

MINNESOTA'S BEST PRACTICES FOR
**Traffic Sign Maintenance/
Management Handbook**

Including Insight on How to Remove Unnecessary and Ineffective Signage

REPORT NO. 2010RIC10

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Document Information and Disclaimer:

- The information in this Best Practices guide is provided to assist agencies in their effort to better maintain the traffic signs on their system of roads and highways.
 - This Best Practices Guide does **not** set requirements or mandates.
 - This Best Practices Guide is **not** a best practice document for design or operations.
 - This Best Practices Guide contains **no** warrants or standards and does **not** supersede other publications that do.
 - This Best Practices Guide is a resource document and is intended to help transportation professionals develop a technically sound set of policies and practices to better maintain their system of traffic signs.
 - This Best Practices 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 Guide does not supersede publications such as the USDOT FHWA’s Manual on Uniform Traffic Control Devices (MUTCD); Association of American State Highway Transportation Officials’ (AASHTO) “Green Book” titled *A Policy on Geometric Design of Highways and Streets*; or other AASHTO and agency guidelines, manuals and policies.

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What's wrong with these pictures?
 (See page G-2 for answer.)

Part A - Background

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Minnesota Manual on Uniform Traffic Control Devices – Background



www.dot.state.mn.us/trafficeng/publ/mutcd/index.html

- 23 Code of Federal Regulations (CFR), Part 655.603 adopts the MUTCD as the national standard for any street, highway or bicycle trail open to the public.
- Section 15 of the Uniform Vehicle Code adopts the MUTCD as the standard of the conformance of signs, signals, markings and other devices intended to regulate, warn or guide traffic.
- The Commissioner of Transportation has adopted the MNMUTCD for all public roadways [and private roadways open to the public] in Minnesota (Commissioner Order No. 88522 – May 5th, 2005).
- MS 169.06 empowers the Commissioner and local road authorities to place and maintain traffic control devices on roadways within their jurisdiction, to regulate, warn, or guide traffic.

Yes, the MNMUTCD applies to your roads – it applies to all public roads and private roads open to the public in Minnesota

Minnesota Manual on Uniform Traffic Control Devices

AMENDED UNIFORM TRAFFIC CONTROL DEVICES MANUAL ORDER NO. 88522

WHEREAS, the United States of Department of Transportation, Federal Highway Administration (FHWA) has adopted and published a Manual on Uniform Traffic Control Devices, dated November 10, 2003) (herein referred to as the Federal MUTCD) including Revision No. 1 (Change List, dated November, 2004), and List of Known Errors (dated September 21, 2004).

WHEREAS, this Federal MUTCD has been approved by the Federal Highway Administrator as the National Standard for all highways open to public travel in accordance with Title 23, U.S.C. Sections 109(d), 315 and 402, and 49 C.F.R. Section 1.48; and

WHEREAS, the Minnesota Department of Transportation has amended the Federal MUTCD by adding Appendices and revising or adding text and figures to make provisions for Minnesota Statutes and department procedures; and

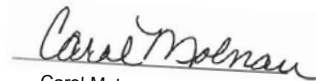
NOW, THEREFORE, pursuant to authority vested in my office and as provided in Minnesota Statutes, Section 169.06, subd. 1 (2004), I do hereby adopt and prescribe the following as the 2005 Minnesota Manual on Uniform Traffic Control Devices (referred to as the "2005 MN MUTCD"):

- I. United States Department of Transportation, Federal Highway Administration Manual on Uniform Traffic Control Devices, 2003 edition (dated November 10, 2003), including Revision No. 1 (Change List, dated November, 2004), and List of Known Errors (dated September 21, 2004).
- II. Minnesota Department of Transportation Appendices:
 - A. APPENDIX A1 - Congressional Legislation
 - B. APPENDIX A2 - Phase-in Compliance Periods
 - C. APPENDIX A3 - Retroreflective Sheeting Identification Guidelines
 - C. APPENDIX B - Warrants, Standards, and Guidelines for traffic Control Devices used at Senior Citizen and Handicapped Pedestrian Crossings
 - D. APPENDIX C - Sign Listings & Recommended Sizes
- III. State of Minnesota, Department of Transportation, additional sections, revisions, and corrections to the 2003 Federal MUTCD.

It is further ordered that the provisions of the 2005 MN MUTCD shall be implemented and applied to all traffic control devices installed on or after July 1, 2005 upon highways within this State except for those traffic control devices which conform to the 2001 edition of the MN MUTCD with its 2 revisions and are on order or under contract prior to July 1, 2005. All existing traffic control devices or installations not in conformance with standards in the 2005 MN MUTCD shall be changes to conform to the new standards herein when replacement occurs.

This Order supersedes Order No. 86252, dated April 15, 1992, which adopted and prescribed the 2001 Minnesota Manual on Uniform Traffic Control Devices along with Orders 87127, dated May 22, 2003, and Order 87570, dated January 2, 2004 which amended Order 86252.

Dated at St. Paul, Minnesota, this 5th day of May, 2005.



Carol Molnau
Lt. Governor/Commissioner

May, 2005

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Minnesota Manual on Uniform Traffic Control Devices



Old Guidelines

- The MNMUTCD previously recommended that agencies **should** establish a process to provide and maintain reasonable nighttime sign visibility and legibility.
- In addition to nighttime inspections, agencies **may** use the following methods:
 - Scheduled sign replacement
 - Inspection panels
 - Measured sign retroreflectivity
- There were no specified minimum levels of retroreflectivity



New Requirements

- In February 2008, language adopted in the MNMUTCD **requires** all agencies that maintain roadways open to public travel to adopt a sign maintenance program designed to maintain traffic sign retroreflectivity at specific levels.
- **All** agencies responsible for maintaining traffic signs are **required** to comply with the new MNMUTCD requirements.
- Public agencies or officials having jurisdiction **shall** use an assessment or management method that is designed to maintain sign retroreflectivity at or above the minimum levels in MNMUTCD Table 2A-3 (page A-4).

Reminder

- In the MNMUTCD words have very specific meanings:
 1. **STANDARD** - a statement of required practice and the verb **SHALL** is used.
 2. **GUIDANCE** - a statement of recommended practice with deviations allowed based on engineering judgement. The verb **SHOULD** is used.
 3. **OPTION** - a statement of practice that is permissive. The verb **MAY** is used.



Specified Levels of Retroreflectivity



Table 2A-3: Minimum Maintained Retroreflectivity Levels

Sign Color	Sheeting Type (ASTM D4956-04)				Additional Criteria
	Beaded Sheeting			Prismatic Sheeting	
	I	II	III		
White on Green	W*: G>7	W*:G>15	W*:G>25	W>250; G>25	Overhead Ground-Mounted
Black on Yellow or Black on Orange	Y*: O*		Y>50; O>50		2
White on Red	Y*: O*		Y>75; O>75		3
Black on White			W>35; R>7		4
			W>50		--

1) The minimum maintained retroreflectivity levels shown in this table are in units of cd/lx/m² measured at an observed angle of 0.2° and an entrance angle of -4.0°.

2) For text and fine symbol signs measuring at least 1200mm (48 in) and for all sizes of bold symbol signs.

3) For text and fine symbol signs measuring less than 1200mm (48in).

4) Minimum Sign Contrast ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity).

* This sheeting type should not be used for this color for this application.

Bold Symbol Signs		
<ul style="list-style-type: none"> W1-1, -2 -- Turn and Curve W1-3, -4 -- Reverse Turn and Curve W1-5 -- Winding Road W1-6, -7 -- Large Arrow W1-8 -- Chevron W1-10 -- Intersection in Curve W1-11 -- Hairpin Curve W1-15 -- 270 Degree Loop W2-1 -- Cross Road W2-2, -3 -- Side Road W2-4, -5 -- T and Y Intersection W2-6 -- Circular Intersection W3-1 -- Stop Ahead 	<ul style="list-style-type: none"> W3-2 -- Yield Ahead W3-3 -- Signal Ahead W4-1 -- Merge W4-2 -- Lane Ends W4-3 -- Added Lane W4-5 -- Entering Roadway Merge W4-6 -- Entering Roadway Added Lane W6-1, -2 -- Divided Highway Begins and Ends W6-3 -- Two-Way Traffic W10-1, -2, -3 -4, -11, -13 -- Highway-Railroad Advance Warning 	<ul style="list-style-type: none"> W11-2 -- Pedestrian Crossing W11-3 -- Deer Crossing W11-4 -- Cattle Crossing W11-5 -- Farm Equipment W11-6 -- Snowmobile Crossing W11-7 -- Equestrian Crossing W11-8 -- Fire Station W11-10 -- Truck Crossing W12-1 -- Double Arrow W16-5p, -6p, -7p -- Pointing Arrow Plaques W20-7a -- Flagger W21-1a -- Worker

Fine Symbol Signs - Symbol signs not listed as Bold Symbol Signs.

Special Cases
<ul style="list-style-type: none"> W3-1 -- Stop Ahead: Red retroreflectivity ≥ 7 W3-2 -- Yield Ahead: Red retroreflectivity ≥ 7; White retroreflectivity ≥ 35 W3-3 -- Signal Ahead: Red retroreflectivity ≥ 7; Green retroreflectivity ≥ 7 W3-5 -- Speed Reduction: White retroreflectivity ≥ 50 For non-diamond shaped signs such as W14-3 (No Passing Zone), W4-4p (Cross Traffic Does Not Stop), or W13-1, -2, -3, -5 (Speed Advisory Plaques, use largest sign dimension to determine proper minimum retroreflectivity level.

Source: MNMUTCD, May 2005

- The minimum retroreflectivity levels are in units of – Candelas / lux / meter² measured at an observation angle of 0.2° and an entrance angle of -4.0°.
- These minimum retroreflectivity levels apply to **ALL** signs, with the following exceptions:

- Parking, Standing and Stopping signs (R7 and R8 series)
- Walking/Hitchhiking/Crossing signs (R9 series, R10-1 through R10-4b)
- Adopt-A-Highway signs
- All signs with blue (motor services) or brown (recreational) backgrounds
- Bikeway signs that are intended for exclusive use by bicyclists or pedestrians



Which meet retroreflectivity requirements?

Retroreflective Sheeting Designations

Frequently Asked Questions about Sign Maintenance

- Can any type of sheeting material be used as long as it meets the minimum retroreflectivity levels?
 - Type I sheeting shall not be used for Warning, Guide or Work Zone signs. Type II and III should not be used on Overhead Guide signs. (Even brand new Type I, II, and III sheeting material is not bright enough to be used in these applications.)
 - Type I sheeting may be used for STOP signs and Black on White Regulatory signs.
 - Even though a particular type of sheeting may initially meet the minimum retroreflectivity levels when new, it might quickly degrade to below the specified threshold levels. The use of higher performance sheeting, even though it has a higher initial cost, usually provides a better life cycle cost.
- Is brighter always better for sign sheeting?
 - Usually. It is generally true that brighter signs are more conspicuous and legible. However, legibility is also a function of letter (or image) size—a good rule of thumb is 30 feet of legibility distance for each inch of letter height.
- When upgrading the sheeting material, do sign supports also need to be addressed?
 - Yes, all sign supports need to be crash worthy (see page E-13 for details)

ASTM Type	Previous Designation	Typical Application
I	Engineering Grade	Highway Signing, construction-zone devices and delineators
II	Super Engineering Grade	Highway Signing, construction-zone devices and delineators
III	High Intensity	Highway Signing, construction-zone devices and delineators
IV	High Intensity Prismatic	Highway Signing, construction-zone devices and delineators
V		Delineators
VI	Diamond Grade Flexibility Signs	Temporary roll-up signs, warning signs, traffic cone collars and post bands
VII	Long Distance Performance (LDP)	Highway Signing, construction-zone devices and delineators
VIII	MVP Prismatic	Highway Signing, construction-zone devices and delineators
IX	Visual Impact Performance (VIP)	Highway Signing, construction-zone devices and delineators
X	Crystal Grade	Highway Signing, construction-zone devices and delineators
XI	Diamond Grade (DG3)	Highway Signing, construction-zone devices and delineators

Comparison of Reflective Sheeting Material

Life Cycle Costs & Initial Retroreflectivity

Sheeting Material (ASTM)	Type I Engineering Grade	Type IV High Intensity Prismatic	Type IX Diamond Grade VIP	Type XI Diamond Grade DG3
Material Cost (\$/SF)	\$0.85	\$1.65	\$4.25	\$3.98
Finished Sign Cost	\$30	\$35	\$51	\$50
Anticipated Life (years)	5 – 7	10-12	15	20
Life Cycle Cost	\$130	\$70	\$119	\$50
Initial Retroreflectivity (white)	70	300	380	580

Source: 3M Traffic Safety Systems Division, April 2010

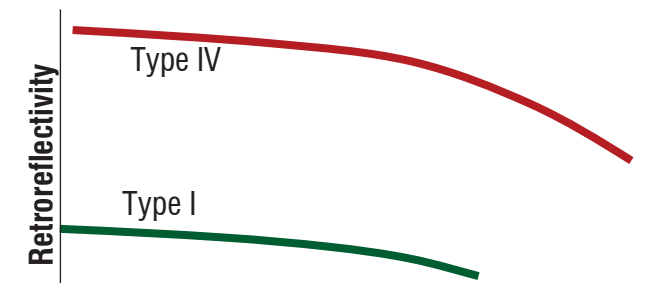
Typical Installation Cost

Stop (30x30)	\$240	\$250	\$260	\$260
Warning (36x36)	\$240	\$260	\$280	\$280
Regulatory (24x30)	\$230	\$240	\$250	\$250

Source: Mn/DOT

- A comparison of the types of reflective sheeting material suggests:
 - The low initial cost material would meet most of the minimum retroreflectivity levels but would be expected to degrade quickly below minimum levels.
 - The higher performance sheeting, initially more expensive, provides a much longer anticipated life, much higher levels of retroreflectivity and superior life cycle costs.
- The fairly narrow range of typical sign installation costs (sign blank + sheeting + posts + labor) suggests that agencies would pay a premium of between 5% to 15% for using higher performance sheeting.
- Additional installation cost information provided by a number of agencies indicates that quantity discounts could reduce the per sign cost by 20% to 30%.

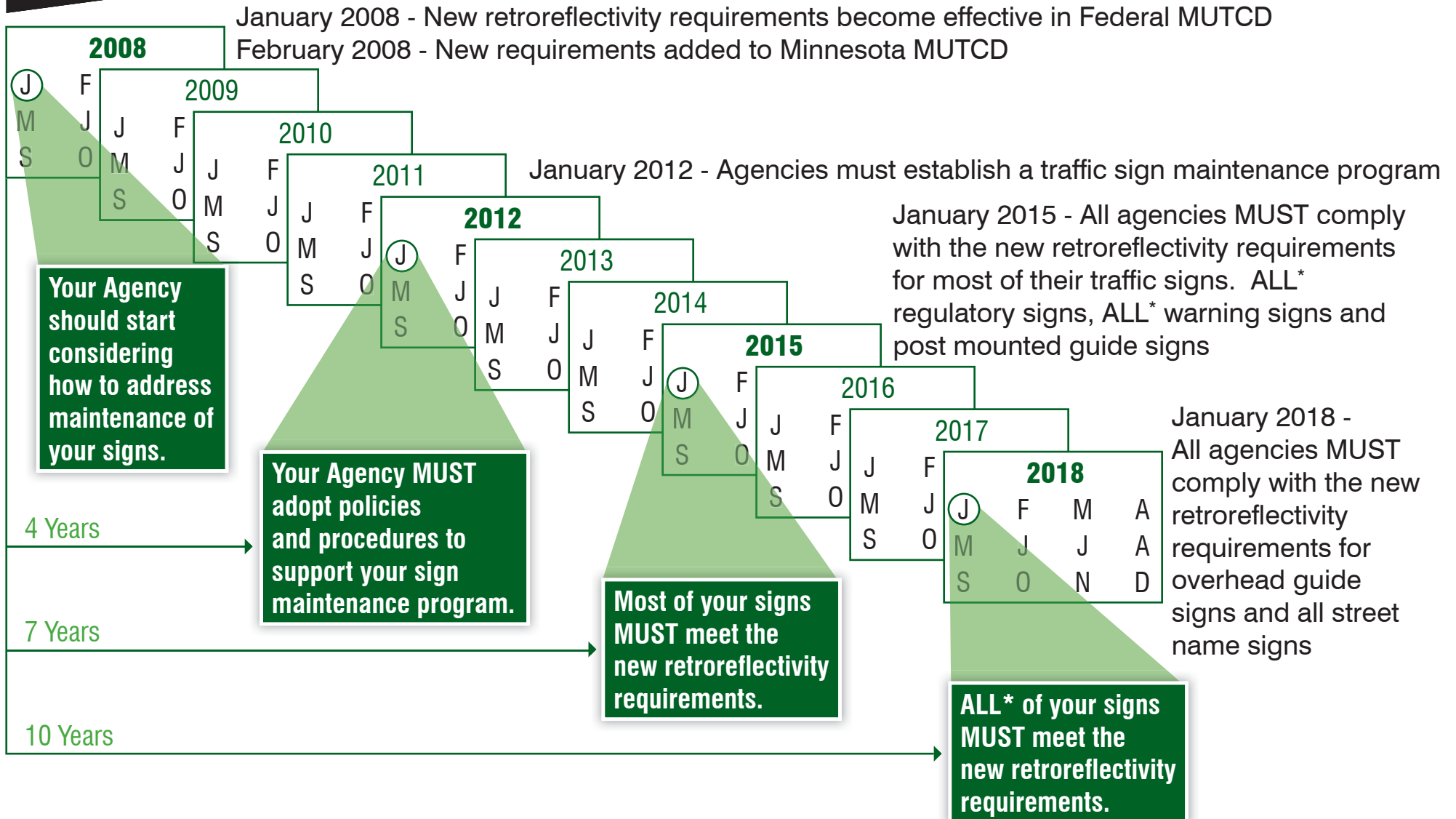
Degradation Curves



Note: Use this with caution, it represents a best guess. Research is underway to develop more reliable information about how retroreflectivity degrades overtime.

Source: FHWA Sign Retroreflectivity Guidebook, September 2009

Retroreflectivity Compliance Dates



*See Page A-4 for exceptions

Consequences for Non-Compliance



- There are no sign police in Minnesota to check to see if your agency is complying with MNMUTCD.
- However, the closer an agency's practices are to being consistent with the guidance in the MNMUTCD, the better the agency will be from a risk-management standpoint.
- In Minnesota the standard of care against which traffic professionals are measured is –what would a reasonable person have done under a given set of circumstances. In most cases the better answer is to have followed the guidance in the MNMUTCD.
- The new retroreflectivity requirements apply to **ALL*** signs – required, not required and even those unique signs that are not listed in the MNMUTCD.



What's wrong with this picture?
 (See page G-2 for answer.)

Part B – Maintenance Methods

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Maintenance Methods

Assessment

- Visual Nighttime Assessment
- Measured Sign Retroreflectivity



Management

- Expected Sign Life
- Blanket Replacement
- Control Signs



Combination or Other Methods

- Some examples include:
- Blanket Replacement & Expected Sign Life
 - Visual Nighttime Inspection & Control Signs
 - Other Methods documented in an Engineering Study

How Do I Decide?

■ What Are The Choices?

- Assessment Methods
 - Visual Nighttime Assessment
 - Calibration Signs Procedure
 - Comparison Panels Procedure
 - Consistent Parameters Procedure
 - Measured Sign Retroreflectivity
- Management Methods
 - Expected Sign Life
 - Blanket Replacement
 - Control Signs
- Combination or Other Methods
 - Blanket Replacement & Expected Sign Life
 - Visual Nighttime Inspection & Control Signs
 - Other Methods documented in an Engineering Study

Assessment Methods (1/2)

1. Visual Nighttime Assessment

This is an on-the-fly assessment of retroreflectivity made by trained inspectors during nighttime conditions. The inspection should be conducted at normal speed from the travel lane, using the low-beam headlights and at typical viewing distances (180 feet for street name blades, 300 feet for stop signs and up to 1,100 feet for symbol type warning signs based on a 30 feet per inch legibility distance). One or more of the following procedures should be used to support the visual nighttime inspections.

Calibration Signs Procedure

- An inspector views a calibration sign each time prior to conducting a nighttime field review. The calibration signs have known retroreflectivity levels at or above the specified minimums. The calibration signs are set up in a maintenance yard where the inspector can view the signs in a manner similar to nighttime field inspections. The inspector uses the visual appearance of the calibration sign to establish the evaluation threshold for that night's inspection activities.

¹ Inspectors must be trained. Training courses are available through many Local Technical Assistance Programs (LTAP); check <http://www.ltp2.org>



Comparison Panels Procedure

- This procedure involves assembling a set of comparison panels that represent retroreflectivity levels above the specified minimums. Inspectors then conduct a nighttime field review and when a marginal sign is found, a comparison panel is attached and the sign/panel combination is viewed. The signs found to be less bright than the panel would then be scheduled for replacement.

Consistent Parameters Procedure

- The nighttime inspections would be conducted under similar factors that were used in the research to develop the minimum retroreflectivity levels. These factors include:
 - Using a sport utility vehicle or pick-up truck to conduct the inspection.
 - Using a model year 2000 or newer vehicle for the inspection.
 - Using an inspector who is at least 60 years old with 20/20 vision (corrected).

Assessment Methods (2/2)



Source: FHWA Sign Retroreflectivity Guidebook, September 2009

2. Measured Sign Retroreflectivity

- The retroreflectivity of every sign in your system is measured with a retroreflectometer (approximate purchase price of \$10,000) and the results are compared to the threshold levels documented in Table 2A-3 of the MNMUTCD. Signs with actual retroreflectivity levels below the specified minimums would be scheduled for replacement.

Management Methods

1. Expected Sign Life

- When signs are installed, the installation date would be recorded so that the age of the sign is known. The age of the sign is compared to the expected sign life – based on the documented retroreflectivity degradation for a specific geographic area compared to the minimum levels. Signs older than the expected sign life would be scheduled for replacement.



Source: FHWA Sign Retroreflectivity Guidebook, September 2009

2. Blanket Replacement

- All signs in an area/corridor would be replaced at specified intervals. The replacement interval would be based on the expected sign life or warranty period. This method eliminates the need to assess retroreflectivity or track the life of individual signs. If the warranty period is 12 years, replacing 1/12 of the signs each year would demonstrate compliance with the specified minimum retroreflectivity levels.

3. Control Signs

- Replacement of signs in your system would be based on the performance of a small sample of control signs. For convenience and safety, the small sample of signs (all of the basic colors, oriented in the most adverse direction) would be located in a maintenance yard and these signs would then be monitored to determine when they are at the end of their retroreflective life. All field signs, represented by the control sample would then be replaced just before the control samples reach the minimum specified levels. New signs would have to be added to the control sample every year.

What Method is Best for Your Agency? (1/2)



Source: FHWA Sign Retroreflectivity Guidebook, September 2009

Assessment Methods (Visual Assessment, Measured Sign Retroreflectivity)

- Requires training and lots of staff hours on the road. Your inspectors will have to view every one of your signs in the field (at 20 signs/hour, 10,000 signs [typical county] ≈ 500 hours per year).
- May require the purchase of technology—a Retroflectometer or reflective sheeting samples—and an investment of training your staff.
- The primary advantage of using one of the Assessment Methods is that your agency will get the most years of service from each sign in your inventory as is practically possible.

Management Methods (Expected Sign Life, Blanket Replacement, Control Signs)

- Reduces staff time in the field versus possibly replacing some signs before they meet the minimum thresholds.
- It has been suggested that if you are concerned about replacing signs with some life left in the sheeting material, you could go through the effort of measuring for retroreflectivity of salvaged signs after they are delivered to your maintenance yard for use as replacements for signs damaged by vandalism or knockdowns.

Maintenance Methods	Types	Staff Hours	Technology	Service Life Lost From Each Sign
Assessment	Visual Nighttime Inspection	\$\$\$	\$\$\$	\$
	Measured Sign Retroreflectivity			
Management	Expected Sign Life	\$	\$	\$\$\$
	Blanket Replacement			
	Control Signs			

What Method is Best for Your Agency? (2/2)

So which Method is Best?

- No one can tell you which method is best. FHWA's Sign Retroreflectivity Guidebook can provide some assistance, but you know the characteristics of your system and your organization better than anyone else. Think about three primary factors:
 - Inventory
 - If the number of signs on your system is small (<500), conducting an annual inspection would be relatively easy.
 - If the number of signs on your system is large (>10,000), conducting an annual inspection could require 500 or more staff hours per year; so you should consider one of the management methods.
 - Staff
 - If your professional staff is trained and has experience conducting nighttime inspections, it would be easy to continue.
 - If you don't have trained staff, the choices would include adding staff and training them or using one of the management methods.
 - Technology
 - If you already own or are willing to purchase a retroreflectometer (\$10,000) or a kit with samples of sheeting material at the thresholds (the kit is currently under development - check Mn/DOT State Aid website for further information), the measurement method may be best.
 - If you are not willing to make these investments, the visual assessment or one of the management methods would be a better choice.



http://safety.fhwa.dot.gov/roadway_dept/night_visib/retrotoolkit/

Make a decision, move forward, evaluate, and make changes if you have to.



What's wrong with this picture?
 (See page G-2 for answer.)

Part C – Financial Budgeting

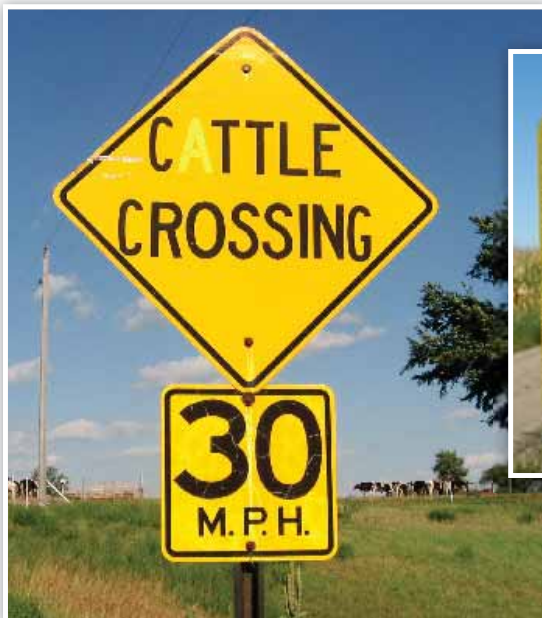
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Financial Budgeting

OK, I get it – the new retroreflectivity requirements apply to my agency! How much is it going to cost to comply?

That depends...

- Number of signs in your inventory
- Selected replacement schedule and method
- Estimated annual cost to address vandalism and knockdowns



Financial Budgeting – Townships (1/3)

- A typical Township has approximately 30 miles of roadway with an average of 6 total traffic signs per mile (both directions).
- A recent Township signing pilot project¹ documented an average cost for sign replacement to be \$150 per sign.*
- The total cost to upgrade/replace regulatory and warning signs in a typical Township would be:

30 miles  **x 6 signs/mile**  **x \$150/sign = \$27,000**

Annual Replacement Cost
 100% of signs = \$5,400
 75% of signs = \$4,050

- All** Regulatory, Warning and Ground Mounted Guide signs must meet retroreflectivity requirements by January 2015.
- The rest of your signs (Overhead Guide And Street Names) must meet the retroreflectivity requirements by January 2018.
- If you have to replace 100% of your signs the annual cost would be \$5,400. But if you only had to replace 75% of your signs, the cost would be \$4,050 per year.
- A strategy to consider in an effort to reduce your costs – **reduce your inventory of signs.**



¹ Mn/DOT Township Sign Inventory and Replacement Pilot Program

* Replacement costs include sign blank, sheeting material, sign posts, and installation.

** See A-4 for exceptions

Constant 2010 \$

Financial Budgeting – Townships (2/3)

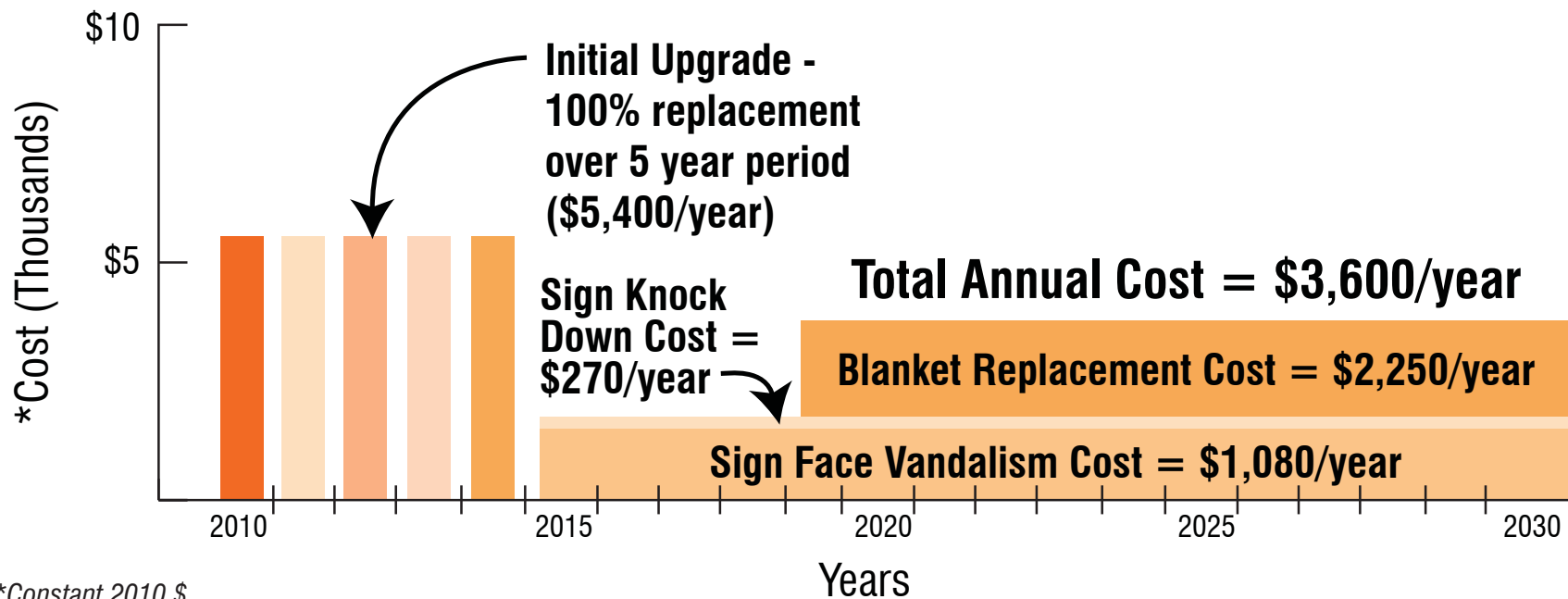
- A typical Minnesota Township has 30 miles of roadway at a density of 6 total traffic signs per mile (both directions).
- If the typical Township decided to replace their regulatory and warning signs and began in 2010, they would have to spend \$5,400 per year over the 5 year period 2010 to 2015.
- After the initial investment in upgrading your signs, you also need to consider Annual Maintenance and beginning the on-going replacement of signs to address maintaining minimum levels of retroreflectivity.
- Annual maintenance consists of:
 - Replacing sign faces that have been damaged by vandalism (paint balls and fire arms) and mother nature (tree sap, water damage, and the sun)
 - Repairing knock downs
 - A report prepared by North Carolina State University¹ found that approximately 4% of signs along the rural secondary system sustained damage to sign faces that required replacement
 - In the typical Minnesota Township, this sign face damage results in annual costs of 30 miles per Township x 6 signs per mile x \$150 per sign x 4% = \$1,080 per year
 - No estimate of sign knockdowns has been determined, but a conservative estimate would be 1%. At this rate repairing knock downs would also cost approximately \$270 per year



¹ Harris, *Road Sign Deterioration and Management*, North Carolina State University, 2006
Constant 2010 \$

Financial Budgeting – Townships (3/3)

- If the typical Minnesota Township selects the blanket replacement method and planned to replace 1/12 of the signs each year (based on the 12 year warranty period for sheeting material) the annual cost would be: 30 miles per Township x 6 signs per mile x \$150 per sign x 1/12 = \$2,250 per year.
- If you are interested in reducing your sign maintenance costs – consider reducing the number of signs in your inventory. (See Part D)



Financial Budgeting – Cities under 5,000 Population (1/3)

- A typical small city has approximately 50 miles of streets with an average of 25 regulatory and warning signs per mile plus 6 guide signs per mile (both directions).
- A typical cost for replacing the regulatory and warning signs is \$200 per sign* and \$250 per sign* for the guide (street name) signs.
- The total cost to upgrade/replace ALL of the signs in a typical small city would be:

50 miles  **x**

25 signs/mile   x \$200/sign	}	= \$325,000		100% of signs = \$65,000
6 signs/mile  x \$250/sign				75% of signs = \$49,000

Annual Replacement Cost

- All** Regulatory, Warning and Ground Mounted Guide signs must meet retroreflectivity requirements by January 2015.
- The rest of your signs (Overhead Guide and Street Names) must meet the retroreflectivity requirements by January 2018.
- If you have to replace 100% of your signs the annual cost would be as high as \$65,000. But if you only have to replace 75% of your signs, the cost would be \$49,000 per year.
- Consider reducing your inventory of signs.



* Replacement costs include sign blank, sheeting material, sign posts, and installation.
 ** See A-4 for exceptions
 Constant 2010 \$

Financial Budgeting – Cities under 5,000 Population (2/3)

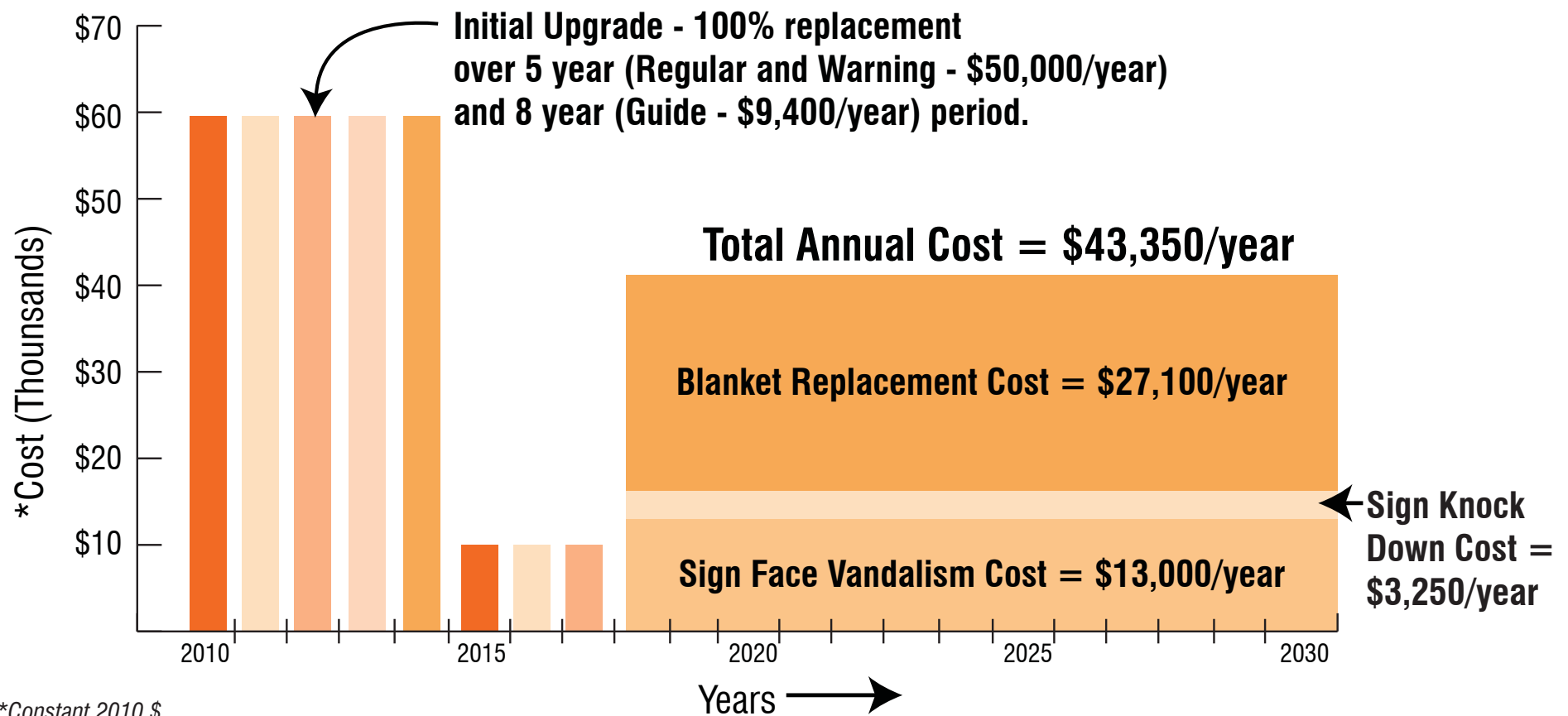
- After the initial investment in upgrading your signs, you also need to consider Annual Maintenance and beginning the on-going replacement of signs to address maintaining minimum levels of retroreflectivity.
- Annual maintenance consists of:
 - Replacing sign faces that have been damaged by vandalism (paint balls, etc) and mother nature (tree sap, water damage, the sun)
 - Repairing knock downs
 - The North Carolina State University¹ report found that approximately 4% of sign faces sustained damage that required replacement
 - In the typical small city this sign face damage results in annual costs of
 - 50 miles x 25 (Reg. & Warning) signs per mile x \$200 per sign x 4% = \$10,000
 - + 50 miles x 6 (Guide) signs per mile x \$250 per sign x 4% = \$3,000
 - \$13,000 per year
 - No estimate of sign knockdowns has been determined, but a conservative estimate would be 1%. At this rate repairing knock downs would cost approximately \$3,250 per year



¹ Harris, *Road Sign Deterioration and Management*, North Carolina State University, 2006
Constant 2010 \$

Financial Budgeting – Cities under 5,000 Population (3/3)

- If the typical small city selects the blanket replacement method and planned to replace 1/12 of the signs each year, the annual cost would be approximately \$27,100.
- If you are interested in reducing your sign maintenance costs - consider reducing the number of signs in your inventory. (See Part D)



*Constant 2010 \$

Financial Budgeting – Cities over 5,000 Population (1/3)

- A typical large city has approximately 200 miles of city streets with an average of 25 regulatory and warning signs per mile plus 6 guide signs per mile (both directions).
- A typical cost for replacing the regulatory and warning signs is \$200 per sign* and \$250 per sign* for the guide (street name) signs.
- The total cost to upgrade/replace ALL of the signs in a typical large city would be:

200 miles  x **25 signs/mile**   x \$200/sign = \$1,300,000

x **6 signs/mile**  x \$250/sign = \$1,950,000

Annual Replacement Cost
 100% of signs = \$260,000
 75% of signs = \$195,000

- All** Regulatory, Warning and Ground Mounted Guide signs must meet retroreflectivity requirements by January 2015.
- The rest of your signs (Overhead Guide and Street Names) must meet the retroreflectivity requirements by January 2018.
- If you have to replace 100% of your signs the annual cost would be as high as \$260,000. But if you only had to replace 75% of your signs, the cost would be \$195,000 per year.
- **Consider reducing your inventory of signs**



* Replacement costs include sign blank, sheeting material, sign posts, and installation.
 ** See A-4 for exceptions
 Constant 2010 \$

Financial Budgeting – Cities over 5,000 Population (2/3)

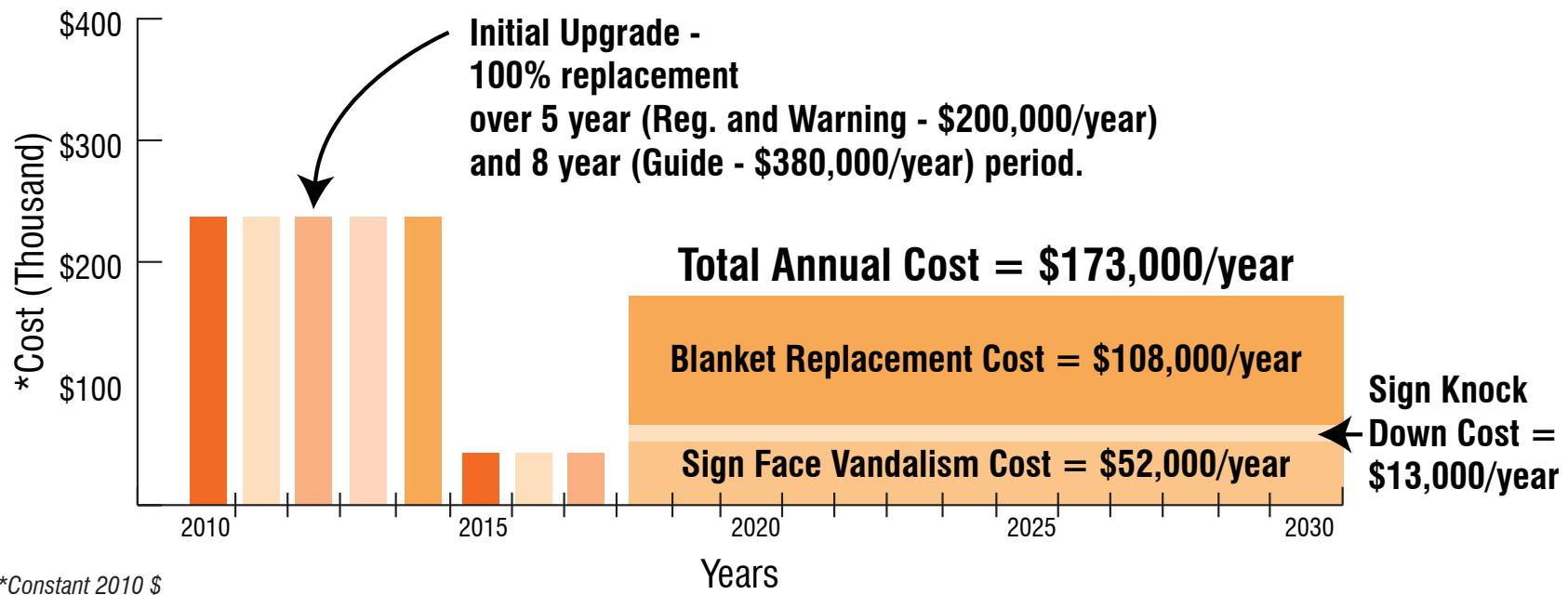
- After the initial investment in upgrading your signs, you also need to consider Annual Maintenance and beginning the ongoing replacement of signs to address maintaining minimum levels of retroreflectivity.
- Annual maintenance consists of:
 - Replacing sign faces that have been damaged by vandalism (paint balls, etc) and mother nature (tree sap, water damage, the sun)
 - Repairing knock downs
 - The North Carolina State University¹ report found that approximately 4% of sign faces sustained damage that required replacement
 - In the typical large city this sign face damage results in annual costs of
200 miles x 25 (Reg. & Warning) signs per mile x \$200 per sign x 4% = \$40,000
+ 200 miles x 6 (Guide) signs per mile x \$250 per sign x 4% = \$12,000
\$52,000 per year
 - No estimate of sign knockdowns has been determined, but a conservative estimate would be 1%. At this rate repairing knock downs would also cost approximately \$13,000 per year



¹ Harris, *Road Sign Deterioration and Management*, North Carolina State University, 2006
Constant 2010 \$

Financial Budgeting – Cities over 5,000 Population (3/3)

- If the typical large city selects the blanket replacement method and planned to replace 1/12 of the signs each year, the annual cost would be approximately \$108,000.
- If you are interested in your sign maintenance costs – consider reducing the number of signs in your inventory.



Financial Budgeting – Counties (1/3)

- A typical county highway system consists of approximately 500 miles of rural roadways with an average of 20 traffic signs per mile (both directions).
- A typical sign replacement cost is \$200 per sign*.
- The total cost to upgrade/replace signs in a typical County would be:

Annual Replacement Cost

500 miles  x 20 signs/mile  x \$200/sign = \$2,000,000

100% of signs = \$400,000
 75% of signs = \$300,000

- All** Regulatory, Warning and Ground Mounted Guide signs must meet retroreflectivity requirements by January 2015.
- The rest of your signs (Overhead Guide and Street Names) must meet the retroreflectivity requirements by January 2018. If you have to replace 100% of your signs, the annual cost would be \$400,000 per year.
- But if you only have to replace 75% of your signs, the cost would be \$300,000 per year.
- Another strategy to consider in an effort to reduce your costs – reduce your inventory of signs.



* Replacement costs include sign blank, sheeting material, sign posts, and installation.
 ** See A-4 for exceptions
 Constant 2010 \$

Financial Budgeting – Counties (2/3)

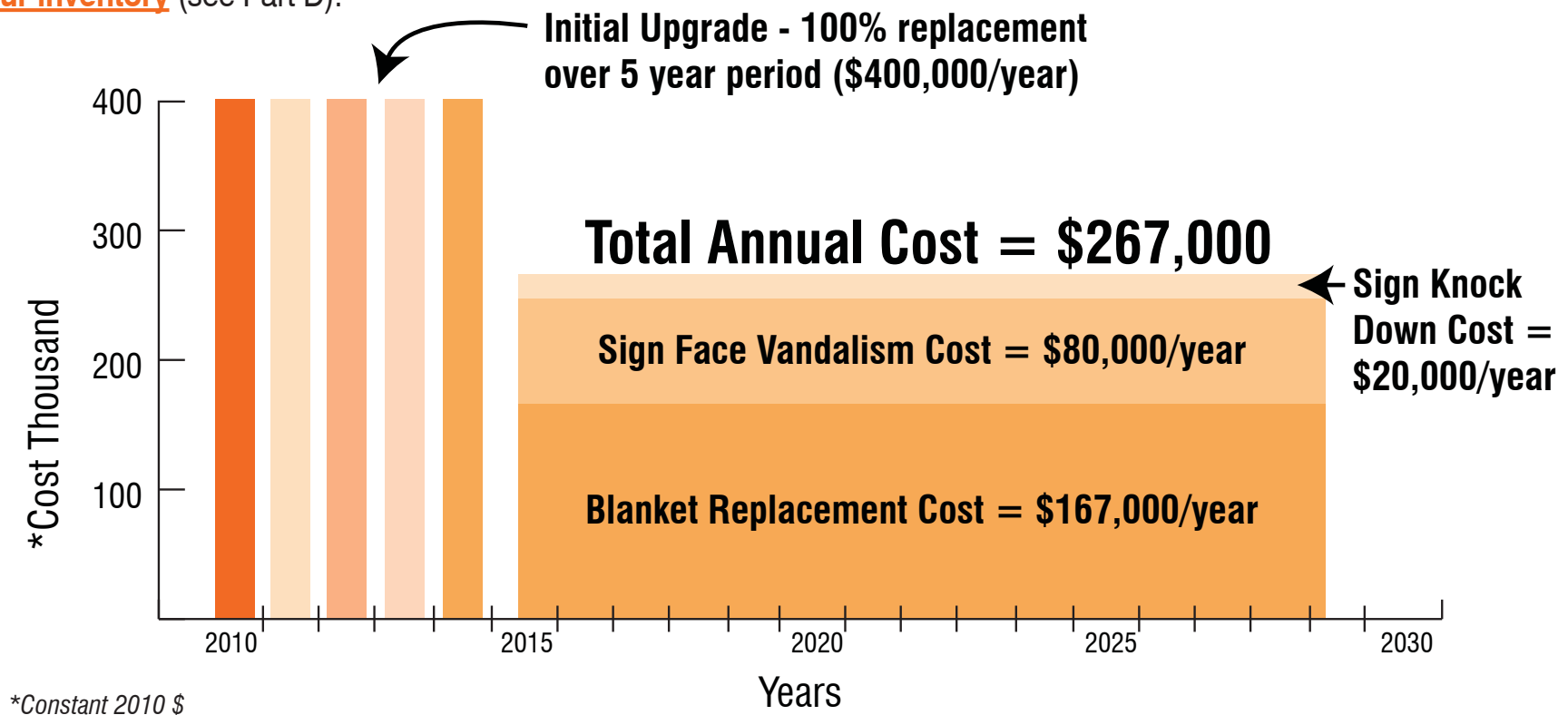
- A typical Minnesota County has 500 miles of roadway and a sign density of 20 traffic signs per mile.
- It was previously determined that if the typical county decided to replace all of their signs and began in 2010, they would have to spend \$400,000 per year over the 5 year period 2010 to 2015.
- However, after your initial investment you also need to consider annual maintenance and beginning the on-going replacement of signs to address maintaining minimum levels of retroreflectivity.
- Annual maintenance consists of:
 - Replacing sign faces that have been damaged by vandalism (paint balls & fire arms), or good old Mother Nature (tree sap & water damage).
 - Repairing knock downs
 - A report prepared by North Carolina State University¹ found that approximately 4% of signs along their rural secondary system sustained damage to sign faces that required replacement.
 - In the typical Minnesota County, this sign face damage results in annual costs of:
 $500 \text{ Miles} \times 20 \text{ Signs/Mile} \times \$200/\text{Sign} \times 4\% = \$80,000/\text{year}$
 - Based on an inventory of signs replaced in Sibley County, it is estimated that approximately 1% of signs sustained damages from knockdowns.
 - In the typical Minnesota County, repairing sign knock downs results in annual costs of:
 $500 \text{ Miles} \times 20 \text{ Signs/Mile} \times \$200/\text{Sign} \times 1\% = \$20,000/\text{year}$



¹ Harris, Road Sign Deterioration and Management, North Carolina State University, 2006
Constant 2010 \$

Financial Budgeting – Counties (3/3)

- If the typical Minnesota County chose the blanket replacement method and planned to replace 1/12 of the signs each year (based on 12 year warranty period), the annual cost would be:
 $500 \text{ Miles} \times 20 \text{ Signs/Mile} \times \$200/\text{Sign} \times 1/12 = \$167,000/\text{year}$
- If you are interested in reducing your sign maintenance costs – consider reducing the number of signs in your inventory (see Part D).



Financial Budgeting – Summary



- You probably found these suggested levels of investments necessary to maintain your inventory of signs as shocking as we did.
- These levels are likely to be 10 to 20 times more than you have previously spent.
- Please don't walk away from this issue and either do nothing or merely continue on with your previous levels of replacement – from a risk management perspective, the stakes are too high.
- The only part of the cost formula that you can control is the size of your inventory.
- It appears that the best way to reduce your sign maintenance costs is to reduce the size of your inventory and that will require removing some signs.
- It also appears that the best way to manage your risk when removing signs is to bring your actions under two umbrella's of immunity (from liability)
 - Discretionary Immunity - policy driven
 - Official Immunity - exercise of engineering judgement
- Intrigued? Please continue...



What's wrong with this picture?
 (See page G-2 for answer.)

Part D – Policy Development

Policy Development.....	D-1	Example Signing Policy – City of Eagan, MN.....	D-5
Example Policy Outline – Sign Maintenance	D-2	Example Signing Policy – Rural County.....	D-6
Model Sign Maintenance Policy	D-3	Case Study #1: Monnens vs. City of Orono.....	D-7 to D-9
Example Policy Outline – Snow Plowing.....	D-4		

Policy Development

- **Guides maintenance and inspection efforts**
 - **Provides direction/information to staff**
 - **Establishes procedures**
 - **Sets priorities**
 - **Supports Statutory Discretionary Immunity**
- The League of Minnesota cities encourages their members to develop and adopt a variety of policies relative to municipal maintenance activities.
 - The League cites five specific benefits associated with policy development:
 1. Guiding allocation of resources
 2. Provide direction to staff
 3. Establish the procedures to be followed
 4. Sets priorities
 5. Supports establishing discretionary immunity
 - The League has developed a number of model policies – check out: www.lmc.org
 - One caution – work with your agency’s attorney when developing a policy.



Example Policy Outline – Sign Maintenance

- Introduction
- Adopted Maintenance Method
- Recurring Schedule
- Field Inventory
- Classification of Roads to be Included
- Sign Removal/Sign Retention
- Financial Considerations
- ...
- ...
- ...
- ...
- Deviation from Policy
- Review and Modification of Policy

STAY TUNED - The League of Minnesota Cities has recently undertaken a process to prepare a sample policy for sign maintenance.

**Please check their website:
www.lmc.org**

The Minnesota Association of Townships is another resource for policy information.

**Please check their website:
www.mntownships.org**

Model Sign Maintenance Policy

- Which sign maintenance method is adopted?
(Blanket Replacement - replace 1/12 of signs/year)
- Which **Roads** are to be covered by the policy?
 - All
 - Low Volume
 - Roadway Classifications
 - Residential
 - Collector
 - Minor Arterial
 - Principal Arterial
- Which **Signs** are to be covered by the policy?
 - All
 - Regulatory
 - Warning
 - Guide
 - All signs must conform to MNMUTCD
- What is the **Objective** of the policy?
 - Document the maintenance method
 - Exclude certain types of signs from usage (Not Required, Not Effective, i.e, No warning signs on residential streets, speed limit signs only on collectors and arterials, no marked pedestrian crossings at uncontrolled intersections, etc.)
- What **Actions** are required to implement the policy?
 - Inventory
 - Sign Replacement
 - Sign Removal
 - Engineering Study
 - Notification of Decisions/Actions
 - Sign Sheeting Material
 - Establish Budget

The following pages provide examples of a snow plowing policy, signing policy for the City of Eagan and a signing policy for a rural county. Additional examples can be found in the appendix.

Example Policy Outline – Snow Plowing

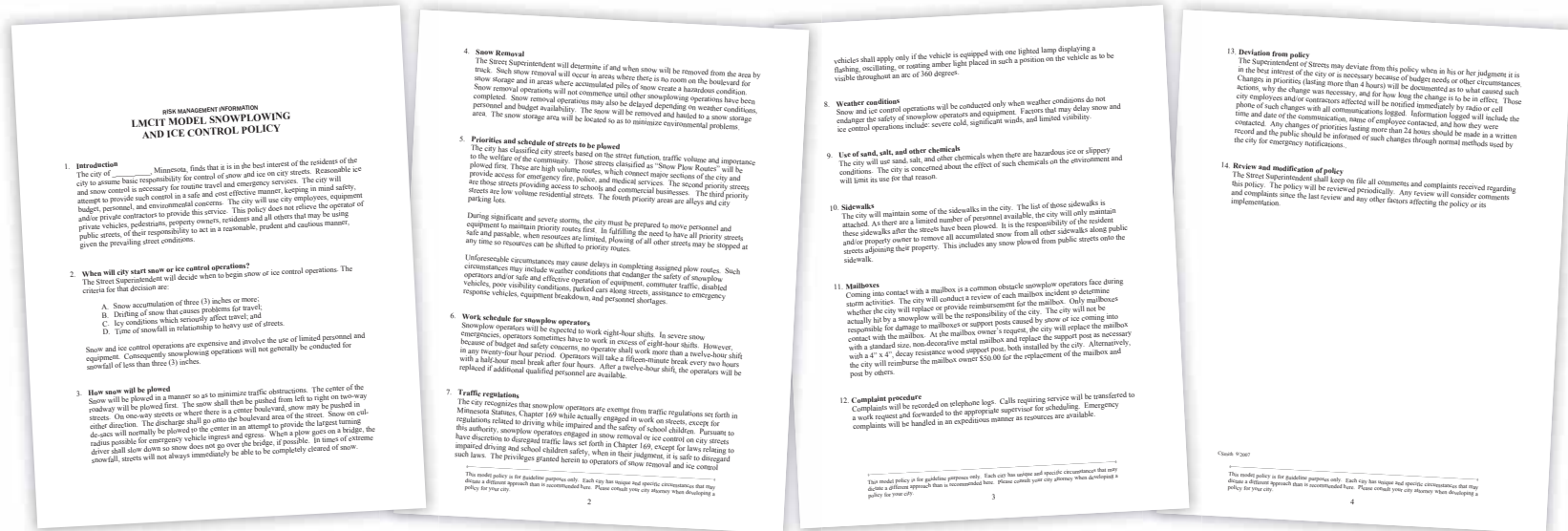


Example Snowplow Policy Outline

- Introduction
- When will city start snow or ice control operations?
- How will snow be plowed?
- Snow Removal
- Priorities and schedule for which streets will be plowed
- Work schedule for snowplow operators

- Weather conditions
- Use of sand, salt, and other chemicals
- Sidewalks
- Deviation from Policy
- Review and modification of Policy

NOTE: The League of Minnesota Cities Snow Plowing Policy is included because a “best practice” sign maintenance policy has not been developed and because it provides an example of a policy generated through the League’s process.



Example Signing Policy – City of Eagan, MN

City of Eagan, MN



Signs, Traffic Signals, Traffic Markings, Pavement Striping & Retro-reflectivity Policy

March, 2010

IV. SIGN MAINTENANCE

Sign Maintenance

- A. Sign Installation: Signs will be installed and maintained to meet federal standards set forth in the most recent Minnesota Manual on Uniform Traffic Control Devices (MnMUTCD) in accordance to City of Eagan guidelines, standard installation plate and practices.
- B. Maintain Signing, Overall Responsibility: Eagan sign maintenance practices are established to meet all requirements and ensure appropriate signing for the traveling public.
- C. Sign Retro-Reflectivity: The City of Eagan has maintained a field sign inventory database in the form of a sign management system (software) since 1993. The city is currently analyzing the database to determine the best approach to meet Federal Sign Retro-reflectivity Standards.
 1. The City of Eagan will use a combination of EXPECTED SIGN LIFE and CONTROL SIGNS as management methods.
 - a. CONTROL SIGNS
 - i. Evaluation of retro-reflectivity of city signs will continue on a 2 year cycle as it has to date (1/2 of city signs each year).
 - ii. As per Federal directives, a group of "calibration signs" will be assembled to represent a sample of each color that is known to have retro-reflectivity levels at or above minimum levels. The signs will be set up so that above minimum levels. The signs will be set up so that the sign technician can view the calibrations signs in a manner similar to nighttime field inspection conditions. The technician will use the visual appearance of the calibration signs to establish the evaluation threshold for that night's inspection activities.
 1. Calibration sign samples are needed for each color of sign in Table 2A-3 (MUTCD Manual)
 2. Calibration signs are viewed at a typical distance using the inspection vehicle. (SUV or standard P/U with low beam head lights)
 3. Calibration signs will be stored appropriately to prevent deterioration.
 4. Calibration signs retro-reflectivity will be verified periodically.
 - iii. A group of small portable samples known to have retro-reflectivity levels at or above minimum levels will be assembled to be used to assess signs that have questionable retro-reflectivity. When the visual inspection identifies questionable signs, a comparison sample may be attached to the sign and viewed as a comparison by the technician.

b. EXPECTED SIGN LIFE

- i. Expected sign life processes/practices will be established utilizing a combination of expected sheeting warranty life estimations of manufacturers/suppliers and "on the ground" experience in the field at the city. The city will develop and update as needed general criteria for life cycle replacement of signs in companion with calibration review and nighttime sign examinations.
 1. The city began installing 3M High Intensity Prismatic (HIP) sheeting signs in 2002 and migrated to 3M Diamond Grade 3 (DG3) sheeting in 2006. A system wide evaluation will occur identifying all signs that are not scheduled for replacement between now and Jan 2015. Following review and planning, the city will implement a program to replace all signs having insufficient sheeting properties (engineer grade) incrementally between now and Jan. 2015 to meet the new Fed retro-reflectivity standards. Additional planning (and implementation of plan) will occur to assure compliance for the Jan 2018 deadline at the same time.
 2. The city will plan for (budget for) replacement of all signs found via the control section/night sign checking process. The eventual goal will be that the majority of retro-reflectivity related sign replacement will be handled through the expected life cycle/sign life process.

D. Sign Maintenance Responsibility: Maintain signs and street identification signs on all City of Eagan roadways (specific agency name) highways, with the exception of:

- a. Signage on approaches to county highways are not installed or maintained by the city. Street name signs and stop signs intersecting with Dakota County Highways are maintained by Dakota county.
- b. Stop signs at Minnesota Department of Transportation (MnDOT) controlled intersections and highway ramps with state/county highways.
- c. Specific signs installed by others (Mn/DOT, transit agencies, and private signs as agreed upon by the City of Eagan.
- d. Signs along county highways, within Mn/DOT right of way, unless specific agreement with Mn/DOT/Dakota County stipulates a city maintenance responsibility for signing.
- e. Bike path and other pedestrian-control signs not pertaining to vehicle traffic installed by government entities other than the city.
- f. Signs on approaches to city streets installed by private business and/or property owners.

- E. Response to Incident Report for Sign Repair Needs: Sign maintenance staff will respond after receiving notice of a repair need to determine appropriate action with the following priorities:
 - a. Stop sign: as soon as practical, no later than one business day, a temporary stop sign will be placed if required.
 - b. Other regulatory signs: no later than three business days.
 - c. Warning signs: within one scheduled workday.
 - d. Informational/guidance signs: as soon as scheduling/delivery permits

- F. Sign replacement resulting from field inspections:
 - a. 3 year cycle review (1/3 each year)
 - b. Night retro-reflectivity sign check:
 - i. Written documentation of the location, sign type, size and reason for sign replacement will be recorded (into database) for each sign that is not in an acceptable condition and needs replacement.
 - ii. Sign replacement will occur as follows:
 1. Stop signs – as soon as scheduling permits
 2. All other signs – concurrent with neighborhood refurbishing replacement schedules or as determined by sign technician.

- G. Miscellaneous Sign Practices:
 - a. Sign staff is not directly on-call after normal working hours. After hours phone numbers for maintenance managers are available to Public Safety dispatchers so staff can be contacted in case of an emergency.
 - b. Training is provided to ensure traffic staff can perform sign maintenance duties in an efficient, effective and responsive manner. Such training shall consist of, at a minimum, appropriate signing and traffic control seminars (when available and funds are available in the city training budget), appropriate available training videos or website trainings, and training as appropriate and available for supervisors.
 - c. Unauthorized signs will be removed from city rights of way, maintenance operations (e.g., schedules and other priority needs or equipment failures) to ensure accurate information is available to respond to telephone inquiries.
 - d. Sign staff may park a sign maintenance vehicle against traffic flow in order to perform necessary emergency and routine maintenance duties.
 - e. Sign staff may drive or park maintenance vehicles on the center medians or boulevards in order to perform necessary emergency and routine maintenance duties.
 - f. Sign staff may drive or park maintenance vehicles on the center medians or boulevards in order to perform necessary emergency and routine maintenance duties.

V. TRAFFIC SIGNALS Traffic Signals

- A. Miscellaneous Signal Practices:
 - a. City maintenance staff (Streets Engineering Technician) will respond to reports of signal damage or malfunctions as soon as possible after

Example Signing Policy – Rural County

The _____ County Highway Department will complete a daytime inspection, twice a year, for traffic signs along the county roads, and complete E-911 daytime inspection once a year. In the process of “Maintaining Traffic Retroreflectivity” the County will use the Expected Sign life method and replace the traffic sign as follows:

Material Grade	From Installation
Engineering	8 Years
HI or HIP	10 Years (South Facing)
	11 Years (East/West Facing)
	12 Years (North Facing)
VIP or DG3	10 Years (South Facing)
	11 Years (East/West Facing)
	12 Years (North Facing)
E-911 Signing (HIP)	12 Years
E-911 Signing (DG3)	15 Years

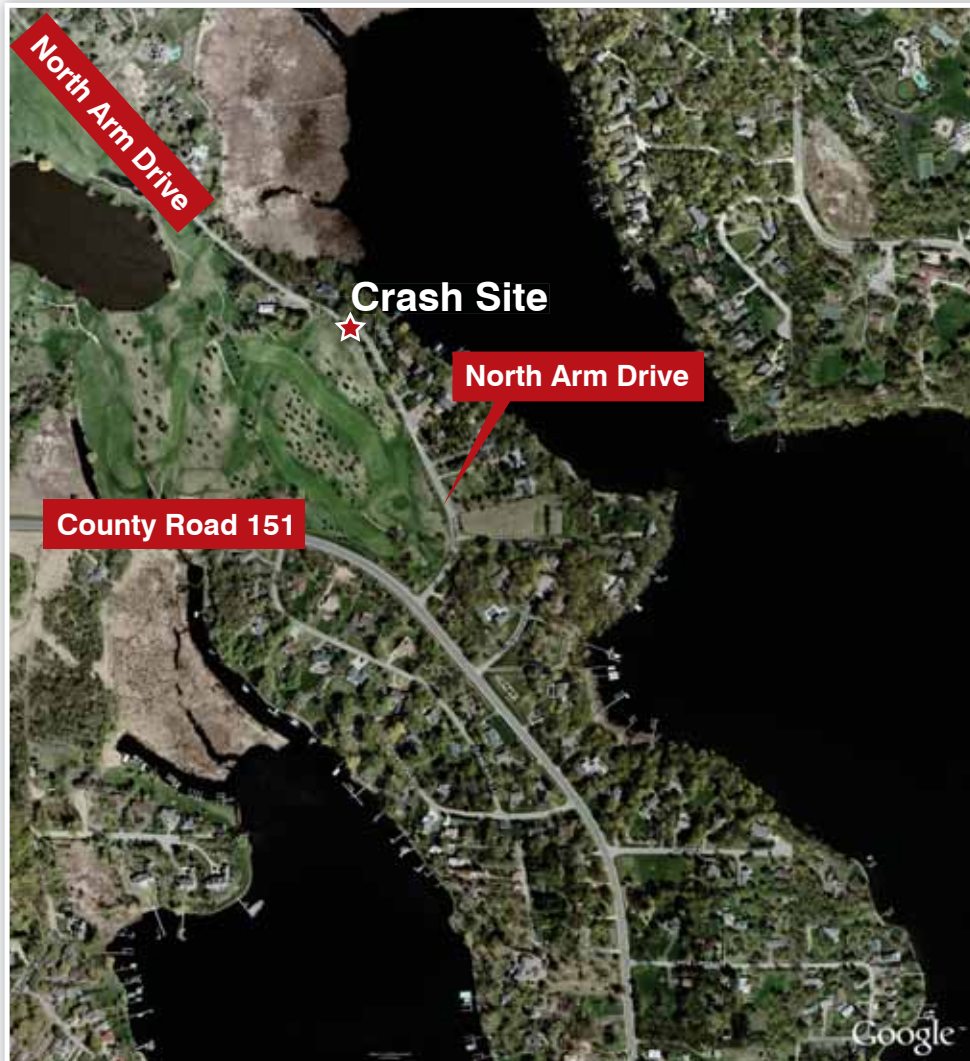
Signs requested to be placed within the right of way, along the county roadway, must meet the requirement of the MNMUTCD and have the _____ County Highway Engineer’s approval. (See *Signing Request Policy*)

Case Study #1: Monnens vs. City of Orono (1/3)



- In 2001, the City of Orono adopted a Community Management Plan that codified the City's desire to maintain the natural, wooded private residential nature of the community and to provide that virtually all city streets be low volume, low speed roadways.
- The Plan also identified general design (paved roads, narrow gravel shoulders, no curb and gutter and no traffic control devices that are **NOT** required by MNMUTCD) and maintenance practices (tree removal and trimming limited to sight line maintenance for motorists) intended to support the preservation of the natural, rural, residential character of the City.
- In May 2001, Kristal Monnens was killed in a single vehicle crash that occurred along one of the local roads - North Arm Drive.

Case Study #1: Monnens vs. City of Orono (2/3)



- The vehicle in which Ms. Monnens was a passenger was drag racing and was estimated exceeding 60 mph. When the vehicle failed to negotiate a curve to the left, it veered off the roadway and collided with a tree.
- The expert for the plaintiffs testified that Orono's failure to place a curve warning sign was the primary cause of the crash and was evidence of the City's negligence because the MNMUTCD **required** the use of the warning sign.
- The City argued summary judgement - dismissal of the lawsuit based on **three** key facts.
 - First, the City's Community Management Plan specifies that in order to support the rural, residential nature of their local roads, traffic control devices that are **NOT** required will **NOT** be used.
 - Second, none of the horizontal alignment series of warning signs are required (a SHALL condition) by the MNMUTCD - they are all optional signs that may be used based on engineering judgement.
 - The City had consistently avoided the use of warning signs along their local roads.

Case Study #1: Monnens vs. City of Orono (3/3)



- Minnesota tort law provides for Discretionary Immunity where actions are found to be consistent with policies enacted by the highest decision making body of an organization (City Council, County Board, etc.) **AND** where there is evidence that the body considered social and economic issues.
- The Court issued the Summary Judgement – agreed that curve warning signs are **NOT** required and that the action (of not installing the curve warning sign) was consistent with the city’s ordinance and was in fact covered by Discretionary Immunity.

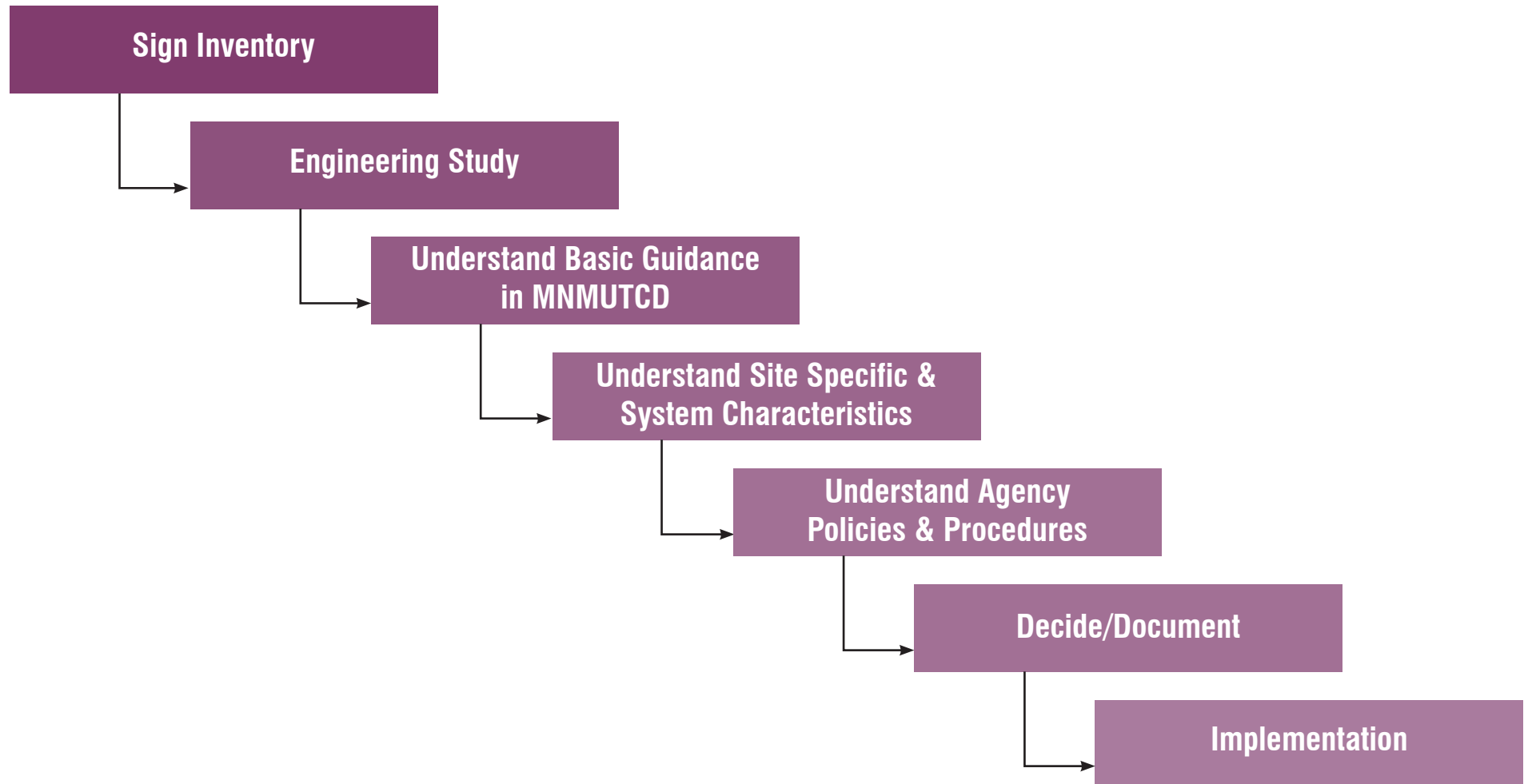
LESSON LEARNED → The establishment of ordinances and/or policies that restrict the use of traffic control devices are a proven method for managing risk associated with actions that are consistent with the adopted ordinances.



Part E – Implementation

Process Chart – Implementation.....	E-1	Engineering Study / System Consideration Example - Urban & Rural Low Volume.....	E-12
Sign Inventory	E-2	MNMUTCD Guidance.....	E-13 to E-15
Sign Inventory – Pencil & Paper.....	E-3	Regulatory Sign Usage	E-16 to E-18
Sign Inventory – Software.....	E-4	Warning Sign Usage	E-19 to E-22
Engineering Study Process	E-5 to E-6	Guide Sign Usage	E-23 to E-25
Engineering Study / MNMUTCD Guidance.....	E-7 to E-9	Low Volume Road Sign Usage.....	E-26 to E-28
Engineering Study / System Consideration Example - Rural Curves.....	E-10 to E-11	Which Signs are Required by the 2005 MNMUTCD?.....	E-29
		Case Study #2: Ireland vs. Lengsfeld and Carver County	E-30 to E-32

Process Chart – Implementation



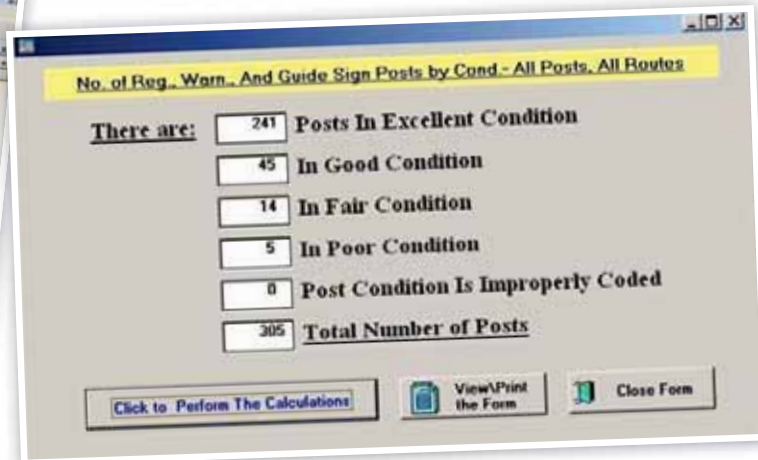
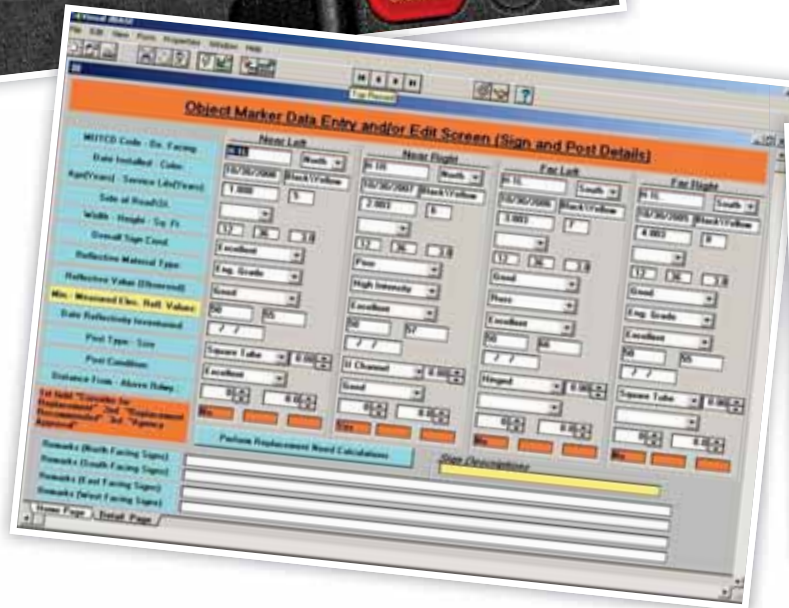
Sign Inventory

- The first step in the Implementation process involves documenting the location, type, installation date, sheeting type, direction facing, sign post type, and condition of all the signs along your system – conduct a Sign Inventory.
 - There are 2 basic approaches:
 - Pencil & Paper
 - Commercially available software
- Both approaches require investing time and resources:
 - Time in the field collecting data
 - Time in the office analyzing data
- Which approach is best for your agency?
 - Probably depends on how many signs are in your system – if you only manage a small system with relatively few signs, it probably wouldn't be worth the expense associated with buying software, attending training, and spending time in the field.



Sign Inventory – Software

- There are many sign management software options available
- Two free versions include:
 - Signs Plugin offered by Utah LTAP
www.utahltap.org
 - Roadway Sign Inventory & Management system offered by North Dakota LTAP
www.ndltap.org/library/software.php



Engineering Study Process (2/2)

Understand Basic MNMUTCD Guidance:

- Objective's of Traffic Control Devices
- Requirements to be Effective
- Engineering Study Process Usage
- Effectiveness

Understand:

- Specific Location Characteristics
- System Characteristics
- Agency Policies

Decide/Document:

- What is the Problem/Issue to be addressed?
 - Safety
 - Speed
 - Congestion
- Identify the applicable Guidelines
 - MNMUTCD
 - AASHTO
 - Mn/DOT
 - Local Agency
- Identify possible Alternatives
 - In virtually ALL cases there will be multiple choices
- Identify the evaluating Criteria
 - Effectiveness
 - Cost (first and ongoing maintenance)
 - Potential Impacts
 - Consistency
- Implementation



Engineering Study / MNMUTCD Guidance (1/3)



- STANDARD: The MNMUTCD describes the application of traffic control devices, but is not a legal requirement for their installation.
- The MNMUTCD provides Standards, Guidance, Options and Support for the design and application of traffic control devices. – It is NOT a substitute for engineering judgement.
- The MNMUTCD previously recommended that agencies **should** establish a process to provide and maintain reasonable nighttime sign visibility and legibility.
 1. **STANDARD** - a statement of required practice and the verb **SHALL** is used.
 2. **GUIDANCE** - a statement of recommended practice with deviations allowed based on engineering judgement. The verb **SHOULD** is used.
 3. **OPTION** - a statement of practice that is permissive. The verb **MAY** is used.

Engineering Study / MNMUTCD Guidance (2/3)



- Purpose of Traffic Control Devices:
 - Notify road users of regulations
 - Provide warning and guidance needed for safe, uniform and efficient operation
 - Any message not related to traffic control is prohibited
- Basic Requirements of Effective Traffic Control Devices:
 - Fulfill a need
 - Command attention
 - Convey a clear, simple message
 - Command respect
 - Give adequate time to respond

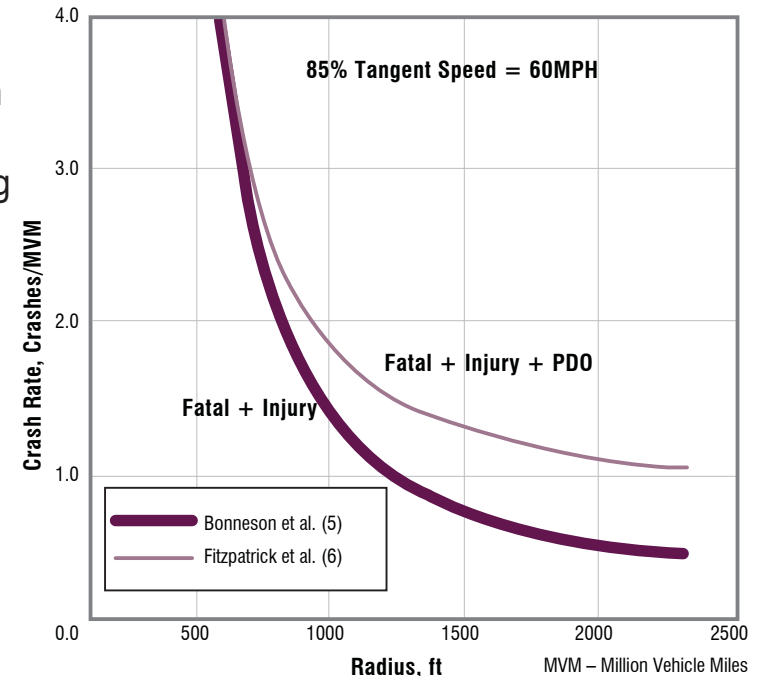
Engineering Study / MNMUTCD Guidance (3/3)



- Use only where a need is indicated by engineering judgement or studies.
- REGULATORY signs give notice of traffic laws or regulations.
- WARNING signs give notice of situations that are not self-evident
- GUIDE signs provide information as to highway routes, directions, destinations, distances, services and points of interest.
- Signs are ordinarily not needed to confirm rules of the road.

Engineering Study / System Consideration Example - Rural Curves (1/2)

- On **Rural** roads a typical system consideration involves the use of curve warning signs. These signs are not required and a recent Mn/DOT research project¹ found that about 80% of the curves in the sample selected for analysis had these signs in place. However, the usage was found to be inconsistent—some curves in each of the radius categories (0-500 feet, 500-1,000 feet, etc.) did not have the advance warning signs. It doesn't appear that any particular set of criteria or strategy was used to identify at-risk curves.
- The Mn/DOT report also noted that the curve warning signs appeared to have only a small effect on crashes and then only on curves in a fairly narrow range of radii. The advance warning signs between approximately 1,000 and 1,800 feet and chevrons at very short radius curves (be careful—very small sample size) appear to be effective.
- The information in Mn/DOT's report combined with the results from a Texas Transportation Institute Report² suggest a possible new approach to systematically deploying warning signs at horizontal curves. Both reports indicate that the crash risk at curves is a function of radius—long radius curves have crash rates similar to the system average for rural roads, but as the radius decreases the crash rate increases.



¹ Pitale, J., Shankwitz, C., Preston, H., Barry, M. Benefit/Cost Analysis of In-Vehicle Technologies and Infrastructure Modifications as a Means to Prevent Crashes Along Curves and Shoulders, Mn/DOT, December 2009

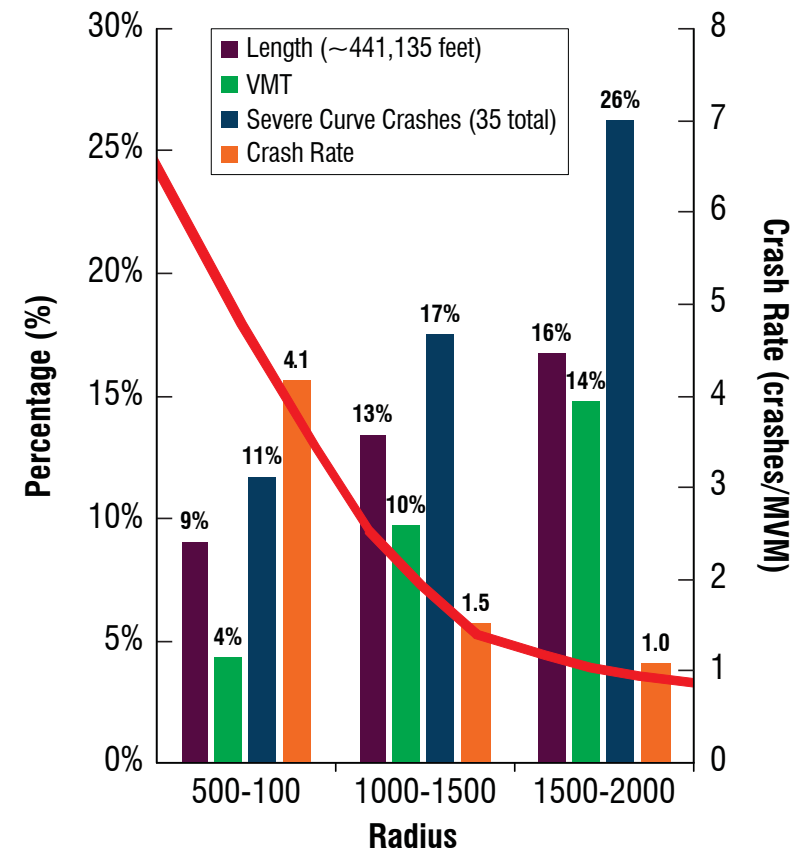
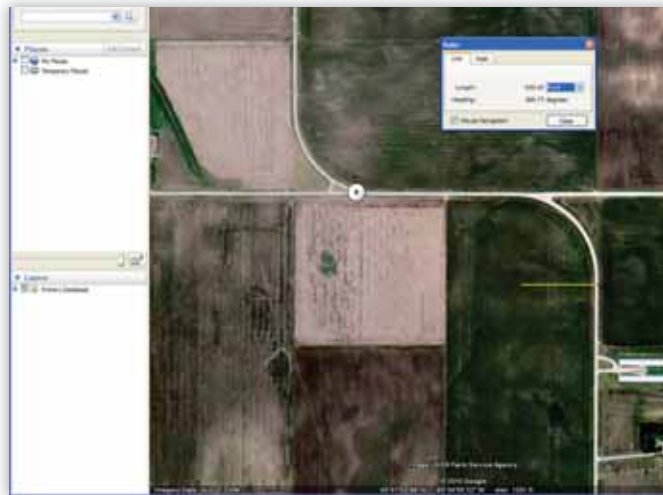
² Texas Transportation Institute (FHWA/TX-07/0-5439-1)

Engineering Study / System Consideration Example - Rural Curves (2/2)

- A sample system curve warning policy could include:
 - Curves > 2,000 foot radius (low crash risk/at system average crash rate) → No advance warning signs
 - Curves between 1,500 and 2,000 foot radii (moderate crash risk/2 x system crash rate) → Advance warning sign
 - Curves < 1,500 foot radius (high crash risk/5 x system average crash rate & 90% of fatal road departure crashes) → Advance warning signs and Chevrons

- To support **ANY** system wide approach to consistently sign curves, an inventory of your curves is required including estimating either the radius or degree of curvature (Radius = 5729.6/Degree of Curve).

- It is **NOT** necessary to have a precise measurement of the radius of every curve - the curve research in Minnesota estimated curve radii using measurements from aerial photography. Other methods could include using as-built plans, county maps, information for a county surveyor or the measuring feature on Google Earth.



Engineering Study / System Consideration Example - Urban & Rural Low Volume

- On urban and rural low volume roads, a typical system consideration involves the use of STOP signs, particularly at low volume residential intersections.
- A casual drive around the Minneapolis/St. Paul metropolitan area reveals that STOP signs are regularly used at low volume intersections where there is rarely a need to actually stop.
- This overuse of STOP signs is likely contributing to the fact that only around 20% of the people actually stop.
- Studies of low volume intersections by Texas Transportation Institute¹ and Iowa State University² found that increasing levels of intersection control at these **low volume** locations does **NOT** improve safety.
- The MNMUTCD also advises against using STOP signs for speed control—because there is no proof of effectiveness.
- It appears that the bottom line relative to the use of STOP signs at low volume intersections is:
 - STOP signs are not required
 - STOP signs are not a safety device
 - STOP signs have been deployed at many locations where we do not mean stop and as a result only about 20% of drivers actually stop
- All of this suggests developing a systemwide STOP sign policy that:
 - Limits the deployment to locations where your judgement indicates that there is a need to stop (residential streets intersecting with collectors, collectors with minor arterials, etc.).
 - Prohibits the deployment (or calls for the removal of existing STOP signs) at locations where there is no need to stop (low volume residential intersections).
- The research clearly indicates that at low volume intersections, there are **NO** safety benefits associated with increasing the level of intersection control; uncontrolled intersections have the lowest frequency of crashes and the highest function of intersections with no crashes.
- If your agency is uncomfortable with the notion of uncontrolled intersections, consider the use of YIELD signs—compared to STOP signs they have a lower crash frequency, a higher fraction of intersections without crashes and would be more consistent with actual driver behavior.

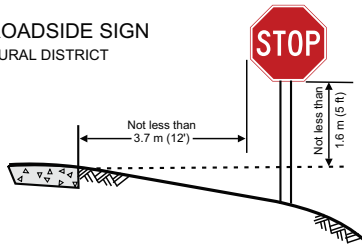


¹ Stockton, W., Brackett, R. and Mounce, J., *Stop, Yield, and No Control at Intersections. Final Report FHWA/RD-81-084. FHWA, US Department of Transportation, June 1981.*

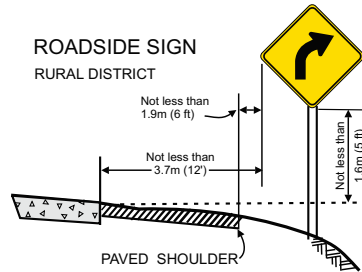
² *Guidelines for Removal of Traffic Control Devices in Rural Areas, Center for Transportation Research and Education and Iowa State University, October 2005.*

MNMUTCD Guidance (1/3)

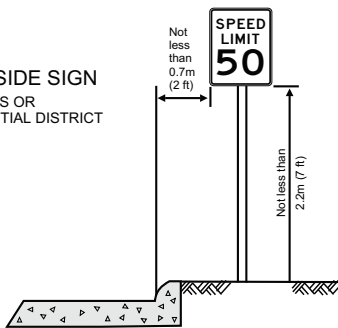
ROADSIDE SIGN
RURAL DISTRICT



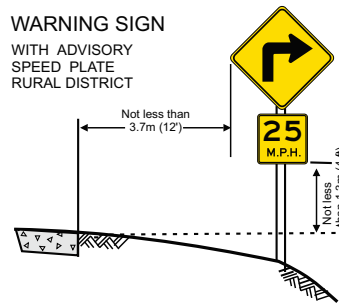
ROADSIDE SIGN
RURAL DISTRICT



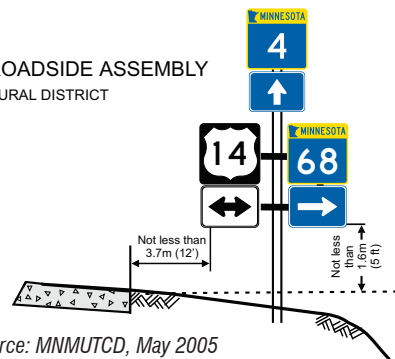
ROADSIDE SIGN
BUSINESS OR
RESIDENTIAL DISTRICT



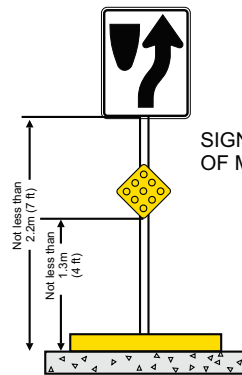
WARNING SIGN
WITH ADVISORY
SPEED PLATE
RURAL DISTRICT



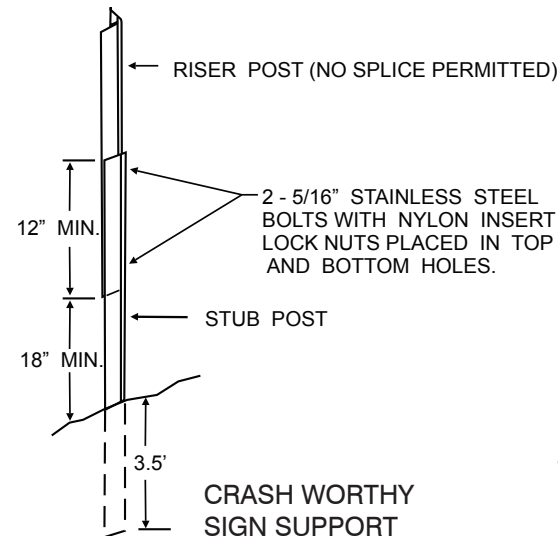
ROADSIDE ASSEMBLY
RURAL DISTRICT



SIGN ON NOSE
OF MEDIAN



- The MNMUTCD identifies suggested sign mounting heights and lateral offsets.
- These are suggestions - but, be careful! Some experts have been known to say that these are standards that **must** be followed.
- Ground-mounted sign supports shall be breakaway, yielding, or shielded with a longitudinal barrier or crash cushion if within the clear zone.
- Do you know how your signs measure up?

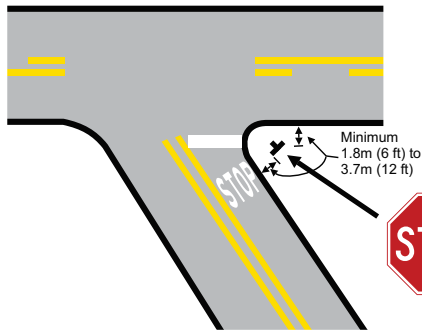


NOTE:
A reduced lateral offset distance may be used along low volume rural roads due to vegetation or terrain.

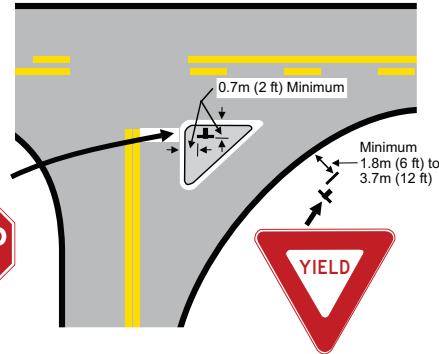
Source: MNMUTCD, May 2005

MNMUTCD Guidance (2/3)

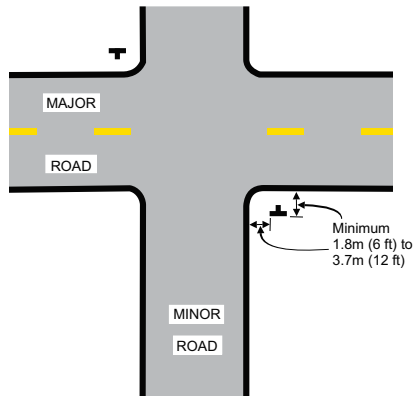
- The MNMUTCD also includes examples for locations for signs at intersections.



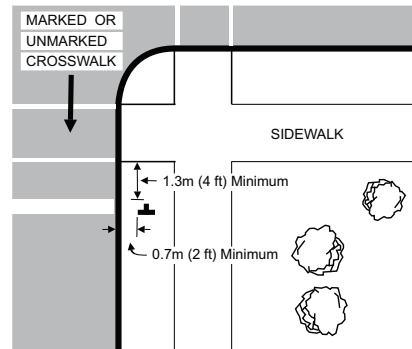
ACUTE ANGLE INTERSECTION



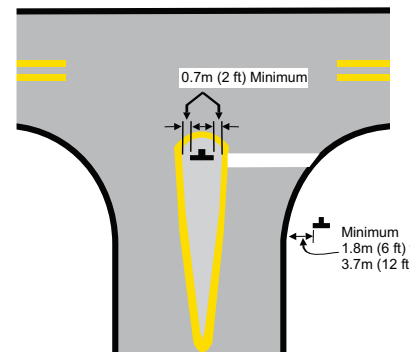
CHANNELIZED INTERSECTION



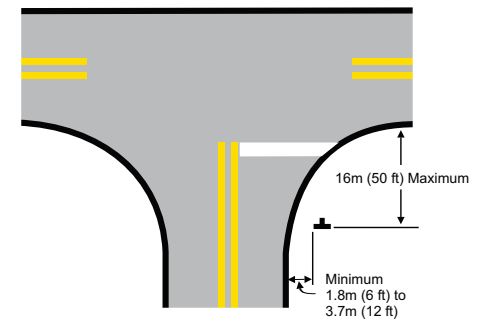
MINOR CROSSROAD



URBAN INTERSECTION



DIVISIONAL ISLAND



WIDE THROAT INTERSECTION

Source: MNMUTCD, May 2005

MNMUTCD Guidance (3/3)

Posted or 85th percentile speed mph (mph)	Minimum Advance Placement Distance ¹								
	Condition A: Speed Reduction and Lane Changing in Heavy Traffic ² (feet)	Condition B: Deceleration to the listed advisory speed (MPH) for the condition							
		0 ³ (feet)	10 ⁴ (feet)	20 ⁴ (feet)	30 ⁴ (feet)	40 ⁴ (feet)	50 ⁴ (feet)	60 ⁴ (feet)	70 ⁴ (feet)
20	225	See Notes ⁵	See Notes ⁵	—	—	—	—	—	—
25	325	See Notes ⁵	See Notes ⁵	See Notes ⁵	—	—	—	—	—
30	450	75	See Notes ⁵	See Notes ⁵	—	—	—	—	—
35	550	125	125	See Notes ⁵	See Notes ⁵	—	—	—	—
40	650	200	175	150	See Notes ⁵	—	—	—	—
45	775	275	250	225	150	See Notes ⁵	—	—	—
50	875	350	350	300	225	150	—	—	—
55	975	450	425	375	325	225	See Notes ⁵	—	—
60	1125	525	525	475	425	325	200	—	—
65	1200	625	625	575	525	425	300	See Notes ⁵	—
70	1275	750	725	700	625	525	400	275	—
75	1375	850	850	800	750	650	525	375	200

- This table provides Guidelines for the advance placement of Warning Signs.
- For example;
 - If you are on a 65 mph rural expressway and want to place a curve warning sign in advance of a 50 mph curve - the suggested distance is 300 feet.
 - If you are on a 55 mph rural two-lane and want to place a STOP AHEAD sign - the suggested distance is 450 feet.










Notes:

1. The distances are adjusted for a sign legibility distance of 175 ft, which is the appropriate legibility distance for a 5 inch Series D word legend. The distances may be adjusted by deducting another 100 feet if alignment symbol signs are used. Adjustments may also be made for grades, limited sign distance, or pavement condition.
2. Typical conditions are locations where the road user might use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. A typical sign is Right Lane Ends. The distances are based on the 2001 AASHTO Policy, Exhibit 3-3, Decision Sight Distance, Avoidance Maneuver E, providing the driver a PIEV Maneuver time of 14.0 to 14.5 seconds minus the sign legibility distances of 175 feet.
3. Typical condition is the warning of a potential Stop situation. Typical signs are Stop Ahead, Yield Ahead, Signal Ahead and intersection Warning signs. The distances are based on the 2001 AASHTO Policy, Equation 3-2, providing the driver a PIEV time of 2.5 seconds, a deceleration rate of 8.1 ft/second² minus the sign legibility distance of 175 ft.
4. Typical conditions are where the road user must decelerate to the advised speed to maneuver through the warned condition. Typical signs are Turn, Curve, Reverse Turn, or Reverse Curve combined with an Advisory Speed sign. The distances are based on the 2001 AASHTO Policy, Equation 3-2, providing the driver a PIEV time of 2.5 seconds a deceleration of 8.1 ft/second² minus the sign legibility distance of 175 ft.
5. No suggested minimum distances are provided for these speeds, as placement location is dependent on site conditions and other signing to provide an adequate advance warning for the driver.

Source: MNMUTCD, May 2005



Regulatory Sign Usage (1/3)

Sign Number	Sign Picture	Sign Colors	Sign Size		Use	Manual Section
			Metric (millimeters)	English (inches)		
R1-1		White on Red	450 x 450	18 x 18	B	2B.4,5,6,7
			600 x 600	24 x 24	M	5B.2
			750 x 750	30 x 30	CR	8B.8
			900 x 900	36 x 36	E	9B.3
			1200 x 1200	48 x 48	O	10C.4
R1-2		White on Red	450	18	B	2B.8,9,10
			750	30	M	5B.2
			900	36	CR	8B.8
			1200	48	E	9B.3
			1500	60	F	10C.4
R1-2a		Black on White	600 x 450 900 x 750 1200 x 900	24 x 18 36 x 30 48 x 36	CR	
R1-3		White on Red	300 x 150 600 x 300	12 x 6 24 x 12	CR E	2B.4
R1-4		White on Red	450 x 150	18 x 6	CR	2B.4
R1-6b		Black on White and Fluorescent Yellow-Green	300 x 900 300 x 1120	12 x 36 (post mounted) 12 x 44 (w/mounting flange)	CR	2B.12 7B.9
R1-X1		Black on White	600 x 750	24 x 30	CR	2B.45 2B.56
R1-X2		Black on White	600 x 450 750 x 600	24 x 18 30 x 12 30 x 24 36 x 18	CR CR E E	2B.4.1
R2-1		Black on White	600 x 750 900 x 1200 1200 x 1500	24 x 30 36 x 48 48 x 60	CR E F	2B.11 5B.3 7B.11

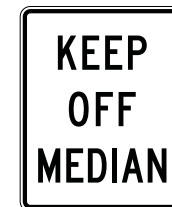
- These are examples of Regulatory signs described in the MNMUTCD.
- Regulatory signs notify drivers of the rules of the road.

Regulatory Sign Usage (2/3)

- This is a more comprehensive list of the Regulatory signs found in Part 2B of the MNMUTCD.
- An all too frequent response to the question – why did your agency install a particular sign is – the MNMUTCD required the installation.

Part 2B - Regulatory Signs

- Road/Bridge/ Sidewalk Closed
- Pedestrian Crossing
- Speed Limits
- Pass With Care
- Do Not Enter
- All Way (Stop) Plaque
- Slower Traffic Keep Right
- Divided Highway
- Turn Prohibition
- Intersection Lane Control
- STOP & Yield
- State Law Signs
- Two-Way Left Turn Lane
- Wrong Way
- Speed Reduction
- Right/Left Turn Lane
- Weight Limits
- Cross Traffic Does Not Stop
- No Parking
- Begin/End One-Way
- Advance Intersection Lane Control
- End Speed Zone
- Keep Right
- Stop For Peds In Crosswalk
- Keep Off Median
- One Way
- Do Not Pass
- Traffic Signal(Clarifications)



Let's determine which Regulatory signs are in fact required.












Regulatory Sign Usage (3/3)

- Understand the difference in the levels of guidance provided in the MNMUTCD.
- In the category – Regulatory Signs – the only signs that are required are:
 - Speed Limits (if in an established speed zone)
 - ONE WAY / DO NOT ENTER
 - Turn Prohibitions
 - ALL-WAY STOP supplementary plaque
- All other Regulatory signs may be used based on your agencies policies, system considerations, and the results of an engineer (or their designated representative) exercising their judgement.
- This is not an error – STOP signs are **NOT** required. The MNMUTCD states that STOP signs **SHOULD** be used based on the results of an engineering study and that one of the suggested applications should be at a street entering a “through highway.” Minnesota Statute §169.30 says that the through highway is generally the approach with the highest traffic flow. Minnesota Statute §169.30 also says that **normally** it is **desirable** to erect STOP signs at all public entrances to highways.

STANDARD (Shall)	GUIDANCE (Should)	OPTION (May)	SUPPORT
Speed Limits	Stop	Yield	No Parking
One Way Do Not Enter	Road/Bridge/ Sidewalk Closed	Slower Traffic Keep Right	End Speed Zone
Turn Prohibition	Pass With Care	Wrong Way	
All Way (Stop) Supplementary Plaque	Intersection Lane Control	Cross Traffic Does Not Stop	
	Two-Way Left Turn Lane	Advance Intersection Lane Control	
	Right/Left Turn Lane	Stop For Peds In Cross Walk	
	State Law Signs	Do Not Pass	
	Speed Reduction	Keep Off Median	
		Traffic Signal (Clarifications)	
		Pedestrian Crossing	
		Weight Limits	
		Begin/End One-Way	
		Divided Highway	
		Keep Right	

Warning Sign Usage (1/4)

- These are examples of warning signs described in the MNMUTCD.
- Warning signs are to provide drivers with notice of conditions that are not readily apparent.

Sign Number	Sign Picture	Sign Colors	Sign Size		Use	Manual Section	Sign Number	Sign Picture	Sign Colors	Sign Size		Use	Manual Section	
			Metric (millimeters)	English (inches)						Metric (millimeters)	English (inches)			
W9-1		Black on Yellow	600 x 600 750 x 750 900 x 900 1200 x 1200	24 x 24 30 x 30 36 x 36 48 x 48	M CR E F	2C.33 5F.46	W10-4		Black on Yellow	450 x 450 600 x 600 750 x 750 900 x 900 1200 x 1200	18 x 18 24 x 24 30 x 30 36 x 36 48 x 48	B M M CR E, F	5F.3 8B.4 10C.15	
W9-2 (R or L)		Black on Yellow	750 x 750 900 x 900 1200 x 1200	30 x 30 36 x 36 48 x 48	CR E,F O	2C.33	W10-5		Black on Yellow	600 x 600 750 x 750 900 x 900 1200 x 1200	24 x 24 30 x 30 36 x 36 48 x 48	M M CR E, F	8B.14 8B.17 10C.16	
W10-1		Black on Yellow	450 x 450 600 x 600 750 x 750 900 x 900 1200 x 1200	18 x 18 24 x 24 30 x 30 36 x 36 48 x 48	B M CR E O	5F.3 6F.46 8B.4 9B.18 10C.15	W10-7		Yellow on Black	600 x 600 750 x 750 900 x 900	24 x 24 30 x 30 36 x 36	M CR E, F	10C.17	
W10-1a		Black on Yellow	600 x 300	24 x 12	CR,E	8B.5 10C.10	W10-8		Black on Yellow	750 x 750 900 x 900 1200 x 1200	30 x 30 36 x 36 48 x 48	M CR E, F	8B.13	
W10-2 (R or L)		Black on Yellow	450 x 450 600 x 600 750 x 750 900 x 900 1200 x 1200	18 x 18 24 x 24 30 x 30 36 x 36 48 x 48	B M M CR E, F	5F.3 8B.4 10C.15	W10-9		Black on Yellow	600 x 450	24 x 18	M CR E, F	8B.14	
W10-3 (R or L)		Black on Yellow	450 x 450 600 x 600 750 x 750 900 x 900 1200 x 1200	18 x 18 24 x 24 30 x 30 36 x 36 48 x 48	B M M CR E, F	5F.3 8B.4 10C.15								

Warning Sign Usage (2/4)

- This is a more comprehensive list of Warning Signs found in Part 2C of the MNMUTCD.

Part 2C - Warning Signs

- Hill
- Pavement Ends
- Dead End/No Outlet
- Horizontal Alignment
- Speed Bump/Hump Road/Bridge Narrows
- Next XX Miles Distance Plaque
- One Direction Large Arrow Divided Highway
- Slippery When Wet
- Chevron Alignment
- Prepare To Stop
- Advisory Speed Plaque
- Lane Ends
- Bump/Dip
- Railroad Crossing
- Two Direction Large Arrow
- No Passing Pennant
- Soft Shoulder
- Two-Way Traffic
- Advance Traffic Control (Limited Sight Distance)
- Added Lane
- Intersection Warning
- Cross Traffic Does Not Stop
- Playground
- Merge Advance Traffic Control (General Application)
- Low Clearance (Less Than 12 In. Above Legal Max. Height)
- Crossings (Pedestrians, Bicycles, Snowmobilers, etc.)



Which Warning Signs are required?

Warning Sign Usage (3/4)

■ In the category – Warning Signs – the only signs that are required are:

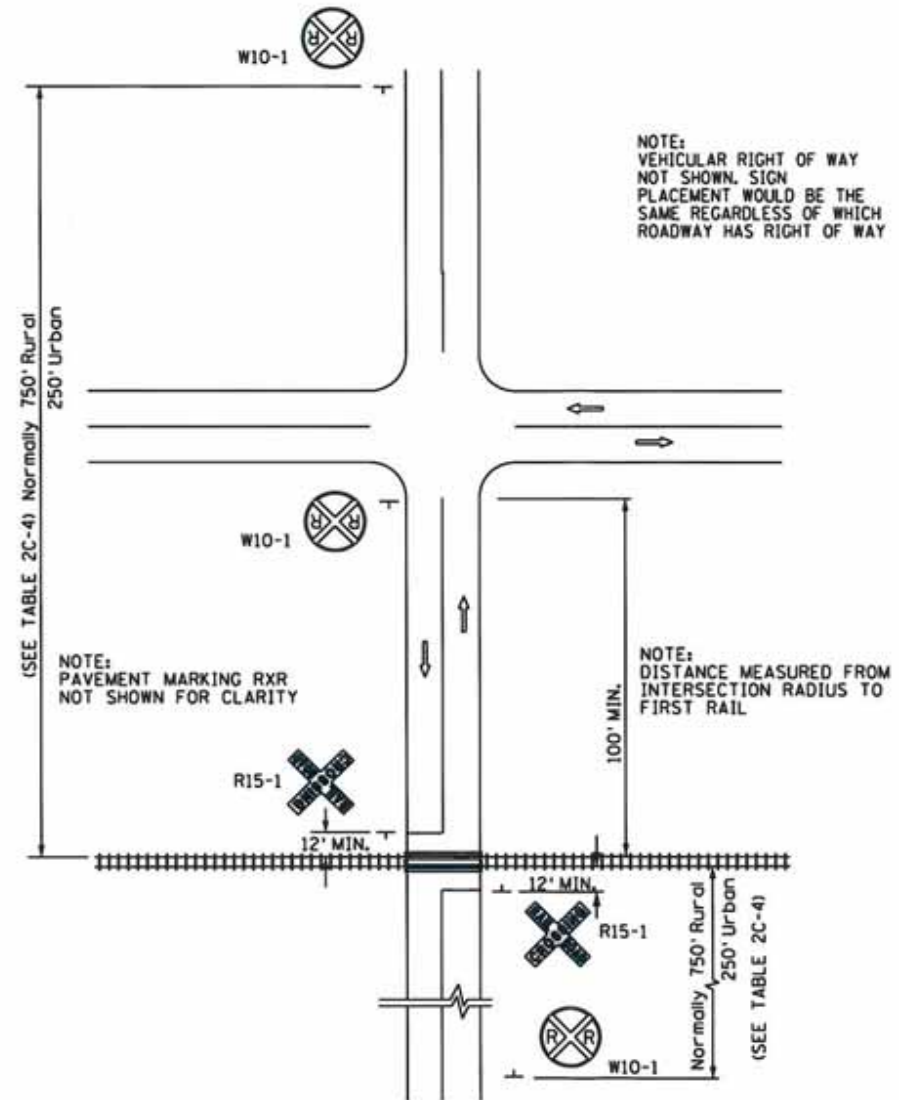
- Railroad Crossing
- Low Clearance
- Advance Traffic Control (if sight distance to the device is limited or impaired)
- No Train Horn

■ All other Warning signs may be used based on your agencies policies, system considerations and the results of an engineer (or their designated representative) exercising their judgement.

STANDARD (Shall)	GUIDANCE (Should)	OPTION (May)
Railroad Crossing	Hill	No Passing Pennant
Low Clearance (Less Than 12 In. Above Legal Max. Height)	Road/Bridge Narrows	Horizontal Alignment
Advance Traffic Control (Limited Sight Distance)	Divided Highway	Next XX Miles Distance Plaque
No Train Horn	Bump/Dip	Advisory Speed Plaque
	Pavement Ends	One Direction Large Arrow
	Speed Bump/Hump	Chevron Alignment
	Soft Shoulder	Dead End/No Outlet
	Added Lane	Slippery When Wet
	Lane Ends	Prepare To Stop
	Two Direction Large Arrow	Crossings(Pedestrians, Bicycles, Snowmobilers, Etc)
	Two-Way Traffic	Merge
		Cross Traffic Does Not Stop
		Playground
		Intersection Warning
		Advance Traffic Control (General Application)

Warning Sign Usage (4/4)








- Railroad Crossing Warning signs are required by the MNMUTCD.
- Various signs and guidelines have been established for various types of railroad crossings. A few scenarios include:
 - Parallel road is over 100 feet from crossing,
 - Parallel road is within 100 feet of crossing and intersecting road traffic must stop
 - Low ground clearance, and
 - Restricted storage distance when intersecting road must stop.
- For more information on Warning sign usage, refer to the Mn/DOT Office of Freight and Commercial Vehicle Operations website:
 - <http://www.dot.state.mn.us/ofrw/railroads.html>



TYPICAL SIGN PLACEMENT WHERE PARALLEL ROAD IS OVER 100 FEET FROM CROSSING

Guide Sign Usage (1/3)

- These are examples of Guide signs described in the MNMUTCD.
- Guide signs identify and confirm the marked routes on State and local highway systems.

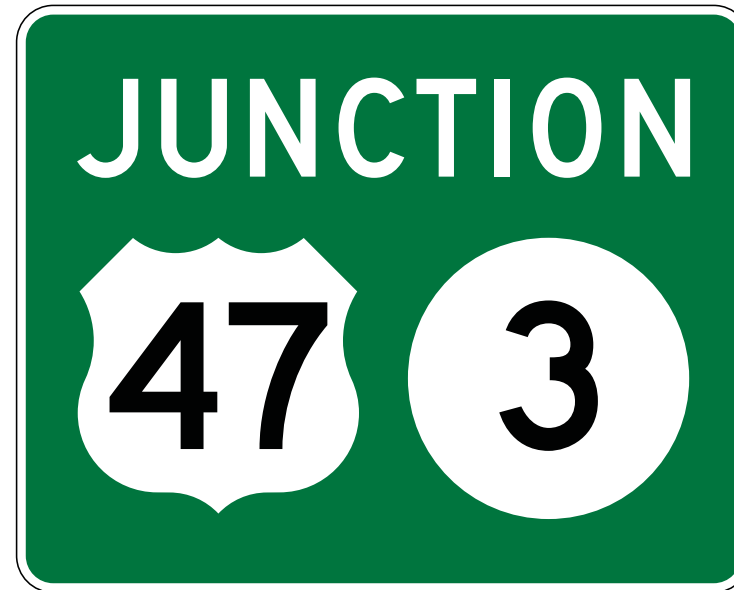
Sign Number	Sign Picture	Sign Colors	Sign Size		Use	Manual Section	Sign Number	Sign Picture	Sign Colors	Sign Size		Use	Manual Section
			Metric (millimeters)	English (inches)						Metric (millimeters)	English (inches)		
M1-1		White on Red and Blue	450 x 450	18 x 18	M	2D.11 2E.25	M1-5a (for Independent use)		White and Gold on Blue	600 x 600	24 x 24	CR E, F	2D.11 2E.25
			550 x 450	22.5 x 18	M					900 x 900	36 x 36		
			600 x 600	24 x 24	CR								
			750 x 600	30 x 24	CR								
			900 x 900	36 x 36	E, F								
			1125 x 900	45 x 36	E, F								
1200 x 1200	48 x 48	O											
1500 x 1200	60 x 48	O											
M1-2		White on Green	450 x 450	18 x 18	M	2D.11 2E.25	M1-5b (used as Overlay)		White and Gold on Blue	450 x 450	18 x 18	M M CR CR E, F E, F	2D.11 2E.25
			550 x 450	22.5 x 18	M					550 x 450	22.5 x 18		
			600 x 600	24 x 24	CR					600 x 600	24 x 24		
			750 x 600	30 x 24	CR					750 x 600	30 x 24		
			900 x 900	36 x 36	E, F					900 x 900	36 x 36		
			1125 x 900	45 x 36	E, F					1125 x 900	45 x 36		
1200 x 1200	48 x 48	O											
1500 x 1200	60 x 48	O											
M1-4 (for Independent Use)		White on Black	600 x 600	24 x 24	CR	2D.11 2E.25	M1-6		White and Yellow on Blue	450 x 450	18 x 18	M CR E, F	2D.11
			900 x 900	36 x 36	E, F					600 x 600	24 x 24		
			1200 x 1200	48 x 48	O					900 x 900	36 x 36		
M1-4A (used as Overlay)		Black on White	450 x 450	18 x 18	M	2D.11 2E.25							
			550 x 450	22.5 x 18	M								
			600 x 600	24 x 24	CR								
			750 x 600	30 x 24	CR								
			900 x 900	36 x 36	E, F								
			1125 x 900	45 x 36	E, F								
1200 x 1200	48 x 48	O											
1500 x 1200	60 x 48	O											

Guide Sign Usage (2/3)

- This is a more comprehensive list of Guide Signs found in Part 2E of the MNMUTCD.

Part 2E - Guide Signs

- Confirming Assemblies
- Street Names
- County Name Marker
- City Name Marker
- Junction Assembly (Jct US 63)
- Route Numbers (On All Numbered Highways)
- Destination and Distance
- Reference Location (Mile Markers)
- Advance Route Turn Assembly



Which Guide signs are required?

Guide Sign Usage (3/3)

■ In the category – Guide Signs – the only signs that are required are:

- Route Numbers (on all numbered highways)
- Junction Assembly (i.e., Jct US 63)
- Advance Route Turn Assembly

STANDARD (Shall)	GUIDANCE (Should)	OPTION (May)	SUPPORT
Route Numbers (On All Numbered Highways)	Street Names	Reference Location (Mile Markers)	Destination and Distance
Junction Assembly (Jct US 63)		City Name Marker	Confirming Assemblies
Advance Route Turn Assembly			County Name Marker

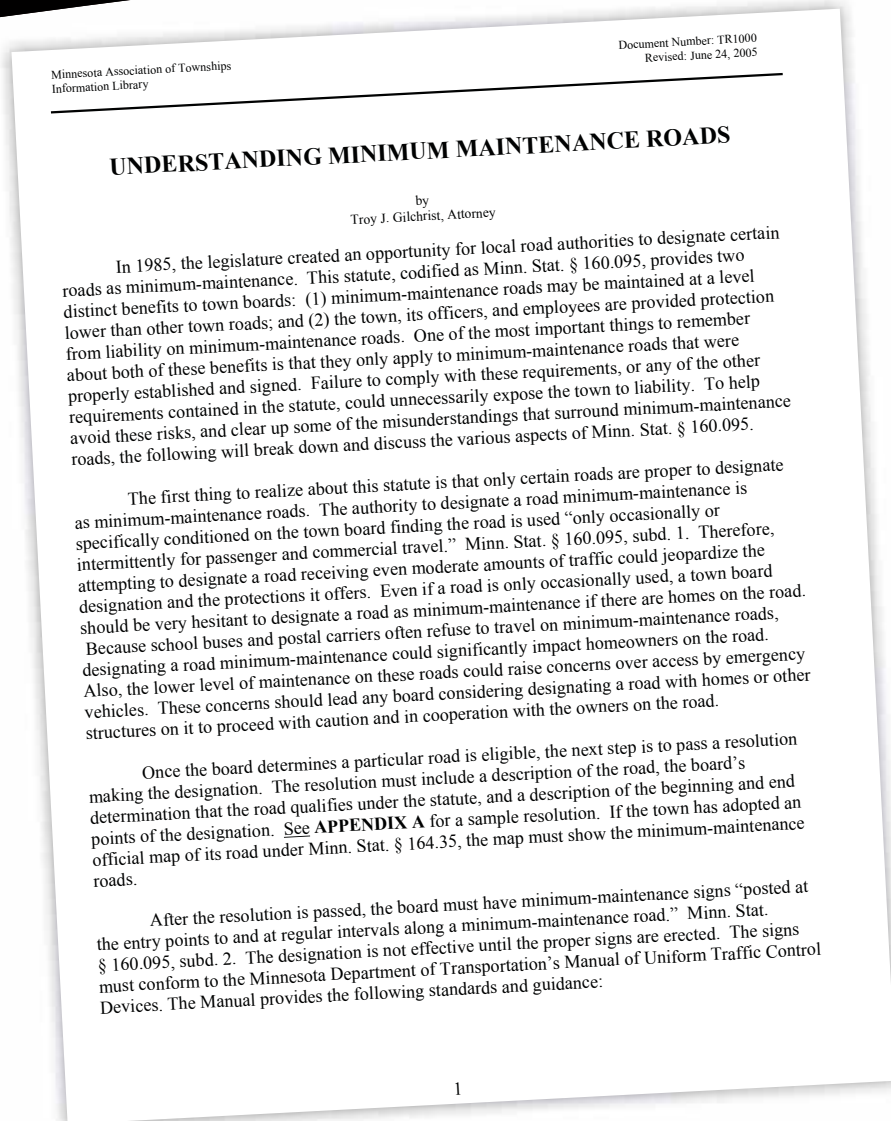
Low Volume Road Sign Usage (1/3)

- For the first time in the 2000 MUTCD, FHWA acknowledged that the typical driver on most low volume roads is different – most likely local residents that need less information about traffic regulations, unexpected conditions or guidance to destinations, thus allowing for the use of fewer signs.
- If your agency has jurisdiction over “Low Volume Roads”, there are even fewer usage requirements.
 - No Regulatory or Guide signs are required – a variety may be used based on engineering judgement
 - Four types of Warning signs are required – Advanced Traffic Control (i.e., STOP AHEAD if sight distance is limited), Vertical Clearance, Railroad Crossing signs and MINIMUM MAINTENANCE ROADS.

- Low Volume Roads are defined in Minnesota Statute § 160.095 as:
 - Having fewer than 400 vehicles per day
 - Not being on a designated State system
 - Outside of built up areas of cities or towns
 - Roads may be paved or unpaved

	STANDARD (Shall)	GUIDANCE (Should)	OPTION (May)
Regulatory Signs		STOP YIELD Traffic Movement Traffic Prohibition	Speed Limit No Parking
Warning Signs	STOP Ahead (Limited Sight Distance) YIELD Ahead (Limited Sight Distance) Vertical Clearance Rail Grade Crossing Rail Advance Warning No Train Horn MINIMUM MAINTENANCE ROAD	ONE LANE BRIDGE Crossings (vehicles)	Horizontal Alignment Intersections Narrow Bridge Hill PAVEMENT ENDS Crossings (Pedestrians) Advisory Speed Plaque DEAD END/NO OUTLET
Guide Signs		Destinations	

Low Volume Road Sign Usage (2/3)

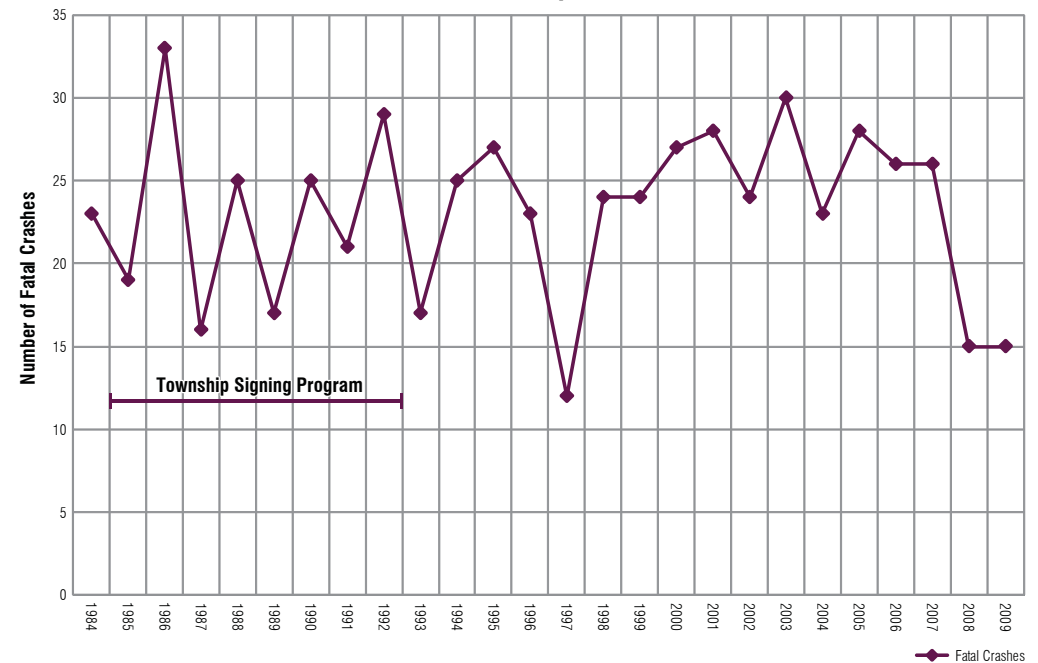


- The Minnesota Legislature enacted the Statute (§ 160.095) that created Minimum Maintenance roads in 1985.
- Minimum Maintenance roads provide two benefits to Townships:
 - These roads may be maintained at a lower level than other township roads.
 - The township, its officers and employees have protection from liability on issues related these roads.
- These benefits only apply to Minimum Maintenance roads that were properly established and have the necessary signs.
- For a township to designate a road as being Minimum Maintenance, the township board must find the road to be used "only occasionally or intermittently for passenger or commercial travel."
- Roads with homes should not be considered due to concerns about access by school buses, postal carriers and emergency responders.




Low Volume Road Sign Usage (3/3)

- We have established that most township roads likely meet the definition of Low Volume Roads, as a result very few signs (four types of Warning signs) are considered required.
- We've also established that the average annual sign maintenance cost for a typical township would be approximately \$3,600 to \$5,400 per year.
- If townships are unable to establish this level of funding in their annual budget, consideration should be given to conducting a sign inventory and study then removing signs that are not required.
- The Federal Highway Administration has suggested that sign reductions in the range of 25% should be easily achieved without any adverse effect on safety.
- The idea of sign reduction has been discussed with a number of township officials and many have been skeptical. A common response involves perceived concerns about safety – the signs were installed to address safety, if they are taken down there will be an adverse effect. In reality, the general safety effect of most signs is not well documented (See Part F) and in particular the effect on low volume township roads has never been studied. However, the graph of fatal crashes on township roads in Minnesota indicates that the long-term trend line is flat – even after the last major township signing initiative in the mid 1980's.
 - This suggests that replacing signs on low volume township roads that are primarily used by local drivers does not appear to be associated with improved safety.

Fatal Crashes Township Roads 1984 - 2009



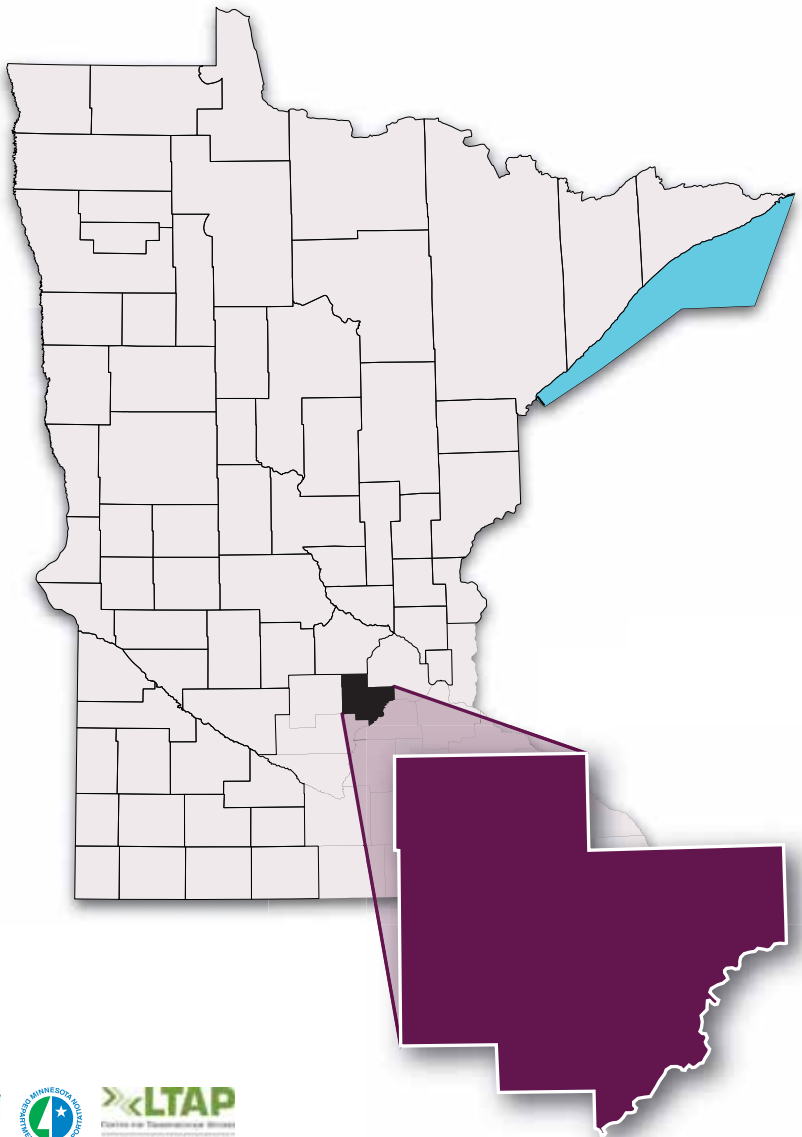
Which Signs are Required by the 2005 MNMUTCD?

<p>Regulatory</p>		<ul style="list-style-type: none"> ■ Speed Limits IF a speed zone (other than a statutory limit) has been established. ■ ONE-WAY & DO NOT ENTER where applicable. ■ The ALL-WAY STOP plaque at All-Way Stops. ■ Prohibition signs where applicable
<p>Warning</p>		<ul style="list-style-type: none"> ■ Rail Road Advance Warning and No Train Horn (if quiet zone established) ■ Clearance IF clearance is less than 14'-6" (12" above the statutory minimum clearance height) ■ Advance Traffic Control IF there is limited sight distance. ■ Minimum Maintenance
<p>Guide</p>		<ul style="list-style-type: none"> ■ Route Numbers on ALL numbered highways ■ Junction Assembly ■ Advance Route Turn Assembly

Note: The determination as to which signs in the MUTCD are required is based on the 2005 version. Subsequent editions may result in additions to or deletions from the list.

- If you have Low Volume roads, only the Warning signs listed above are required.
- Bottom Line – out of the hundreds of signs contained in the MNMUTCD – 13 types of signs are actually required.
- This suggests that if you decide to put up a sign – most of the time that action will be based on exercising your judgement and NOT on the requirements in the MNMUTCD.

Case Study #2: Ireland vs. Lengsfeld and Carver County (1/3)



Background:

- Design
- Crash History
- Issues

Lessons Learned:

- Importance of Documentation
- Application of Doctrine of Official Immunity Applied to Traffic Engineering

Case Study #2: Ireland vs. Lengsfeld and Carver County (2/3)

Background

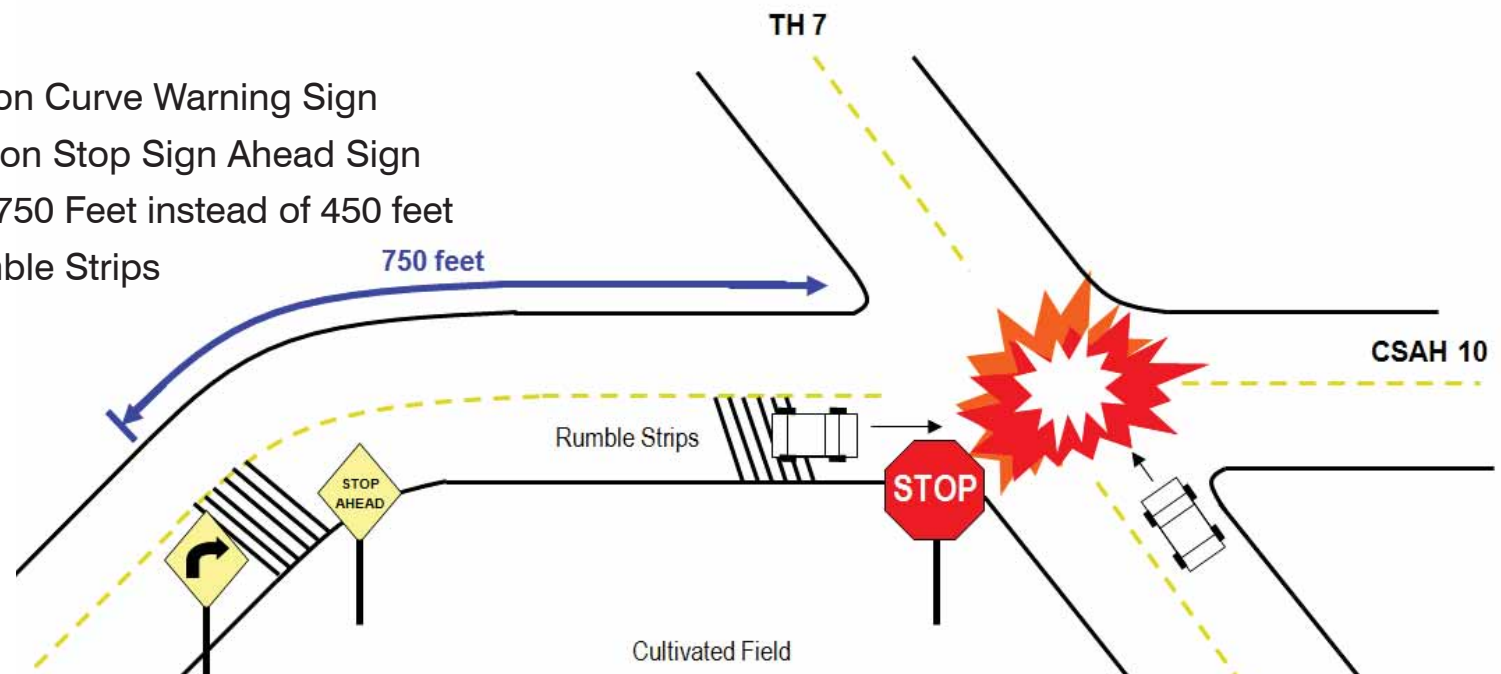
- 55 MPH Speed Limit
- Curve Warning Sign in Place
- Stop Ahead Sign in Place
- Rumble Strips in Place/Partially Filled
- Crash Occurred in the Middle of a Clear, Bright Summer Day

Crash History

- 2 Crashes per Year
- Crash Rate = 0.5 Crashes/Million Entering Vehicles
- Statewide Average = 0.6 Crashes/Million Entering Vehicles
- Critical Rate = 1.3 Crashes/Million Entering Vehicles

Issues

- No Speed Advisory on Curve Warning Sign
- No Distance Plaque on Stop Sign Ahead Sign
- Stop Ahead Sign at 750 Feet instead of 450 feet
- Maintenance of Rumble Strips



Case Study #2: Ireland vs. Lengsfeld and Carver County (3/3)

Legal Process:

1. Criminal Trial
2. Civil Case
 - County's Motion for Summary Judgement (Denied)
 - County's Appeal (Reversed District Courts Decision)
 - Plaintiffs Appeal to State Supreme Court (Refused to Hear the Case - Appeals Court Decision Stands)

Court of Appeals Decision (CX-96-19)

1. Reversed District Court Decision
 - Affirmed the sign placement was discretionary
 - Acknowledged MNMUTCD's express deference to the judgement of engineers in installing traffic control devices
 - Affirmed that rumble strip maintenance is discretionary
 - Extended the Doctrine of Official Immunity to the decision making of a traffic engineer
 - In the future, plaintiffs will have to demonstrate that the government employee engaged in willful or malicious acts

Lessons Learned → Written documentation of decisions regarding the placement of traffic signs (including a clear understanding of the guidance, facts that caused you to vary from the guidance and your ultimate decision) is a proven method for managing risk associated with actions that may not be entirely consistent with the MNMUTCD. No one expects you to document every decision you make – you will need to exercise your judgement to decide which of your decisions are potentially controversial enough to make the added investment of your time worth the effort.



What's wrong with these pictures?
 (See page G-2 for answer.)



Part F – Effectiveness of Traffic Signs

How to Measure Effectiveness?.....	F-1	Sign Effectiveness Summary.....	F-9
Effectiveness of Regulatory Signs – Speed Limit.....	F-2	Making the Case For Considering Sign Removal.....	F-10
Effectiveness of Regulatory Signs – STOP signs.....	F-3	Sign Removal – Which Signs Are Candidates?.....	F-11 to F-12
Effectiveness of Warning Signs – Children at Play.....	F-4	Potential Sign Removal Examples.....	F-13 to F-16
Effectiveness of Warning Signs – Horizontal Alignment.....	F-5	Sign Removal – Managing Risk.....	F-17
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How to Measure Effectiveness?

Regulatory



Warning



Guide



- In order to determine the effectiveness of signs – you have to ask what is the Performance Measure?
- The most commonly cited measure is **CRASHES**, but that is a very difficult piece of information to work with because only a very few signs are related to safety and there are too few crashes at most locations to produce statistically reliable results.
- It appears that a second (and possibly better) measure of effectiveness would be **DRIVER BEHAVIOR**. Did the sign change behavior in the desired way? Was the response consistent among drivers?

Effectiveness of Regulatory Signs – Speed Limit

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
62 nd Ave. N	SPEED LIMIT 35	SPEED LIMIT 30	-5	37 37	0
Miss. St.	SPEED LIMIT 30	SPEED LIMIT 35	+5	39 40	+1

**TH 210
Baxter**

	Before	After
Posted	55	45
85%	57	53
% Compliance	68	38

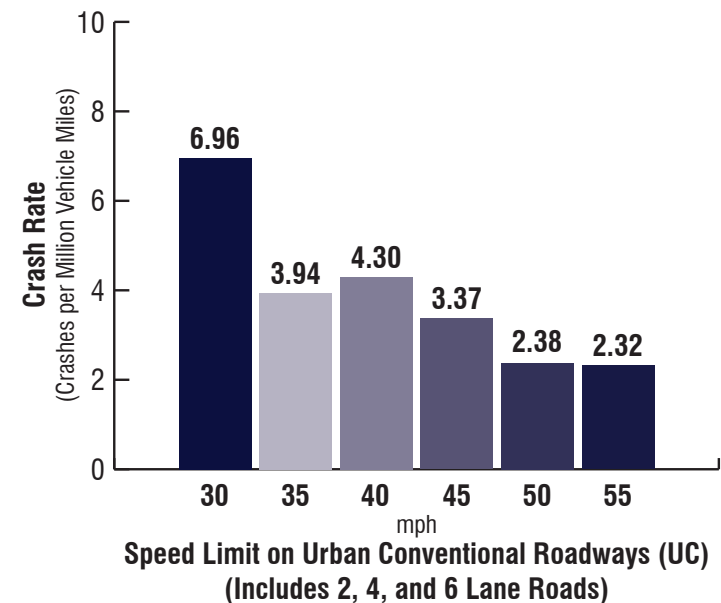
**TH 316
Hastings**

	Before	After
Posted	45	35
85%	47	45
% Compliance	60	12

Source: Unpublished Mn/DOT Data

- 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.
- Speed limit signs have never proven to change driver behavior.
- Drivers only comply with speed limits (and the signs) if the posted limits are consistent with a driver's perception of the road environment and their selection of a safe speed, that is approximated by the 85th percentile speed.
- Lower speed limits are frequently requested in order to improve safety. There is one very substantial problem with this theory – it is **NOT** consistent with actual crash data. Analysis of a sample of urban, conventional roads found that crash rates decreased with increased speed limits.

MN Urban Roadway Crash Rates vs. Posted Speed Limits



Source: Preston, H., Statistical Relationship Between Vehicular Crashes and Highway Access, Minnesota Department of Transportation Report No. 1998-27, August 1998.

Effectiveness of Regulatory Signs – STOP signs



- A comprehensive study of a sample of low volume rural intersections with STOP, YIELD and NO CONTROL found that the number of crashes was **NOT** related to the degree of control.¹

Summary of Significant Data¹

	Control Type			Statistical Significance
	Stop	Yields	No Control	
Number of intersections	48	48	44	—
Average Volume (vpd)				
Major Roadway	2,530	2,380	3,800	—
Minor Roadway	200	190	120	—
Average Crashes/Int	0.44	0.42	0.32	—
Intersections w/NO Crashes	69%	83%	95%	Significant
Driver Behavior				
Voluntary Stops	19%	8%	9%	Not Significant
Slow Entries (<=5mph)	65%	79%	80%	Not Significant
Fast Entries (>=5mph)	16%	13%	11%	Not Significant

Summary of Previous Research on Driver Behavior at STOP Signs¹

Company	Morrison (1931)	Fisher (1935)	Elliot (1935)	Hanson (1960)	Leisch (1963)	Beaubien (1976)	Dyar (1977)
Full Stops	47%	45%	38%	20%	17%	22%	12%
Partial Violation (Rolling Stop)	42%	34%	42%	69%	69%	48%	60%
Full Violation (No Stop)	11%	21%	20%	11%	14%	30%	28%

¹ Stockton, Brackett and Mounce, "STOP, YIELD and NO CONTROL at Intersections, Report No. FHWA/RD-81/084, 1981

² Souleyrette, Tenges, McDonald, Maze, "Guidelines for the Removal of Traffic Control Devices in Rural Areas", Iowa Highway Research Board Project TR-527, 2005

- Increasing levels of control at low volume intersections did **NOT** reduce the number of crashes.
- The fraction of intersections with **NO** crashes is inversely related to the level of control – 95% of the intersections with No Control had no crashes compared to 69% for STOP controlled intersections.
- STOP signs have proven to have only a marginal effect on driver behavior at the low volume intersections, where the need to stop (based on interacting with conflicting vehicles) may not be obvious. Fewer than 20% of vehicles voluntarily stopped at STOP signs (vs. 9% at No Control intersections) and the fraction of Fast Entries at STOP controlled intersections was 45% higher than at intersections with No Control.
- A recent study of intersections in Iowa² found that at low volumes (less than 150 entering vehicles per day), there was no statistically significant difference between the safety performance of a STOP controlled versus an uncontrolled intersection.

Effectiveness of Warning Signs – Children at Play

- A research synthesis prepared for the Wisconsin Department of Transportation¹ found that there is no evidence that special warning signs of this sort either change driver behavior (reduce travel speeds) or improve safety (reduce crash frequency).
- The synthesis supplements the research with common sense observations that such signs:
 - Do not give clear and enforceable guidance to drivers.
 - Provide a false sense of security to parents and children that may increase risk
 - Give the false impression that areas without signs do not have children
 - Represent an unnecessary cost that then propagates as additional signs are requested.
 - Violates the principle that signage should be based on engineering, not political, judgement.
- The Minnesota Department of Transportation and the Local Road Research Board are currently conducting a research project to determine the effects on driver behavior associated with placing a playground warning sign along a 30 mph city street in Bloomington. Preliminary results of Before vs. After speed study found this sign had no effect on the maximum, mean or 85th percentile speed.²
- Traffic control devices are intended to change driver behavior and improve safety – these special warning signs have been found to do neither.



¹ Wisconsin Department of Transportation, "Effectiveness of Children at Play" Warning Signs, Transportation Synthesis Report, 2007

² Unpublished Mn/DOT document dated July 1, 2010, Office of Research Services, Investigation 890

Effectiveness of Warning Signs – Horizontal Alignment

- The most frequently used Horizontal Alignment Warning signs include the Advanced Curve Warning and the Speed Advisory.
- FHWA's Desktop Reference for Crash Reduction¹ indicates that the standard Advance Curve Warning signs have been found to reduce road departure crashes by about 20 to 30% and the use of enhanced delineation (Chevrons) reduced crashes by 20 – 50%.
- A study of a sample of approximately 200 curves in Minnesota² found the crash reduction associated in the Advanced Curve Warning was limited to curves with radii between 1,000 and 1,800 feet.
- The analysis of over 1,300 curves along highways in five counties in Minnesota (part of the Mn/DOT sponsored project to prepare safety plans for all counties) found that 80% of severe crashes occurred in curves with radii between 500 and 1,500 feet. This same analysis also found that longer radius curves present a much lower total crash risk and very short radius curves a much lower severe crash risk. This kind of information can be used to prioritize curves across a system and aid in the development of a systemwide approach to deploy horizontal alignment signs.
- A recent study³ of the effect of enhanced delineation – Chevrons – in Connecticut and Washington found crash reductions in the range of 20-30% and a benefit/cost ratio of 8:1.

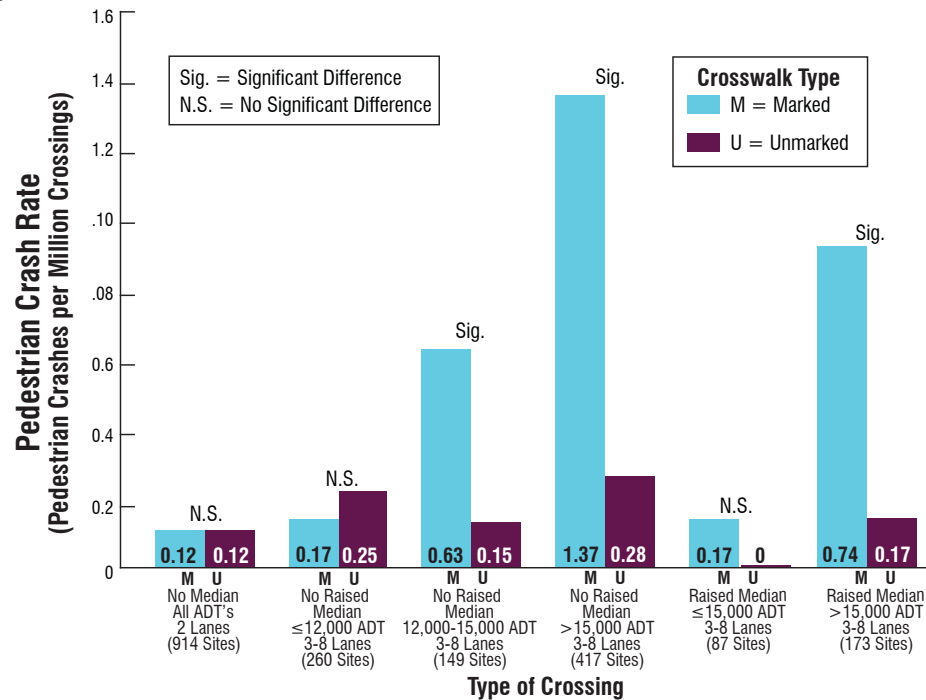


¹ Desktop Reference for Crash Reduction Factors, Report No. FHWA-SA-07-015, September 2007

² Pitale, Shankewitz, Preston and Barry; Benefit:Cost Analysis of In-Vehicle Technologies and Infrastructure Modifications to Prevent Crashes along Curves and Shoulders, MnDOT Research Report 2008-XX, June, 2009

³ Techbrief: Safety Evaluation of Improved Curve Delineation, FHWA Report – HRT-09-046, November, 2009

Effectiveness of Warning Signs – Pedestrian Crossings



- One of the most commonly requested strategies to address pedestrian safety is the installation of a marked crosswalk accompanied by pedestrian crossing warning signs.
- However, the results of two recent studies indicate that marked crosswalks (with pedestrian crossing warning signs) are NOT safety devices when used at uncontrolled intersections.
- A cross-sectional study of 2,000 intersections in 30 cities across the U.S. found that marked crosswalks at uncontrolled intersections resulted in higher pedestrian crash rates¹ (then at unmarked/signaled crosswalks) and this effect is greatest for multi-lane arterials with traffic volumes over 15,000 vehicles per day.²
- A Before vs. After study at over 500 intersections in San Diego and Los Angeles found a 70% reduction in pedestrian crashes following the removal of marked crosswalks at uncontrolled intersections.³

¹ Crash rate is the frequency of crashes divided by the number of pedestrians crossing at a particular location.
² Charles V. Zegeer, et al., *Safety Effects of Marked vs. Unmarked Cross-Walks At Uncontrolled Locations: Executive Summary and Recommended Guidelines, 1996-2001*
³ ITE (Institute of Transportation Engineers) Journal, September 2000



Effectiveness of Warning Signs

- A search of the safety research literature found **NO** documentation of crash reductions associated with **any** other Warning signs.
- It appears the use of warning signs is more out of fear of litigation as opposed to the strategic application of a traffic control device to solve a specific problem at a specific location.
- The most comprehensive study¹ of a Deer Crossing warning signs found these signs did NOT either change driver behavior (reduce vehicle speeds) or reduce deer-vehicle crashes and concluded that in order to increase effectiveness, research should focus on developing a dynamic system that would provide accurate real time information
- There appears to be a consensus among traffic engineers that static signs that warn of infrequent conditions or general possibilities – deer crossings, pavements that are slippery only when wet, rocks that may have fallen, low volume intersections and driveways with limited sight distances – are routinely ignored by drivers. This suggests that these signs would fail the effectiveness test because drivers do not choose to change their behavior based on information they determine to be either regularly wrong or of no value.

¹ Knapp, K., *Deer-Vehicle Crash Counter Measure Toolbox: A Decision and Choice Resource*, University of Wisconsin. Report No. DVCIC-02, June 2004



Effectiveness of Guide Signs


















- The MNMUTCD suggests the use of Guide Signs – Junction, Advance Junction and Street Name to support navigation and way-finding.
- A recent study of the safety effectiveness of advanced street name signs at signalized intersections found a minimal and statistically insignificant effect on crashes.¹
- A preliminary evaluation of one rural expressway corridor in Minnesota found that upgrading the Advance Junction and street name signs from conventional to a freeway style sign resulted in a 30% reduction of right angle crashes. (Note: this is an interesting conclusion, moves the crash data in a desired direction, but is not statistically significant. The sample size is too small.)²
- Many Minnesota counties have decided to participate in the program to provide a complete set of street name signs to improve way-finding for emergency response. There is a general consensus that these signs are a high priority and an important component of an overall effort to reduce emergency response time.

¹ Safety Evaluation of Advance Street Name Signs. Federal Highway Administration. FHWA-HRT-09-030.

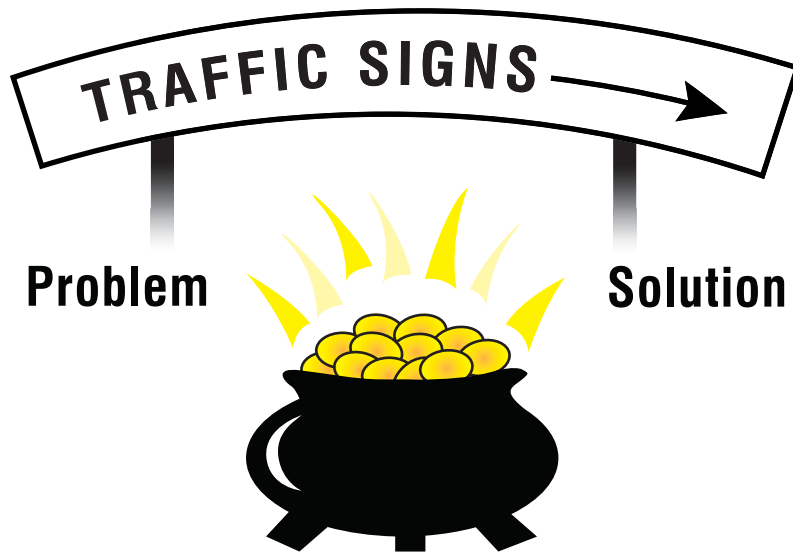
² NCHRP Report 650, Median Intersection Design for Rural High-Speed Divided Highways. Maze, T. April, 2010.

Sign Effectiveness Summary

	Signs that ARE proven to be effective	Signs that have not been tested for effectiveness	Signs that appear to be ineffective	Signs that are proven ineffective
Regulatory		 	 	
Warning	 	  	 	 
Guide			 	

- OK, which signs have been proven effective at either reducing crashes or changing driver behavior?
 - A search of the traffic safety literature found that the only types of signs that have been proven effective are the Horizontal Alignment Series (but only in a fairly narrow range of curve radii).
 - Research published by NCHRP found that pedestrian warning signs in combination with marked crosswalks at uncontrolled intersections in fact resulted in greater numbers of pedestrian crashes.
 - Guide Signs have been found to only have a minimal effect on intersection crashes but are assumed to improve way finding and navigation.
 - Bottom line – if your decision to install a sign is based on an expectation of effectiveness – either reducing crashes or changing driver behavior – the literature in support is virtually non-existent.
 - It appears that most signs fall into a category of hope - hope they do some good and an expectation that at least they don't do any harm.

Making the Case For Considering Sign Removal



- When evaluating your inventory of signs and deciding which signs should be retained versus which would be candidates for removal, consider the following issues:
 - What is the problem you are attempting to resolve and has the particular sign ever been effective at either changing driver behavior or reducing crashes?
 - What is the cost of maintaining your inventory? Can you afford this?
 - Is the use of a particular sign consistent with the guidance in the MNMUTCD? For example, the MNMUTCD discourages the use of stop signs for speed control because they aren't effective.
 - Think systematically – is the usage of a type of sign consistent along all of your roads?
- If the answer to these questions are negative – not effective, can't afford to maintain the system and inconsistent – then you should give very careful consideration to removing some signs in your inventory.

Sign Removal – Which Signs Are Candidates? (1/2)



- Speed Limit signs are only effective if the limit is near the 85th percentile speed. Speed Limit signs that merely state the statutory limit are not necessary.



- STOP and YIELD signs at low volume intersections are not safety devices, uncontrolled intersections have a lower expected crash frequency.



- Turn prohibitions relying solely on signage have only proven to be effective in the presence of law enforcement – you need to ask, how often will officers be present?



- The use of turn lane signs are linked to helping law enforcement get convictions and snow plow drivers clearing turn lanes. Ask law enforcement how much time they devote to going after passing on the shoulder? Would a delineator be sufficient to assist the plow drivers?



- Statements of the obvious are a waste of money if there is little or no enforcement of the law.



- Research suggests that typical drivers do NOT understand the concept of "CROSS TRAFFIC". To traffic engineers "Cross Traffic" means traffic approaching from the right and left but some drivers thought that this referred to vehicles coming towards them (Crossing the highway) from the opposing minor leg approach to the intersection.

Sign Removal – Which Signs Are Candidates? (2/2)



- Static signs that warn drivers of hazardous conditions they rarely encounter quickly lose credibility and become part of the background noise that drivers tune out.



- Mn/DOT is removing DEER CROSSING Warning signs because they have not proven to be effective at reducing deer/vehicle collisions. (They also determined that the signs had proven ineffective at training the deer where to cross the highways.)



- Advance curve warning signs were found to be effective in only a fairly narrow range of curve radii – curves with radii between 1,000 feet and 1,800 feet. There was no safety effect in larger radius curves and in shorter radius curves it was found that a combination of Advance Curve Warning **PLUS** Chevrons was required to produce a crash reduction. Try to achieve consistency across your system. If you have curve warning signs in advance of long radius curves, those could be candidates for removal based on system wide considerations.



- A number of studies have found that marked pedestrian crosswalks and their advance warning signs are **NOT** safety devices when used at uncontrolled locations. Pedestrian crash rates are actually higher at marked locations.



- There is no evidence that special warning signs of this type either change driver behavior (reduce travel speed) or improve safety.

Potential Sign Removal Examples (1/4)

If you can't think of any opportunities in your system to remove signs, consider these examples:

- The Children at Play sign isn't required (it isn't even listed in the MNMUTCD) and recent studies couldn't find any history of either crash reduction or changed driver behavior. In other words, this sign has never been observed to have a positive effect and may even contribute to making the situation worse – giving the parents a false sense of security that the sign is somehow protecting their children.
- The Keep Right and Left Turn Lane signs in this photo are along a 30mph, multi-lane city street that has continuous street lighting. These signs aren't required. The Left Turn Lane sign is merely telling drivers what they should already know – they are in a turn only lane. The Keep Right sign might provide guidance at night (the median noses are entirely visible in daylight), however, all of the intersections have street lights. When asked why all these signs were installed, the response was – they are in the MNMNTCD (absolutely true) and State Aid would pay for them. But the local agency has to pay for ALL future costs forever.
- On the approach to this STOP sign located along a 30 mph city street, an Intersection Ahead and a STOP AHEAD sign are provided to help drivers comply with a STOP sign that is entirely visible along a road that is travelled primarily by residents that live in the area. The Intersection Ahead warning sign is not required and has never been proven effective at either reducing crashes or changing driver behavior. The STOP AHEAD sign would be required – if there was any sight restriction on the approach, which isn't the case.



Potential Sign Removal Examples (2/4)



- These signs were obstructed by tree limbs – if they are not important enough to trim the vegetation, they could be candidates for removal.



- A 30 mph Speed Limit sign was installed along this narrow, winding residential street. The sign merely restates the statutory residential speed limit and was likely installed to placate residents. However it has been proven that speed limit signs have virtually no effect on driving behavior unless the limit is consistent with the driver's perceptions of the road or there is a significant presence of law enforcement. (This city does **NOT** have a police force).



- STOP signs have been routinely installed at hundreds of low-volume residential intersections where there is no compelling reason to stop. Also, there is no proof that these signs have ever accomplished anything other than wasting fuel. STOP signs could be removed if an engineering study determined that to do so did not result in an unusual level of hazard (or if an agency is uncomfortable with right-of-way at the intersection being based on drivers exercising the rule of the right, the STOP signs could be replaced with YIELD signs).

Potential Sign Removal Examples (3/4)



- Limited sight distance signs have never been proven effective at either reducing crashes or changing driver behavior. These signs do not convey a clear, simple message and doesn't provide the driver with any guidance relative to an intended action.
- If you have any of these signs (or are ever considering installation), a better idea would involve adopting ordinances that prohibit land owners from planting trees or shrubs that impair visual sight lines at street or driveway intersections and that allow city crews to enter private property to trim landscaping in cases where there is a danger to the public.
- These examples were provided by Faribault and Eagan.

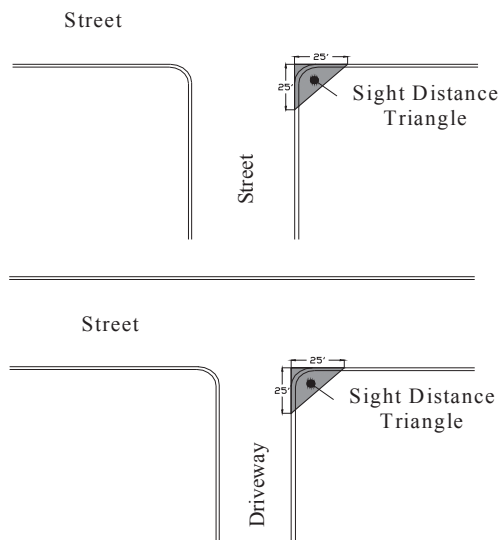
– Faribault

Information from City Code of Ordinances, Appendix B - Unified Development Regulations

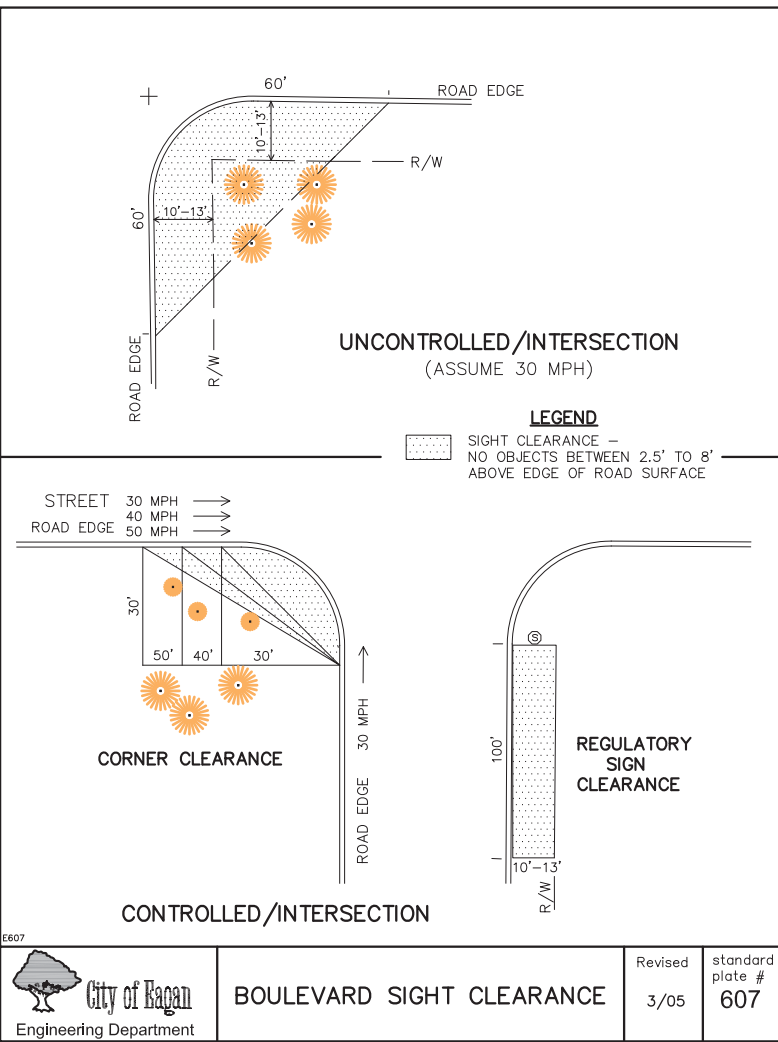
Sight distance triangle. A triangular shaped portion of land established at street or driveway intersections in which nothing is erected, placed, planted, or allowed to grow in such a manner as to limit or obstruct the sight distance of motorists entering or leaving an intersection. Such triangle shall be defined beginning at the intersection of the projected curb lines of two (2) intersecting streets or at the intersection of projected curb lines where a driveway intersects a street, measured twenty-five (25) feet along each curb line and connected by a diagonal line.

Fences. (2) Any fence extending into a front building setback area, a corner side building setback area, or within a required sight distance triangle shall not exceed three (3) feet in height, except as provided under [Subsection] (3) below.

Signs. (F) *Safety obstructions.* No sign in the city shall be placed or installed that obstructs access to fire escapes or required windows, doors, exits, or standpipes. Additional, no sign shall be placed within the twenty-five (25) foot sight distance triangle required at all intersections including driveways and alleys.



Potential Sign Removal Examples (4/4)



– Eagan

Information from City Code of Ordinances, Appendix B - Unified Development Regulations

D.4. Trees, shrubbery, and other plant material shall not be planted or maintained on public or private property in such a manner as to obscure or impede the visual sight lines required to ensure the safe and efficient circulation of vehicles and pedestrians on streets, intersections, trails, and sidewalks. Trees, shrubbery or other plant material shall not be planted as to block the visibility of any regulatory warning, or street identification sign or block the illumination of streetlights. The city shall have the authority to determine the minimal amount of required setback and clear zones in such circumstances. Property owners in violation of said requirements shall be given written notice, which notice shall be given by mail to their last known address, to remove, relocate, or trim all related plant materials in compliance with the directives given therein. If any owner or occupant fails to assume the responsibility of these requirements, the city may proceed to order the work done in accordance with subsections D.5. and D.6 of this subdivision.

E. Any tree, shrub or landscaping within a street right-of-way, which is in violation of this section, shall be trimmed or removed, as the city shall require, as to ensure elimination of any threat to public safety due to sight line or physical obstruction. The city shall have the authority to remove or trim any tree, shrub or landscaping, without first notifying the property owner, in the case where imminent public danger exists if removal or trimming is not immediately completed. It shall be the property owner's responsibility to trim, or remove when necessary, any shrub or landscaping within the street right-of-way which is in violation of this subdivision. It shall be the responsibility of the city to trim and the responsibility of the property owner to remove when trimming is not a feasible option, any tree in violation of this subdivision. The city may perform the work that is the responsibility of the property owner when the property owner has failed to do so. The city may charge the property owner the cost incurred by the city in performing any work required under this paragraph pursuant to subdivision 5 herein.

Sign Removal – Managing Risk



- Have the highest decision making body (City Council, County Commission, Township Board) adopt a policy or pass a resolution – specifying types of signs that will be installed and those that will not (candidates for removal)
- Document the outcome of your actions relative to installing/ replacing signs vs. removing signs, consistent with the direction provided by your decision making body.



- Conduct an engineering study.
- Document the applicable guidelines in the MNMUTCD.
- Document the conditions in the field.
- Document your decision.

Why Consider Removing Signs

- Maintenance Costs
- Problem → Solution Link
- Effectiveness/Ineffectiveness
- System Considerations
- Safety-Crosswalks, Unnecessary STOP signs, Children at Play – these types of signs could actually increase the number of crashes.

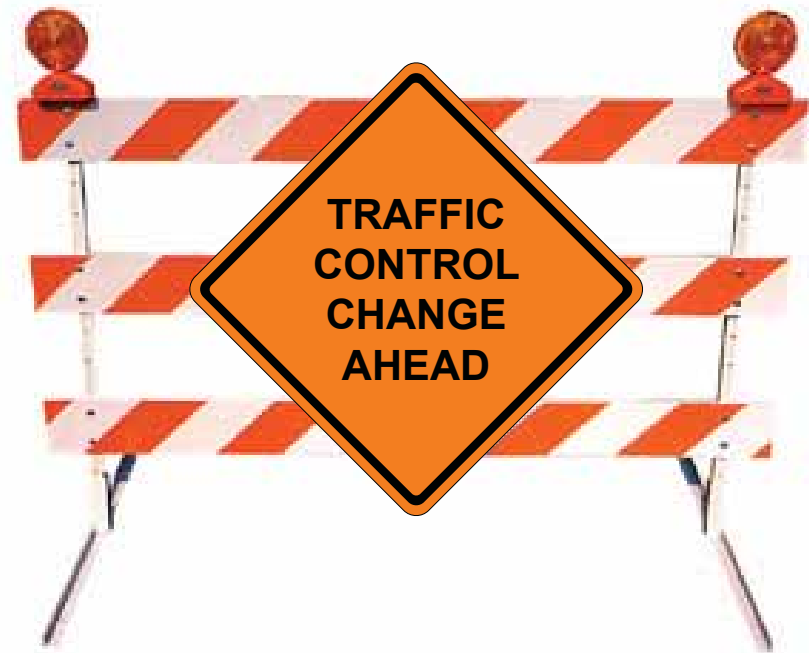
Process to Follow – Manage Risk

- Bring your decisions under an umbrella of immunity.
- Discretionary Immunity is generated by actions consistent with adopted policies and ordinances.
- Official Immunity is generated by exercising your engineering judgement as part of an engineering study and then documenting your actions.

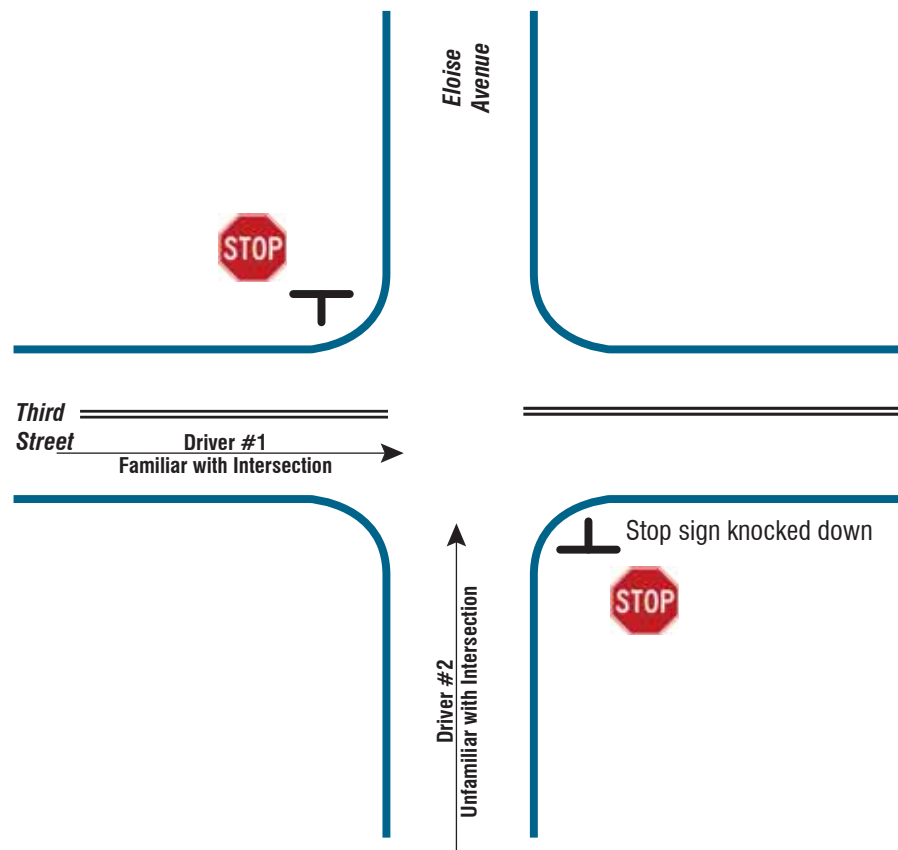
A Final Thought About Sign Removal



- If you decide to include sign removal as an integral part of your comprehensive sign maintenance/management program and intend to remove a variety of signs along your roads/streets - consider two public information/outreach actions.
- First, prepare a short public notice that could be run in your official paper, be distributed with newsletters or utility bills, posted on your website, etc.
- Second, if the sign removal involves intersection control (STOP or YIELD) consider the temporary placement (four weeks would be a typical duration) of Traffic Control Change Advance Warning Signs on a TYPE III barricade or a temporary support (supplement with flags to draw attention to the sign).



Case Study #3: City of South Lake Tahoe, CA vs. Markham (1/2)¹



Key Issue: STOP Sign Removal

Key Facts:

- The STOP sign for NB traffic on Eloise Avenue was knocked down early in the day, but no one notified the City.
- Driver #1 was traveling EB on Third Street and was familiar with the intersection knowing that EB/WB traffic had the right-of-way.
- Driver #2 was traveling NB on Eloise Avenue and was not familiar with the intersection, didn't see the STOP sign that was down, and drove into the intersection hitting driver #1.
- The City was sued by both drivers for not maintaining the STOP sign – the lack of maintenance was alleged to have caused the crash.
- There have been a number of similar cases where a STOP sign had been knocked down and the roadway agency failed to re-erect the sign in a reasonable time and a crash resulted. In these cases the key issue was NOTICE – the agency was aware of the situation and simply failed to act in a timely fashion.

¹ Souleyrette & Maze, "Guidelines for Removal of Traffic Control Devices in Rural Areas," Iowa Highway Research Board Project TR-527, October, 2005.

Case Study #3: City of South Lake Tahoe, CA vs. Markham (2/2)¹

- In this case, the City asserted that there was a very important difference → a STOP sign was NOT required and due to the very low traffic volumes the operation of the intersection without 2-way STOP control would not present a hazard.
- The California legal code contains a statutory exception where an agency has immunity from liability for injuries caused by not erecting a sign. However, once a sign is erected, there is no immunity for failure to maintain the sign.
- The California Appellate Court granted Summary Judgement and found:
 - The City had **NO** duty to provide the sign and could **NOT** be held liable if no sign had ever existed. Therefore, the City cannot become liable if the sign is removed, whatever the reason for the removal (including knocked down by another motorist). To conclude otherwise would require the court to accept the proposition that once the STOP sign was in place, it could never be removed and that motorists, particularly those on Third Street, could forever after rely on its presence. This reasoning, which is implicit in the Plaintiff's arguments, finds no support in Statute or State law.

Lesson Learned → An agency can remove a STOP sign(s) as long as the resulting intersection control does not present a hazard.

¹ Souleyrette & Maze, "Guidelines for Removal of Traffic Control Devices in Rural Areas," Iowa Highway Research Board Project TR-527, October, 2005.



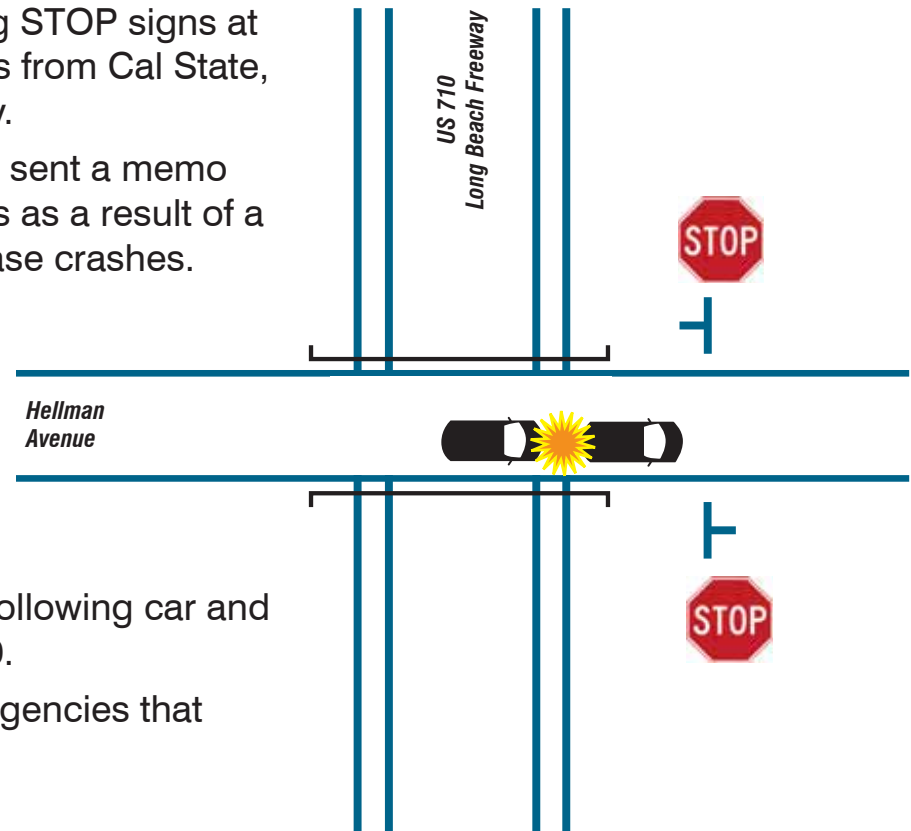
Case Study #4: Pedrosa vs. City of Alhambra, CA

Key Issue: Political Installation of STOP sign

Background:

- On September 15, 1982 a Rear End crash occurred at a mid-block STOP sign located on Hellman Avenue, just east of the Long Beach Freeway.
- The City of Alhambra, CA City Council debated installing STOP signs at the mid-block location in an effort to slow down students from Cal State, located just west of the freeway, when entering their City.
- During the City Council debate, the City Traffic Engineer sent a memo to the Council advising against installing the STOP signs as a result of a concern that the mid-block STOPs would actually increase crashes.
- The City Council decided to install the STOP signs – their desire to respond to residents complaints about students speeding through the neighborhood was more compelling than the concern for crashes.
- Following the crash, the driver of the lead vehicle sued the City and the driver of the following vehicle.
- A Pasadena Superior Court jury found the driver of the following car and the City negligent and awarded the lead driver \$810,000.

Lesson Learned → There can be real consequences for agencies that choose to disregard the advice of their professional staff.





What's wrong with this picture?
(See page G-2 for answer.)

Part G – Summary of Key Points

Key Points..... G-1 Answers to Quiz..... G-2

Key Points

- The MNMUTCD is a compilation of guidelines regarding the design and installation of signs, markings and signals. However, unlike other design guides, the MNMUTCD carries with it a higher level of authority because it has been adopted by the State for use on **ALL** roads in the State.
- BUT – do not fall into the trap of saying that the MNMUTCD made you install a particular device. The authors clearly intended all of the guidance to be filtered through **YOUR** judgment and specifically states that the MNMUTCD is **NOT** a legal requirement for the installation of anything.
- The rules regarding an agency’s approach to sign maintenance have fundamentally changed. It was always a good idea to keep your signs in good shape – now it is required!
- The regulations require agencies to select a maintenance method and to engage in a program to keep levels of retroreflectivity above specified minimum levels.
- Your agency is now “On the Clock”. You have until January 2012 to evaluate, discuss and then declare what maintenance method your agency will use. You have until January 2015 to bring your Regulatory, Warning, and Ground Mounted Guide signs up to the minimum level and until January 2018 to get your Overhead Guide and Street Name signs above the minimums. Think about getting your agency to start on this effort **Tomorrow!**
- You are encouraged to work with your elected officials to develop a policy to guide your sign maintenance program. The policy would establish direction for your staff and support statutory discretionary immunity.
- Your agency will need to develop an implementation process – create one of your own or modify the approach identified in this guide. **But** make sure to include exercising engineering judgment and to create some kind of **written record** regarding signs to remain and signs to be removed – this supports establishing official immunity for your agencies actions.

* See page A-4 for exceptions

Answers to Quiz

Part A Divider

In both photos the STOP AHEAD signs are clearly not needed – the STOP signs are completely visible. The use of these STOP AHEAD signs was likely based on a blanket practice of installing these warning signs at every intersection. Getting back to a location specific decision process would represent an opportunity to reduce an agency's inventory of signs by supporting the removal at intersections with adequate sight distance.

Part B Divider

This speed limit sign merely states the statutory speed limit for urban streets. It is entirely obvious that the area is residential. The road is narrow and curvilinear. The sign fulfills no real purpose and could be considered for removal.

Part C Divider

The STOP and YIELD signs in the photo are at the intersection of two, low-volume residential streets. These signs are not required and research shows that the use of these signs in low-volume conditions are not safety devices. These signs could be candidates for removal at this particular location and across the system.

Part D Divider

The chevron in this photo is on a city street and is approximately 100 feet from a STOP sign at a multi-lane urban arterial. The horizontal alignment series of warning signs has proven to be effective at reducing road departure crashes, but never at curves with a 60 foot radius. It appears that the chevron is being used to supplement the STOP sign, a use for which it was never intended. It appears that this sign at this location is a candidate for removal.

Part E Divider

The static Deer Crossing Warning sign has been found to be ineffective at reducing vehicle/deer crashes. As a result, a number of agencies (including Mn/DOT) have identified these signs as candidates for removal (not replacing them when knocked down or removed as part of corridor-based upgrades).

Part F Divider

Watch for Children and Slow Children signs have never been proven effective at either reducing crashes or changing driver behavior. As a result, their usage does NOT result in any real improvement for either the children or drivers and could actually make matters worse by giving parents a false sense of security based on the hope that a sign can somehow replace their own responsibility to supervise their children. These types of warning signs should be considered for removal because agencies cannot afford to install signs that are ineffective.

Part G Divider

This static Intersection Warning sign has never been proven effective at improving safety. In this case, the intersection has very low volumes and drivers almost certainly live in the area, knowing that there is an intersection ahead. The low volume at the intersection suggests that the probability of a crash is low and this sign has no history of reducing crashes – it should be considered a candidate for removal.

Appendix Divider

STOP and YIELD signs at low volume intersections are not safety devices, nor should they be used for traffic calming purposes. STOP signs have a marginal effect on driver behavior at low volume intersections with fewer than 20% of vehicle voluntarily stopping.



What's wrong with this picture?
 (See page G-2 for answer.)

Appendix

Example Signing Policy – Metro County	AP-1	Why Won't They Put Up "CHILDREN AT PLAY" Signs?	AP-4
Example Signing Policy – Cass County	AP-2	Why Don't They Put In More STOP SIGNS?	AP-5
Sample Response to Request for SLOW CHILDREN Sign	AP-3	When Will a Lower Speed Limit be Posted on My Street?	AP-6

Example Signing Policy – Metro County

Sign Maintenance Policies and Procedures
Sample Document for use by Public Agencies (Sample from County) Page 1 of 3

(Specific agency name) Transportation
Sign Maintenance Policies and Procedures – Sample Document
Adopted by (____ County) Board: Date – Resolution _____

Purpose

The purpose of the Traffic Operations Policies and Procedures is to establish and maintain uniform definitions and practices concerning sign maintenance and operations on (specific agency name) highways. The county will provide such control in a safe and cost-effective manner balancing the needs of safety for highway users and county personnel, budget, social and environmental concerns. It is in the county's best interest to have traffic operation and maintenance procedures. Because of variables in the weather, traffic issues, changing driver demographics, road design, standards and other factors, these procedures must remain flexible. The county may use county employees or other entities under contract to provide this service.

I. Procedure

The sign maintenance supervisor or designated lead worker will make decisions concerning scheduling and the procedures to be followed for daily traffic operation maintenance needs and subsequent yearly detailed condition inspections. Scheduling and the procedures to be followed will be based upon consideration of the following factors: significance of the traffic device to driver safety, condition and effectiveness of the device, standards compliance, and whether damage or condition creates an immediate safety hazard.

In every instance, the onsite Traffic Technician must assess the conditions of the traffic control device and rely on judgment and experience to determine the appropriate action to correct or maintain the device. Factors that may delay completion of traffic operation maintenance include other repair needs; utility locates needs; fabrication of necessary material, weather conditions including severe cold or significant winds, limited visibility, and other staff and field condition issues.

II. General Practices: Subject to the factors set forth in Section II, Procedures, the county will maintain traffic control devices (signs, traffic signals and pavement markings) to ensure a safe and efficient operation. Note: This example details sign practices but, can be expanded to pertain to all traffic operation practices.

Sign Maintenance

- A. **Sign Installation:** Signs will be installed to meet federal standards set forth in the most recent Minnesota Manual on Uniform Traffic Control Devices (MnMUTCD) in accordance to (specific agency name) guidelines and practices.
- B. **Maintain Signs:** Overall Responsibility: County sign maintenance practices are established to meet all requirements and ensure appropriate signing for the traveling public.
- C. **Sign Retro-Reflectivity:** (Specific name) county is currently creating a field sign inventory database. Once data collection is done and the system is in place, County will utilize the database for sign management through the expected sign life practice

Sign Maintenance Policies and Procedures
Sample Document for use by Public Agencies (Sample from County) Page 2 of 3

to meet federal sign retro-reflectivity standards. Expected sign life will be conducted through a combination of review of signs that are at the sheeting warranty life and sample measurements to establish a base line life for each sign type.

Prior to completion of the database, County will utilize the Visual Inspection Method, following the general criteria of the calibrated sign procedure to conduct a nighttime inspection as outlined in the specific section below.

Once the sign management practice is fully implemented nighttime sign survey may be conducted periodically (up to every four years) to supplement the management program and monitor for sign replacement needs based on vandalism or other premature sign degradation.

- D. **Sign Maintenance Responsibility:** Maintain highway signs and street identification signs on all (specific agency name) highways, with the exception of:
- 1) All signing on approaches to county highways are not installed or maintained by the county other than street name signs and stop signs intersecting the county Highway which are maintained by the county
 - 2) Stop signs at Minnesota Department of Transportation (MnDOT) controlled intersections and highway ramps with county highways;
 - 3) Specific signs installed by others (MnDOT, transit agencies, and Cities permitted to place signs on county highways) as outlined in the advanced signing guideline document.
 - 4) Signs along county Highway within MnDOT right of way, unless specific agreement with MnDOT stipulates a county maintenance responsibility for signing.
 - 5) Bike path and other pedestrian-control signs not pertaining to vehicle traffic.

Response to Incident Report for Sign Repair Needs: Sign maintenance staff will respond after receiving notice of a repair need to determine appropriate action with the following priorities:

- 1) Stop signs: as soon as practical, no later than one business day, a temporary stop sign will be placed if required.
- 2) Other regulatory signs: no later than three business days.
- 3) Warning signs: within one scheduled workday.
- 4) Informational/guidance signs: within two scheduled workweeks.

Visual Sign Inspection: Traffic staff will perform a night time survey as follows:

- 1) Acceptable retro reflectivity will be determined by the technicians conducting the night time inspect.
- 2) Staff will be given direction as training by the supervisor or take a night time sign inspection course if available in the area for conducting the study appropriately. The night of the inspection, staff will view each sign type mounted at the standard sign height (regulatory black/white, stop sign, warning sign and guidance sign) that are at or above minimum criteria from the standard county pick-up truck with low-beams to mimic field conditions as much as practical.

Sign Maintenance Policies and Procedures
Sample Document for use by Public Agencies (Sample from County) Page 3 of 3

- 3) Written documentation of the location, sign type, size and reason for sign replacement will be recorded for each sign that is not in an acceptable condition and needs replacement.
- 4) Sign replacement will occur as follows:
 - a) Stop signs – within three working days
 - b) All other signs – by segment with the entire replacement program for signs identified through the survey being replaced within four months of completion of the review.

G. Miscellaneous Sign Practices:

- 1) Sign staff is not directly on-call after normal working hours. After hours phone numbers for traffic operation sign staff is provided to the Communications Center (911 response) so staff can be contacted in case of an emergency. In addition, a sign maintenance and highway maintenance person is on-call at all times after normal working hours and can respond to emergency situations in case traffic operation staff cannot be contacted.
- 2) Training is provided to ensure traffic staff can perform sign maintenance duties in an efficient, effective and responsive manner. Such training shall consist of, at a minimum, appropriate signing and traffic control seminars (when available and funds are available in the county training budget), appropriate available training videos or website trainings, and yearly training by supervisors.
- 3) Unauthorized signs will be removed from county right of way consistent with the (specific agency name) Sign Placement Policy 8252.
- 4) Support staff will be informed and updated regarding sign maintenance operations (e.g., schedules and other priority needs or equipment failures) to ensure accurate information is available to respond to telephone inquiries.
- 5) Sign staff may park a sign maintenance vehicle against traffic flow in order to perform necessary emergency and routine maintenance duties.
- 6) Sign staff may drive or park maintenance vehicles on the center medians or boulevards in order to perform necessary emergency and routine maintenance duties.

Example Signing Policy – Cass County

Cass County Highway Department Guidance Policy Roadway Signage & Striping

Introduction

The Cass County Highway Department believes it is in the best interest of the residents of the county to assume basic responsibility for installation and maintenance of roadway signage and pavement markings on county roadways. Roadway signage and pavement markings are essential for routine travel and safety of the motoring public. The County Highway Department will provide such services in a safe and cost effective manner, keeping in mind safety, budget, personnel and environmental concerns.

Striping

The Cass County Highway Department is committed to providing and maintaining roadway markings and striping on all paved county roadways. Due to the volume of paved roadways (approximately 420 miles in 2003) and budget constraints, it is not financially feasible for the Department to re-stripe all of the roadways on an annual basis. As such, the effects of traffic volume and maintenance activities on the striping performance were reviewed. Following this review, the Department determined schedules needed to maintain an adequate stripe for different traffic counts. The re-striping schedules are as follows:

- 1) All highways with traffic counts of 1,000 vehicles per day or greater will be re-stripped annually (every year).
- 2) All highways with traffic counts greater than 500 and less than 1,000 vehicles per day will be re-stripped bi-annually (every other year).
- 3) All highways with traffic counts of less than 500 vehicles per day will be re-stripped once every five (5) years.

To gain the most effective performance of the stripe and to allow sufficient time for the striping point to cure, it is the Department's goal that all re-striping operations that are made a part of the striping program should be completed by June 30th of each year.

Signage

The Cass County Highway Department is committed to providing adequate signage on all County roadways. However, with the volume of roadways that the Department maintains, it is not financially feasible to sign all roadways. Because of this, it has been decided that signs will be provided only on paved roadways with some signs on gravel roads in exceptional circumstances. All signs that are deemed to be required on a roadway will be placed, constructed and maintained in accordance with the "Minnesota Manual On Uniform Traffic Control Devices" (Mn/MUTCD) that was current at the time that the sign was installed. All new signs that are placed or replaced within Cass County right-of-way should be constructed with High Intensity Diamond grade facing or higher, dependent on the Department's budget.



Cass County Highway Department

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CASS COUNTY HIGHWAY DEPARTMENT

SIGNING POLICY

"Slow, Children at Play" Signs
"Watch for Children" Signs

The Cass County Highway Department will not utilize these signs, because it is not recognized by the State of Minnesota Manual on Uniform Traffic Control Devices (MUTCD), the legal sign manual in the State. The reasons why these signs are not accepted by the MUTCD are:

1. These signs are unenforceable. Local law enforcement cannot write tickets based solely on these signs, unless motorists are exceeding the posted speed limit.
2. Motorists should be aware that children might be playing near all highways. To sign specific highways would imply that those highways without signs have no children nearby. If one highway is signed, all highways should be signed, which would be impractical.
3. These signs give parents and children a false sense of security.
4. There is no data to support that these signs effectively modify driver behavior.

Adopted by Cass County Board of Commissioners - May 17, 2005

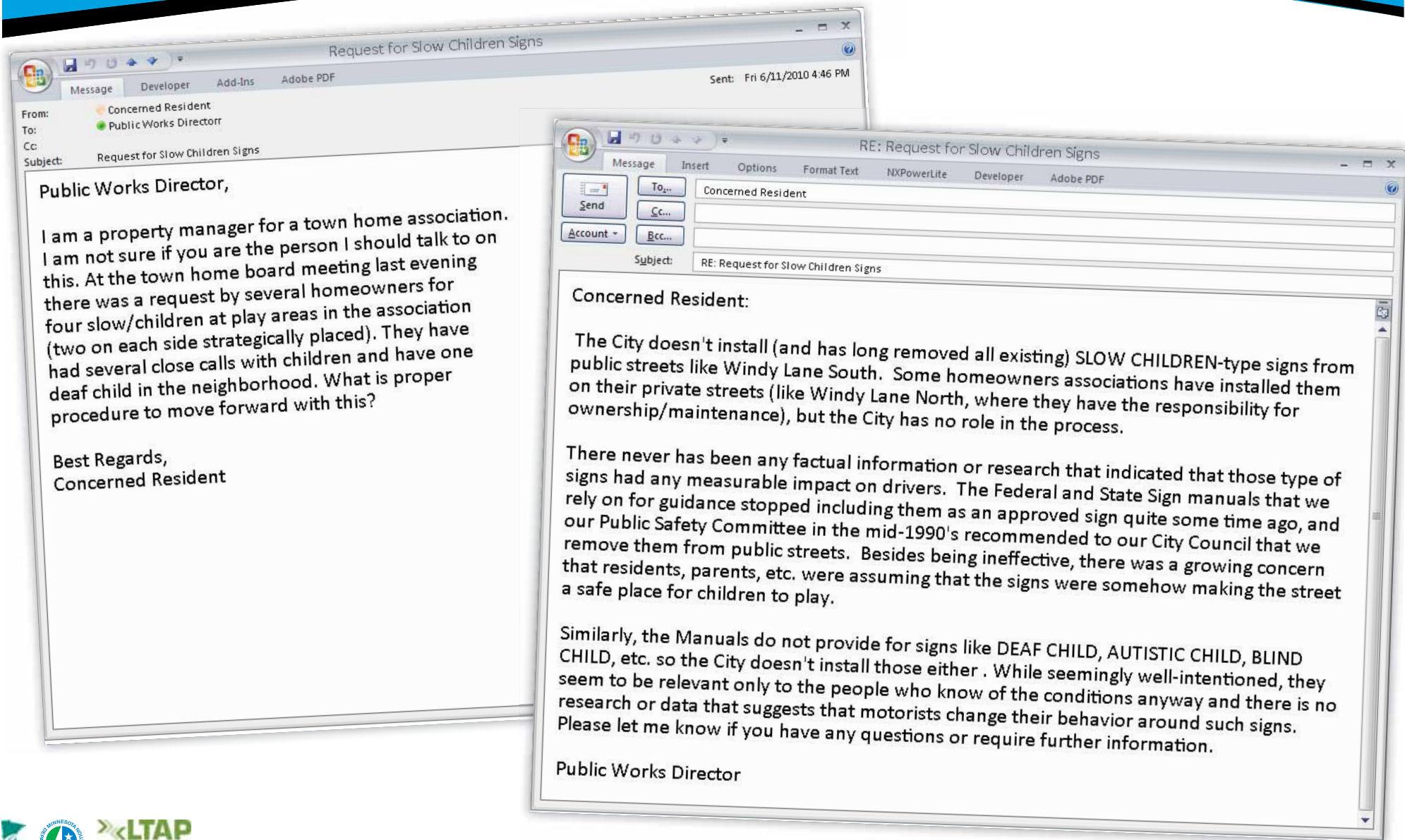
Sign Maintenance Practices

- 1) **Recurring Maintenance Schedule** - All signs that are necessary for traffic control should be placed on a recurring maintenance schedule and should be replaced on a 10 to 12 year life cycle. The Department should also conduct periodic nighttime reflectivity observations of all signs within the right-of-way in order to monitor the performance of the signs reflective quantities. These observations should also include all signs in County right-of-way that face traffic entering from local roads.
- 2) **Traffic Sign Field Inventory** - The Department shall develop and maintain a field inventory of all signs located within the right-of-way of all County roadways. This record of signage is vital to sign management practices and to allow budgeting costs to be determined for changes in sign maintenance policy. The information included in this inventory should include but not be limited to type and size of sign, type of reflective coating, location of the sign, and date that the sign was installed.
- 3) **Missing or Damaged Signs** - It is the counties responsibility to replace all missing or damaged signs on the County roadway system. Signs can become missing and/or damaged due to being stolen, involved in an accident or vandalized as well as becoming dysfunctional due to typical aging and/or weathering processes. When the sign is considered vital to the safety of the motoring public (i.e. stop signs, etc.), the sign will be replaced as soon as possible once the problem has been identified. This means that County personnel will be dispatched to repair the deficiency as soon as the Department is notified. This indicates that crews will be dispatched regardless of time of day and/or overtime. If the sign is of a type important to the safe and efficient use of the roadway system (i.e. speed limit signs, warning signs, etc.) it will be replaced as soon as possible during normal Department working hours, generally within three (3) business days. If the sign is of a type that its existence is not important to the general safety of the motoring public (i.e. route markers, guide signs, adopt-a-highway signs) it will be replaced as soon as practical within the Departments normal operations. All sign maintenance operations will be performed at the discretion of the Engineer and will be subject to Department budget and personnel constraints.

When the Department is contacted regarding missing or damaged signs within the right-of-way of other authorities (i.e. Mn/DOT or townships) the governing authority should be contacted to notify them of the deficiency.

Source: http://www.co.cass.mn.us/highway/pdfs/signing_policy.pdf

Sample Response to Request for SLOW CHILDREN Sign



Why Won't They Put Up "CHILDREN AT PLAY" Signs?

An often heard neighborhood request concerns the posting of generalized warning signs with the "SLOW-CHILDREN AT PLAY" or other similar messages. Parental concern for the safety of children in the street near home, and a misplaced but wide-spread public faith in traffic signs to provide protection often prompt these requests.

Although some other states have posted such signs widely in residential areas, no factual evidence has been presented to document their success in reducing pedestrian accidents, operating speeds or legal liability. Studies have shown that many types of signs attempting to warn of normal conditions in residential areas have failed to achieve the desired safety benefits. If signs encourage parents and children to believe they have an added degree of protection, which the signs do not and cannot provide, a great disservice results.

Because of these serious considerations, Minnesota law does not recognize, and Federal Standards discourage, use of "Children at Play" signs. Specific warnings for schools, playgrounds, parks and other recreational facilities are available for use where clearly justified.

Children should not be encouraged to play within the street travelways. The sign has long been rejected since it is a direct and open suggestion that this behavior is acceptable.



Why Don't They Put In More STOP SIGNS?

A stop sign is one of our most valuable and effective control devices when used at the right place and under the right conditions. It is intended to help drivers and pedestrians at an intersection decide who has the right-of-way.

One common misuse of stop signs is to arbitrarily interrupt through traffic, either by causing it to stop, or by causing such an inconvenience as to force the traffic to use other routes. Where stop signs are installed as “nuisances” or “speed breakers,” there is a high incidence of intentional violation. In those locations where vehicles do not stop, the speed reduction is effective only in the immediate vicinity of the stop sign, and frequently speeds are actually higher between intersections. For these reasons, it should not be used as a speed control device.

A school crossing may look dangerous for children to use, causing parents to demand a stop sign to halt traffic. Now a vehicle which had been a problem for 3 seconds while approaching and passing the intersection becomes a problem for a much longer period. A situation of indecision is created as to when to cross as a pedestrian or when to start as a motorist. Normal gaps in traffic through which crossings could be made safely no longer exist. An intersection which previously was not busy now looks like a major intersection. It really isn't – it just looks like it. It doesn't even look safer and it usually isn't.

Most drivers are reasonable and prudent with no intention of maliciously violating traffic regulations; however, when an unreasonable restriction is imposed, it may result in flagrant violations. In such cases, the stop sign can create a false sense of security in a pedestrian and an attitude of contempt in a motorist. These two attitudes can and often do conflict with tragic results.

Well-developed, nationally recognized guidelines help to indicate when such controls become necessary. These guidelines take into consideration, among other things, the probability of vehicles arriving at an intersection at the same time, the length of time traffic must wait to enter, and the availability of safe crossing opportunities.



When Will a Lower Speed Limit be Posted on My Street?

A common belief is that posting a speed limit will influence drivers to drive at that speed. The facts indicate otherwise.

Research conducted in many parts of this country over a span of several decades has shown that drivers are influenced more by the appearance of the highway itself and the prevailing traffic conditions than by the posted speed limit.

Minnesota's Basic Speed Law requires that:

“No person shall drive a vehicle on a highway at a speed greater than is reasonable and prudent under the conditions and having regard to the actual and potential hazards then existing. In every event speed shall be so restricted as may be necessary to avoid colliding with any person, vehicle or other conveyance on or entering the highway in compliance with legal requirements and the duty of all persons to use due care.”

In Minnesota, the maximum speed limit in an urban district is 30 miles per hour unless otherwise posted. An urban district is defined as the territory contiguous to and including any street which is built up with structures devoted to business, industry, or dwelling houses situated at intervals of less than 100 feet for a distance of a quarter of a mile or more. Outside urban districts, the maximum speed limit for any passenger vehicle is currently 55 miles per hour. These speeds are not always posted but all Minnesota motorists are required to know these basic 30 and 55 mile per hour speed laws.

Under Minnesota law, intermediate speed limits (except school speed limits) between 30 and 55 miles per hour may be established on any road, including county highways and city streets, only by the State Commissioner of Transportation. The commissioner must establish the speed limit upon the basis of an engineering and traffic investigation. This investigation includes an analysis of roadway conditions, accident reports, and the prevailing speed of prudent drivers. If speed limit signs are posted for a lower limit than is needed to safely meet these conditions, many drivers will simply ignore the signs. At the same time, other drivers will stay within the posted limits. This generally increases the conflicts between faster and slower drivers, reduces the gaps in traffic through which crossings could be made safely and increases the difficulty for pedestrians to judge the speed of approaching vehicles. Studies have shown that where uniformity of speed is not maintained, accidents generally increase.





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