MINNESOTA'S BEST PRACTICES FOR

Traffic Sign Maintenance/ Management Handbook

Including Insight on How to Remove Unnecessary and Ineffective Signage

REPORT NO. 2014RIC20
VERSION 2.0
October 2014

MnDOT Research Services Section
MS 330, 395 John Ireland Blvd.
St. Paul, Minnesota 55155
Phone: 651-366-3780
Fax: 651-366-3789
E-mail: research.dot@state.mn.us

LRRB Local Road Research Board

Minnesota Department of Transportation

LTAP Center for Transportation Studies University of Minnesota

CH2MHILL

Table of Contents

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 MN MUTCD for all public roadways [and private roadways open to the public] in Minnesota (Commissioner Order No. 92452 – December 15, 2011).
- 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 MN MUTCD 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

Current Requirements

- Signs have always been required to be retroreflective. No minimum values had previously been required.
- Language adopted in the MN MUTCD requires all agencies that maintain roadways open to public travel to adopt a sign maintenance program designed to maintain traffic sign retroreflectivity at or above specific levels.
- All agencies responsible for maintaining traffic signs are required to comply with the new MN MUTCD requirements.
- **STANDARD** 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 the MN MUTCD Table 2A-3 (page A-5).
  COMPLIANCE DATE: June 13, 2014

Reminder

- In the MN MUTCD 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

Which meet retroflectivity requirements?

Table 2A-3: Minimum Maintained Retroreflectivity Levels

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

1. The minimum maintained retroreflectivity levels shown in this table are in units of cd/lx/m² measured at an observation angle of 0.2° and an entrance angle of -4.0°.
2. For text and fine symbol signs measuring at least 48 inches and for all sizes of bold symbol signs.
3. For text and fine symbol signs measuring less than 48 inches.
4. Minimum Sign Contrast ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity).
* This sheeting type shall not be used for this color for this application except as noted in 2A.8.

Bold Symbol Signs

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

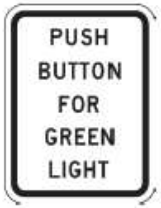
Fine Symbol Signs - Symbol signs not listed as Bold Symbol Signs.

Special Cases

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

Source: 2014 MN MUTCD

- 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°.
- All Regulatory, Warning and Guide signs and object markers are required to be retroreflective or illuminated to show the same shape and similar color by both day and night.The requirement for sign illumination is not considered to be satisfied by street, highway or strobe lighting. An agency may exclude the following signs from the retroreflectivity maintenance policy. Guide signs should be added to an agency's policy as resources allow.



  - Guide Signs
  - Parking, Standing and Stopping signs (R7 and R8 series)
  - Walking/Hitchhiking/Crossing signs (R9 series, R10-1 throughR10-b)
  - 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

Comparison of Reflective Sheeting Material

Life Cycle Costs & Initial Retroreflectivity

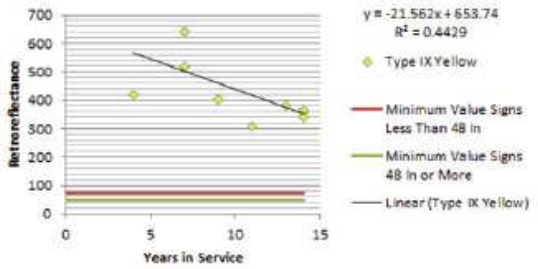
Sheeting Material (ASTM)	Type I	Type IV	Type IX	Type XI
Material Cost ($/SF)	$0.85	$1.20	$4.25	$3.50
Finished Sign Cost	$30	$25	$51	$45
Anticipated Life (years)	5 – 7	10-12	15	20
Life Cycle Cost	$130	$50	$119	$45
Initial Retroflectivity (white)	70	300	380	580

Source: 3M Traffic Safety Systems Division, August 2014

Typical Installation Cost				
Stop (30x30)	$240	$240	$260	$250
Warning (36x36)	$240	$260	$280	$275
Regulatory (24x30)	$230	$230	$250	$255

Source: MnDOT

Sample Degradation Curve Type IX Yellow

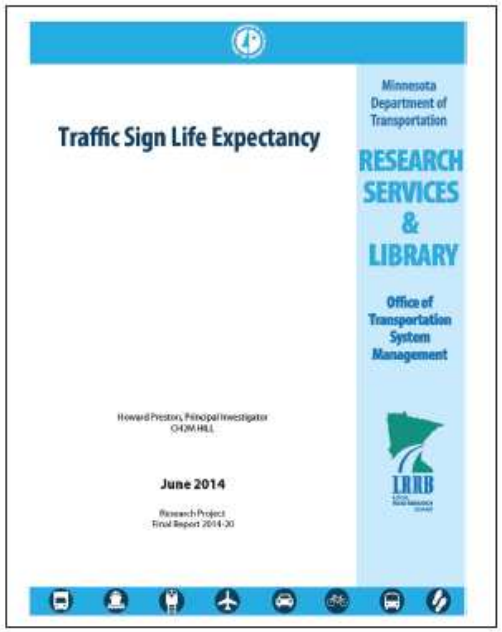


Source: MnDOT Research Report 2014-20 "Traffic Sign Life Expectancy"

- 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%.

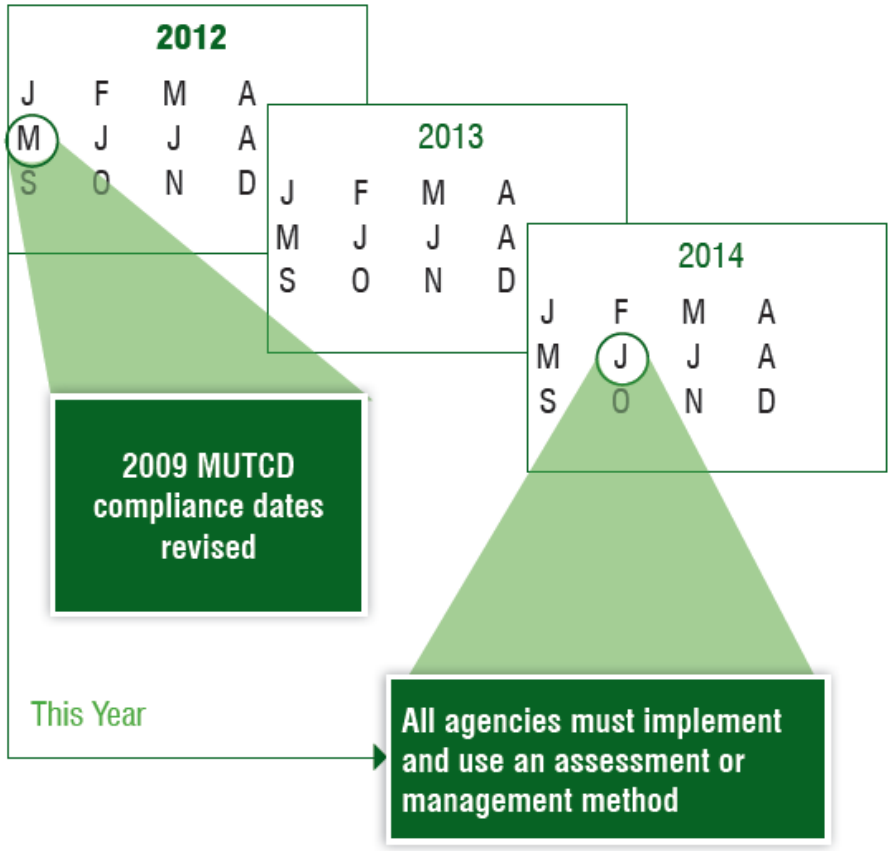
Traffic Sign Life Expectancy

- Regarding the anticipated life of signs – there is a high level of interest in establishing a specific value for each type of sheeting material. However, current research suggests that available data is inconclusive, but supports a life expectancy range of 12 to 20 years for beaded sheeting material (Types I, II and III) and 15 to 30 years for prismatic sheeting (Types III, IV, VI, VII, VIII, IX, X, XI). A summary of this research is provided in a recent report published by MnDOT (Traffic Sign Life Expectancy – Report No. 2014-20).
- MnDOT Report No. 2014-20 analyzed retroreflectivity readings from approximately 400 signs in Minnesota and concluded that the results were similar to those reported in other states, but that the small sample size was not sufficient to produce statistically reliable results.
- As part of this study, MnDOT established a sign sheeting test deck at the MnROAD facility and has indicated that they intend to maintain the test deck and continue recording the retroreflectivity until the sheeting material degrades below the established thresholds. This effort would help define the expected life of sheeting material in Minnesota.

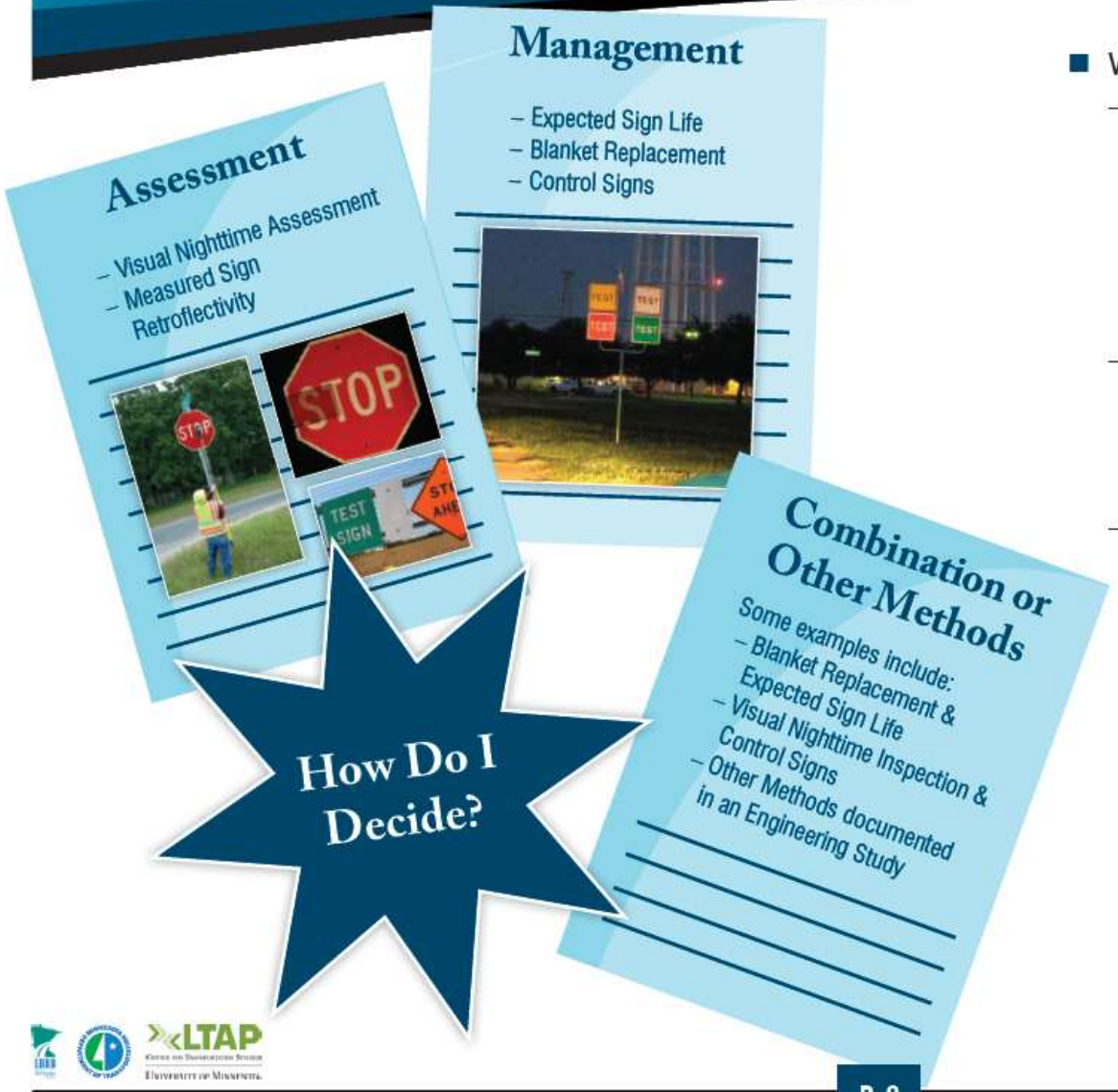


Retroreflectivity Compliance Dates

- May 14, 2012 - 2009 MUTCD compliance dates revised (most eliminated).
- June 13, 2014 – All agencies must implement and use an assessment or management method that is designed to maintain Regulatory and Warning traffic sign retroreflectivity at or above the established minimum levels.
- ALL signs must now be at or above minimum retroreflectivity levels or illuminated to show the same shape and similar color by both day and night.
- Existing signs must be compliant as outlined in the sign assessment or management method.



Maintenance Methods



- 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

Financial Budgeting – Cities under 5,000 Population (1/2)

- 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:

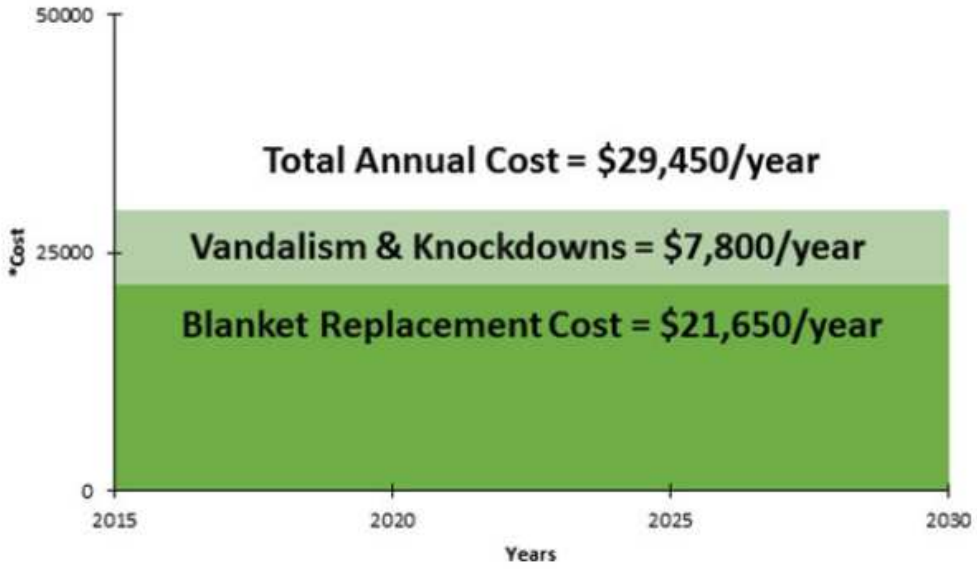
50 miles  x (25 signs/mile  x $200/sign + 6 signs/mile  x $250/sign) = $325,000

- All signs must be retroreflective or illuminated. Only Regulatory and Warning signs must be a part of your assessment or management method. Add Guide signs as resources allow.
- Consider reducing your inventory of signs.

* *Replacement costs include sign blank, sheeting material, sign posts, and installation. Constant 2014 $*

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

- Maintaining your system of signs has always been a good idea, but now it's a required action.
- Given the minimum level of required maintenance, agencies should re-evaluate their sign maintenance budgets.
- Annual sign maintenance budget = cost to address retroreflectivity + cost to address vandalism, knockdowns and mother nature.
- A study from the North Carolina Department of Transportation[1] found that approximately 2.4% of signs are vandalized or knocked down in a year.
- Annual cost to address degradation of retroreflectivity (Assuming a 15 year replacement cycle) = $21,650
- Annual cost to address damage by vandalism and knockdowns = $7,800
- A typical small city annual sign maintenance budget = $29,450
- Reduce the sign maintenance budget by removing signs that are NOT required.



1 *North Carolina Department of Transportation, "Designing an Efficient Nighttime Sign Inspection Procedure to Ensure Motorist Safety"*

Financial Budgeting – Cities over 5,000 Population (1/2)

- 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:

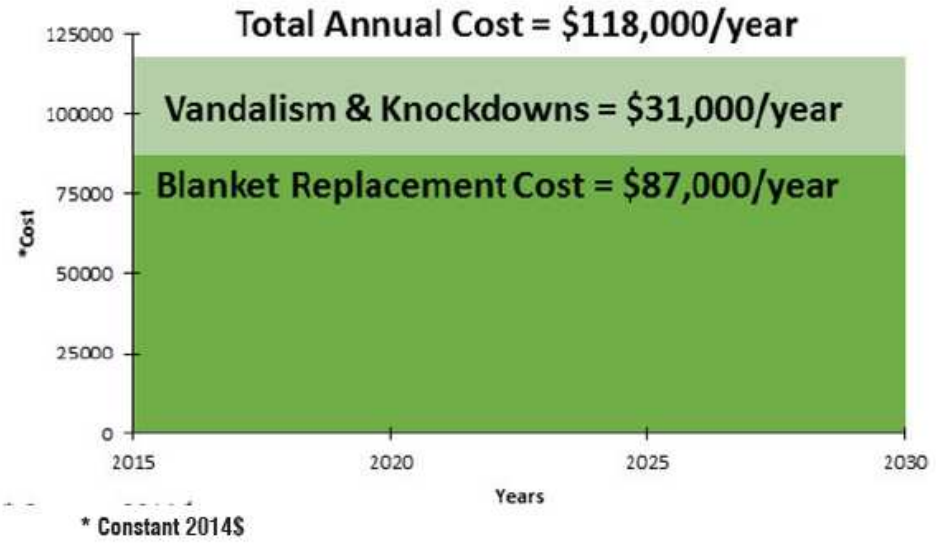
200 miles  x (25 signs/mile  x $200/sign + 6 signs/mile  x $250/sign) = $1,300,000

- All signs must be retroreflective or illuminated. Only Regulatory and Warning signs must be a part of your assessment or management method. Add Guide signs as resources allow.
- Consider reducing your inventory of signs

* *Replacement costs include sign blank, sheeting material, sign posts, and installation. Constant 2014 $*

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

- Maintaining your system of signs has always been a good idea, but now it's a required action.
- Given the minimum level of required maintenance, agencies should re-evaluate their sign maintenance budgets.
- Annual sign maintenance budget = cost to address retroreflectivity + cost to address vandalism, knockdowns and mother nature.
- A study from the North Carolina Department of Transportation[1] found that approximately 2.4% of signs are vandalized or knocked down in a year.
- Annual cost to address degradation of retroreflectivity (Assuming a 15 year replacement cycle) = $87,000
- Annual cost to address damage by vandalism and knockdowns = $31,000
- A typical large city annual sign maintenance budget = $118,000
- Reduce the sign maintenance budget by removing signs that are NOT required.



1 *North Carolina Department of Transportation, "Designing an Efficient Nighttime Sign Inspection Procedure to Ensure Motorist Safety"*

Financial Budgeting – Counties (1/2)

- 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:

500 miles  **x 20 signs/mile** 

x $200/sign = $2,000,000

- All signs must be retroreflective or illuminated. Only Regulatory and Warning signs must be a part of your assessment or management method. Add Guide signs as resources allow.
- 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. Constant 2014 $*

Financial Budgeting – Counties (2/2)

- Maintaining your system of signs has always been a good idea, but now it's a required action.
- Given the minimum level of required maintenance, agencies should re-evaluate their sign maintenance budgets.
- Annual sign maintenance budget = cost to address retroreflectivity + cost to address vandalism, knockdowns and mother nature.
- A study from the North Carolina Department of Transportation[1] found that approximately 2.4% of signs are vandalized or knocked down in a year.
- Annual cost to address degradation of retroreflectivity (Assuming a 15 year replacement cycle) = $133,000
- Annual cost to address damage by vandalism and knockdowns = $48,000
- A typical county annual sign maintenance budget = $181,000
- Reduce the sign maintenance budget by removing signs that are NOT required.

1 *North Carolina Department of Transportation, "Designing an Efficient Nighttime Sign Inspection Procedure to Ensure Motorist Safety"*

Real Life Sign Removals – Stevens County Townships

How do I get my agency on board with removing signs?

- In 2011 and 2012, MnDOT piloted a program with Townships in Stevens County to inventory signs and conduct an engineering investigation to determine which signs could be removed.
- The investigation identified 285 Regulatory, Warning and Guide Signs (28% of the total number of signs in these townships) as candidates for removal. The townships have agreed to the removals!
- Of 285 signs to be removed:
  - 93% are Warning (i.e., STOP/YIELD Ahead, Cross Road, T-Intersection signs)
  - 4% are Regulatory (i.e., YIELD, Speed Limit signs)
  - 1% are Guide (i.e., Street signs)
- The townships then benefit from long term savings by reducing costs for installation, along with yearly inventory and maintenance.

What Could This Mean for my Township Sign Maintenance Budget?

- Reducing your sign inventory by 28%, would result in a 28% savings in your annual sign maintenance budget.
- This is a representation of total savings in Townships. In jurisdictions with larger sign inventory, the savings would be even greater.

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 umbrellas of immunity (from liability)
  - Discretionary Immunity - policy driven
  - Official Immunity - exercise of engineering judgement
- Another way to reduce your sign maintenance costs is to group your agency's signs with another or multiple agencies to perform maintenance and get a bulk savings.
- Intrigued? Please continue...

Model Sign Maintenance Policy

- Which sign maintenance method is adopted? (Blanket Replacement - replace 1/15 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 MN MUTCD
- 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 signing policies from around Minnesota. Additional examples can be found in the Appendix.

Regulatory Sign Usage (3/3)

- Understand the difference in the levels of guidance provided in the MN MUTCD.
- 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
  - STOP or YIELD* at at-grade passive railroad crossings (railroad responsibility)
- All other Regulatory signs may be used based on your agency's policies, system considerations, and the results of an engineer (or their designated representative) exercising their judgment.
- This is not an error – STOP signs are **NOT** required. The MN MUTCD 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	
Stop or Yield* at at-grade passive railroad crossings (railroad responsibility)	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	

**Determination of a STOP or YIELD sign is based on a site visit with MnDOT, the railroad and road authority.*

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
  - Horizontal Alignment series on roads with more than 1,000 AADT
- 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 judgment.

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
Horizontal Alignment series on roads with more than 1,000 AADT	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)

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)

- Low volume roads are defined in the Manual as:
  - Having fewer than 400 vehicles per day
  - Not being on a designated State road system
  - Being in a rural area outside of towns and cities
  - Not a neighborhood street or a freeway frontage road
- "Low Volume Roads" there are few usage requirements:
  - Only STOP or YIELD signs are required at passive railroad crossings – several should/may be used based on engineering judgment.
  - Three types of Warning signs are required – Advance Intersection Traffic Control, Rail Road Crossing signs and MINIMUM MAINTENANCE ROAD signs.

These are the only signs REQUIRED by the MN MUTCD. Other signs may be used based on Engineering Judgment.

	STANDARD (Shall)	GUIDANCE (Should)	OPTION (May)
Regulatory Signs	STOP or YIELD at passive railroad crossing	STOP YIELD Traffic Movement Traffic Prohibition	Speed Limit No Parking
Warning Signs	STOP Ahead (Limited Sight Distance) YIELD Ahead (Limited Sight Distance) Rail Grade Crossing Rail Advance Warning 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		

Which Signs are Required by the 2014 MN MUTCD?

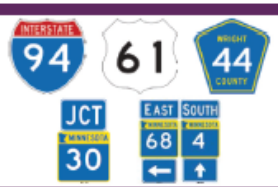
Regulatory

- 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.
- STOP or YIELD **IF** at a passive railroad crossing
- Prohibition signs where applicable

Warning

- 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.
- Horizontal Alignment **IF** more than 1,000 AADT
- Minimum Maintenance

Guide



- Route Numbers on ALL numbered highways
- Junction Assembly
- Advance Route Turn Assembly

Note: The determination as to which signs in the MN MUTCD are required is based on the 2014 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 MN MUTCD – 15 types of signs are required.
- This suggests that if you decide to put up a sign – most of the time that action will be based on exercising your judgment and NOT on the requirements in the MN MUTCD.

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?

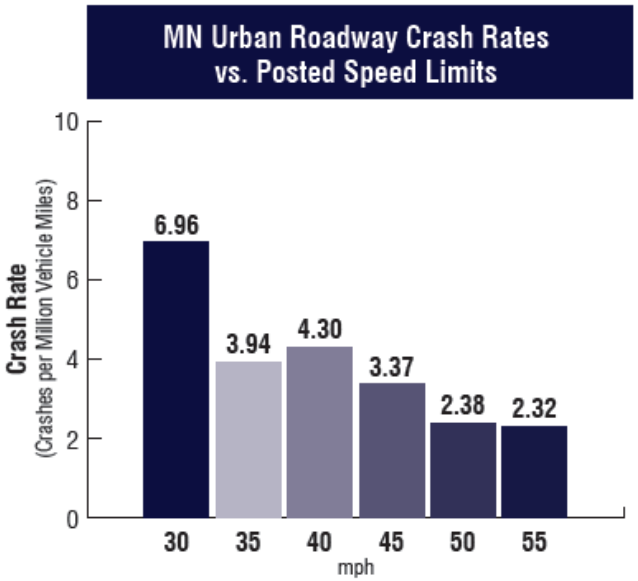
Effectiveness of Regulatory Signs – Speed Limit

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

		Before	After
TH 210 Baxter	Posted	55	45
	85%	57	53
	% Compliance	68	38
TH 316 Hastings	Posted	45	35
	85%	47	45
	% Compliance	60	12

Source: Unpublished MnDOT 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.



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 Data[1]

	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 Signs[1]

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%

- 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 Iowa[2] 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.
- St. Louis County, MN recently added flags to an ALL-WAY STOP intersection and studied driver behavior. There was no statistical difference in STOP sign violations from before, during or after the flags were in place.

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*

Effectiveness of Warning Signs – Children at Play

- A research synthesis prepared for the Wisconsin Department of Transportation found that there is no evidence that special Warning signs of this sort either change driver behavior or improve safety.
- MnDOT and the LRRB published research[2] that found no evidence that Playground Warning signs reduced vehicle travel speeds. Instead, at these locations, vehicle speeds appeared to be related to the number of cars parked along the street.
- Traffic control devices are intended to change driver behavior and improve safety – these special Warning signs have not been found to do either.

1 *Wisconsin Department of Transportation, "Effectiveness of Children at Play" Warning Signs, Transportation Synthesis Report, 2007*
2 *CTC & Associates, Impacts of Playground Warning Signs on Vehicle Speeds, Minnesota Department of Transportation Report No. 2012-06TS, May 2012.*

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 Reduction[1] 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 to 50%.
- A study of a sample of approximately 200 curves in Minnesota[2] 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 approximately 19,000 curves along highways in Minnesota Counties (part of the MnDOT sponsored project to prepare safety plans for all counties) found that 70% of severe crashes occurred in curves with radii between 500 and 1,200 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 system wide approach to deploy horizontal alignment signs.
- A recent study[3] 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.

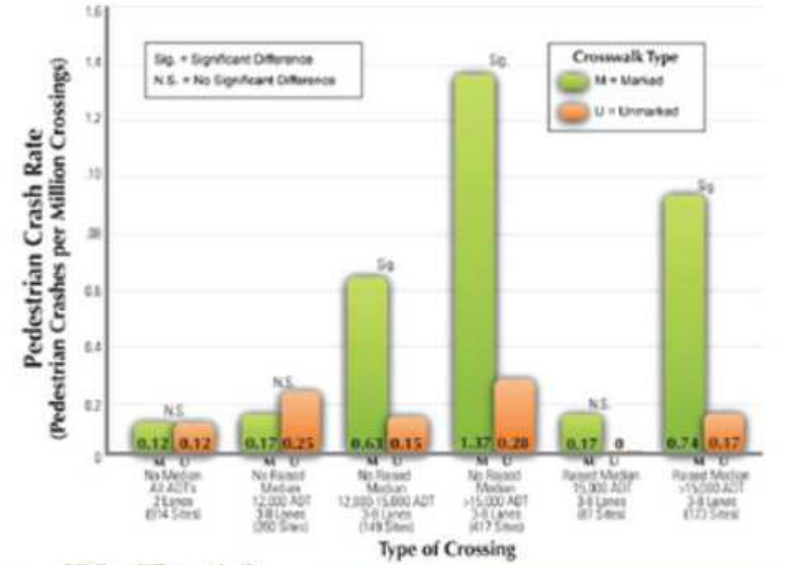
NEW STANDARD: In advance of horizontal curves on freeways, on expressways, and on roads with more than 1,000 AADT that are functionally classified as arterials or collectors, Horizontal Alignment Warning signs shall be used in accordance with Table 2C-5 based on the speed differential between the roadway's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

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, Mn DOT Research Report 2008-XX, June, 2009*

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

Effectiveness of Signs (Pedestrians)



- 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 rates[1] (than at unmarked/ signalized 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. Zegger, 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 study[1] 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.

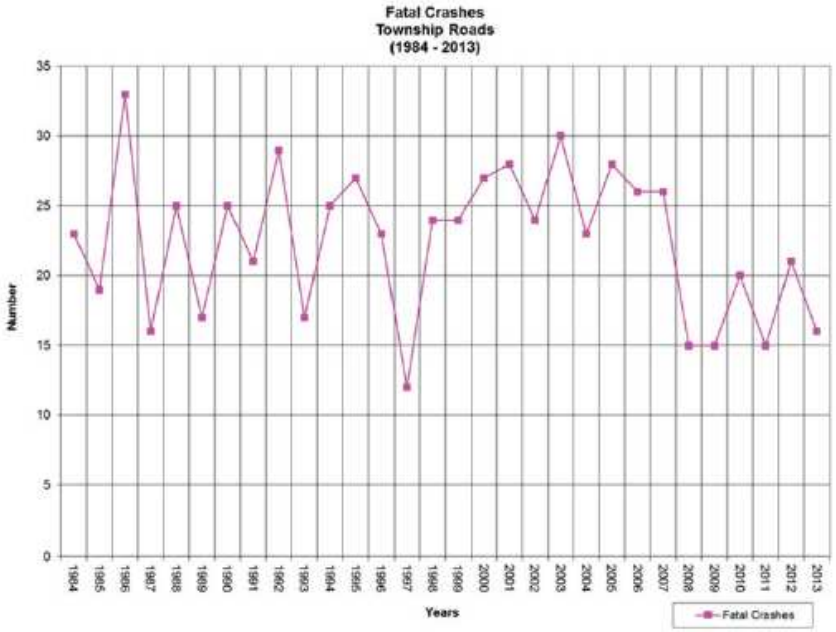
1 *Knapp, K., Deer–Vehicle Crash Counter Measure Toolbox: A Decision and Choice Resource, University of Wisconsin. Report No. DVCIC-02, June 2004*

Sign Effectiveness Summary

- 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.

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 (see E-27) are considered required.
- We've also established that the average annual sign maintenance cost for a typical township would be approximately $2,450 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.



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.

- MnDOT 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.

NOTE: On roads with 1,000 ADT or greater, the Horizontal Alignment sign series is required.

- ONE WAY signs are not required in medians that are less than 30 feet wide if KEEP RIGHT signs are installed.

Potential Sign Removal Examples (1/5)

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 MN MUTCD) 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 30 mph, 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 MN MNTCD (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 (2/5)

- 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).

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 sheeting material you use, expected sign life, signs to 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 MN MUTCD.
- 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 judgment as part of an engineering study and then documenting your actions.

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 MN MUTCD) 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 occured along one of the local roads - North Arm Drive.

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

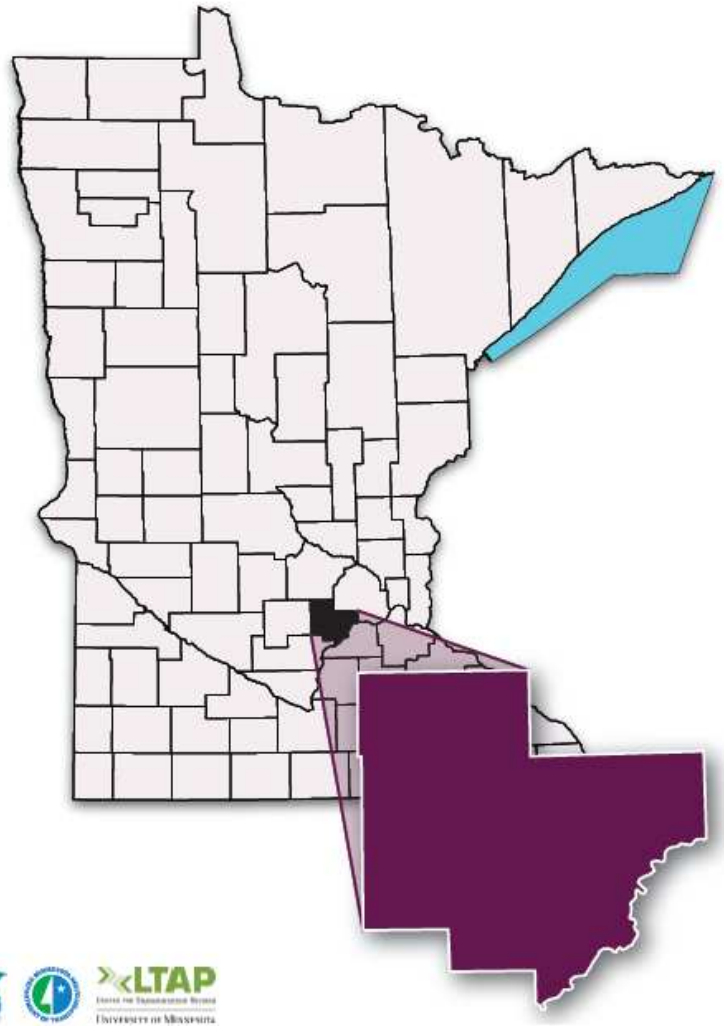
- The vehicle in which Ms. Monnens was a passenger was drag racing and was estimated exceeding 60 mph. When the vehicle failed to negotiate a curve to the left, it veered off the roadway and collided with a tree.
- The expert for the plaintiffs testified that Orono's failure to place a curve warning sign was the primary cause of the crash and was evidence of the City's negligence because the MN MUTCD **required** the use of the warning sign.
- The City argued summary judgment - 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 were required (a SHALL condition) by the MN MUTCD - they were all optional signs that could be used based on engineering judgment.
  - 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 Judgment – agreed that Curve Warning signs were **NOT** required at that time 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 consisted with the adopted ordinances.

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

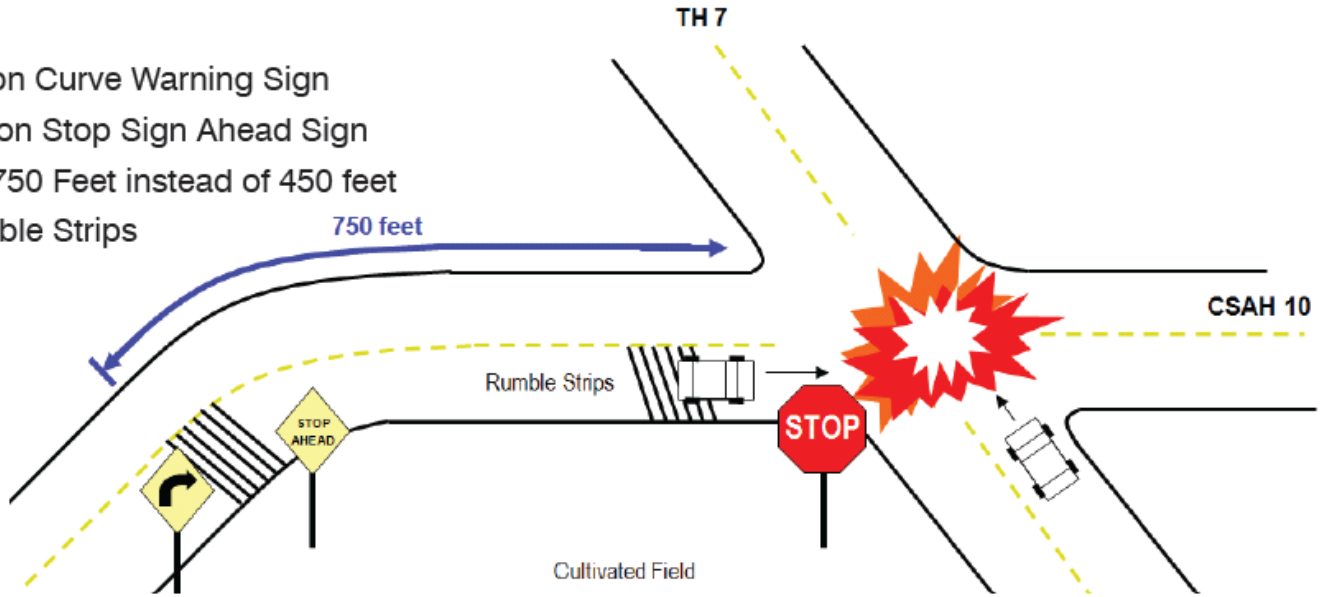
- 55 MPH Speed Limit
- Curve Warning Sign in Place
- Stop Ahead Sign in Place
- Rumble Strips in Place/Partially Filled
- Crash Occurred in the Middle of a Clear, Bright Summer Day

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 MN MUTCD's express deference to the judgment 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 MN MUTCD. No one expects you to document every decision you make – you will need to exercise your judgment to decide which of your decisions are potentially controversial enough to make the added investment of your time worth the effort.

Questions?

Howard Preston, P.E.

Howard.Preston@ch2m.com

(651) 365-8514

CH2MHILL