Traffic Sign Life Expectancy

Howard Preston, Principal Investigator
CH2M HILL

June 2014

Research Project
Final Report 2014-20

Minnesota Department of Transportation

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Highway agencies with an inventory of traffic signs must adopt a method of maintaining those signs so that the retroreflectivity exceeds established thresholds. Understanding expected sign life can help agencies phase sign replacements over a number of years in order to manage maintenance costs. The primary goal of this research is to provide objective data about sign life based on the degradation of retroreflectivity and color over time. A literature review found sign retroreflectivity research around the country, however, none of the studies are conclusive. Eight Minnesota agencies took retroreflectometer readings on in-place signs across the state. Disaggregated measurements by sheeting material and color did not leave a large enough sample for conclusive results, and very few signs fell below minimum retroreflectivity thresholds. Data suggests sign life exceeds the manufacturer's warranty and that a controlled environment with known conditions will produce more reliable data. MnDOT established a test deck at MnROAD to take multiple retroreflectivity and color readings over time to the point of failure in a controlled environment. The best information inferred from the results is an estimate for an expected sign life of 12 to 20 years for beaded sheeting and 15 to 30 years for prismatic sheeting. Agencies are encouraged to move forward and adopt a sign maintenance method and expected sign life by bringing sign management decisions under an umbrella of immunity. This document has suggested best policy practices and statements for sign maintenance and management assembled by a panel including engineers and risk management specialists.

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Traffic Sign Life Expectancy

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Executive Summary

The genesis of this project involves the requirement in the *Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD)* that all highway agencies with an inventory of traffic signs must adopt a method of maintaining those signs so that the retroreflectivity exceeds the established thresholds. This requirement has an implementation date of June 13, 2014.

A key element of typical sign maintenance programs is an understanding of the expected life of traffic signs, which helps agencies phase their sign replacements over a number of years. However, this data does not currently exist for the inventory of signs in Minnesota and is only available on a limited national basis, especially for the newer prismatic sheeting material (ASTM Type IX and Type XI) that has been in use for fewer than ten years. As a result, agencies are faced with a dilemma – use a value that is available, the sheeting manufacturer's warranty period, or to subjectively select another value. Both choices present some level of risk to the agency, as well as maximizing investment and safety. The use of the warranty period likely results in replacing signs that have not reached the end of their useful lives which drives maintenance costs up. Subjectively selecting a value that is not in common practice could increase an agency's exposure to claims of negligence and not address sign legibility and safety.

As a result, the primary objective of this research is to provide objective data about expected sign life based on the degradation of retroreflectivity and color over time. In the likelihood that a statistically reliable set of data could not be assembled within the limited timeframe of this project, a secondary objective involved providing local agencies with a subjective, "best practice" set of suggestions. This includes involving both the expected sign life and an approach to incorporating an adopted sign life into a comprehensive sign maintenance program.

The approach to conducting this project consisted of four key parts:

- Reviewing previously published research that focused on the deterioration of traffic signs and provided estimates of sign life.
- Obtaining measured retroreflectivity levels of in-place signs from participating local agencies around Minnesota.
- Establishing a test deck of traffic signs at the Minnesota Department of Transportation's (MnDOT) MnROAD facility and documenting retro-reflectivity levels over the short term duration of this project and then into the future.
- Assembling an expert panel to discuss the documented objective data provided by the participating local agencies and from the MnROAD test deck. From this and a risk management perspective, identifying an expected sign life (or range of years) that could be used by local agencies to more effectively manage their system of traffic signs.

The results of these tasks include the following:

Research Review (Chapter 2)
Eleven previously published research reports were found that focused on identifying the expected life of traffic signs. The authors looked at between approximately 140 and 5,700 signs, the vast majority of which were in-place (along the public road system) and consisted of either

ASTM Type I or Type III beaded sheeting material. These reports contained four key lessons learned:

- Sign orientation and weather did NOT appear to play substantial roles in the deterioration of sign retroreflectivity although south facing red signs did experience an increase in variability of retroreflectivity readings.
- The failure rates of the observed signs were in the range of 1% to 8%, depending on the age of the sign. One study also identified an overall 6% sign replacement rate, with approximately equal portions attributed to retroreflectivity failure and vandalism.
- Many of the studies developed regression equations that forecast the long term deterioration of retroreflectivity. In virtually every case, the regression equations forecast sign life far beyond the manufacturer's warranty period. However, in each case the authors warned of possible credibility issues with their efforts because of environmental factors associated with the in-place sample of signs that they couldn't account for in the equations, small sample sizes and unrealistic results (sign lives in excess of 100 years).
- The final lesson is the most important and speaks to the credibility of the results. None of the research continued collecting retroreflectivity readings long enough to observe failure from the perspective of actually watching retroreflectivity of a set of signs drop below the established thresholds in a controlled setting. A number of the authors concluded that until that kind of research is conducted, any results regarding sign life will continue to be estimates as opposed to definitive values.

Measured Retro-Reflectivity of In-Place Signs (Chapter 3)
Three cities, four counties and MnDOT's Metropolitan District used a retroreflectometer to collect readings at in-place signs around the State. A total of 379 valid readings were recorded and analyzed and approximately 10% of the readings were rejected, primarily due to errors in readings (zero readings on white sheeting, extraordinarily high readings on black sheeting or signs with Type XI sheeting listed as more than 7 years old as this material was only introduced 7 years ago). By the time data was disaggregated by sheeting material, color and age of sign, no data set had more than the desired 100 readings and no individual sign had more than one retroreflectivity reading.

This data was analyzed and regression equations were developed that attempted to predict the long term life of the signs based on both color and type of sheeting material. These results were similar to those documented in the literature – basically sign lives greater than the manufacturer's warranty with some unusual results (trend lines indicating improved retroreflectivity over time or estimated lives greater than 100 years). These results suggest the need to provide the same caution to readers about the credibility of the results, similar to those contained in the previous research.

Measured Retro-Reflectivity of Test Deck (Chapter 3)
The project anticipated that the information in prior research and generated from retroreflectivity readings of in-place signs in Minnesota might not be sufficient to determine, with a high degree of certainty, the expected lives of signs. As a result, a third approach to establishing sign life was included in this project – installing a test deck of signs at MnDOT's MnROAD facility. The test deck was set up in June 2013 and signs were oriented in a way to try and cause accelerated

deterioration (both south facing vertical and at a 45 degree angle). Readings for both retroreflectivity and color have been taken. The conclusion of this effort is that there simply have neither been enough readings nor enough time lapsed to determine a definitive value for sign life.

The in-field retroreflectometer readings demonstrate similar findings to those in the literature, however, after disaggregation; more readings need to be performed. Due to difficulties identifying types of sheeting material and other factors such as sign knock downs or vandalism of in-field signs, the test deck will provide valuable information over the years. The key for the test deck is that the history of the signs is known (exact age and type of material), it is in a controlled environment and signs can continue to be measured until retroreflectivity failure to determine a more accurate sign life expectancy.

These results suggest two key points for local agencies. First, from both a risk management and sign management perspective it is very important for agencies to develop and adopt a sign maintenance method, including identification of expected sign life. However, there is no definitive information currently available to assist agencies in determining an exact value for the life of a sign. The best information that can be inferred from the results of previous testing is that the expected life is most certainly longer than the manufacturer's warranty period, with a reasonable estimate in the range of 12 to 20 years for beaded sheeting and 15 to 30 years for prismatic sheeting.

Agencies are encouraged to move forward and adopt both a sign maintenance method (prior to June 13, 2014) and an expected sign life using the best practices technique of bringing sign management decisions under an umbrella of immunity. In Minnesota, this is done by having agencies sign management decisions based on policies adopted by their elected officials and the results of engineering studies conducted by the agency's professional staff or qualified contractors.

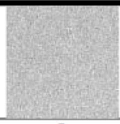
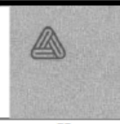
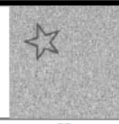
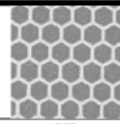
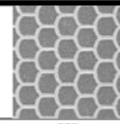
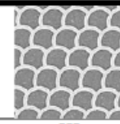
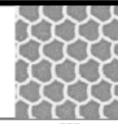
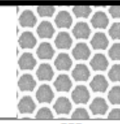
In order to help agencies with policy development, a panel including both engineers and risk management specialists was assembled as part of this project. This group generated a best practices list of suggested statements (Appendix A) that is a useful tool and could be included in an agency's sign maintenance policy and address topics such as – the adopted maintenance method, selected type(s) of sheeting material, expected sign life, details about the agency's sign maintenance priorities and the types of signs that are considered candidates for removal.

2014 Traffic Sign Retroreflective Sheeting Identification Guide

U.S. Department of Transportation
Federal Highway Administration

This document is intended to help identify sign sheeting materials for rigid signs and their common specification designations. It is not a qualified product list. FHWA does not endorse or approve sign sheeting materials. Many other sheeting materials not listed here are available for delineation and construction/work zone uses.
Many sign sheeting materials have watermarks and/or patterns that are used to identify the material type and manufacturer. The watermarks shown in this guide have been enhanced. The watermarks will be less visible in practice and may not be present on smaller pieces of sheeting due to the spacing.

Retroreflective Sheeting Materials Made with Glass Beads

Example of Sheeting (Shown to scale)								
ASTM D4956-04	I	II	II	III	III	III	III	III
ASTM D4956-13	I	II	II	III	III	III	III	III
AASHTO M268-13	(1)	(1)	(1)	A	A	A	A	A
Manufacturer	Several companies	Avery Dennison®	Nippon Carbide	3M™	ATSM, Inc.	Avery Dennison®	Nippon Carbide	ORAFOL Americas Inc
Brand Name	Engineer Grade	Super Engr Grade	Super Engr Grade	High Intensity	High Intensity	High Intensity	High Intensity	ORALITE® High Intensity
Series	Several	T-2000	15000	2800 3800	ATSM HI	T-5500	N500	5800
NOTES:	(2) (8)	(3) (4) (9)	(4)	(3) (4) (9)	(4)	(4)	(4)	(4)

1) Sheeting material does not meet minimum AASHTO classification criteria.
2) Glass Bead Engineer Grade sheeting is uniform without any patterns or identifying marks.
3) Material no longer sold in the United States as of the date of this publication.
4) Section 2A.08 of the 2009 MUTCD (http://mutcd.fhwa.dot.gov) does not allow this sheeting type to be used for new legends on green signs.

- ASTM D4956-04 is referenced in Table 2A-3 of the 2009 MUTCD.
- ASTM D4956-13 is the most current ASTM sign sheeting specification (the 2013 version is designated by "-13").
- AASHTO M268-13 is the most current AASHTO specification (the 2013 version is designated by "-13").

Manufacturer Contact Information

3M - http://www.3M.com/roadwaysafety
ATSM, Inc. - http://www.atsminc.com
Avery Dennison - http://www.reflectives.averydennison.com
Nippon Carbide - http://www.nikkalite.com
ORAFOL Americas Inc. – http://www.orafolamericas.com

FHWA Publication Number: FHWA-SA-14-022. You may download and print the electronic version of this document, available at www.fhwa.dot.gov/retro

Beaded sheeting types. Printed with permission from Federal Highway Association to assist with identifying sheeting type. Last Accessed May 2014.
http://safety.fhwa.dot.gov/roadway_dept/night_visib/sign_visib/sheetguide/sheetguide2014.pdf

2014 Traffic Sign Retroreflective Sheeting Identification Guide

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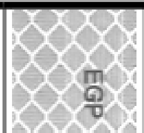
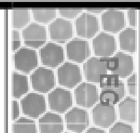
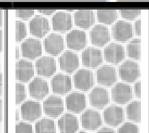
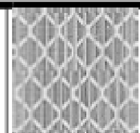
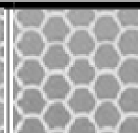
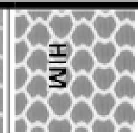
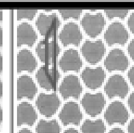
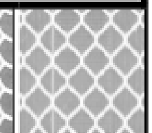
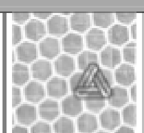
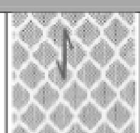
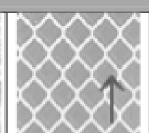
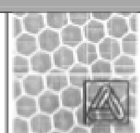
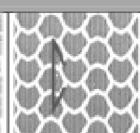
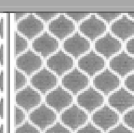
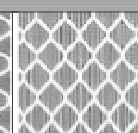
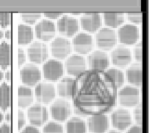
This document is intended to help identify sign sheeting materials for rigid signs and their common specification designations. It is not a qualified product list. FHWA does not endorse or approve sign sheeting materials. Many other sheeting materials not listed here are available for delineation and construction/work zone uses.
Many sign sheeting materials have watermarks and/or patterns that are used to identify the material type and manufacturer. The watermarks shown in this guide have been enhanced. The watermarks will be less visible in practice and may not be present on smaller pieces of sheeting due to the spacing.

Retroreflective Sheeting Materials Made with Micro-Prisms

Example of Sheeting (Shown to scale)								
D4956-04	(5)	(5)	III, IV	III, IV, X	(5)	(5)	(5) / X	(5)
D4956-13	I	I	III, IV	III, IV	III, IV	III, IV	VIII	VIII
M268-13	(6)	(6)	B	B	B	B	B	B
Manufacturer	3M™	Avery Dennison®	Avery Dennison®	3M™	ORAFOL Americas Inc	Nippon Carbide	Nippon Carbide	3M™
Brand Name	EGP	PEG	HIP	HIP	ORALITE® HIP	HIM	Crystal Grade	Reflective Sheeting
Series	3430	T-2500	T-6500	3930	5900/5930	CRG 94000	CRG 92000	3940
NOTES:	(8)	(8)						

Example of Sheeting (Shown to scale)								
D4956-04	VIII	VII, VIII, X	IX	IX	(5)	(5)	(5)	(5)
D4956-13	VIII	VIII	IX	IX	IX	IX	XI	XI
M268-13	B	(7)	B	B	B	B	D	D
Manufacturer	Avery Dennison®	3M™	3M™	Avery Dennison®	Nippon Carbide	ORAFOL Americas Inc	3M™	Avery Dennison®
Brand Name	MVP Prismatic	Diamond Grade™ LDP	Diamond Grade™ VIP	OmniView™	Crystal Grade	ORALITE®	Diamond Grade™ DG3	OmniCube™
Series	T-7500	3970	3990	T-9500	95000	7900	4000	T-11500
NOTES:		(9)			(9)			

5) Material was either unavailable in 2005 (previous version of this Guide) or unassigned in the 2004 version of ASTM D4956.
6) Sheeting material does not meet minimum AASHTO classification criteria.
7) Material has been discontinued prior to AASHTO M268-10.
8) Section 2A.08 of the 2009 MUTCD (http://mutcd.fhwa.dot.gov) does not allow this sheeting type to be used for new yellow or orange signs, or new legends on green signs.
9) Material no longer sold in the United States as of the date of this publication.

Resources

Federal Highway Administration – http://www.fhwa.dot.gov/retro
Manual on Uniform Traffic Control Devices (MUTCD) – http://mutcd.fhwa.dot.gov
Texas A&M Transportation Institute – http://tti.tamu.edu/visibility
ASTM – http://www.astm.org
AASHTO – http://www.transportation.org

Prismatic sheeting types. Printed with permission from Federal Highway Association to assist with identifying sheeting type. Last Accessed May 2014.
http://safety.fhwa.dot.gov/roadway_dept/night_visib/sign_visib/sheetguide/sheetguide2014.pdf

Chapter 1. Introduction

This project was encouraged and supported by local highway agencies in Minnesota because of the lack of sufficient information about the life expectancy of traffic signs, primarily as a function of the degradation of the level of retroreflectivity over time. The approach to providing an answer to the question – what's the expected life of a traffic sign – consisted of four key parts:

- Reviewing the literature documenting the results of previously published research.
- Obtaining measured retroreflectivity information from local agencies in Minnesota.
- Establishing a test deck of traffic signs at the Minnesota Department of Transportation's (MnDOT) MnROAD facility and documenting the retroreflectivity over the short term duration of this project, and into the future.
- Assembling an expert panel to discuss the documented objective data and then from the perspective of risk management, identify a sign life expectancy (or range of years) that could be used by local agencies to more effectively manage their systems of traffic signs.

The primary information that currently provides insight about sign life expectancy is the warranty period provided by manufacturers – 7 years for ASTM Type I, 10 years for ASTM Type IV, 12 years for ASTM Type IX and ASTM Type XI sheeting. The concerns expressed by many local agencies is that warranty values are probably conservative and their use in a sign maintenance program could result in many signs being replaced with possibly many years of effective life left, which would ultimately drive up agencies annual sign maintenance costs. This concern about assumptions regarding sign life unnecessarily increasing the costs of sign maintenance drove the local agencies in Minnesota to seek the most current and regional information possible to help them make informed and cost-effective decisions about their sign maintenance programs, while remaining consistent with best practices for risk management.

The primary objective of this research is to provide objective data about sign life that is not currently available, especially for the newer, prismatic sheeting material (i.e., ASTM Type XI and IX) that has only been in use for fewer than ten years. In addition, in anticipation of the likelihood that a statistically reliable sample of objective data couldn't be assembled, a secondary objective involved providing local agencies with a subjective, "best practices" set of suggestions involving both the expected sign life and an approach to incorporating an adopted sign life into a comprehensive sign maintenance policy.

Chapter 2. Literature Search

Prior to the addition of required minimum values of retroreflectivity to the Minnesota *Manual on Uniform Traffic Control Devices (MN MUTCD)*, sign maintenance was a recommended activity and highway agencies were left to determine how they would proceed [1]. Some agencies conducted nighttime inspections and some used expected sign life to determine a replacement cycle. At that time, the only information available was the warranty period established by the sheeting manufacturers, which is based on factors other than meeting minimum retroreflectivity. However, as sign sheeting material improved and new sheeting was developed, the retroreflectivity became significantly higher than the *MN MUTCD* minimum. It is therefore reasonable to expect the service life of signs from these newer materials to be much longer before degrading to minimum required values. Because of the improvements to sign sheeting materials, sign retroreflectivity has been studied by multiple agencies with a focus on determining a realistic sign life for different sheeting materials.

2.1 Literature Review

The Federal Highway Administration (FHWA) and several states have conducted studies to determine deterioration rates of sign sheeting. The majority of these studies have focused on Type I and III sheeting materials, since that was what the majority of agencies had installed and were available for a field aging study.

2.1.1 FHWA [2]

In 1992, FHWA conducted a national study to determine the factors that contribute to retroreflective degradation and to develop predictive models for Type III sheeting. Data was collected on 5,722 signs in 18 different states across the country. The study found that there was significant variation in readings and that age, precipitation, elevation and temperature affected deterioration. It also showed that sign direction was not a factor in retroreflectivity deterioration. Linear prediction models were developed, and showed that signs Type III performed adequately for up to 12 years.

2.1.2 NCHRP [3]

The NCHRP Synthesis 431, “Practices to Manage Traffic Sign Retroreflectivity”, documented the state of practice agencies are using for maintaining sign retroreflectivity. The study found that most agencies report that the various sheeting materials outlast the warranty period and that Type I is the least efficient and shortest lasting sheeting material. Study participants noted that it is more cost-effective to install Type III or IV sheeting material than Type I.

2.1.3 Oregon [4]

In 2001, Oregon conducted a study to understand the drivers of retroreflectivity degradation to provide guidance to the Oregon Department of Transportation (ODOT). Data was collecting on 80 Type III (HI) signs that had been in service for 10 years. Red, yellow, green and white sign data was collected (20 signs each) and 10 readings were taken on each sign background. The initial data set of 80 signs was found to be insufficient, so an additional 57 signs were measured to provide a more complete data set. The second data set had markedly higher readings than the first (71% to 107%). Between the two sets of readings, the meter used was calibrated at the factory, possibly accounting for the difference in readings. Thus, a weighting factor derived from the average percentage difference of the second round readings compared to the first was applied to the first round of data. The average of the 10 readings per sign was used to represent the overall sign retroreflectivity due to the variability in the reflective surface.

Linear trend lines applied to the data showed little relationship between the age of signs and their retroreflectivity values. It was determined that there may not have been a great enough age range (12 years) of signs to provide a complete picture of the retroreflectivity performance over time and any weathering effects.

The study showed that over a twelve year span most signs exceeded the minimum standard. The study found some indications that retroreflectivity may be affected by sign orientation due to weathering effects of windblown dust and precipitation, but there was no strong trend in the data to support this. It was noted that west-facing signs resulted in lower retroreflectivity readings for white, yellow and green signs, while south-facing signs resulted in lower retroreflectivity readings for red signs. However, the variability in the average levels of retroreflectivity is not as evident.

2.1.4 Purdue [5]
In 2002, Purdue University conducted a study for the Indiana DOT on their Type III signs. Retroreflectivity on 1,341 in-service Type III red, white and yellow sign backgrounds were measured across Indiana. Sign types included, but were not limited to STOP, DO NOT ENTER, WRONG WAY, No Passing and route markers. Conclusions from the study were:

- Retroreflectometer readings varied depending upon which measuring instrument was used and raises concerns regarding state liability.
- There was no real link between age and retroreflectivity readings of white and yellow signs.
- There was a more apparent downward trend in the retroreflectivity of red signs as the signs age. This trend was not considered very strong as there was only a 33 percent correlation between age and average retroreflectivity of the sign.
- Orientation did not play a major role in sign deterioration.
- The majority (98%) of signs that had white and yellow backgrounds kept retroreflectivity levels above the proposed minimums out past 15 years of age.

The overall study concluded that due to the long lasting nature of signs it is possible that the white and yellow type III signs could be left out in the field longer than they currently are and could save INDOT money in life cycle costs. The study recommended that for white and yellow background signs, service life could be safely extended to 12 years. The study recommended that red sign service life remain at the 10 year warranty not because of retroreflectivity, but due to color fade.

2.1.5 North Carolina [6]
North Carolina State University conducted a study for the North Carolina Department of Transportation (NCDOT) in 2005 and 2006, where they evaluated the DOT's nighttime inspection process, determined sign retroreflectivity expected life, and determined factors that affect sign performance. The field study sign damage rate was 2.37% of the inspected signs per

year with 1.3% damaged by humans, 0.9% by natural causes and 0.17% by humans and natural causes. The most common causes of damage were paint balls, gun shots, eggs and tree sap. In a second investigation, the researchers found that 4.7 % of signs are replaced due to damage each year and includes 2.4 % of signs replaced outside the nighttime inspection process due to vandalism. Based on this, an overall sign replacement rate of 6.9% was determined. Retroreflectivity was measured on 1,047 Type I and III in service signs and compared the results to field inspectors' night-time visual assessments. A linear trend line was found to be the best fit for the retroreflectivity degradation over time. The study determined that signs would reach zero retroreflectivity after 20 to 30 years. Table 2.1 demonstrates the determined sign life from the study based on the best fit linear trend lines.

Table 2.1 North Carolina Predicted Sign Life

Sign Color	Type I Sign Life	Type III Sign Life
White	24-45	67- >80
Yellow	26-31	42- >80
Red	21-24	22-42
Green	29	30

In addition to sign life, the study determined a visual inspection cost of $0.55/sign. For comparison, a typical Minnesota county has 10,000 signs and the annual visual inspection cost would be $5,500 per year. Inspection cost using a retroreflectometer was determined to be $2.80 per sign, which would cost a Minnesota county $28,000 per year to inspect all of the agency's signs. Accuracy of the nighttime visual inspectors of the North Carolina study compared to retroreflectometer readings varied from 54% to 83%.

2.1.6 Vermont [7]

In 2008 the Vermont Transportation Agency measured retroreflectivity of 398 Type III signs in green, red, yellow and white. Two-hundred twenty yellow and yellow-green Type IX signs that had been in service for 6 years were also measured. The study found no significant correlation to orientation or offset, though north facing signs had higher retroreflectivity than south facing. The study also found that red sign retroreflectivity deteriorated faster than other sign colors, while white deteriorates the slowest. Type III sign life based on trend lines ranged from 15 (red) to over 9,000 (green) years. The researchers mentioned that the extremely high sign life is unreasonable and likely due to limited long term data. Type IX sign life expectancy was 95 years for both yellow and yellow-green. Based on this study, Vermont adopted a 15 year life for all sign colors, retroreflectivity measurements of signs will continue as no signs were found to be below the minimum retroreflectivity requirements.

2.1.7 Texas [8]

In 2009 Texas A&M measured retroreflectivity of 1,385 Type I, III and prismatic red, white, green and yellow signs for the Texas DOT to identify compliance rates. Overall, 70 signs failed to meet minimum retroreflectivity requirements, including 2 prismatic signs, which were considered outliers resulting from accelerated environmental deterioration. The study found that sign direction was not a factor in retroreflectivity and that daytime visual assessments are NOT a good indicator for retroreflectivity. Regional variations were also not significant to warrant different sign management practices for different regions. Sign life expectancy is important to the Texas DOT due to the number of signs on its system, similar to Minnesota concerns. Table 2.2 demonstrates the comparison of signs per mile on each roadway system.

Table 2.2 Texas Average Number of Signs Per Mile vs. Minnesota Average

Location	Freeway	Arterial	Collector	Local	Overall TX Average	Overall MN Counties Average
Rural	9	13	11	7	14	10
Urban	13	25	30	8		

Based on linear regression, many of the signs in the various regions had service lives ranging from 15 to 155 years. The study found that the failure rate for Type III signs 10-12 years of age was 2 percent and 8 percent for signs 12-15 years. Researchers also conducted a long term accelerated weathering study on Types I through IX that showed color fading is a significant issue. Projected sign life ranged from 15 to 155 years and the trends are similar to those completed in other studies.

The study also reviewed a mobile data collection technology that takes readings from a vehicle. It was found that this system failed to accurately measure sign retroreflectivity and could result in waste to agencies removing signs that are still meeting minimum retroreflectivity requirements. The study ultimately concluded that none of the management and maintenance practices identified and in use in Texas meet FHWA intent for conducting nighttime visual inspections, despite the processes being documented across the state.

2.1.8 Indiana [9]

Indiana DOT conducted an evaluation in 2010-11 for their sign sheeting materials. Up to that point, Indiana had been using a 14 year service life. Researchers performed measurements on 211 signs facing different directions from northern and southern Indiana. Most of the signs were Type III (some Type I) with one group of Type IV that was 10 to 11 years old. All but 11 signs (approximately 5 percent) were above the *MN MUTCD* minimum, and several of these seemed to be damaged. The Type IV sign readings were significantly higher than minimum retroreflectivity requirements.

Researchers also measured color and found that all the green signs were within the color specification limits. The majority of the white and yellow were also within specifications, but the red signs, including the 10 year old Type IV signs failed to meet specifications. Indiana DOT adopted an 18 year life for sheet signs and 20 year life for panel signs.

2.1.9 Utah [10]

In 2011 and 2012, Utah State University conducted a study for the Utah DOT and collected retroreflectivity data on 1,716 signs. By the end of the study, 28 percent of the signs were significantly damaged, while 7 percent did not meet minimum retroreflectivity levels. Damage was categorized into aging (cracking or peeling), environmental (wind, snow, vehicle knock downs or tree sap) and vandalism (paintballs, bullet holes, eggs, bumper stickers and spray paint). Overall, only 1% of signs would have needed replacement that would not have already been replaced due to damage (6% of damaged signs did not meet minimum retroreflectivity requirements). This is consistent with the FHWA study that found rural areas can have high incidence of damage.

2.1.10 Louisiana [11]

In 2005, the Louisiana Department of Transportation (LADOT) collected sign retroreflectivity data to predict the sign performance. They used expected sign life for their management method, and evaluated data measurements on 237 signs (Type I and III, white, green and yellow). Overall, 92% of the signs still covered under warranty were above the minimum retroreflectivity requirements. Signs outside of the warranty had 43% at or above minimum retroreflectivity. The study noted the benefits of cleaning signs and that retroreflectivity levels increased when signs were cleaned. After this study, the LADOT adopted a 25 year service life for prismatic and 20 year life for all beaded sheeting, which took into account other national studies and research.

2.1.11 Texas Transportation Institute [12]

Bradford Brimley and Paul Carlson from Texas Transportation Institute (TTI) presented their latest work at the 2013 Transportation Research Board (TRB) annual meeting from their paper "The Current State of Research on the Long-Term Deterioration of Traffic Signs" [12]. They reviewed some of the projects listed above along with others and summarized the expected years to failure of each study. Table 2.3 summarizes Type I sign sheeting life expectancy and Table 2.4 summarizes Type III sign life expectancy.

The TTI review noted that Vermont was the only source of information for Type IX sheeting data and based on only 6 years of data. The authors concluded that the data did not produce reasonable predictions (more than 70 years) to failure. The researchers also discussed the problems with bias in field studies that drop early failures (due to replacements), have unbalanced numbers of signs, in addition to the problems of wide scatter in the data from unknown causes.

From a previous study by Brimley, Hawkins and Carlson titled "Analysis of Retroreflectivity and Color Degradation in Sign Sheeting", [13], results from an experiment of 9 different sheeting products were weathered on an outdoor 45 degree rack for 10 plus years, (or a simulated 21 years of service based on an assumption of twice the normal rate of degradation when installed at 45 degrees) were discussed. Most of the sheeting met retroreflectivity requirements over a 15 year simulated life, but some fell outside of the color (fade) specifications in less than five simulated years. Overall the authors found that products failed due to color fade loss of before retroreflectivity. As color fades, retroreflectivity can increase initially, complicating the analysis. The study also noted that this study included only one sample of each sheeting type and color.

Table 2.3 Type I Sheeting Life Expectancy Research

Color	Number of Studies	Publication Years	Sample Sizes	Years to Failure (2009 MUTCD)
White	5	1990-2006	40-1,084	6-13
Yellow	5	1990-2006	42-931	Not Permitted
Red	2	1991-2006	50-697	9-16
Green	5	1990-2006	42-704	10-16

Table 2.4 Type III Sheeting Life Expectancy Research

Color	Number of Studies	Publication Years	Sample Sizes	Years to Failure (2009 MUTCD)
White	8	1990-2012	35-909	34-740
Yellow	7	1991-2012	32-409	17-53
Red	6	1990-2012	84-662	15-Never
Green	5	1991-2009	46-326	9-740

2.2 Literature Review Conclusions

Eleven different sign retroreflectivity research documents were reviewed. Overall, each study looked at between approximately 140 and 5,700 signs, the vast majority of which were in-place (along the public road system) and consisted of either ASTM Type I or Type II sheeting material. The literature review resulted in four key conclusions as follows:

- Sign orientation and weather did NOT appear to play substantial roles in the deterioration of sign retroreflectivity although south facing red signs did experience an increase in variability.
- Daytime inspections were NOT as good as nighttime inspections for identifying signs that fail via retroreflectivity or color fade.
- The failure rates of the observed signs were in the range of 1% to 8%, depending on the age of the sign. One study also identified an overall 6% sign replacement rate, with approximately equal portions attributed to retroreflectivity failure and vandalism.
- Linear regression equations were the best fit in most studies for forecasting retroreflectivity degradation.
- Many of the studies developed regression equations that forecast the long term deterioration of retroreflectivity. In virtually every case, the regression equations forecast sign life far beyond the manufacturer’s warranty period. However, in each case the authors warned of possible credibility issues with their efforts because of environmental factors associated with the in-place sample of signs that they couldn’t account for in the equations, small sample sizes and unrealistic results (predicted sign lives in excess of 100 years).
- Color fade may be as large of an issue or cause for failure as retroreflectivity degradation.
- The final lesson is the most important and speaks to the credibility of the results. None of the research continued collecting retroreflectivity readings long enough to observe failure from the perspective of actually watching retroreflectivity of a set of signs drop below the established thresholds in a controlled setting. A number of the authors concluded that until that kind of research is conducted, any results regarding sign life will continue to be estimates as opposed to definitive values.

Chapter 3. Minnesota Data Collection

At the outset of the approach to acquiring readings of retroreflectivity through local Minnesota agencies, it was determined that the ideal number of signs necessary to produce statistically credible results would be one-hundred. In addition, to precisely determine sign life would require being able to observe the same signs over a long enough span of years for observed levels of retroreflectivity to drop below the established minimum thresholds. A sign test deck was established in order to observe individual signs fabricated with the newest sheeting materials over many years to better understand sign retroreflectivity degradation.

3.1 Local Agency Data Collection

Project staff worked with seven local agencies and the MnDOT research lab to collect retroreflectivity data on existing signs in the field. Data collection focused on 4 ASTM sheeting types, Type I, IV, IX and XI with green, red, white or yellow backgrounds. Readings were mostly taken from south facing signs, as these signs are subject to the most sunlight year-round and have been observed in previous studies to degrade faster that signs facing other directions. Existing sign inventories from each agency were used to determine the age of the sign.

Three-hundred seventy-nine valid readings were recorded by the City of Eagan, City of Golden Valley, City of Brooklyn, Dakota County, St. Louis County, Watonwan County, MnDOT Research and the MnDOT Metro District using a MnDOT provided retroreflectometer. Approximately ten percent of the initial data was removed or modified due to one of the following:

1) Data was corrected or removed if it was evident the background and legend had been accidentally misidentified during the data recording process.
2) Readings of zero on white sheeting and high readings on black were removed, possibly due to the instrument being improperly placed on the sign.
3) Signs listed as more than 7 years old and identified as Type XI sheeting were removed as the material was introduced 7 years ago.

By the time data was disaggregated by sheeting material, color and age of sign, no sign data set had more than 100 sign retroreflectivity readings. In addition, a limitation of the data is that no sign had more than one individual retroreflectometer reading, preventing that particular sign's retroreflectivity to be measured over time. Therefore, each sign only has a single data point associated with it. Only background color retroreflectivity data was analyzed due to the increased error potential in the smaller and narrower legend text. The data was graphed in Microsoft Excel® and linear trend lines were added to the data points to estimate sign life expectancy with regards to retroreflectivity failure. These trend lines were then compared to the minimum retroreflectivity requirements from the *MN MUTCD* (Figure 3.1).

Sign Color	Sheeting Type (ASTM D4956-04)				Additional Criteria
	Beaded Sheeting			Prismatic Sheeting	
	I	II	III	III, IV, VI, VII, VIII, IX, X	
White on Green	W*; G≥7	W*;G≥15	W*;G≥25	W≥250; G≥25	Overhead
	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.

Table 2A-3 Minimum Maintained Retroreflectivity Levels ①

Figure 3.1 - MN MUTCD Minimum Maintained Retroreflectivity Levels Table 2A-3 [1]

3.1.1 ASTM Type I Sheeting

Data was collected on 17 red signs and 23 yellow signs with Type I sheeting. Red sign data was collected on signs of two ages (11 and 15 years) and yellow on signs of 4 ages (11, 15, 17 and 21 years). While none of the signs fell below the minimum retroreflectivity levels, both trend lines slope upward and are therefore inconclusive due to insufficient data or the affects of color fade. It should also be noted that the *MN MUTCD* now states that Type I sheeting should not be used for black on yellow signs. Figure 3.2 demonstrates the results of the Type I retroreflectometer readings.

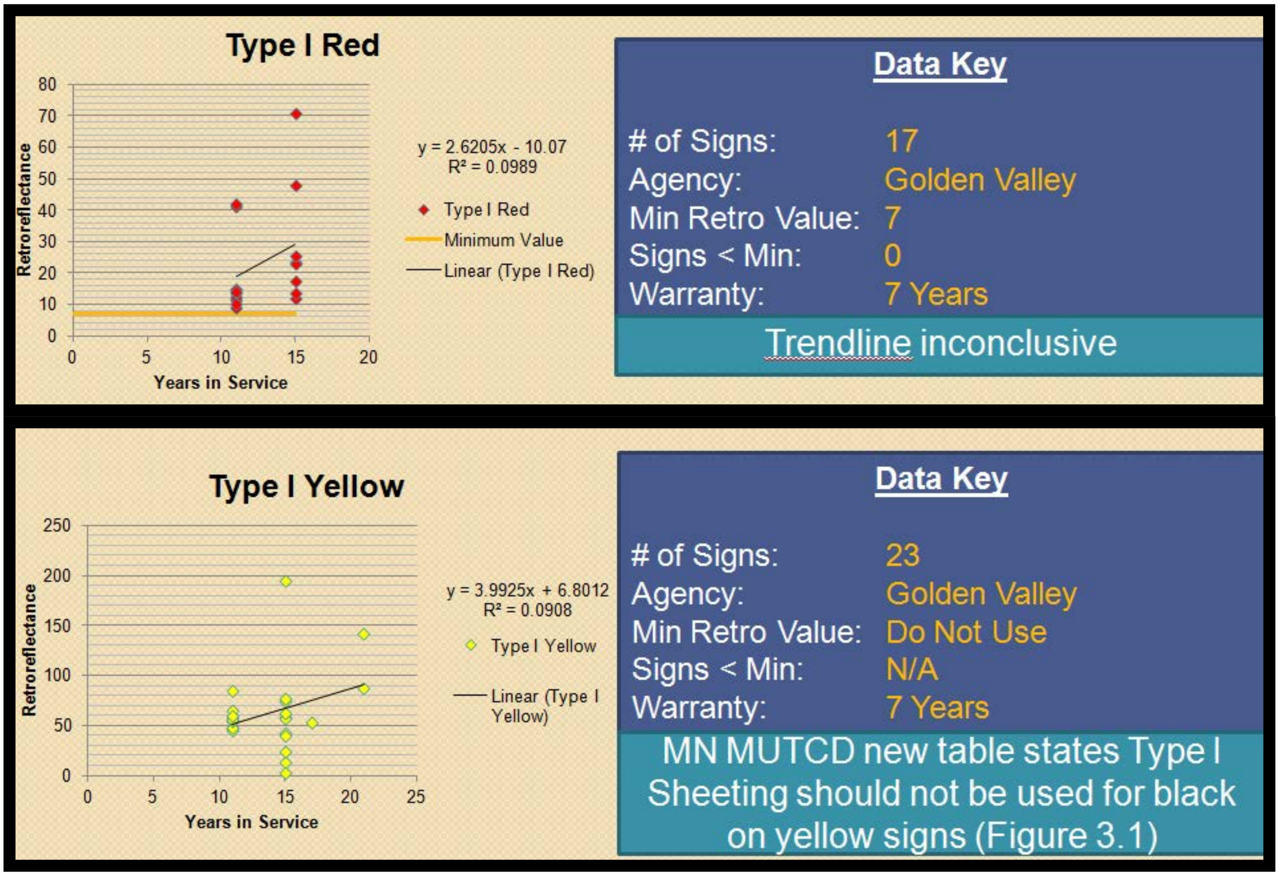


Figure 3.2 – Type I Sheeting Retroreflectivity Results

3.1.2 ASTM Type IV Sheeting

Data was collected on 5 green signs, 9 red signs, 14 white signs and 11 yellow signs with Type IV sheeting. Green sign data was collected on signs of 4 ages (13, 19, 21 and 22 years), red collected on signs of 5 ages (7, 11, 15, 19 and 22 years), white on signs of 9 ages (7, 9, 13, 15, 17, 19, 20, 22 and 23 years) and yellow on signs of 10 ages (2, 7, 12, 13, 14, 15, 16, 17, 19 and 24 years). Only 2 signs fell below the minimum retroreflectivity levels, one white sign (13 years) that would not meet overhead minimum values for legend on green signs and one yellow sign (24 years) that would not meet any minimum levels. Green Type IV trend line data sloped upward and was inconclusive. Red, white and yellow sign data trended downward, crossing minimum retroreflectivity levels between 23 and 82.5 years. However, due to low number of data points, the trend lines are considered inconclusive. Figure 3.3 demonstrates the results of the Type IV sheeting retroreflectometer readings.

Figure 3.3 – Type IV Sheeting Retroreflectivity Results

3.1.3 ASTM Type IX Sheeting

Data was collected on 14 red signs, 5 white signs and 11 yellow signs with Type IX sheeting. Red sign data was collected on signs of 8 ages (3, 4, 9, 12, 14, 16, 17 and 24 years), white sign data was collected on 4 ages (4, 8, 9 and 10 years) and yellow on signs of 6 ages (4, 7, 9, 11, 13 and 14 years). No signs fell below the minimum retroreflectivity levels. White Type IX trend line data sloped upward and was inconclusive. Red and yellow sign data trended downward, crossing minimum retroreflectivity levels between 27 and 50 years. However, the data for all colors is also considered inconclusive due to an insufficient amount of sign data. Figure 3.4 demonstrates the results of the Type IX sheeting retroreflectometer readings.

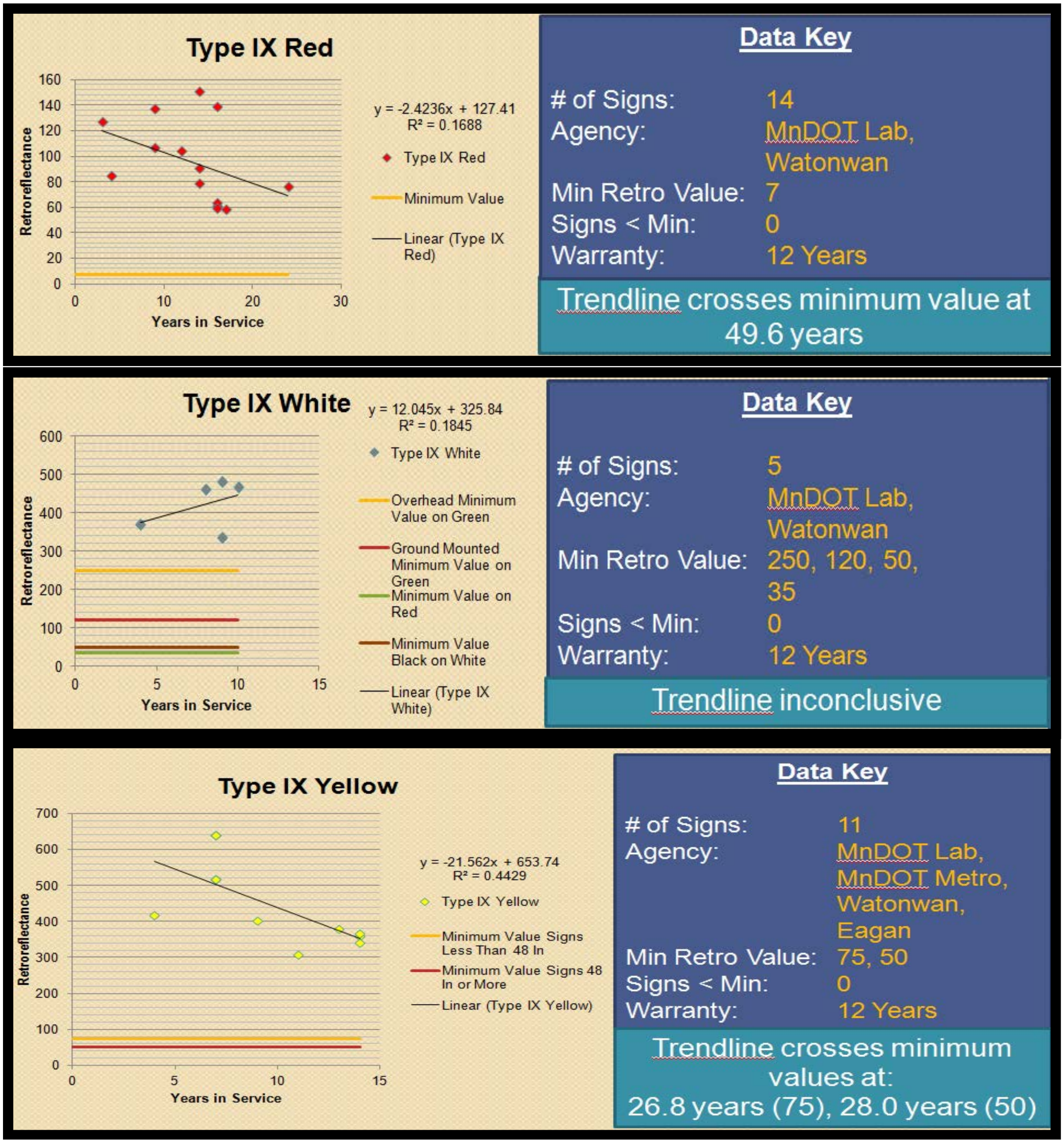


Figure 3.4 – Type IX Sheeting Retroreflectivity Results

3.1.4 ASTM Type XI Sheeting

Data was collected on 35 green signs, 78 red signs, 91 white signs and 65 yellow signs with Type XI sheeting. Green sign data was collected on signs of 7 ages (New, 1, 3, 4, 5, 6 and 7 years), red was collected on signs of 7 ages (New, 2, 3, 4, 5, 6 and 7 years), white on signs of 8 ages (New, 1, 2, 3, 4, 5, 6 and 7 years) and yellow on signs of 7 ages (New, 1, 2, 4, 5, 6 and 7 years). No signs fell below the minimum retroreflectivity levels. Green Type XI trend line data sloped upward and was inconclusive. Red, white and yellow sign data trended downward, crossing minimum retroreflectivity levels between 36 and 133 years. However, due to insufficient data, all sign color trend lines are considered inconclusive. Figure 3.5 demonstrates the results of the Type XI sheeting retroreflectometer readings.

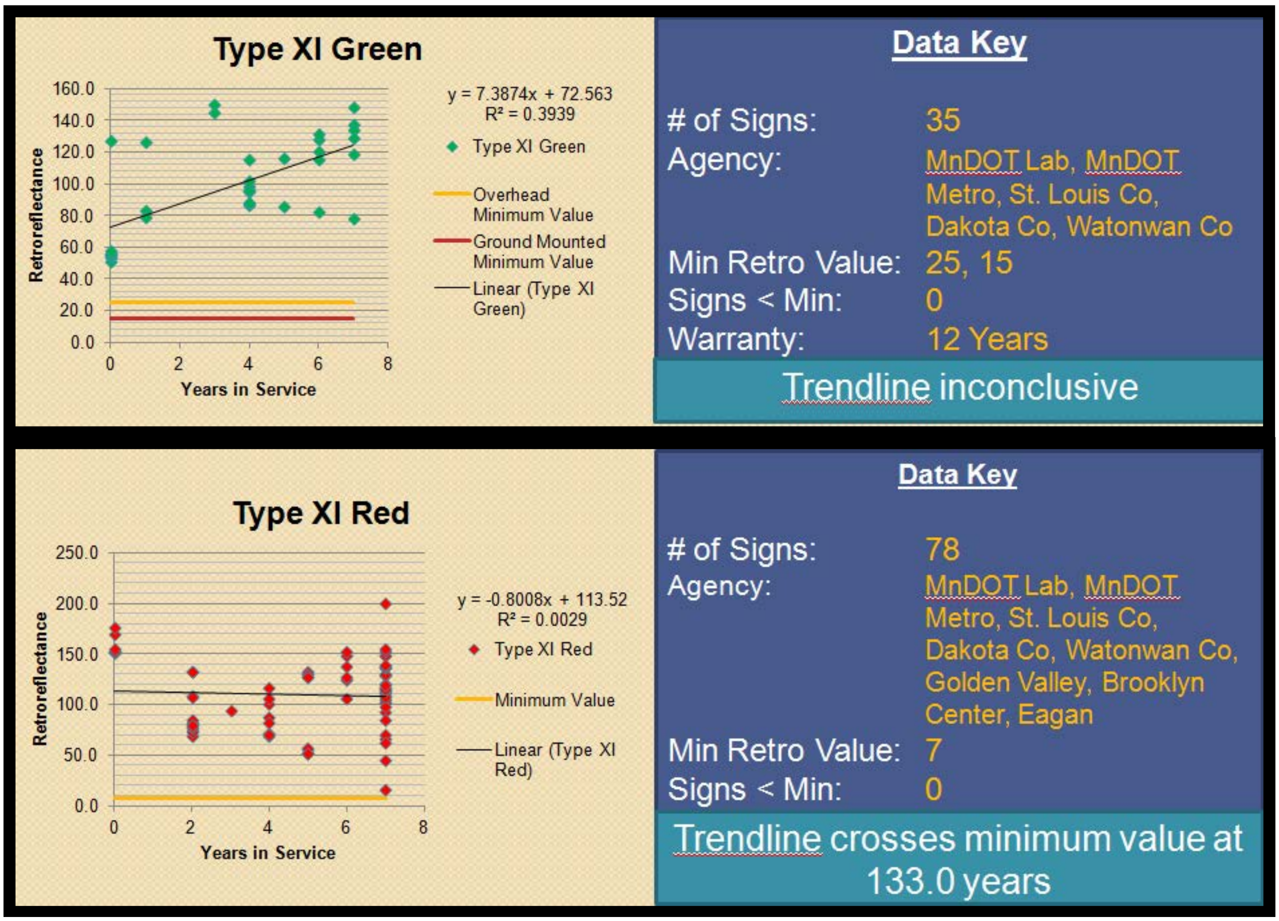


Figure 3.5 – Type XI Sheeting Retroreflectivity Results

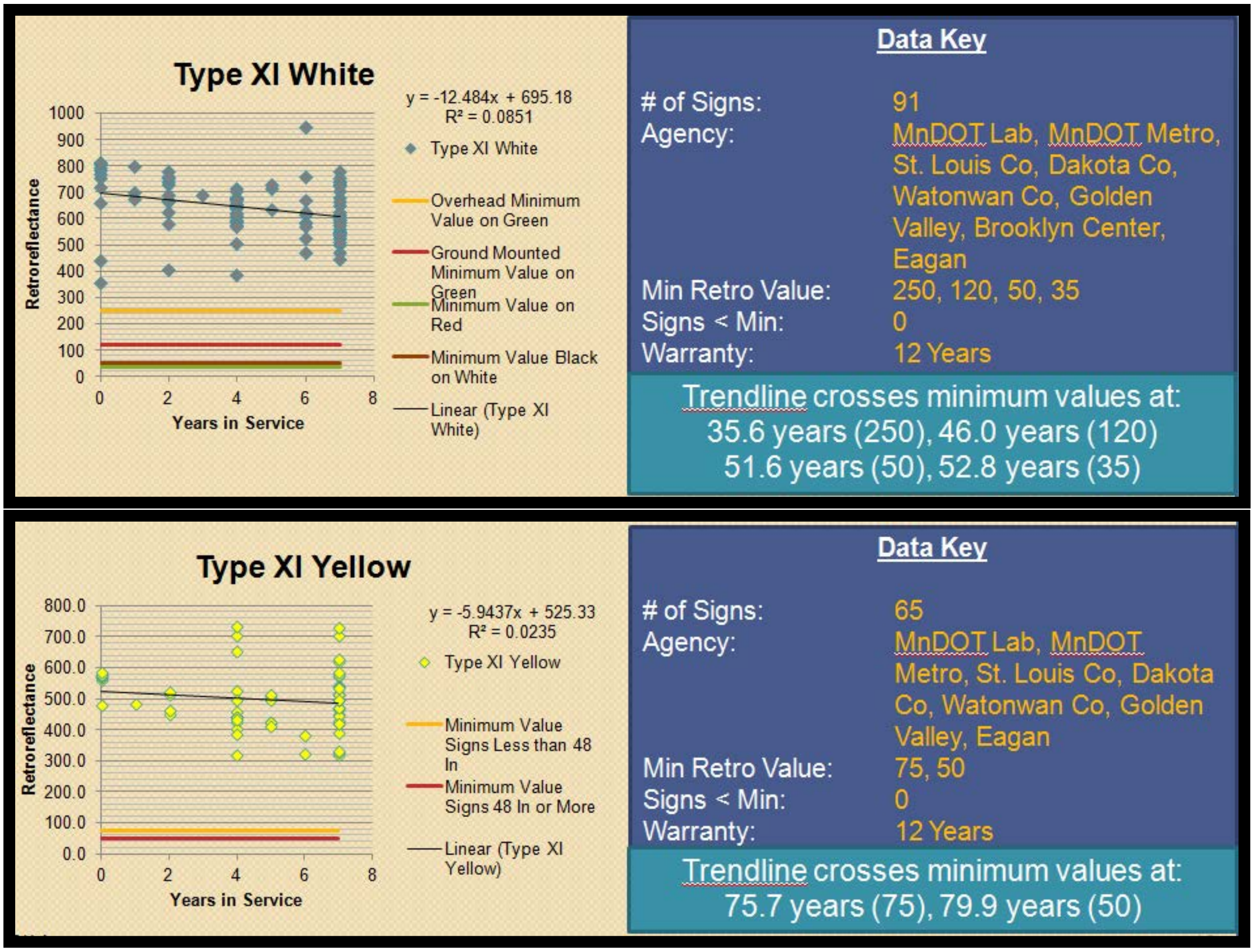


Figure 3.5 (Continued) – Type XI Sheeting Retroreflectivity Results

3.1.5 Agency Data Summary

While most trend lines for the different sheeting types are in the downward direction and indicates a sign life greater than the warranty periods, there was not enough data (less than 100 signs per data set) once the information was disaggregated by sheeting type and color for analysis to come to a definite sign life conclusion. In addition, only a handful of signs fell below the minimum retroreflectivity requirements. Toward the end of this study, after retroreflectivity readings were analyzed, a few agencies noted that sign types had been misidentified in the original readings. This further reinforces a need for retroreflectivity readings on signs in a controlled environment, over a long period of time to the point of failure.

While the data is inconclusive, it does seem feasible to suggest a range for sign life that can be reevaluated as more data is collected from the test deck for more conclusive results. Initial trend lines suggest a sign life of 12 to 20 years for beaded sheeting and 15 to 30 years for prismatic sheeting could be a reasonable sign life expectation for Type I, IV, IX and XI sheeting material of all colors, but further study and data is needed. It is important to reevaluate this sign life range as more data is available. It should be noted that color degradation can result in an initial increase in retroreflectivity. More research is required to clarify the relationship.

3.2 MnROAD Sign Test Deck

MnDOT planned to install a sign test deck at the outset of this project because of a concern that the retroreflectivity readings of in-place signs may not provide the desired high level of statistical reliability. The results of the agency retroreflectometer readings were determined to be inconclusive and this reinforces the need for the test deck and testing both retroreflectivity and color degradation of different sheeting materials and colors over the course of time, in a controlled environment. A controlled environment ensures correct sign sheeting identification and sign knock downs, vandalism or other outside factors will not interfere with data collection. Signs will ideally be tracked to the point of failure in order to develop a more conclusive trend line for sign life.

A traffic sign test deck was established in June 2013 at MnDOT's MnROAD site near Albertville, MN. Figures 3.6 and 3.7 show the test deck location at the MnROAD facility and the as-built layout of seven sign racks with the different sheeting materials facing four cardinal directions. The majority (4) of the sign racks are south facing since other studies have shown south facing signs are typically the first for retroreflectivity to degrade (though not significantly faster than other directions) as they are exposed to the sun for longer periods throughout the year. In addition, other studies have found that some colors, red in particular, fade faster on south facing signs.

Figure 3.6 - MnROAD Sign Test Deck Location

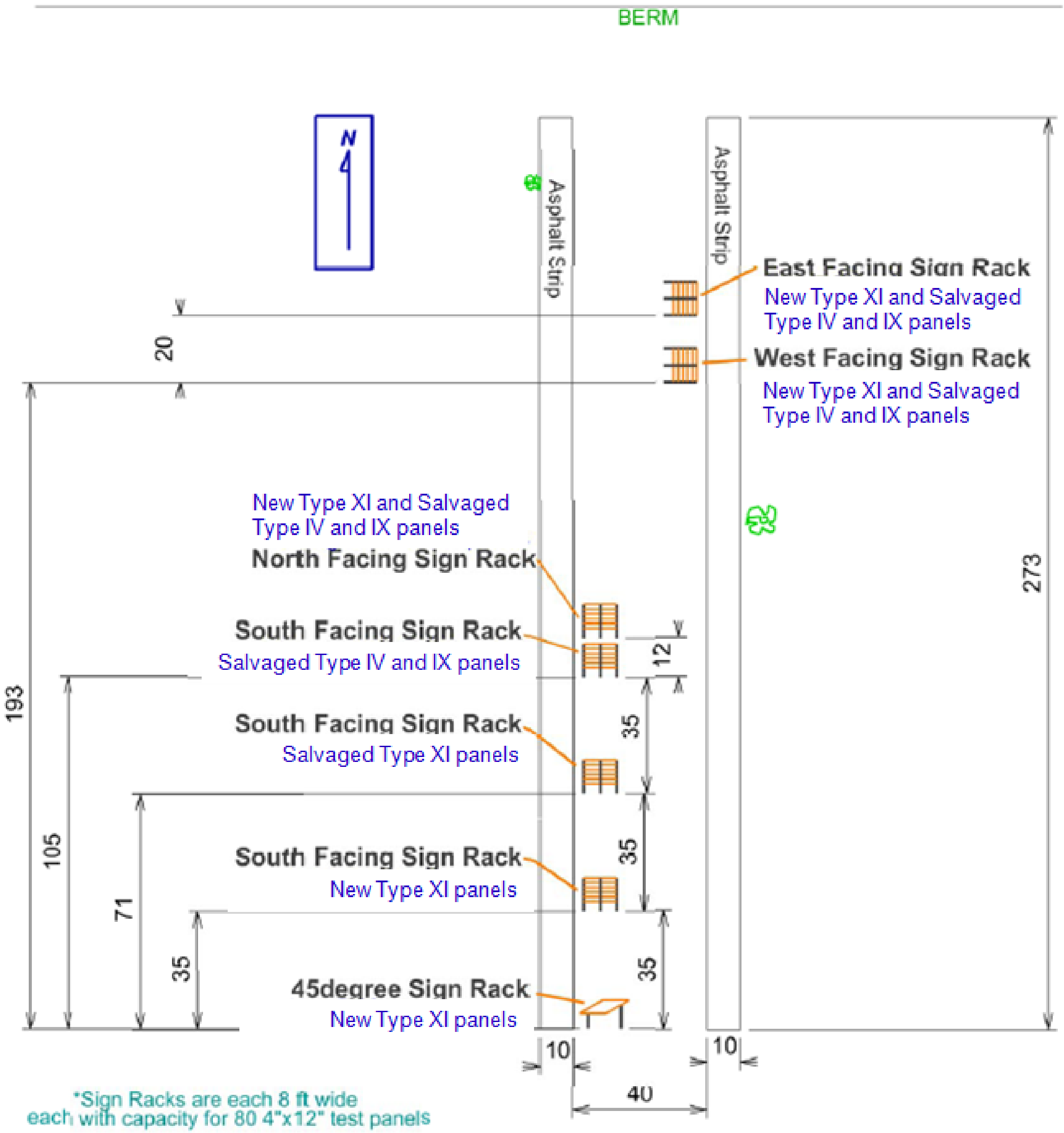


Figure 3.7 - MnROAD Sign Test Deck Layout

One of the south facing sign racks is placed at a 45 degree angle to simulate speeding the degradation process by approximately twice as much as a vertical sign. This sign rack will provide sign life results sooner than the vertical racks for agencies to use for sign replacement that will eventually be supported by data from the vertical sign racks. Figure 3.8 shows the sign test deck in place at MnROAD in July 2013 with the initial Type XI test panels installed.

Figure 3.8 - MnDOT Sign Test Deck Racks

Retroreflectivity and color (color is being collected to see if it falls below minimum thresholds prior to retroreflectivity, which could affect sign life expectancy) data will be collected over multiple years from the MnDOT sign test deck in order to obtain more data points, repeated retroreflectivity readings on the same sign panels, and to better determine an actual sign life for signs in a Minnesota climate.

3.3 Data Conclusions

Based on the collected data and data evaluated during the literature review, key conclusions include:

- There is not enough Minnesota retroreflectivity data (in-place and on the test deck) as of the end of 2013 to establish a statistically reliable data set that would allow the determination of an exact value for sign life. After signs were disaggregated by sheeting material and sign color, there were too few overall numbers of signs, no repeated testing of the same signs, misidentified sheeting materials and virtually no signs observed to failure at this time.
- Vandalism and knock-downs effect sign life at different rates in different agencies, but are a key factor in expected sign life spans.
- The data suggest a reasonable estimation of sign life in the range of 12 to 20 years for ASTM Type I and IV sheeting material.
- The data suggest a reasonable estimation of sign life in the range of 15 to 30 years for ASTM Type IX and XI sheeting material.
- Color (especially for red signs) may fall below adopted thresholds (contrast/fade) prior to retroreflectivity failure.
- Continued data collection is planned at the MnROAD test deck and will be reevaluated in the future in order to observe signs in a controlled setting until they fail.

There is not sufficient local retroreflectivity data to definitely establish sign life with a high degree of statistical reliability. As a result, the subjective risk management approach, involving suggestions from an expert panel to help establish a best practices approach for local agencies use in establishing their sign maintenance programs is recommended.

The MnROAD test deck will provide valuable results over time with continued retroreflectivity and color readings to failure in a controlled environment. Agencies may also continue to check in on the MnROAD sign test deck to see if retroreflectivity or color readings and trendlines are more statistically reliable and indicating a different sign life than their sign maintenance programs. Ideally, data collection will occur on the test deck until sign failure to determine a more narrow range, or definitive sign life.

Chapter 4. Conclusions

Sign life is a topic of interest across the spectrum of Government agencies in Minnesota because it is a key part of developing a comprehensive sign maintenance program, which all agencies are required to have in place by June 13, 2014.

A review of eleven published research articles indicates that a variety of analyses have been started but none of the results are considered definitive for Minnesota due to a variety of reasons, including:

- Most of the studies are on Type I or III signs with limited data on newer sheeting types.
- Authors frequently warned of possible credibility issues with data due to a variety of issues including environmental factors, small sample sizes and unrealistic results (projected sign lives in excess of 100 years) that could not be accounted for.
- Daytime inspections are NOT as good as nighttime inspections for identifying failures or retroreflectivity or color fade.
- Retroreflectivity failure rates of signs were observed in the range of 1% to 8%.
- Tests were performed in different climates than Minnesota.
- Many studies brought forth concerns regarding limited information about the actual sign histories.
- None of the research collected retroreflectivity readings long enough to observe failure of in-place signs, while other test decks have not been in-place long enough for newer sheeting material to approach adopted retroreflectivity thresholds.

Retroreflectivity data collected on in-place signs from eight Minnesota agencies resulted in expected sign life trendlines similar to those of published research. However, none of these signs have been in-place long enough to observe failure and factors such as knock-downs, vandalism and sign sheeting misidentification make it difficult to collect reliable retroreflectivity data on the same signs over a period of time, making it difficult to narrow in on a definitive expected sign life. Minnesota data and previous research suggests a definitive sign life determination would require observing a test deck in a controlled environment and observing retroreflectivity to failure below established thresholds.

The test deck of signs installed by MnDOT at the MnROAD facility should add valuable information to the discussion of sign life, but not until several years in the future as multiple retroreflectivity readings are taken on the same signs with known information and no environmental factors affect the signs. These signs have not been in-place long enough to either have enough readings to be considered statistically credible at this time or to establish trend lines that are reliable. However, MnDOT has committed to continue collecting both retroreflectivity and color data on the MnROAD test deck, to a point of failure to better determine a definitive expected sign life.

Initial data from agency readings of in-place signs and the MnROAD test deck suggests a reasonable sign life expectancy of 12 to 20 years for beaded sheeting and 15 to 30 years for prismatic sheeting. These values will continue to be updated and reviewed as more information is available from the MnROAD test deck to determine a definitive expected sign life.

In the near future, these results suggest two key points for agencies. First, from both a risk management and sign management perspective it is very important for agencies to develop and adopt a sign management method, including the identification of expected sign life. However, there is no definitive information currently available to assist the agencies in determining a sign life. As a result, agencies are encouraged to move forward using the best practices technique of bringing sign management decisions under an umbrella of immunity by having sign management decisions based on policies adopted by their elected officials and the results of engineering studies conducted by the Agency’s professional staff or qualified consultant.

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APPENDIX A
THE POLICY ISSUE

The following section summarizes the process local agencies can use to establish a sign management approach.

The Federal *Manual on Uniform Traffic Control Devices (MUTCD)* and the Minnesota version *(MN MUTCD)* contain a requirement that all highway agencies must adopt a method of traffic sign maintenance by June 13, 2014 [14]. Since there is no enforcement mechanism for this new requirement, it is incumbent on the staff at each agency to take the necessary steps to achieve compliance. Being consistent with the requirements contained in the *MUTCD* is an important part of each agencies best practices efforts to manage both their system of traffic signs and their risk because the *MN MUTCD* has been officially adopted for use on all public roadways in Minnesota and because the document is considered to be a standard against which an agencies actions will be compared if allegations of negligence arise.

A review of Minnesota's tort law indicates that local agencies should consider two proven methods. In order for agencies to bring their actions, relative to traffic sign maintenance, under an umbrella of immunity: Discretionary Immunity that is policy driven and Official Immunity that is generated through the exercise and documentation of engineering judgment.

A.1 Policy Discussion

Pursuant to Minn. Stat. § 466.03, Subd. 6, a city is immune from liability for: *"any claim based upon the performance or failure to exercise or perform a discretionary function or duty whether or not the discretion is abused."* As a practical matter, the more it looks like discretion was abused the more likely a court may determine that discretion was not exercised. Discretionary immunity exists because the government must make decisions. It must make decisions on how to best spend taxpayers' money and to prioritize the use of limited financial, personnel and other resources. In addition, there are frequently competing policy considerations concerning what a city should do. Discretionary immunity recognizes that difficult decisions sometimes need to be made. Discretionary immunity should apply when a government decision involves the weighing of competing political, social, economic or safety factors.

Discretionary immunity is policy driven – actions that are consistent with adopted written policies and ordinances are considered as a matter of law to be immune from allegations of negligence. Therefore, it is considered to be a best (risk management) practice to have an agency's decision regarding the adoption of a traffic sign maintenance method included in a policy or resolution enacted by the highest governmental decision making body (city council, county board, township board) following a discussion and consideration of the technical details of your system of signs, your maintenance capabilities and non-technical issues including social, economic, environmental and political considerations. In addition to the topic of traffic sign maintenance methods, it is considered a best practice to also include a discussion and consideration of a number of related signing topics. The topics and a brief description for each are provided in the following paragraphs.

A.1.1 Sign Maintenance Methods

There are three documented traffic sign maintenance methods; Assessment methods, Management methods and a Combination of methods [15]. The Assessment methods are basically quantitative and involve having trained inspectors drive the agency's highway system, observing each sign and assessing the observed or measured level of retroreflectivity. The Management methods are basically qualitative and are primarily based on the expected life of the sign's sheeting material. The Combination of methods would employ elements of both the quantitative and qualitative approaches to sign maintenance.

A.1.1.1 Assessment Methods

Assessment methods require trained inspectors to conduct an in-field review of every sign in an agency's system. The Visual Nighttime assessment is conducted during periods of darkness, at normal speeds from the travel lane, using low-beam headlights and at typical viewing distances based on 30 feet of legibility distance per inch of letter height (180 feet for street name blades with 6-inch letters, 300 feet for STOP signs with 10-inch letters and up to 1,100 feet for symbol type warning signs). FHWA guidance suggests that one of the following procedures should be used to support the visual nighttime inspections:

1.) Calibration Signs – This procedure involves an inspector viewing a calibration sign prior to conducting each nighttime field review. The calibration signs would have known levels of retroreflectivity, preferably just above the minimum threshold for a particular color and type of sheeting material. The calibration signs would be set up in a maintenance yard where the inspector could view the signs in a similar manner to the nighttime field inspections. The inspector would then use the visual appearance of the calibration sign to establish the evaluation threshold for that night's field inspections.

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

3.) Consistent Parameters – The nighttime inspections would be conducted under similar factors (vehicle and human) that were used in the original research to establish the minimum retroreflectivity thresholds. These factors include; using a year 2000 or newer Sport Utility Vehicle or Pick-Up truck (similar type and height of head lamps) and using an inspector at least 60 years of age with 20/20 vision (corrected).

An alternative Assessment method involves measuring the retroreflectivity of every sign in an agency's system with a calibrated retroreflectometer (approximate purchase price = $10,000). The results from multiple readings of each color are averaged and recorded and the results are compared to the minimum threshold levels. Signs with actual retroreflectivity levels below the adopted minimums would be scheduled for replacement.

A.1.1.2 Management Methods

The Management method is qualitative, does not involve in-the-field inspections and is fundamentally based on estimating the expected life of signs using the manufacturer's warranty, research or the performance of a small set of control signs. The Expected Sign Life and the Blanket Replacement methods are similar from the perspective that an agency would adopt an expected sign life for their inventory based on an understanding of the sheeting materials warranty, prevailing weather conditions and levels of vandalism (for example, if signs need to be replaced every few years because they are being shot, selecting an expected sign life would probably not be a good strategy). Then all of the signs in the inventory that are older than the expected life along a specific route, corridor or in an area are "blanket" replaced at one time. An example of using expected sign life to drive a sign maintenance program involves MnDOT's adoption of 15 years as the expected life of their inventory of signs and then scheduling replacement of 1/15 of all the signs in each of their Districts on an annual basis.

The Management method also includes a technique that uses a small set of control signs (all of the basic colors oriented in the most adverse direction) that, for convenience and safety, could be located in a maintenance yard. These control signs would be set up similar to signs installed along the highway system and then monitored to determine when the retroreflectivity drops below the established minimum thresholds. All of the in-the-field signs represented by the control sample would then be replaced just before the control samples reach the minimum specified levels. New signs would periodically be added to the control sample when signs are upgraded in-the-field.

A.1.1.3 Combination of Methods

The Combination of methods would describe a process that includes elements of both the Assessment and Management methods. An example would be combining the replacement of signs based on the expected sign life and conducting annual nighttime inspections to find the few signs that might be outliers or that have the kind of damage that is only visible at night (i.e., damage from paint balls).

Determining which method is best for a particular agency would involve consideration of the probable costs and benefits. The Assessment methods require training staff and many staff hours conducting the annual nighttime field inspections. For example, it's estimated that to observe all of the signs along a typical county highway system (10,000 signs) would require approximately 500 hours, or one-quarter of a full time employee operating after normal business hours. The primary advantage of using an Assessment method is that agencies will likely get the most possible years of service from each sign in the inventory. On the other hand, the Management methods require less staff time since there are no in-the-field inspections, but it is also probable that some signs in the inventory will be replaced when they have some life remaining. If the issue of replacing signs with some remaining life is considered critical, an agency could salvage the signs being removed based on reaching the expected life, measure the retroreflectivity in the shop, and retain those still meeting specifications as potential replacements for signs damaged by vandalism or knockdowns.

There is no uniform best practice for selecting a method of maintaining an agency's system of traffic signs, because the characteristics of each agency's system assets and the number and composition of the staff and other resources are different. However, FHWA suggest that agencies consider three factors. The first is the size of an agency's sign inventory. If the number of signs in the inventory is relatively small (fewer than 500), conducting annual inspections would be fairly easy and not too time consuming. If the number of signs in the inventory is large (more than 5,000), conducting the annual inspection could require hundreds of staff hours and suggests consideration of one of the Management methods. The second factor involves an agency's professional staff. If the professional staff are trained and have experience conducting nighttime inspections, it would be easy to continue. If an agency does not have trained staff, the choices would include adding staff and training them or adopting one of the Management methods. The third factor involves the willingness to purchase measurement devices. If an agency already owns or is willing to purchase a retroreflectometer or a kit with samples of sheeting material at the thresholds (a kit is currently under development at MnDOT State Aid or Avery Dennison® has a kit available for purchase), one of the Assessment methods may be best. If an agency chooses not to make these investments, the Visual Assessment or one of the Management methods would be a better choice.

One final point regarding the adoption of a sign maintenance method – it doesn't have to be permanent – weigh the various factors, understand the characteristics of the system and staff, make a decision and move forward and then re-evaluate periodically.

A.1.2 Best Practice Statements for Sign Maintenance Policy

<u>A.1.2.1 Sign Maintenance Policy Best Practice</u>

The *MN MUTCD* requires agencies that manage systems of traffic signs to adopt a method for maintaining minimum levels of retro-reflectivity. The optional methods available for use have been previously described and include either some manner of annual visual inspection of each sign in the system by trained inspectors or a system approach based on the expected life of the reflective sheeting material used by the agency. In Minnesota, a suggested best practice approach involves documenting an agency's decision to adopt a particular sign maintenance method in a policy enacted by the agencies elected officials. This approach is based on Minnesota's tort law that provides for discretionary immunity (from claims of negligence) for policy driven actions, such as sign maintenance.

A best practices statement suitable for inclusion in a sign maintenance policy would be:

"The ______________ County Highway Department/the City of ______________ Public Works Department will conduct one nighttime inspection per year on its system of roadways and will use the Blanket replacement method to maintain traffic sign retroreflectivity."

A.1.2.2 Type of Reflective Sheeting Material Best Practice
Decisions regarding the type of sheeting material to use across a system of roadways usually come down to three factors; performance, cost (including expected life/life cycle costs) and the extent to which an agency's signs are vandalized.

The newer, higher grade prismatic sheeting materials (ASTM Type IX & Type XI) are significantly brighter and have probable life expectancies in the range of two to four times longer than the older beaded materials (ASTM Type I, Type IV). However, the initial cost of the prismatic sheeting is three to four times higher than the cost of the beaded sheeting. Due to longer life expectancies, the life cycle costs of the prismatic sheeting could be as much as 50 percent below the costs for the beaded sheeting (sign lasts longer based on retroreflectivity and replacement is needed less often).

It should also be noted that because the cost of the reflective sheeting material makes up only a part of the installation costs, the total cost of installing a traffic sign (sign blank + sheeting + posts + labor) actually falls in a fairly narrow range and that suggests that agencies would likely pay a premium of between 5 and 15 percent for the initial installation of the higher performance sheeting when all components are taken into account and little effect over the entire sign life cycle.

Finally, if many of an agency's signs are being vandalized such that virtually none of the signs actually approaches the expected sign life, the use of the longer lived/higher performance material would likely not be a cost effective strategy.

A best practices statement would be:

"The ______________ County Highway Department/the City of _______________ Public Works Department will use ASTM Type XI sheeting material for all traffic signs."

A.1.2.3 Citation of Expected Sign Life Best Practice
The dilemma for agencies in the selection of an expected sign life stems from the fact that it cannot be said with a high degree of certainty at this time what the expected life is for a particular sheeting material on a particular sign. Not enough data has been collected, not enough analysis has been completed and not enough research published. What is known is the warranty period provided by manufacturers (7 to 10 years for beaded material and 12 years for prismatic). However, there is an expectation that the actual life of a sign is considerably longer based on observations of agency staff and there is some preliminary evidence that supports this notion. A survey of other state DOT's found that four of the five states interviewed adopted sign lives in the range of 15 to 20 years [16]. In addition, the readings of retroreflectivity documented as part of this project suggest a reasonable life expectancy is beyond the warranty period and would likely be in the range adopted by a number of other state DOT's in the range of 10 to 20 years for beaded sheeting and 15 to 30 years for prismatic sheeting.

A best practices statement would be:

“The _______________ County Highway Department/the City of _______________ Public Works Department adopts a sign life of 15 years for all signs in our inventory.”

<u>A.1.2.4 Damaged Sign Replacement Best Practice</u>

It is important for agencies to establish reasonable time frames for their crews to repair damaged signs following receipt of a notice that a sign has been damaged. It is also important for agencies to acknowledge that all signs are not equally important for the safety of motorists, therefore, response times for the repairs should vary based on the assumed importance of the sign. There appears to be agreement that replacing damaged STOP signs should have the highest priority because of the concern for severe crashes if the STOP sign is not visible. A reasonable approach to addressing damaged STOP signs would be repair/replacement within one business day of notification. There also appears to be agreement about lower priority signs, generally Guide signs and street name signs. A reasonable approach to addressing damaged Guide signs would be repair/replacement within three business days (an agency may determine and change the timeframe based on weighing political, social, economic and safety factors). There was not general agreement based on sample policies on which types of signs belonged in the intermediate category. One agency’s policy identified this intermediate category as being “not directly vital” for safety, such as speed limit and most warning signs. Another agency identified the entire category of Warning signs as the intermediate priority. A third possibility could identify all of the Regulatory, Warning and Guide signs that are a SHALL description for installation in the *MN MUTCD*. This group of signs would include; Speed Limit signs (for established speed zones), ONE WAY /DO NOT ENTER, Turn Prohibitions, All-Way STOP Plaque, Advanced Rail Road Crossing, Bridge Clearance & Weight Limits, Horizontal Alignment series (Average Daily Traffic based), Route Numbers, Junction Assembly and the Advanced Turn Assembly.

A best practices statement would be:

“The _______________ County Highway Department/the City of _______________ Public Works Department will repair/replace signs after receipt of notice that a sign has been damaged based on the following schedule:

- High Priority Signs (STOP signs) – within one business day
- Intermediate Priority Signs (Reg., Warning and Guide Signs required by the MN MUTCD) – within 2 scheduled business days
- Lower Priority Signs (All other Regulatory, Warning & Guide signs) – within 3 scheduled business days”

<u>A.1.2.5 Signs Requested to be Installed on Agency’s Right-of-Way Best Practice</u>

Experiences shared by county and city engineers suggest that agencies will at some time be asked by the public to investigate a segment of roadway or an intersection because of a perceived safety problem, for which the public’s suggested solution is to install a particular traffic sign. If the agency’s investigation concludes there is not a problem and no signing change that would make the situation better, the public’s response in some cases is to offer to pay for installing the requested sign themselves. It appears that the requestor attributes the conclusion to not install their suggested sign because of the cost as opposed to any consideration of effectiveness. In order to be responsive to the public, agencies are required to provide an explanation for their decision and there are two primary approaches to crafting this response. First, the agency can explain the technical reasons for their decision, including; documenting the data they collected, the results of the analysis that was completed, determination as to whether the documented conditions were different than what would be expected and finally explaining that the decision to not install a sign was based on either not finding a real problem or a conclusion that no sign would be effective at achieving the public's desired outcome. More often than not, this type of technical explanation fails to be persuasive with the public; it is counter-intuitive plus they may have seen a sign installed in a similar situation in another jurisdiction. The second and more effective strategy is to refer to a policy adopted by the county board/city council that says that all signs requested to be placed in the right-of-way of the county roadway/city street must meet the requirements of the *MN MUTCD* AND have the approval of the county engineer/city engineer. These provisions should be sufficient to prevent the installation of virtually all unusual signs (i.e., SLOW CHILDREN, CHILDREN AT PLAY, etc.) which have never proven to be effective at improving safety but will increase an agency's maintenance costs and increase an agency's risks if they are not consistent in the application across their system of roads. The discussion of the merits of such a policy with the county board/city council in advance of securing the adoption may prove challenging, but issues of an agency's annual maintenance budgets and risks should be discussed publicly, with the goal of informing the public.

A best practices statement would be:

"All traffic signs requested to be placed in county's/city's right-of-way must meet the requirements of the *MN MUTCD* and be approved by the County/City Engineer."

A.1.2.6 Exclusions/Removals Best Practice

The analysis of potential budget implications for local agencies of the recently adopted retroreflectivity thresholds was reported in *Minnesota's Best Practices for Traffic Sign Maintenance/Management Handbook* [17]. These results along with feedback from local agency staff suggest that a number of agencies may need to consider increasing maintenance budgets as they adopt expected lives and specified replacement cycles for traffic signs in their system. It has been a fairly common practice to underfund sign maintenance because agencies could do so with no immediate consequences. There were no specified performance measures and sign maintenance was suggested but not required. It also appears that local agencies' inventories of signs have a tendency to grow unchecked, for a variety of reasons; a desire to please elected officials and the public, a focus on the low initial cost of installing signs without sufficient regard for the implications of ongoing maintenance, a lack of understanding about how few signs are required, and their potential lack of effectiveness.

A potential solution, as part of a comprehensive traffic sign maintenance program, is to remove signs when feasible and reduce the size of an agency's inventory, thus lowering

the number of signs that must now be maintained and the associated annual maintenance costs. A best practices approach, in this case, is to take actions removing traffic signs consistent with provisions of a sign maintenance policy because of the discretionary immunity associated with policy driven implemenation. The most comprehensive approach would be to remove all signs that are not required by the *MN MUTCD*. Since there are only 14 required types of signs, this approach could potentially result in the removal of a large number of signs, and save local agencies significant costs of sign maintenance and as the research suggests not adversely affect driver safety [17].
A less aggressive approach would involve a focus on removing particular types of signs (that are not required to be installed according to the *MN MUTCD*) along particular types of roads. Examples of potential candidates include:

- Regulatory Signs – three candidates for removal are Speed Limit signs that merely replicate statutory speed limits (particularly along urban local streets and collectors), STOP and YIELD signs at very low volume intersections and Right/Left Turn Lane signs.
- Warning Signs – four candidates for removal are advanced intersection warning signs (Intersection Ahead and STOP Ahead), Deer Crossing signs, Watch for Children and all warning signs along local roads. The Intersection advanced warning, Deer Crossing and Watch for Children signs have been proven to be ineffective [17].

A contractor working on upgrading the signs along township roads in Stevens and Wright Counties incorporated sign removal into their plan development process and ended up removing approximately 25 percent of the signs across 34 townships, most of which were intersection advance warning signs, speed limit signs and Watch for Children signs [17].

A best practices statement would be:

"The _______________ County Highway Department/the City of _______________ Public Works Department has considered the requirements of the *MN MUTCD*, the cost and effectiveness of the types of traffic signs in our system and has determined that the following types of traffic signs will no longer be installed and in-place signs will be removed:
- Regulatory Signs – __________, __________,,,,,,,,.
- Warning Signs - __________, __________, ,,,,,,,."

A.2 Engineering Judgment Discussion

In addition to the protection against claims of negligence afforded by discretionary immunity, Minnesota tort law provides agencies with a second level of risk management by way of official immunity. "Official immunity" is a common law doctrine (developed from court decisions) that protects individual public officials or employees from personal liability for their discretionary actions taken in the course of their official duties as long as their conduct was not malicious. The purpose of official immunity is to protect the public official or employee from the fear of personal liability that might deter independent action and impair effective performance of their duties.

In the absence of malice, the critical issue in a claim of official immunity is whether the public official's conduct is discretionary or ministerial. A discretionary act requires the exercise of individual judgment in carrying out the challenged duties. In contrast, a ministerial act is absolute, certain, and imperative, involving merely execution of a specific duty arising from fixed and designated facts.

Whether discretion was involved and official immunity applies turns on the facts of each case. **Official immunity for actions taken by individuals acting within the scope of their employment in a highway agency is generated by exercising engineering judgment as part of an engineering study and documenting the decisions about the actions to be taken.** The typical steps in the study process are described in the following paragraphs.

A.2.1 Understand the Basics

The first step in the study process involves gaining a basic understanding of the guidance for traffic signs documented in the *MN MUTCD*. This would include noting which types of signs are required to be installed versus which ones may be installed on the basis of engineering judgment, the characteristics of the locations where particular signs are suggested and the basic objectives for various types of signs.

Other information that would be helpful in conducting a comprehensive engineering study would include a review of research documenting the effectiveness of signs and information about an agency's historic sign maintenance budget.

A.2.2 Conduct a Study

A comprehensive engineering study begins with having a complete inventory of the signs along the agency's road system, documentation of the basic site characteristics at each sign (rural or urban, speed limit, roadway cross-section, functional classification, traffic volume) and the age/general condition of each sign.

A.2.3 Document the Decision

From a risk management perspective, the most important part of the study process is documenting both the steps in the analysis and the decision relative to the actions that the agency will take as part of their sign maintenance program. A typical outline for the study report would include:

- Statement of the objective of the study
- Documentation of the agency's knowledge of the applicable guidelines as contained in the *MN MUTCD*.
- Documentation of the physical conditions – the sign inventory and the characteristics of each site.
- Documentation of the effectiveness for various signs as documented in published research.
- Documentation of the financial considerations associated with various approaches to sign maintenance – the expected costs of maintaining the existing number of signs and the expected costs associated with maintaining an alternative system with fewer signs.

The most comprehensive approach to managing an agency's risks associated with removing traffic signs from the inventory would involve a process that takes advantage of both discretionary immunity (policy driven) and official immunity (engineering study driven).

A best practices statement would be:

"The _______________ County Highway Department/the City of _______________ Public Works Department has conducted an engineering study that considered the requirements of the *MN MUTCD*, the cost and effectiveness of the types of traffic signs in our system and has determined that the following types of traffic signs will no longer be installed and in-place signs will be removed:

- Regulatory Signs – __________, __________,,,,,,,,.
- Warning Signs - __________, __________, ,,,,,,,."