveway
Principal Arterial	LTL	LTL	LTL	LTL (N.R)	N.A.
Minor Arterial	LTL	LTL	Min LTL	Min LTL	Paved Shoulder
Collector	LTL	Min LTL	Min LTL	Paved Shoulder	Paved Shoulder
Local Street	LLT	Min LLT	Paved Shoulder	Paved Shoulder	Paved Shoulder

Definitions:

LTL = Left Turn Lane

Min LTL = Minimum Length Left Turn Lane (480 feet = 180 feet of taper + 300 feet of storage)

N.A. = Not Allowed

(N.R.) = Intersections of local streets with Principal Arterials are not recommended

Turn Lanes Policy (2 of 2)

INTERSECTIONS

Operations Analysis—Another way to determine the need for turn lanes is based on a traffic impact operational analysis. New development or redevelopment projects would complete an impact analysis to determine traffic operations on all adjacent roadways and assess the need for turn lanes based on operational impacts.

Some considerations when analyzing the need for turn lanes based on new development or redevelopment adjacent to ***<Insert Agency>***'s roadway include:

- A developer should install right turn lanes on the ***<Insert Agency>***'s roadways at its expense at all subdivisions and public roads, or at any entrance serving commercial or industrial property that is estimated to generate over 100 right turns per day.
- A left turn bypass lane may be required if warranted in MnDOT's ***Road Design Manual***.
- Turn lanes and/or bypass lanes may be required if other similar accesses along the same segment of the roadway already have turn lanes and/or bypass lanes.
- Turn lane lengths should be consistent with guidance provided in MnDOT's ***Design of Turn Lanes Guidelines*** (July 2010), which includes length for both deceleration and necessary storage of queued vehicles.
- Turn lanes and bypass lanes shall be designed and constructed to ***<Insert Agency>*** standards.
- If turn lanes or bypass lanes cannot be constructed due to limitations in right-of-way, the developer will be required to pay an amount determined by the ***<Insert Agency>*** engineer, pursuant to state standards, to be adequate to cover the cost of such items.

Rural Through/ STOP Intersections (1 of 3) INTERSECTIONS

DESCRIPTION AND DEFINITION

The most common type of intersection in rural roadway systems is the through/STOP controlled intersection, and the most severe type of crash occurring at through/STOP intersections is the right-angle crash. Research completed in Minnesota indicates that in approximately 60 percent of the crashes, the at-fault driver stopped at the STOP sign and then pulled into traffic. As a result, the key contributing factor is gap recognition as opposed to intersection recognition. Strategies that can be implemented to address the majority of gap recognition right-angle crashes include:

- *Intersection Geometry*—Roundabouts and directional median intersections designs are effective at reducing, if not eliminating, right-angle crashes (see Intersection Treatments). Consideration should be given to location characteristics (traffic volumes on approaches, topography, truck volumes, adjacent signalized intersections, etc.) before implementation of a roundabout.
- *Mainline Dynamic Warning Sign*—Implementation of a mainline dynamic warning sign includes the installation of loop detectors on the minor leg approaches and a dynamic flashing sign on the major leg approaches. When a vehicle approaches on a minor leg, the loop detectors send a signal to the mainline sign and flashers warn drivers of a vehicle at the STOP sign.
- *Clearing and Grubbing*—Sight distance at intersections can be improved by clearing and grubbing adjacent right-of-way.
- *Street Lights*—See the Rural Lighting Practice Summary for more information on the ability of street lights to reduce right-angle crashes.

If crash records or comments by law enforcement indicate that intersection recognition (drivers running the STOP sign) is contributing to angle crashes, three additional strategies should be considered:

- *Upgraded Signs and Markings*—Installation of standard set of signs and markings, shown in the figure at end of this practice summary, that may also include larger signs or a flashing light on or around STOP sign or far-left STOP signs. The figure also provides a suggested prioritization of the signs and markings if the group of traffic control is going to be implemented individually.
- *Transverse Rumble Strips*—Transverse rumble strips are horizontal grooves in the pavement at approaches to intersections, typically between 450 to 700 feet from the intersection. Their purpose is to alert drivers to the approaching intersection by both noise and tactile sensation. The goal is to reduce unintentional running of STOP-controlled intersections in rural settings.
- *Flashing Lights*—STOP sign-mounted flashing lights. Overhead flashing lights are not recommended because they may confuse drivers into thinking the intersection was controlled by an All-Way STOP.

Typical Costs

Estimated Implementation Costs:

- Roundabouts and Directional Medians = $500,000 to $1,000,000 per intersection
- Mainline Dynamic Warning Sign = $30,000 per intersection
- Clear Sight Triangle = $4,500 for 4-leg intersection and $2,450 for 3-leg intersection
- Street Lighting = $5,000 to $15,000 per intersection
- Upgraded Signs and Markings = (entire layout) $1,850 per minor leg approach (In the event that an agency has already upgraded signs at an intersection, the pavement markings estimated cost is $700 per minor leg approach.)
- Transverse Rumbles = $2,000 to $3,000 per intersection
- Flashing Lights = $1,000 to $2,500 per sign

ROADWAY OPERATIONS

A Local Road Research Board (LRRB) study documented that drivers approaching an intersection with transverse rumbles slowed down sooner than at intersections without the rumbles.

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

The 2006 LRRB study suggests that a good candidate for transverse rumble strip installation are intersections where cross-traffic is obscured by man-made structures or vegetation on one or both sides of the intersection.

Rural Through/ STOP Intersections (2 of 3)

INTERSECTIONS

SAFETY CHARACTERISTICS

Rural through/STOP intersections on the state trunk highway system averaged 0.6 crashes per year in Minnesota in 2009. Of the right-angle crashes, most are associated with the atfault driver's selection of appropriate gaps in traffic to make his or her maneuvers through the intersection. A minority of the crashes are associated with vehicles not recognizing the control at the intersection and running through without stopping.

Roundabouts and directional medians are high-cost strategies for addressing gap selection type crashes. The strategies prevent the minor road traffic from crossing the major road, minimizing the potential for right-angle crashes. While they are the highest cost, roundabouts and directional medians provide the most benefit, with crash reductions between 40 to 70 percent.

Low-cost strategies, such as street lights, dynamic warning signs, and upgraded signs and markings, also provide benefits, but with crash reductions between 25 and 50 percent. Transverse rumbles, while low-cost, have varying results in terms of crash reductions, from 30 percent reduction in one study to another study finding an overall increase of up to 30 percent in crashes.

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

Roundabout—Considered a **PROVEN** strategy (see more information in Intersection Treatment Practice Summary).

Directional Median—NCHRP 500 series considers restriction turning maneuvers as a **TRIED** strategy (see more information in Intersection Treatments).

Mainline Dynamic Warning Sign—Considered an **EXPERIMENTAL** strategy, but initial evaluations in other states indicate a 25 to 35 percent reduction in right-angle crashes.

Upgrade Signs and Markings—Considered a **TRIED** strategy, but initial evaluations in other states indicate an up to 25 percent reduction in right-angle crashes.

Street Lights—Considered a **PROVEN** strategy (see more information in Rural Lighting Practice Summary).

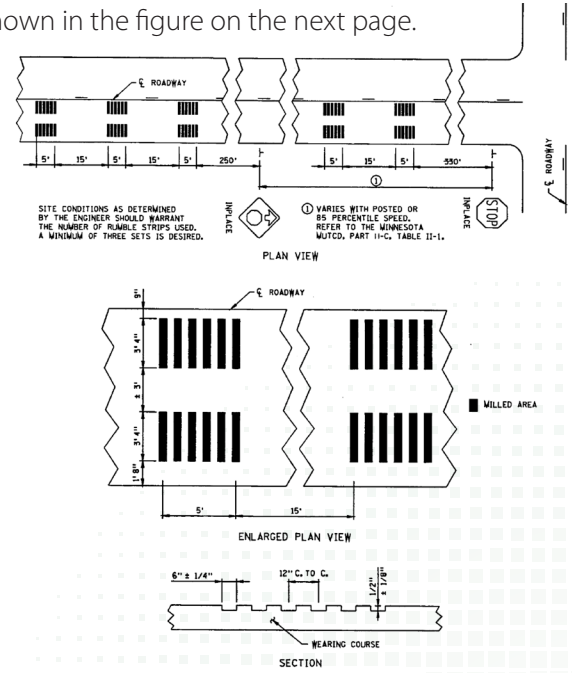
Transverse Rumble Strips—Review of the FHWA Crash Reduction Clearinghouse produced varying results. The crash factors ranged from 30 percent reduction to 30 percent increase in crashes. The challenge with defining a crash reduction is the inability to predict at which end of the range the crash will occur at any given location. Since there is not a clear convergence of crash reduction results, transverse rumbles are considered a **TRIED** strategy.

DESIGN FEATURES

Mainline Dynamic Warning Signs—An example of a mainline dynamic warning sign is shown in the photograph at the end of this Practice Summary.

Upgrade Signs and Markings—The current proposed layout, including sign and marking locations and sizes, is shown in the figure on the next page.

Transverse Rumble Strips—Transverse rumbles should be designed in accordance with MnDOT's Figure 4-4.02D in the *Road Design Manual*.

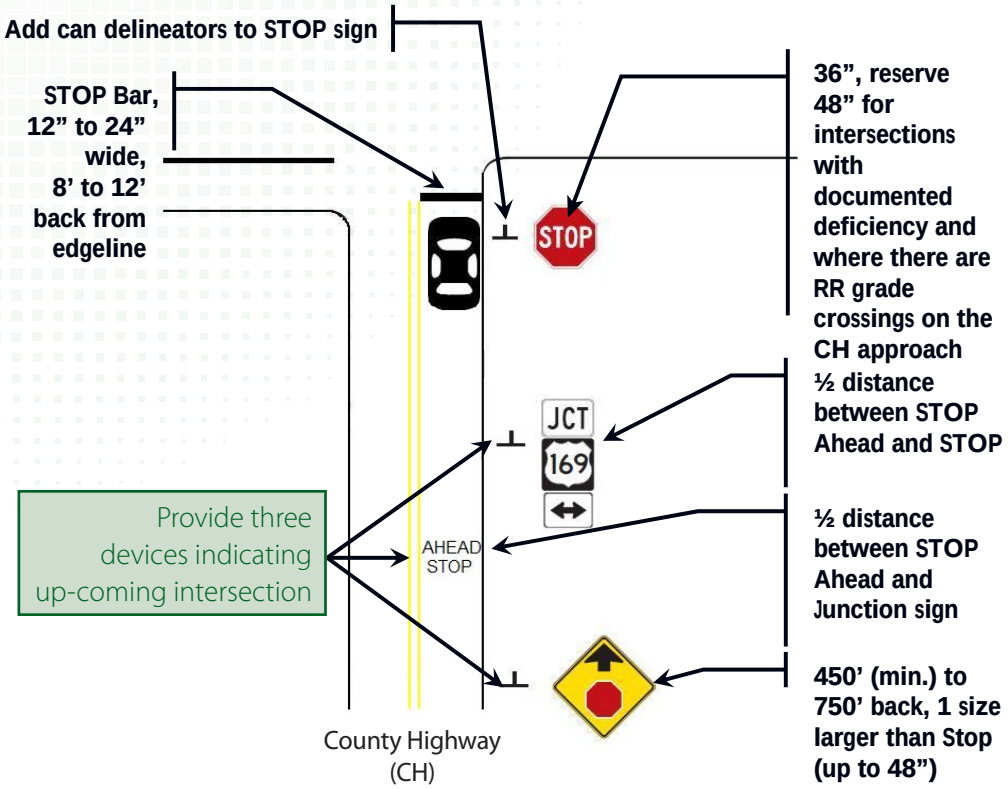


In-lane rumble stips, plan and section views

Rural Through/ STOP Intersections (3 of 3)

INTERSECTIONS

Upgrade Sign and Markings Layout



Source: MnDOT Dist 3-13 County RSA - CH2M HILL 2006 Intersections (3 of 8)

Prioritized/Phasing

1. STOP bar
2. STOP sign
3. Junction sign
4. Stop Ahead Message
5. Stop Ahead Sign

Mainline Dynamic Warning Sign

SOURCES

1970d/80d Iowa Highway and Research Board HR-235, Carstens & Woo, A982.
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Stopping Behavior at Real-World Stop-Controlled Intersections with and without In-Lane Rumble Strips, Minnesota Local Road Research Board, Report 2006-42, Harder, K., 2006.
Identification of Causal Factors and Potential Countermeasures for Fatal Rural Crashes, Minnesota Local Road Research Board, Report 2005-42, 2005.
The Effects of In-Lane Rumble Strips on the Stopping Behavior of Sleep-Deprived Drivers, Minnesota Local Road Research Board, Report 2005-16, 2005.
The Effects of In-Lane Rumble Strips on the Stopping Behavior of Attentive Drivers, Minnesota Local Road Research Board, Report 2002-11, 2002.
The Effect of Rumble Strips on Drivers Approaching Rural, Stop-Controlled Intersections, Minnesota Local Road Research Board, Report 2006-42TS, 2006.
Safety Evaluation of Transverse Rumble Strips on Approaches to Stop-Controlled Intersections in Rural Areas, 2010 Annual Meeting of Transportation Research Board, Srinivasan, R., Baek, J., Council, F., November 2009.

Rural Through/ STOP Intersections Policy

INTERSECTIONS

POLICY PURPOSE/INTRODUCTION

The purpose of this policy is to establish uniformity and consistency in the application, installation, and maintenance of through/STOP intersection safety strategies on the ***<Insert Agency>*** roadway system.

POLICY

It is the policy of ***<Insert Agency>*** to implement safety strategies on through/STOP intersections based on a review and prioritization of intersections risk assessment. Strategies that will be considered to address the majority of gap-recognition, right-angle crashes include:

- *Change in Intersection Geometry*—Roundabouts and directional median intersections designs are effective at reducing, if not eliminating, right-angle crashes.
- *Mainline Dynamic Warning Sign*—Implementation of a mainline dynamic warning sign includes the installation of loop detectors on the minor leg approaches and a dynamic flashing sign on the major leg approaches. When a vehicle approaches on a minor leg, the loop detectors send a signal to the mainline sign and flashers warn drivers of a vehicle at the STOP sign.
- *Clearing and Grubbing*—Sight distance at intersections can be improved by clearing and grubbing adjacent right-of-way.
- *Street Lights*—Adding rural street lighting at intersections.

If crash records or comments by law enforcement indicate that intersection recognition (drivers running the STOP sign) is contributing to angle crashes, three additional strategies will be considered:

- *Upgraded Signs and Markings*—Installation of a standard set of signs and pavement markings on the minor intersection approaches.
- *Transverse Rumble Strips*—Transverse rumble strips are horizontal grooves in the pavement at approaches to intersections, typically between 450 to 700 feet from the intersection. Their purpose is to alert drivers to the approaching intersection by both noise and tactile sensation. The goal is to reduce unintentional running of STOP-controlled intersections in rural settings. The long-term success of transverse rumble strips as a traffic control enhancement lies in their very select, limited, and uniform application across an agencies system of intersections that have been identified as being at-risk for right-angle crashes associated with intersection recognition. Transverse rumble strips should not be used as the standard treatment for alerting motorists to conditions ahead. Overuse of transverse rumble strips could reduce their effect on road users, thereby reducing their effectiveness as a safety tool.
- *Flashing Lights*—Flashing lights mounted on STOP signs.

POLICY CRITERIA

Installation of safety strategies should be considered across the system, as opposed to only at individual locations as a reactive application. Research has proven that crashes are not the only indication of risk at rural intersections and decisions to implement should be based on a system-wide evaluation based on the following intersection risk factors:

- Geometry of intersection (skew)
- Geometry of roadway (on or near curves—both vertical and horizontal)
- Commercial development in quadrants
- Distance from previous STOP sign (greater than 5 miles from the previous stop)
- Average Daily Traffic (ADT) ratio (a ratio of 0.4 to 0.8)
- Railroad crossing on minor approach
- Crash history

Rumble strips should be considered only after an adequate trial of less intrusive strategies such as upgrading of signs and marking or flashing STOP signs. The installation of transverse rumble strips should be implemented only after an assessment of the system of intersections, including the review of the following factors:

- The traffic control issues at the site
- Traffic control devices currently in use
- Traffic control alternatives considered or previously used
- Collision history of the site
- The reason transverse rumble strips are being considered
- A description of the location, including distances to nearby residences

Pavement Markings (1 of 3)

DESCRIPTION AND DEFINITION

A typical approach to marking a road involves placing a 4-inch-wide white line for the road edge and yellow line for the centerline.

Minnesota has been experimenting with the use of an enhanced, 6-inch-wide edge line in an effort to better delineate the road edge.

6-Inch Edge line

Advantages

- 50 percent wider lane line
- Low cost—approximately $650 per mile
- Initial positive feedback from drivers
- Initial indication that 6-inch edge line results in a small crash reduction (5 to 10 percent)—not yet statistically significant

Disadvantages

- Higher cost than for 4-inch lines
- Still susceptible to snowplow damage
- No improvement in wet conditions
- No tactile effect

Embedded Wet Reflective Markings

A wet, reflective paint made of large glass beads is installed in a longitudinal trough that is approximately 0.04 inch deep. The larger beads provide improved visibility at night and during wet conditions, and the trough protects the beads from damage by snowplow blades. MnDOT considers this strategy experimental; limited installation has taken place, but approximately 250 miles have been approved for funding in 2012.

Advantages

- Improved visibility at night and during wet conditions
- No noise concerns
- Little/no snowplow damage expected

Disadvantages

- Relatively high cost (over typical painted edge line)
- Crash reduction as yet unknown
- No tactile effect

The STOP AHEAD pavement marking at intersections is intended to reduce crashes related to lack of driver awareness of stop-control at unsignalized intersections.

ROADWAY OPERATIONS

The installation of edge line and centerline pavement markings does not have an effect on the mobility of traffic on the roadway.

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- NCHRP 500 series considers pavement markings a **TRIED** strategy.
- The only study in the FHWA Crash Reduction Clearinghouse that studied the effects of converting a 4-inch edge line to a 6-inch edge line found a 10 to 60 percent reduction in all rural crashes.
- MnDOT is evaluating the first round of installations of 6-inch edge lines. Preliminary results indicate crash reductions in the 5 to 10 percent range.
- STOP AHEAD pavement markings at intersections have a 15 percent reduction in crashes, a higher reduction than transverse rumble strips.

Example of 6" Edgeline

Example of Embedded Wet Reflective Marking

Pavement Markings (2 of 3)

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

The 2009 Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD) provides the following guidance in the location of center and edge lines on roadways:

- Centerline markings shall be placed on all paved urban arterials and collectors with Average Daily Traffic (ADT) volume of 6,000 vehicles per day or greater
- Centerline markings should be placed on paved urban arterials and collectors with an ADT rate of 4,000 vehicles per day or greater
- Edge line markings shall be placed on paved streets or highways with ADT volume of 6,000 vehicles per day or greater
- Edge line marking should be placed on paved streets with ADT volume of 3,000 vehicles per day or greater

TYPICAL COSTS

Implementation Costs

- 6-inch edge line = $650 per mile
- Embedded wet reflective paint = $8,500 per mile

According to MnDOT's Policy for Pavement Marking Operations, traffic volumes and resulting snow and ice operations have the greatest effect on performance of pavement markings. The following table provides a summary of the pavement marking life expectancy and typical costs for latex, epoxy, and preformed polymer tape.

Pavement Marking Life Expectancy and Typical Costs

	Latex Markings	Epoxy	Poly-Preform (tape)
Life Expectancy	1 to 2 years	3 to 4 years	4 to 7 years
4-inch marking – white ($/ft)	$0.06	$0.18	$3.20
4-inch marking – white skip ($/ft)	$1.00	$0.45	$3.20
24-inch marking, stop bars ($/ft)	$1.14	$5.00	$17.85
Arrows (each)	$22.00	$96.00	$289.00
Messages (each)	$101.00	$196.00	N/A

Pavement Markings (3 of 3)

DESIGN FEATURES

The 2009 MN MUTCD provides examples of two-lane, two-way pavement marking applications for both passing permitted and marking for no-passing zones.

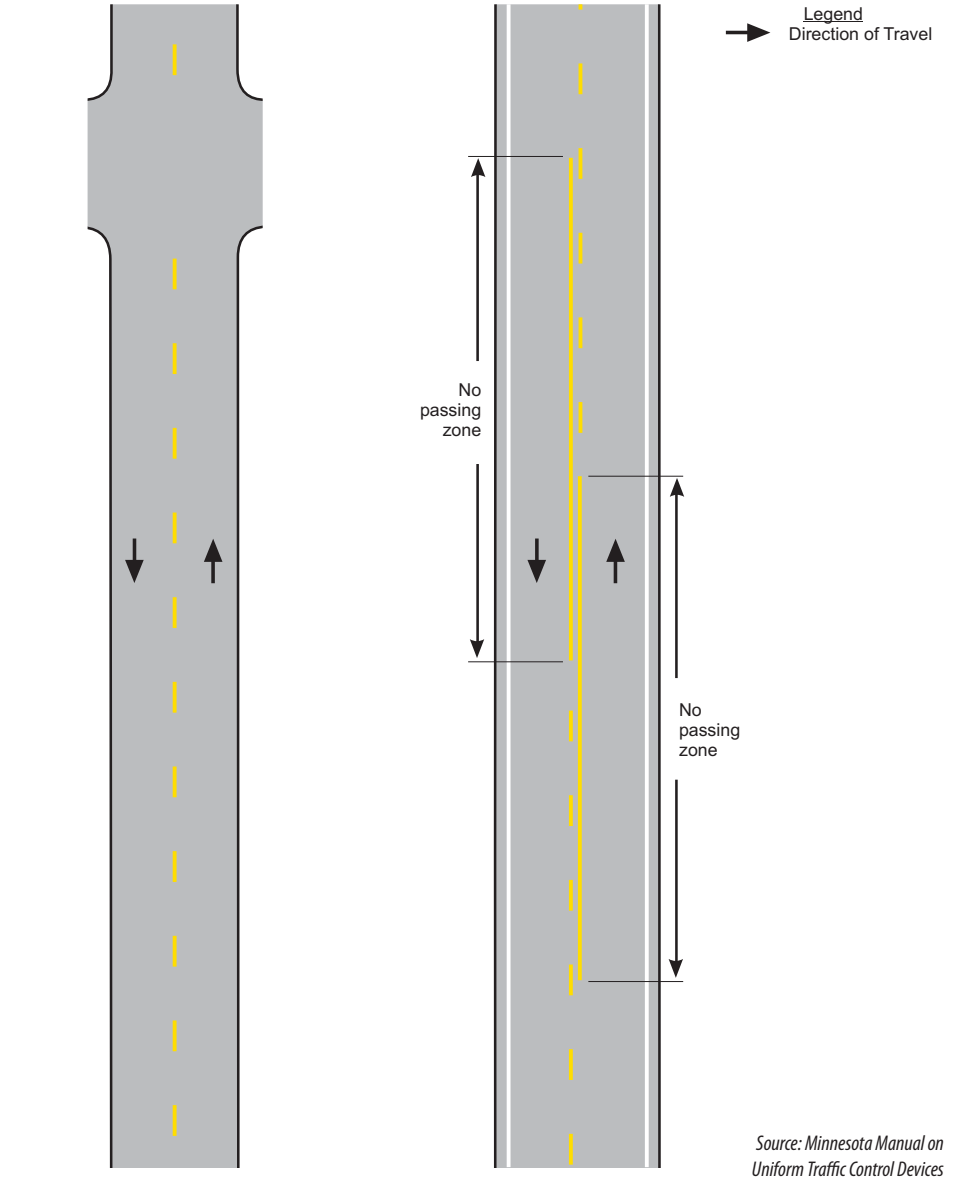
The designation of passing zones is unique; the regulatory device, not a sign, is the marking. As a result, if an agency chooses to install a centerline along a segment of road where it is not required (such as on residential or other urban streets) in an attempt to slow traffic, the lines must be appropriate for the passing conditions.

BEST PRACTICE

Maintain an inventory of pavement markings and develop a management approach for maintaining retroreflectivity of the markings that is consistent with available funding.

SOURCES

Minnesota *Manual on Uniform Traffic Control Devices,* 2009.
MnDOT *Policy for Pavement Marking Operations*
Safety Evaluation of STOP AHEAD Pavement Markings, FHWA-HRT-08-043, Gross, F and et. Al., December 2007.
State of Practice for Minnesota Local Agency Pavement Marking Management, Minnesota Local Road Research Board, Report 201005TS, 2010.
Minnesota Local Agency Pavement Marking Practices—Phase I, Minnesota Local Road Research Board, Report 201005, 2010
Developing and Implementing Enhanced Pavement Marking Management Tools: Phase I—Mapping Tool, Minnesota Local Road Research Board, Report 200837ts, 2008.
2008-37 Developing and Implementing Enhanced Pavement Marking Management Tools for the Minnesota Department of Transportation, Minnesota Local Road Research Board, Report 200837, 2008.
Cost of Pavement Marking Materials, Minnesota Local Road Research Board, Report 200011, 2000.



a - Typical two-lane, two-way marking with passing permitted in both directions

b - Typical two-lane, two-way marking with no-passing zones

Source: Minnesota Manual on Uniform Traffic Control Devices

Pavement Markings Policy (1 of 2)

POLICY PURPOSE/INTRODUCTION

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

The Commissioner of Transportation has adopted the MN MUTCD for use on all streets and highways of the State of Minnesota. The MN MUTCD contains guidelines relating to the design and application of traffic control devices—signs, markings, and signals—and is in substantial conformance with the national manual prepared by the Federal Highway Administration (FHWA).

The FHWA is in the process of developing minimum retroreflectivity criteria for pavement markings, similar to the recently adopted requirements for maintaining minimum levels of retroreflectivity for traffic signs. When the criteria are formally added to the MN MUTCD, ***<Insert Agency>*** will be responsible for maintaining pavement markings on the agency's system of highways such that the markings meet or exceed the minimum level criteria.

DEFINITIONS

Centerline—A 4-inch wide solid or skip line (10 feet of painted line followed by a 40-foot gap) that denotes the center of road and that the adjacent lane to the left carries traffic in the opposite direction. The solid line is the regulatory device that designates where passing is not allowed, and the skip line designates where passing is allowed.

Edge line—A 4- or 6–inch-wide line that denotes the edge of rural roads and separates lanes of traffic moving in the same direction on multi-lane highways.

Latex paint—A water-based paint that typically costs $0.05 to $1.00 per linear foot for a 4-inch line and has a life expectancy of 2 years on low-volume roads (under 1,500 vehicles per day) and 1 year on high-volume roads (more than 1,500 vehicles per day).

Epoxy—A multiple component liquid that is generally more durable than latex, costs $0.20 to $0.50 per linear foot for a 4-inch line, and has a life expectancy of 6 years on low-volume roads and 4 years on high-volume roads.

Edge line rumble strip—A 12- to 16-inch-wide grooved pattern, approximately ½ inch deep, constructed on the outside edge of the travelled lane or in the shoulder.

Edge line rumble stripE—An 8- to 12-inch-wide grooved pattern, approximately ½ inch deep, constructed on the outside edge of the traveled lane that contains the edge line pavement marking.

POLICY

<Insert Agency> will have a pavement marking program consisting of both construction and maintenance elements in order to provide reasonable levels of markings (presence and retroreflectivity) on all county and city roadways, consistent with adopted statewide performance measures, 365 days per year.

POLICY CRITERIA

It must be recognized that it is not possible to maintain pavement marking minimum retroreflectivity levels for all markings at all times. Winter operations and maintenance activities can damage and even obliterate markings such that pavement markings in the winter and spring may have little or no measurable retroreflectivity. In addition, during wet conditions the performance of conventional pavement markings is typically much less effective than during dry conditions. Also, pavement marking replacement periods are limited to seasonal cycles (dry pavements and pavement temperatures above 50 degrees Fahrenheit) making it impractical to perform pavement marking maintenance activities during winter months.

Pavement Markings Policy (2 of 2)

The maintenance element of the pavement marking program consists of two parts—a visual assessment of in-place markings combined with a management approach to identify the segments of ***<Insert Agency>***'s system that will be refurbished in any given year. The visual assessment will consist of ***<Insert Agency>*** staff conducting a nighttime inspection of all county and city highways and recording their determinations relative to whether or not the markings meet the adopted performance measures. The visual observations will supplement the management approach, which will track the service life of the markings on every ***<Insert Agency>*** highway. The annual program for refurbishing the pavement markings will then be developed based on addressing those facilities where the markings have been determined to no longer meet the adopted performance measures.

Edge and centerlines will be refurbished with latex paint and with the schedule based on the following expected frequency:

- *Low-volume highways*
  - Centerlines: Every year
  - Edge lines: Every other year
    This frequency yields a refurbishing project that includes the centerline and one edge line (westbound) being done during one year and the same centerline and the other edge line (eastbound) being done the next year.
- *High-volume highways*
  - Centerlines: Every year
  - Edge lines: Every year

To address the issue of the performance of the pavement markings during wet conditions, ***<Insert Agency>*** will deploy edge line rumble stripEs along rural ***<Insert Agency>*** highways. Experience has demonstrated that installing the edge line pavement marking over the grooves of the rumble stripE provides improved visibility of the marking at night and during wet pavement conditions—the paint on the nearly vertical sides of the grooves in the pavement remains above the film of water during most rain events. In addition, the paint in the grooves is protected from damage by snowplows; as a result, the service life of the pavement marking is extended.

<Insert Agency> will not deploy pavement markings on residential streets. If markings are placed on residential streets, they will be consistent with required passing/no passing markings.

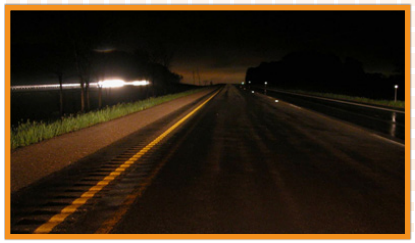
FINANCIAL CONSIDERATIONS

The construction element of the ***<Insert Agency>***'s pavement marking program consists of using the epoxy material for all center and edge lines on new surfaces that are associated with construction and maintenance projects supported by state and federal funds. The additional state and federal funds on these projects allows ***<Insert Agency>*** to deploy the more durable and longer lasting epoxy markings at a reduced first cost and will also result in a long-term reduction in annual maintenance costs (because of the documented longer service life).

Edge Line Rumbles (1 of 2)

DESCRIPTION AND DEFINITION

Rumble Strips—Grooves cut into the paved shoulder outside the edge/fog line.



Rumble StripEs—Grooves cut into the outer edge of the traffic lane. The edge/fog line is placed on the grooves.

TYPICAL COSTS

Implementation Costs = $3,000 per mile

SAFETY CHARACTERISTICS

The primary objective of edge line rumbles is to reduce the number of road departure crashes by enhancing drivers' ability to stay on the road. Over 700 miles of edge line rumbles have been installed in Minnesota, and over 200 are planned to be implemented in the year 2011.

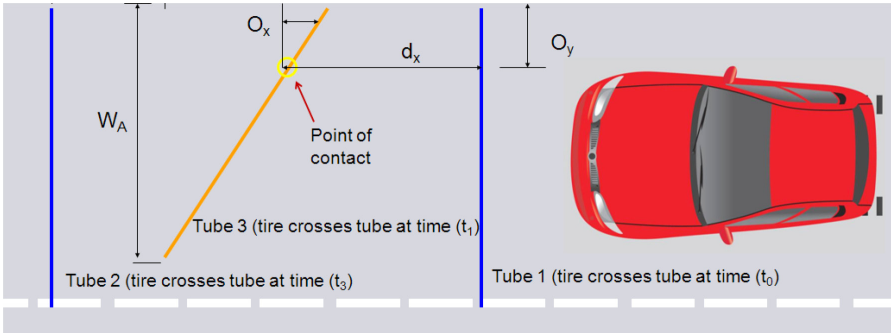
Advantages	Disadvantages
▪ Positive/tactile warning for drivers approaching the road edge ▪ Relative low cost compared to other safety strategies ▪ Rumble stripEs offer improved visibility during at night and in wet conditions ▪ Considered to be PROVEN effective at reducing road departure crashes	▪ Concern expressed by residents about noise ▪ Concern expressed by bicyclists about increased risk to riders ▪ Concern expressed by maintenance forces about road edge deterioration

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- The edge line rumble strip is considered to be **PROVEN** effective at reducing road departure crashes. The Federal Highway Administrations Crash Modification Factors (CMF) Clearinghouse documents 12 studies with crash reduction ranging from 7 to 79 percent, with an average reduction in road departure crashes of 20 percent.
- One study in the CMF examines ways to reduce crashes on rural two-lane roadways in Minnesota. The documented crash reduction was 18 percent of severe road departure crashes.

ROADWAY OPERATIONS

A concern about the installation of edge line rumble strips is that they cause vehicles to move away from the edge of the road and may increase head-on collisions. Iowa State University recently completed an evaluation along two-lane roadways. The study found that there was a lateral displacement of approximately 7 inches. For vehicles between 6 and 8 feet wide on a 12-foot lane, a 7-inch displacement should not induce cross-centerline crashes.



Source: Evaluation of Rumble Stripes on Low-Volume Rural Roads in Iowa—Phase I, Iowa State University Institute for Transportation, Dr. Shauna Hallmark, July 2009.

DESIGN FEATURES

The following issues should be considered when implementing edge line rumble strips:

- *Noise*—A number of county engineers in Minnesota that have deployed edge line rumbles reported receiving several complaints about increased traffic noise levels

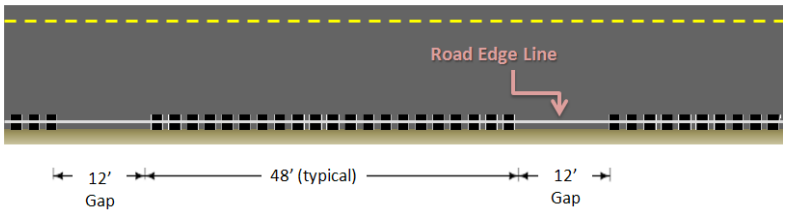
Edge Line Rumbles (2 of 2)

associated with errant vehicles. A 2011 MnDOT study found that noise levels would likely increase by about 1 decibel—the equivalent of one heavy truck driving down the road. Observations in the Brainerd area found actual "hit rates" to be in the range of 0.5 to 1 percent of vehicles travelling along the roadway.

- ***Bikes***—Bicycle advocates have expressed concerns that the installation of edge line rumble strips would be a hazard to bicyclists. The following bicycle-friendly patterns are recommended:
  - At locations with paved shoulder, move the rumble to the outside edge of the paved shoulder to provide space for the bicyclist to move between the roadway lane and shoulder without having to run over the rumbles.
  - At locations without a shoulder, consider bike-friendly designs (such as 48-foot grooves with a 12-foot skip) or adding narrow paved shoulder, moving the edge line to 11 feet, and adding the rumbles to the outside edge of the shoulder.

Additional design features to consider at these locations are:

- An 8-inch wide rumble should be used instead of the standard 16-inch
- Attempt to keep the depth of the rumble strips as close to ⅜-inch as possible
- For narrow 2-foot shoulders, keep the strip as close to the outside edge as possible without damaging the shoulder edge



Rumble strip layout for section without paved shoulders

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

Typical candidate locations for rumble strips and stripEs are:

- Rural roadways
- Areas with low density of residential development (few noise sensitive receivers)
- Roadways with curvilinear alignment
- Specific horizontal curves
- Areas with few or no other noise sensitive receivers (lake cabins, golf ourses, etc.)
- Roads with hazardous edges—no shoulder, lack of clear zones, etc.

AASHTO's ***Roadside Design Guide*** suggests a three-step prioritized approach to dealing with road departure crashes:

1. Improve road edges to keep drivers on the road
2. Improve clear zones
3. Improve highway hardware

Deployment of edge line rumbles strips is consistent with this prioritized approach, and is one of the least costly to implement.

BEST PRACTICE

Minnesota has adopted the intermittent pattern as its recommended approach to balancing the needs of addressing road departure crashes while still providing bicyclists with a reasonable opportunity to move between travel lanes and shoulders without having to cross the grooves of edge line rumble strips and stripEs.

SOURCES

Evaluation of Rumble Stripes on Low-Volume Rural Roads in Iowa – Phase I, Institute for Transportation, Iowa State University, Hallmark, S. et. al., 2009.
Guidance for the Design and Application of Shoulder & Centerline Rumble Strips, NCHRP Report 641, 2009.
Effects of Center-Line Rumble Strips on Non-Conventional Vehicles, MnDOT Research Report 2008-07.
Synthesis on the Effectiveness of Rumble Strips, Minnesota Local Road Research Board, Report 200207, 2007.
Identification of Causal Factors and Potential Countermeasures for Fatal Rural Crashes, Minnesota Local Road Research Board, Report 200542, 2005.

Edge Line Rumbles Policy (1 of 2)

POLICY PURPOSE/INTRODUCTION

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

In response to an overrepresentation of road departure crashes along the rural county highway system in Minnesota, ***<Insert Agency>*** identified a variety of potential mitigation strategies (as documented in the NCHRP 500 Series reports on implementation of AASHTO's ***Strategic Highway Safety Plan*** and in the Federal Highway Administration's Technical Memorandum on Consideration and Implementation of Proven Safety Countermeasures). Current safety-related guidance suggests that the first step in addressing road departure crashes involves considering the deployment of techniques and features along road edges that help keep vehicles on the road. The techniques include enhancing edge line pavement markings, enhancing delineation of highway curves, constructing wider or paved shoulders, providing a safety wedge as part of bituminous paving projects, and installing edge line rumble strips/stripEs.

Considering implementation costs and estimated effectiveness, the use of edge line rumble strips/stripEs has been selected as a targeted strategy for reducing the occurrence of road departure crashes along segments of rural county highways.

DEFINITIONS

Edge Line Rumble Strip—A 12- to 16–inch-wide grooved pattern, approximately ½ inch deep, constructed on the outside edge of the travelled lane or in the shoulder.

Edge Line Rumble StripE—An 8- to 12-inch-wide grooved pattern, approximately ½ inch deep, constructed on the outside edge of the travelled lane that contains the edge line pavement marking. Experience has demonstrated that installing the edge line pavement marking over the grooves of the rumble strip provides improved visibility of the marking at night and during wet conditions, as well as extends the life of the pavement marking material.

6-inch Wet Reflective Epoxy in Grooves—A 6-inch wet reflective epoxy marking within a groove. A contractor must cut a 20-millimeter groove in the edge of the pavement and then install a wet reflective marking within the groove. The wet reflective beads in the marking reflect light during wet conditions and better delineate road edges for driving in wet conditions. The groove protects the more expensive marking from damage by snowplows.

6-inch Latex Marking—A 6-inch road edge using latex paint.

Rural County Highways—Segments that are generally categorized as having a rural drainage system (ditches and culverts), a 55-mph speed limit, average daily traffic volumes under 3,500 vehicles per day, and low levels of development (farmsteads and low-density residential).

POLICY

It is ***<Insert Agency>***'s long-term goal to reduce road departure crashes along all of the rural county and city highway system. Effective strategies to achieve this goal are the use of enhanced road edge treatments. Given that the rural system includes approximately _____ miles of ***<Insert Agency>*** highways, the total implementation costs could exceed millions of dollars. This level of funding will require using a phased approach to construct and install the edge line rumble strips/stripEs over several years, as funding permits.

<Insert Agency> will periodically evaluate the rural county highway system, based on traffic volumes, road departure crashes, and shoulder characteristics, and will establish a priority for implementation of edge line rumble strips/stripEs consistent with the following guidelines:

- Rumble strip—High-priority segments (more than 200 vehicles per day [vpd]) with existing shoulders
- Rumble stripE—High-priority segments (more than 200 vpd) with no paved shoulders and 12-foot lanes
- 6-inch wet reflective epoxy in grooves—High-priority segments (more than 200 vpd) with adjacent noise sensitive land uses
- 6-inch latex marking—High-priority segments with low volumes (less than 200 vpd)

Edge Line Rumbles Policy (2 of 2)

<Insert Agency>'s approach to implementing edge line rumble strips/stripEs will include two basic components:

1. Including safety strategies in traditional maintenance and regular construction projects.
2. Adding safety strategies by undertaking stand-alone projects that capitalize on securing state and federal highway safety improvement funds.

POLICY CRITERIA

Rumble strips in the travelled way have several potential pitfalls that should be considered carefully in any decision to implement them, including the following:

1. Noise that may disturb nearby residents
2. Potential loss-of-control problems for motorcyclists and bicyclists
3. Difficulties created for snowplow operations
4. Inappropriate driver responses, such as using the opposing travel lanes to drive around the rumble strips

Bicycle advocates have expressed concern on the use of edge line rumble strips/stripEs, citing a potential impact to their safety when bicycle tires cross over the grooves of the rumble strips/stripEs. A review of the highway traffic safety literature found several references to concerns about the interaction of bicyclists and edge line rumble strips/stripEs, but no documentation of any injuries or fatalities because of them.

However, in response to bicyclist's concerns, a number of states (including Alaska, Arizona, Colorado, Florida, Iowa, and Minnesota) developed and evaluated alternative rumble strip/stripE designs. The designs included a narrower groove (between 4 and 12 inches instead of the typical 16 inches), a shallower profile (the lower end of MnDOT's specification range of 3/8 to ½ inch), and an intermittent pattern (48 feet with grooves followed by 12 feet without grooves). The literature goes on to indicate that most of the states that have implemented rumble strips/stripEs, including Minnesota, have dismissed the idea of using the narrower 4-inch grooves because there is not enough tactile sensation to adequately warn drivers.

Minnesota, as well as other states, has adopted the intermittent pattern as its recommended approach to balancing the need of addressing road departure crashes while still providing bicyclists a reasonable opportunity to move between travel lanes and shoulders without having to cross the grooves of the edge line rumble strip/stripE.

For locations designated as bike routes or routes with regular bike traffic, also consider:

- At locations with paved shoulder, moving the rumble to the outside edge of the paved shoulder to provide space for the bicyclist to move between the roadway lane and shoulder without having to run over the rumbles
- At locations without shoulders, consider bike-friendly designs (such as 48-foot grooves with a 12-foot skip) or adding a narrow paved shoulder, moving the edge line to 11 feet, and adding the rumbles to the outside edge of the shoulder.

FINANCIAL CONSIDERATIONS

Edge enhancements eligible for Highway Safety Improvement Program (HSIP) funding and state aid funds will require long-term maintenance.

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?

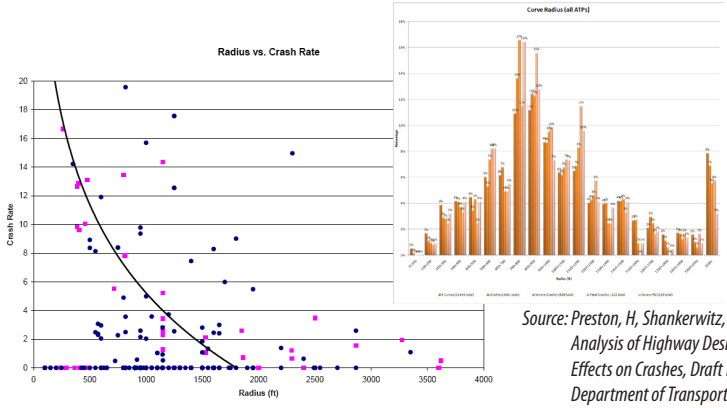
The county road safety plan efforts resulted in the review of over 10,000 curves on both the state and county systems. Reviewing the curves has provided information on the geometric and traffic-related characteristics of curves that pertain to crash risk.

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.



Source: Preston, H, Shankerwitz, C, Barry, M; Analysis of Highway Design and Geometric Effects on Crashes, Draft Report; Minnesota Department of Transportation, July, 2009.

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.

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.

Examples of Visual Traps

Example of Intersection on a Curve "T's Up"

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

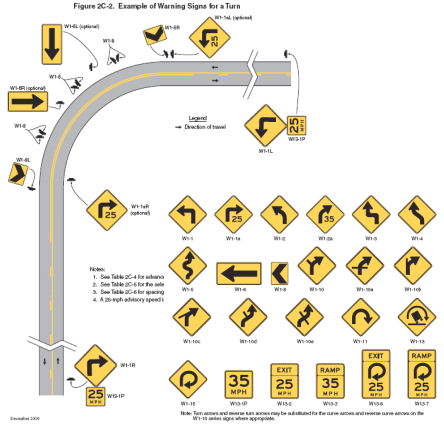
Best Practice

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.

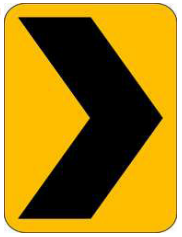
Horizontal Curves Delineation Policy

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.

	Difference between Speed Limit and Advisory Speed				
Type of Signs	**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.

Safety Edge (1 of 2)

DESCRIPTION AND DEFINITION

The safety edge is a treatment that allows drivers who drift off roadways to return to the road safely. Instead of encountering a vertical dropoff, the safety edge shapes the edge of the pavement to 30 degrees. Vertical dropoffs greater than 2 inches have been found to cause drivers to lose control when attempting to re-enter the highway. The 30-degree angle allows drivers to re-enter the roadway safely and prevents the tire-scrubbing on vertical surfaces that causes vehicles to lose control.

Without Safety Edge

With Safety Edge

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

Typically, the safety edge is most appropriate on rural two-lane roadways without paved shoulders, but the safety edge is appropriate on all primary highways unless one of the following conditions is met:

- The paved shoulder width is 4 feet or greater
- The roadway or shoulder is curbed

SAFETY CHARACTERISTICS

"The safety edge treatment is suitable for use by highway agencies under a broad range of conditions on two-lane highways. While the evaluation results for total crashes were not statistically significant, there is no indication that the effect of the safety edge treatments on total crashes is other than positive."—***Safety Evaluation of the Safety Edge Treatment,*** FHWA-HRT-11-024.

"That the overall effectiveness of the safety edge treatment found in this study was not statistically significant is not surprising given that the magnitude of that safety effects appears to be small (approximately 5.7 percent). However, the safety edge treatment is so inexpensive that its application under most conditions appears to be highly cost-effective. The effect of the safety edge treatment would be cost-effective for two-lane highways with traffic volumes over 1,000 vehicles per day even if its effectiveness were 2 percent rather than 5.7 percent."—***Safety Evaluation of the Safety Edge Treatment,*** FHWA-HRT-11-024.

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- The safety edge is considered a **TRIED** strategy.
- The overall effectiveness of the safety edge treatment found in the FHWA's Safety Evaluation of the Safety Edge Treatment Study was small at around 6 percent; however, the safety edge treatment is so inexpensive that even with this small reduction in crashes it is highly cost-effective.

Safety Edge (2 of 2)

TYPICAL COSTS

Implementation Costs = $500 to $2,000 per mile

ROADWAY OPERATIONS

Installation of the safety edge does not affect roadway traffic operations.

DESIGN FEATURES

The safety edge is installed during paving using a special, commercially available shoe that attaches to existing equipment in just a few minutes. Typically, less than 1 percent additional asphalt is needed.

FHWA recommends grading the material that is adjacent to the pavement edge flush with the top of the pavement. The safety edge takes effect as the graded material settles, erodes, or is worn down.

The safety edge is also recommended for concrete pavements adjacent to graded materials. There are some additional costs and special considerations for concrete application.

BEST PRACTICE

Include safety edge installation as part of bid packages on all reconstruction and resurfacing projects.

The shoe that creates the safety edge

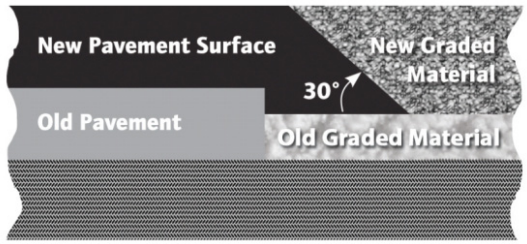


Diagram of how the Safety Edge is created

SOURCES

Safety Evaluation of the Safety Edge Treatment, FHWA-HRT-11-024. 2011. March.
Safety Evaluation of the Safety Edge Treatment, Year 1 Interim Report. 2008. University of North Carolina, MRI Project No. 110495.1.001. April.
The Safety Edge, FHWA Publication Number FHWA-SA-09-023.
The Safety Edge Brochure, FHWA Publication Number FHWA-SA-10-034.
"Effects of Pavement Shoulder Drops-Offs on Highway Safety." 1986. TRB *State of the Art Report 6.* John Glennon.

Safety Edge Policy

POLICY PURPOSE/INTRODUCTION

The purpose of this policy is to establish uniformity and consistency in the application of the safety edge on ***<Insert Agency>***'s roadway system.

DEFINITIONS

The safety edge is a treatment that allows drivers who drift off roadways to return to the road safely. Instead of encountering a vertical dropoff, the safety edge shapes the edge of the pavement to 30 degrees. Vertical dropoffs greater than 2 inches have been found to cause drivers to lose control when attempting to re-enter the highway. The 30-degree angle allows drivers to re-enter the roadway safely and prevents the tire-scrubbing on vertical faces that causes vehicles to lose control.

POLICY

The policy of ***<Insert Agency>*** is to use the safety edge on all reconstruction or maintenance overlays with gravel shoulders or paved shoulders equal to or less than 4 feet wide.

POLICY CRITERIA

Design criteria for the safety edge can be found in MnDOT's technical memorandum titled " 11-01-T-01—Pavement Edge Treatment—Safety Edge."

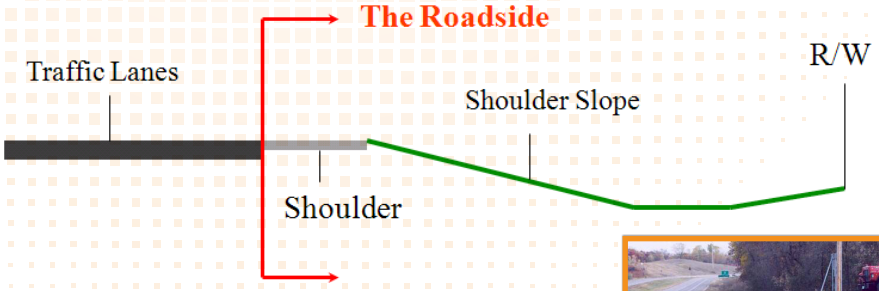
FINANCIAL CONSIDERATIONS

The additional cost of implementing the safety edge as part of a reconstruction or maintenance overlay project is associated with the less than 1 percent additional asphalt that is needed.

Clear Zones (1 of 2)

DESCRIPTION AND DEFINITION

Provide a traversable and unobstructed roadside area (clear zone) beyond the edge of the roadway by removing, relocating, redesigning, or shielding adjacent objects.



Strategies for minimizing the consequences of leaving the road include:

- Considering or providing clear recovery areas wherever possible
- Removing hazardous trees (collisions with trees result in more deaths than any other fixed object)
- Providing setback to utility poles
- Improving ditch slopes
- Upgrading roadside safety hardware (construction, reconstruction, and maintenance)

Example of Unobstructed Roadside

Example of Re-graded Roadside and the Use of Grates on Culverts

SAFETY CHARACTERISTICS

A comparison study found that two rural roads in northern Minnesota (TH 6 and TH 38) have similar characteristics (volumes and functions) and traverse the Chippewa National Forest. TH 6 was reconstructed, but TH 38 was not.

TH 38 has the following crash characteristics when compared with TH 6:

- More than twice as many crashes
- More than twice as many injuries
- A crash rate more than twice the average for two-lane rural roads (and 30 percent greater than the critical rate)
- Ten times as many trees hit
- More than twice as many nighttime crashes

 TH 6		 TH 38
11.2	Length (Miles)	11.2
23	Total Crashes (5 Years) +122%	51
11	PDO Crashes	25
12	Injury Crashes +117%	26
0	Fatal Crashes	0
1,100	Volume (VPD)	1,100
22.48	MVM	22.48
1.0	Crash Rates (Crashes/MVM) +130%	2.3
1.5	Severity Rate +173%	4.1
1.3	Critical Crash Rates	1.3
10 (43%)	SVRD Crashes	37 (73%)
3	Hit Trees +1000%	30
8 (35%)	Passing Crashes	3 (6%)
2	Angle Crashes	4
6	Deer Hits	1
10 (43%)	Night	21 (41%)

Source: MnDOT District 1, Traffic Engineering Roadside Safety Strategies (6 of 6)

Clear Zones (2 of 2)

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- All studies in the FHWA Crash Reduction Clearinghouse documented crash reductions associated with providing clear zones and traversable slopes.
- Documented crash reductions are in the range of 20 to 40 percent.
- Providing clear zones and traversable slopes is considered a **PROVEN** and effective safety strategy.

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

The concept of providing for clear recovery area is primarily intended for high-speed rural roadways; however, the concept can be applied to suburban or urban roadways if road departure crashes are a concern.

ROADWAY OPERATIONS

Clear zones contribute to drivers perception of the road conditions, suggesting a rural environment, and may result in higher operating speeds.

TYPICAL COSTS

Implementation Costs = $100,000 to $500,000 per mile

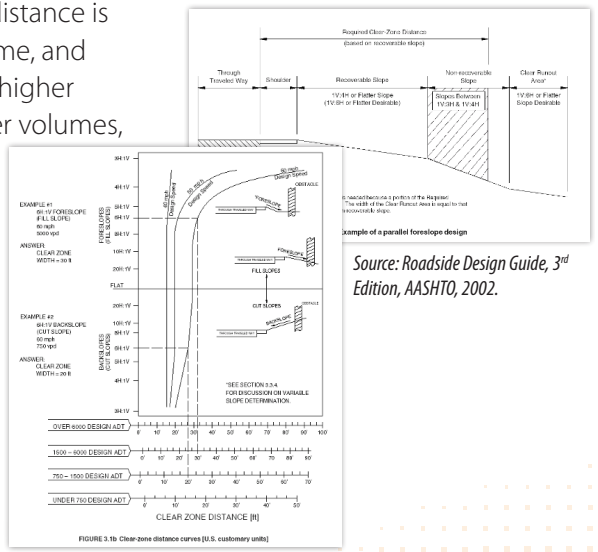
Example of Traversable Roadside

A Vision for Improved Roadside Safety

"A highway system where drivers rarely leave the road, but when they do, the vehicle and the roadside work together to protect vehicle occupants from serious harm."—Roadside Design Manual

DESIGN FEATURES

The recommended clear zone distance is a function of speed, slope, volume, and horizontal curvature. Generally, higher speeds, steeper fill slopes, higher volumes, and locations along the outsides of horizontal curves require larger clear zones. More information can be found in AASHTO's ***Roadside Design Guide***.



Source: Roadside Design Guide, 3rd Edition, AASHTO, 2002.

BEST PRACTICE

Lower cost safety strategies should be considered first.

Before changes in the clear zone are implemented, clear zones should be reviewed for reconstruction projects, and improvements should be incorporated into the design when possible.

SOURCES

Roadside Design Guide, 3rd Edition, AASHTO, 2002.

Mn/DOT District 1, Traffic Engineering TH 6/TH 38 Before and After Study.

Clear Zones Policy

POLICY PURPOSE/INTRODUCTION

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

There are four general methods of providing a clear zone. In order of preference, the methods to attain roadside safety are:

1. Remove the obstacle.
2. Redesign the obstacle so it can be safely traversed.
3. Relocate the obstacle to where it is less likely to be struck.
4. Reduce impact severity by using an appropriate breakaway device.

DEFINITIONS

The clear zone is a roadside border area that is available for the safe use by errant vehicles as determined in accordance with Chapter 3 of the AASHTO ***Roadside Design Guide***. It is measured from the edge of the roadway pavement.

POLICY

It is the policy of ***<Insert Agency>*** to review clear zones as part of new construction and reconstruction projects on ***<Insert Agency>*** roadways. Clear zones will not be addressed on maintenance (overlay) projects.

POLICY CRITERIA

Clear zone width is a function of speed, volume, cross slopes, and alignment. Higher speeds result in vehicles travelling farther off the roadway before control is recovered. Horizontal curvature also increases the likelihood of a vehicle leaving the roadway. Steeper slopes adjacent to the roadway increase the distance an errant vehicle travels after leaving the roadway. It is important for clear zone distances not to be used as boundaries for introducing roadside hazards such as bridge piers or trees, which should be as far from the roadway as practical.

The clear zone width is to be determined based on design guidance in MnDOT's ***Road Design Manual*** or AASHTO's ***Roadside Design Guide***. Roadside slopes apply an important part in the clear zone width determination. Fill slopes of 1V:4H/1V:3H are preferred in areas of high fill (a 1V:4H slope extending from the shoulder line out for a distance necessary to obtain the clear zone then break the slope to 1V:3H or flatter). If feasible, the flattening of slopes is preferable to installation of guardrail.

<Insert Agency> will provide clear zones where the anticipated posted speed of the roadway is 45 mph or more. When the anticipated posted speed is less than 45 mph, clear zones are still beneficial, but they are to be considered based on engineering judgment. Non-traversable slopes or fixed objects will be removed, relocated, or shielded by a barrier if they are within the indicated minimum clear zone width and if it is cost-effective to do so.

FINANCIAL CONSIDERATIONS

The clear zone is not to be obtained at all costs. It is acknowledged that it will not be possible to achieve the suggested clear zones on all projects because of a variety of potential environmental and land use constraints. Variations from the clear zone guides will be documented.

Mailboxes (1 of 2)

DESCRIPTION AND DEFINITION

Provide breakaway mailbox supports for new installations, as part of rehabilitation projects, and when new homes and businesses apply for entrance culverts.

ROADWAY OPERATIONS

Installation of the swing-away design mailbox support has no effect on traffic operations. However, the swing-away design benefits snowplow operations by allowing more maneuverability of the snowplow with less chance of hitting the support and damaging the mailbox.

TYPICAL COSTS

Implementation Costs = $100 to $200 per mailbox support

SAFETY CHARACTERISTICS

A review of crash data for roadways in the State of Minnesota from 2001 to 2010 found an average of 85 crashes per year involving a mailbox support, with an average of 3 severe crashes per year.

The MN MUTCD requires that all roadside sign supports in clear zones be breakaway, yielding or shielded by a barrier or crash cushion. State Statute 169.072 considers any mailbox not meeting breakaway requirements to be a road hazard and gives agencies the ability to remove non-conforming mailboxes. A review of rural roadways in northern Minnesota shows that there is an equal chance of a vehicle leaving the road to hit a mailbox as there is to hit a roadway sign. A preliminary review of the number of signs and the number of mailboxes was conducted on three roadways (Itasca CH 35, TH 6, and Itasca CH 3). Over a total of 16 miles, there were 134 traffic signs and 135 mailboxes. The density of mailboxes was equal to the density of roadway signs. Having crashworthy mailbox supports should be as high of a priority as having crashworthy signs supports.

The MnDOT research has found that the swing-away mailbox assembly meets the requirements of the AASHTO ***Manual for Assessing Safety Hardware*** for breakaway support structure.

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- The design has been **PROVEN** crashworthy.
- From a crash perspective, using a breakaway mailbox design would be considered **TRIED**—no rigorous evaluations of the deployment were found in the literature.

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

Examples of candidate mailbox replacement opportunities are shown below. Steel tractor wheels, milk cans filled with concrete, chains, and massive I-beams are only a few of the devices used to support mailboxes. Agencies can develop a policy that replaces existing mailbox structures with the MnDOT Standard Swing-Away design during reconstruction, resurfacing, or new access permitting processes.

Examples of Unacceptable Installations

Mailboxes (2 of 2)

Examples of Acceptable Installations

DESIGN FEATURES

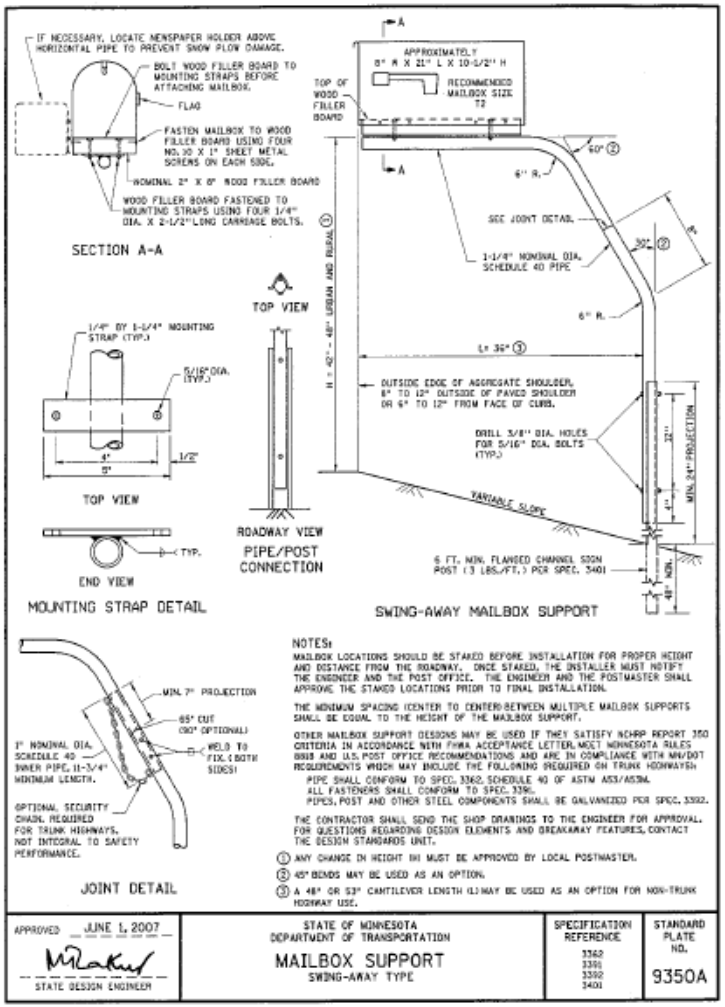
Mailbox supports should:

- Yield or collapse if struck
- Bend or fall away from the vehicle
- Not create severe deceleration
- Not be set in concrete
- Resist damage from snow removal operations
- Not be fitted with an anchor plate (metal post)
- Not block sight distance

MnDOT's Standard Plate 9350-A provides the design for the swing-away mailbox support that accomplishes these goals.

BEST PRACTICE

The important features of an approved, conforming mailbox design include the following: (1) the post located a minimum of 3 feet from the edge of the road shoulder, (2) the front of the mailbox located above the edge of the shoulder, (3) the bottom of the box at the proper height (normally 38 to 42 inches; check with the mail carrier), and (4) an installation that will pivot or rotate in some fashion when a snowplow hits the mailbox.



MnDOT's Standard Plate 9350A

SOURCES

MnDOT's Standard Plate 9350A

Crash Tests of Minnesota Mailbox Supports, LRRB 1981-08, Althea, A. and Ross, R., July 1981.

Urban Mailbox Installation Guidelines, Minnesota Local Road Research Board, Report MN/RC 2010MAIL, July 2010.

Is Your Mailbox a Hazard? Minnesota Local Road Research Board, Brochure, 2010.

Mailboxes Policy (1 of 2)

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

It is the goal of ***<Insert Agency>*** to provide public rights-of-way for the travelling public that are safe, efficient, and free of unnecessary hazards, while providing minimum inconvenience to property owners. Minnesota law declares certain mailbox installations to be a public nuisance, a road hazard, and a danger to the health and safety of the travelling public (Minnesota Rules Chapter 8818), and authorizes the road authority to remove and replace the nonconforming supports (Statute 169.072).

DEFINITIONS

The important features of an approved, conforming mailbox design for rural roadways include the following:

1. The post located a minimum of 3 feet from the edge of the road shoulder
2. The front of the mailbox located above the edge of the shoulder
3. The bottom of the box at the proper height (normally 38-inch minimum to 42-inch maximum—check with the mail carrier)
4. An installation that will pivot or rotate in some fashion when a snowplow hits the mailbox

POLICY

The ***<Insert Agency>*** will replace all nonconforming mailbox supports as part of a reconstruction/resurfacing project. The county/city will continue to monitor existing mailbox supports and notify owners of their noncompliance and offer installation of approved supports for a fee. Mailbox supports will be provided to landowners as part of the entrance permit process; all new developments will receive new mailbox supports.

POLICY CRITERIA

Replacement of Mailbox Supports under County Highway Improvement Program

<Insert Agency> will provide and install, at the county's expense, conforming mailbox supports within the limits of all ***<Insert Agency>*** highway reconstruction and highway resurfacing projects. The county/city is able to provide this service only on reconstruction/resurfacing projects since they are an eligible state aid expense and are therefore reimbursable.

Replacement of Unlawful Mailbox Supports and Installations

Any mailbox support deemed unlawful by the ***<Insert Agency>*** Highway Department, as defined by Minnesota Rules Chapter 8818, must be replaced. Once a support is deemed unlawful, the owner will be notified in writing that the owner must replace if within 60 days. As an incentive to use approved supports, the county/city provides the following options:

1. The owner may purchase the support from the county/city at the current rate, install it him- or herself, and remove the unlawful support.
2. The county/city will furnish and install an approved support for the fee currently in effect.

An unlawful support remaining after the expiration of the 60-day period will be removed and replaced by the county/city at the owner's expense—up to $75.00—to cover the costs incurred.

Mailboxes Policy (2 of 2)

Replacement of Damaged Mailbox Supports by Agency

The Highway Department will replace all lawful mailbox supports damaged by county/city equipment during snowplowing operations or other maintenance activities provided the support was properly installed according to U.S. Postal and ***<Insert Agency>*** Highway Department standards. The county/city will not replace supports damaged by third parties.

Mailbox Support Requirements—Access Permits

The ***<Insert Agency>*** Highway Department will require that all mailbox supports associated with the issuance of an access permit be constructed in accordance with the Department's specifications for lawful supports. The property owner will pay for the cost of the supports. The county/city will furnish and install an approved support for the fee currently in effect. The owner may opt to purchase the support from the county/city at the current rate, and install it him- or herself.

Miscellaneous Attachments to Mailbox Supports

Newspaper delivery boxes, advertisement delivery boxes, nameplates, address plates, etc., must not be installed underneath the mailbox, whether attached to the mailbox support or on a separate post. The area underneath the mailbox must remain free of obstructions in order to allow the unhindered passage of the snowplow wing blade. Obstacles interfering with the wing blade force the plow to swerve, often into the oncoming lane, creating an unsafe situation for motorists and plow operators.

Ownership of Mailbox Supports

Mailboxes and mailbox supports are the property of the mail route patron. *<Insert Agency>* does not issue written permits for the placement of mailboxes within the road right-of-way, nor does its easements provide for mailbox construction. All mailboxes placed within the road right-of-way are placed there at the owner's risk. Replacement or installation of mailbox supports by the county does not signify any change of ownership. The support remains the property of the owner, and it is the owner's responsibility to maintain to conformance standards.

Interruption of Mail Delivery

When the county/city must remove and replace a mailbox support, it must be done in such a manner as to cause no interruption of mail delivery, if at all possible.

Spacing of Mailbox Supports

In accordance with Minnesota Rules Chapter 8818, mailbox supports shall be spaced no closer than 30 inches.

Call Before You Dig (Gopher State One Call)

Forty-eight hours before installation of any new mailbox support, contact the Gopher State One Call for utility locates (1-800-252-1166).

FINANCIAL CONSIDERATIONS

The new mailbox supports that have been installed by ***<Insert Agency>*** become and remain the property of the owner upon completion of the installation. Maintenance of mailbox supports becomes the responsibility of the owner. Mailboxes are the owner's responsibility and must conform to U.S. Postal Service requirements.

Guardrail and End Treatments (1 of 2)

DESCRIPTION AND DEFINITION

Guardrail and end treatments are used to prevent vehicles from hitting fixed objects along the roadside and to minimize the severity of a road departure crash. The latest practice is to use modern hardware and current standards on guardrails and end treatments to reduce the severity of collisions with guardrail.

Current End Treatment

ROADWAY OPERATIONS

Implementing guardrail along a roadway does not affect traffic operations.

TYPICAL COSTS

Implementation Costs

- Impact attenuator = $2,500
- Guardrail terminal = $2,000
- Guardrail transition = $1,000
- W-Beam or cable guardrail = $45,000 to $110,000 per mile

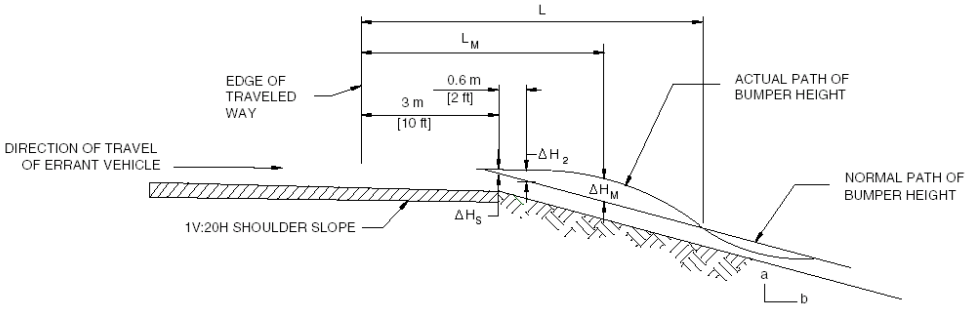
SAFETY CHARACTERISTICS

Guardrail itself is a roadside hazard and should only be placed when the roadside conditions pose a greater threat than the guardrail itself.

DESIGN FEATURES

Guardrail and end treatments come in a wide variety of designs for different applications; the design should match the application. Some key characteristics of guardrail that should be considered with design and implementing include the following:

- *Angle of Impact*—Guardrail is not meant to be hit head-on. It is intended to be hit at angles of less than 30 degrees by passenger cars and light trucks.
- *Deflection*—Vehicles hitting guardrail will be deflected; the plate beam has less deflection than cable guardrail.
- *Curbs*—If possible, guardrail should not be installed behind curbs. Even at modest speeds and shallow impact angles, curbs can cause vehicles to either vault over or dive under guardrail. If guardrail is placed behind a curb, it should be parallel to the curb and within 9 inches of the face of the curb.



L = Lateral distance where bumper height returns to normal height

L_M = Lateral distance when maximum bumper height occurs

ΔH_S = Height of bumper above normal height at outer edge of shoulder

ΔH_M = Maximum height of bumper above normal height

ΔH_2 = Height of bumper above normal height at 0.6 m [2 ft] from outer edge of shoulder

Design parameters for vehicle encroachments on embankments

Guardrail and End Treatments (2 of 2)

PROVEN, TRIED, INEFFECTIVE, OR EXPERIMENTAL

- The only three-star quality rated or higher guardrail study in the FHWA Crash Reduction Clearinghouse documented crash reductions in the range of 10 to 45 percent for the various crash severities.
- Providing guardrail along the roadside is considered a **TRIED** safety strategy.

TYPICAL CHARACTERISTICS OF CANDIDATE LOCATIONS

There is no analytical way of precisely determining whether the guardrail is needed in a given situation. Guidelines and methodologies have been developed but must be supplemented with engineering judgment.

Before guardrail is implemented, a prioritized approach should consider the following strategies before guardrail is installed:

1. ***Remove the object***—Completely remove the object that the guardrail was going to be constructed around (see Clear Zones).
2. ***Redesign the object***—Redesign the fixed object so it can be safely traversed.
3. ***Relocate the object***—Move the object to a point where it is less likely to be struck.
4. ***Do nothing***—Sometimes, adding guardrail only provides another hazard for a vehicle to hit.

Examples of Guardrail Creating a Greater Hazard than the Object

BEST PRACTICE

Guardrail is an obstacle and should only be considered when engineering judgment suggests that hitting the obstacle it protects would be worse.

SOURCES

AASHTO *Roadside Design Manual.*
Minnesota *State Aid Manual.*
MnDOT Guardrail Replacement and Maintenance Guidelines, Final Report #2010RIC13.

Guardrail and End Treatments Policy

POLICY PURPOSE/INTRODUCTION

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

DEFINITIONS

Three-strand cable guardrail—Three strands of cable are mounted on breakaway posts. Penetration of the vehicle is prevented by the tensile strength of the cable. Cable guardrail contains errant vehicle through the development of lateral forces, which gradually redirect the vehicle through the roadway.

W-beam guardrail—A W-beam is mounted on wood posts with blockouts. Upon impact, the posts break away and the tensile strength of the beam contains the vehicle.

POLICY

It is the policy of ***<Insert Agency>*** that installation of guardrail will be considered as part of new construction or reconstruction projects and not part of maintenance projects. Installation will be consistent with MnDOT and AASHTO guidelines; engineering judgment will be used for the location and type of guardrail installed.

POLICY CRITERIA

The following guidance should be used in the consideration of guardrail installation:

- Guardrail is an obstacle and should only be considered when judgment suggests that hitting the obstacle would be worse.
- If guardrail is placed behind a curb, it should be parallel to the curb and within 9 inches of the face of the curb.
- No curb configuration has good redirection characteristics at high speeds and large impact angles.
- Guardrail is a hazard and can cause serious injury.
- Guardrail is intended to be hit at angles of less than 30 degrees and by passenger cars and light trucks.
- The choice between plate beam or three-strand able guardrail is usually a function of dynamic deflection, with three-strand cable being preferred if there is room for deflection and no snow drifting issues.
- Check state aid rules; typically, guardrail is not required if the average daily traffic is less than 400 vehicles per day, but it may be used based on engineering judgment.
- If guardrail is used, the location must have standard end treatments and be maintained.
- Guardrail will not be used where speeds are less than 40 mph unless determined to be needed based on an engineering evaluation. Engineering judgment must be exercised in the application of the guidelines with regard to special hazardous locations.
- Based on MnDOT's Road Design Manual, if maintenance activities are being conducted along a roadway with twisted-end treatments and if it has fewer than 1,000 vehicles per day the guardrail is permitted to remain until a reconstruction project, as long as the in-place guardrail is not disturbed .

FINANCIAL CONSIDERATIONS

All guardrail is to be maintained. The amount of guardrail on ***<Insert Agency>***'s system should match the available funding for maintaining the guardrail. If funding is not available for maintenance, a review of existing guardrail and potential removal of guardrail should be considered based on engineering judgment.