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Cost Effectiveness of Traffic Sign Materials

Minnesota Local Road Research Board

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This report presents information on the various types of sign sheeting material available. It is intended to provide readers with sufficient data to make educated decisions regarding the purchase of traffic sign sheeting for their community and maintaining the signs in their inventory.

This report pulls together information on signing terminology, retroreflectivity and the aging problem, signing materials, life-cycle costs, best management practices and sign management systems. Additionally, the information is condensed into easy to follow tables which highlight the costs of the various sheeting materials as well as their advantages and disadvantages.

A review of the existing signing materials indicates that some of the higher-priced and higher-quality sheetings have lower life-cycle costs than the less expensive sheetings. As a result, long-term cost savings can be achieved by using the material that is initially more expensive. In addition, it was found that the higher-quality sheetings provide better detection and recognition for drivers.

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Cost Effectiveness of Traffic Sign Materials

Final Report

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March 2000

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EXECUTIVE SUMMARY

Engineers and public officials are concerned with safety and the need to budget wisely. They have seen the choices in traffic sign materials increase substantially in the last ten to 15 years. The increased number of choices has proven beneficial to drivers; there are materials available that enable signs to be more visible from greater distances. Early detection and comprehension of traffic signs affords drivers, especially older drivers, the time necessary to react to changing traffic conditions.

However, the increased number of sheeting choices can be confusing when selecting the material that is best for a community. In addition, the prices and estimated life-cycle of different sheeting materials can vary considerably. Decisions based solely on initial costs of sheeting materials may result in reduced sign legibility for drivers and higher life-cycle costs for communities. This report provides information on evaluating sign sheeting materials and how sheeting material cost is only a part of the consideration of potential alternatives. The table on the following pages provides the initial costs, life-cycle costs, retroreflectivity, and advantages and disadvantages of the various sheeting materials. The sheeting materials are arranged from lower reflectivity (Type I) to higher reflectivity (proposed Type IX). It should be noted that:

1. Initial sign sheeting costs are only a small percentage of the total cost. Labor and equipment costs are factors that need to be considered as well.

2. Higher quality (long-life) sheetings can lead to lower life-cycle costs; lower quality (short-life) sheetings can lead to higher life-cycle costs.

3. Frequent replacement of signs (shorter life-cycle) increases staff exposure to traffic.

Several measures can ensure that an organization is getting the most for its signing investment. The following list highlights best management practices that can be implemented:

- Consider purchasing sign sheeting off of Mn/DOT's contract or other agency contracts. Bulk purchasing can sometimes result in a better price than direct bids.

- Consider placing larger and brighter signs in urban areas where there are other activities competing for the driver's attention.

- Use higher-grade reflective sheeting on the more critical regulator and warning signs such as stop, yield, stop ahead, yield ahead and curves.

- Consider increasing the size of signs at intersections or locations where there have been safety problems or conditions that limit visibility.

- Consider the use of VIP sheeting at locations where signs are at angles to traffic, signs are further from the roadway due to wider radii at intersections or have other limitations. VIP has a broad range of observation angles from which it can be easily identified.

- Develop a sign inventory or a sign management system. A sign inventory can be used by agencies to develop a listing of signs that will need to be replaced within a certain timeframe. The inventory can be a useful tool for planning and budgeting improvements.

MATRIX OF MATERIALS

Sheeting Material	Material Type	Material Cost[(1)]	Sign Face Cost[(2)]	Anticipated Life[(3)]	Life-cycle Costs[(4)]	Initial Retroreflectivity[(5)] (white)	Advantages	Disadvantages
Type I Engineering Grade	Enclosed Lens	$0.85	$3.00 - $3.50	5 - 7	$108	70	▪ Low initial cost per square foot.	▪ Needs to be replaced approximately every six years. ▪ Workers have higher exposure to traffic. ▪ There is no warranty. ▪ Materials used to make the sheeting have changed over the years due to environmental concerns – the result is that the material is not as durable. ▪ Suffers damage from cold cracking. ▪ Not as bright as other sheeting materials, making it difficult for older drivers to identify.
Type II Super Engineering Grade	Enclosed Lens	Not Available – this material is generally not used in Minnesota	Not Available	5 - 7	Not Available	Twice as bright as Type I	▪ Relatively low initial cost per square foot.	▪ Needs to be replaced approximately every six years. ▪ Workers have higher exposure to traffic. ▪ Not as bright as the high-intensity sheeting materials – it is still difficult for older drivers to identify and respond to quickly. ▪ Warranty is only for one year.
Type III High Intensity	Encapsulated Lens	$3.51	$5.40 - $5.90	14	$78	3.5 times brighter than Type I	▪ Moderate cost per square foot. ▪ Has a ten-year warranty. ▪ Expected life is 14 years. ▪ More visible to older drivers than the Type I and Type II sheetings. ▪ Lower life-cycle costs than Type I and Type II sheetings because it does not have to be replaced as often. ▪ Workers have less exposure to traffic.	▪ Not as bright as the Type VII sheeting for older drivers. ▪ Higher initial costs versus Type I or Type II sheetings.

MATRIX OF MATERIALS (continued)

Sheeting Material	Material Type	Material Cost[1]	Sign Face Cost[2]	Anticipated Life[3]	Life-cycle Costs[4]	Initial Retroreflectivity[5] (white)	Advantages	Disadvantages
Type IV Stimsonite Prismatic	Non-metallized Microprismatic Retroreflective Material	Not Available	Not Available	Not Available	Not Available	3.5 times brighter than Type I	▪ Has a seven-year plus three-year warranty. ▪ More visible to older drivers than the Type I and Type II sheetings. ▪ Workers have less exposure to traffic.	▪ Not as bright as the Type VII sheeting for older drivers.
Proposed Type VII Stimsonite 6200	Non-metallized Microprismatic Retroreflective Material	Not Available	Not Available	Not Available	Not Available	3.5 times brighter than Type I	▪ Has a seven-year plus three-year warranty. ▪ More visible to older drivers.	▪ Higher initial costs.
Proposed Type VIII LDP	Non-metallized Microprismatic Retroreflective Material	$4.25	$7.10 - $7.60	15 - 20	$84	6 times brighter than Type I	▪ Has a ten-year warranty. ▪ Expected life is 15-20 years. ▪ Highly visible to older drivers. ▪ Low life-cycle costs. ▪ Workers have less exposure to traffic.	▪ Higher initial costs.
Proposed Type IX VIP	Non-metallized Microprismatic Retroreflective Material	$4.25	$7.10 - $7.60	15 - 20	$84	11 times brighter than Type I	▪ Has a ten-year warranty. ▪ Expected life is 15-20 years. ▪ Most visible to older drivers. ▪ Low life-cycle costs. ▪ Workers have less exposure to traffic.	▪ Higher initial costs. ▪ Material is transparent, allowing defects in sign backing material to show through.

(1) Material costs are per square foot and are in 1999 dollars.

(2) Sign face costs include the sheeting material and the sign backing material for a typical 30" x 30" stop sign. Costs are per square foot and are in 1999 dollars. A minimum order of 25 signs was assumed for the prices – costs will vary depending upon the number of signs ordered.

(3) Anticipated life for materials with a range was the midpoint. For Type I and Type II, this was six years; for Proposed Types VIII and IX, the midpoint was 18 years.

(4) Life-cycle costs include initial cost of installation and replacement costs needed to maintain a 18-year life cycle. The values are discounted using a 5 percent rate. For a more detailed analysis, please refer to Section 4. 1999 dollars are used.

(5) Measures the retroreflectivity for the different sheeting types. Improvements in performance are fairly consistent across most colors: (i.e., a Type II sheeting material is 2 times brighter than Type I sheeting material for white signs, yellow signs, green signs red signs and blue signs). Measures of retroreflectivity are in $cd/fc/ft^2$

CHAPTER 1
INTRODUCTION

Engineers and public officials concerned with public safety, and the need to budget wisely, have seen the choices in sign materials increase substantially in the last ten to 15 years. What are the characteristics, costs and benefits of these materials? What factors should one consider when selecting the type of sign sheeting material?

This document presents information on the various types of sign sheeting material available, their ability to be detected by drivers and their costs. In addition, it highlights some best management practices that can be used to ensure minimum retroreflectivity requirements for traffic signs. The synthesis will be of interest to city and county engineers, as well as townships.

Since there are limited guidelines that suggest the type of sheeting material to be used, often the decision regarding material is dictated by the cost of the sheeting material. This approach to traffic sign installation and replacement utilizing the least expensive sheeting can result in higher "life-cycle" costs and reduced retroreflectivity. It is the intent of this synthesis to provide background information to assist county, city and township engineers and officials in the selection of appropriate sheeting materials. It should be noted that the recommendations provided are to be used only as a tool; they are not intended to serve as official policy.

The information provided in this synthesis is divided into five sections and two appendices:

Section 1: Signing Terminology

Provides the reader with the terminology that will be used to describe the elements and properties of the various sheeting materials referenced throughout this report.

Section 2: Sign Retroreflectivity and the Aging Problem

Describes the visibility problem for older drivers, as well as the implications of that problem.

Section 3: Signing Materials

Sheeting materials, their uses and their ability to address the nighttime problem are explained. Included in this section are quick reference sheets by material type and a matrix highlighting the advantages and disadvantages of all the sheeting types.

Section 4: Lifecycle Cost Analysis

Supplies the user with average lifecycle costs for the various sheeting materials.

Section 5: Best Management Practices

Underscores the importance of initiating some best management practices.

Appendix A: Minimum Retroreflectivity Guidelines

Provides the reader with minimum retroreflective guidelines for the various sheeting types.

Appendix B: Sign Management Systems

Provides the reader with the basic steps necessary to develop an effective sign management system.

A copy of *"Maintenance of Small Traffic Signs"* has been included for the reader. This manual describes basic information on the installation and repair of traffic signs. It is distributed by the Federal Highway Administration.

CHAPTER 2
SIGNING TERMINOLOGY

The reader's ability to determine which sheeting material will best suit his or her needs is based on an understanding of the sheeting material and its properties. Several similar-sounding terms are used to describe the properties and the visibility of sign sheeting material. Although the words sound similar, their meanings can be quite different. With the aim of clarifying the terminology, this section provides the reader with definitions and diagrams of the most prevalent expressions.

In addition to providing the reader with definitions and diagrams, this section of the report will list the common names for the various sheeting material types. The listing of product names is intended to give the reader a point of reference when referring to sheeting types; it is not to be viewed as an endorsement of a particular brand or product.

Angularity

Angularity of a sign refers to the range of angles at which a sign will remain retroreflective. An entrance angle of 30 degrees is considered wide for highway signing. The greater the angularity, the longer the sign remains reflective to the approaching vehicle (readable at closer distances) (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs,* p. 4).

Coefficient of Retroreflectivity

The coefficient of retroreflectivity is the principal feature that distinguishes various types of retroreflective materials. It is basically defined as the amount of light (luminance) that comes out from the retroreflective material per amount of light coming in from the light source (illuminance) (*Ibid*).

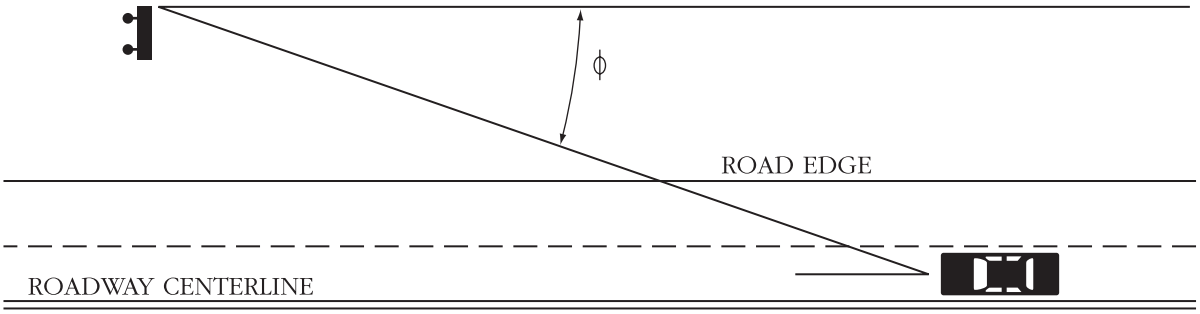
Conspicuity

Conspicuous objects are ones that will, for a given background, be seen with certainty, having a probability of more than 90 percent within a short observation time of 250 ms regardless of the location of the object relative to the line of sight (Mn/DOT VIP Sheeting Committee Minutes – November 9, 1998).

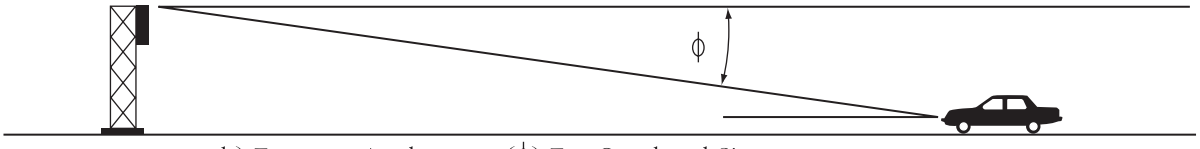
Entrance Angle

The entrance angle, or incidence angle, is the angle formed between a light beam striking the surface of a sign and a line coming out perpendicular from the surface. This angle changes with the distance between the vehicle and the sign, and is a function of the location of the sign and the vehicle (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs,* p. 4).

Entrance angle for a roadside sign and an overhead sign



a) Entrance Angle (ϕ) For Roadside Sign



b) Entrance Angle (ϕ) For Overhead Sign

Illuminance

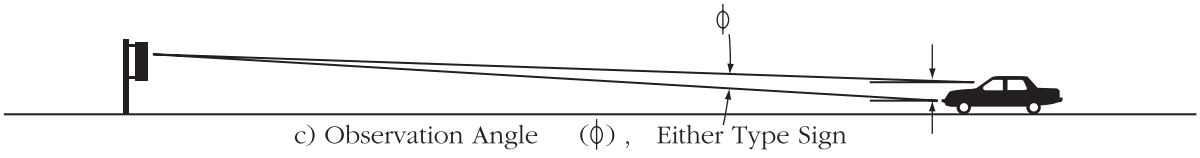
This is the intensity of light on the sign surface. It is usually measured in terms of foot-candles or lux (metric equivalent) (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs,* p. 3).

Luminance

Luminance is known as the light that is returned to the observer near the light source. Luminance is, therefore, what the motorist actually sees when the vehicle headlights hit the sign. It is measured as candelas per square foot or square meter (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs,* p. 3).

Observation Angle

The observation angle is the angle between the incoming light beam and the reflected light beam as the motorist sees it. This angle changes with the distance between the vehicle and the sign, and is a function of the location of the sign and the height of the driver's eye with respect to the vehicle headlamps (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs,* p. 4).



Retroreflectivity

Retroreflectivity is the ability of a sign to reflect light from the vehicle headlamps back towards the driver's eyes. It is usually measured in candelas/lux/square meter, which is equivalent to candelas/foot-candle/square foot (Mn/DOT *VIP Sheeting Committee Minutes – November 9, 1998*).

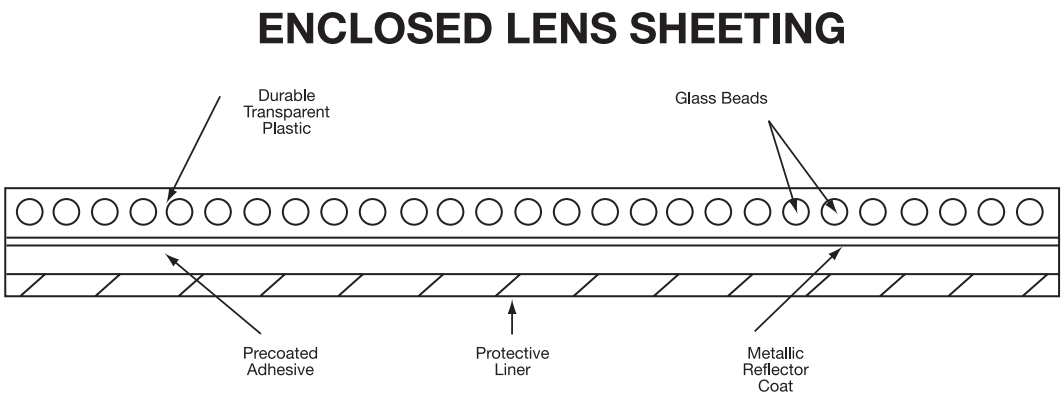
Sign Detection

Sign detection refers to the distance at which a typical traffic sign is noticed. The threshold detection for typical traffic signs is over 3,000 feet. Although the signs are detectable at this distance, they are not conspicuous.

Type I Sheeting Material

A medium-intensity retroreflective sheeting referred to as "engineering grade," which is typically enclosed lens glass-bead sheeting. Typical applications for this material are permanent highway signing, construction zone devices, and delineators. M/DOT no longer uses this sheeting material, however it is still referenced as spec number 3352.2A2a because a number of counties, cities and townships use the material. 3M makes engineering grade sheeting (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs* pp. 6-8).

Enclosed Lens Sheeting



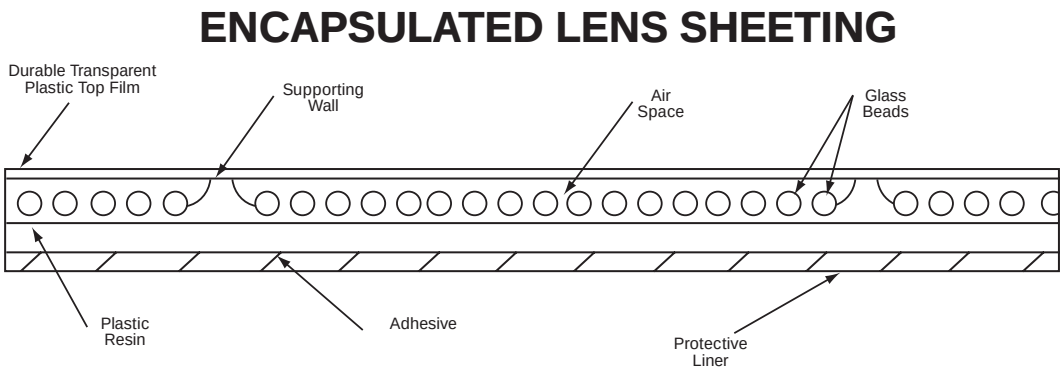
Type II Sheeting Material

A medium-intensity retroreflective sheeting sometimes referred to as "super-engineering grade," which is typically enclosed lens glass-bead sheeting. Typical applications for this material are permanent highway signing, construction zone devices, and delineators. This material is an Avery product (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs,* pp. 6-8).

Type III Sheeting Material

A high-intensity retroreflective sheeting that is typically encapsulated glass-bead retroreflective material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators. This material can be found in Mn/DOT's spec number 3352.2A2b. Often referred to as HI – High Intensity (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs,* pp. 6-8).

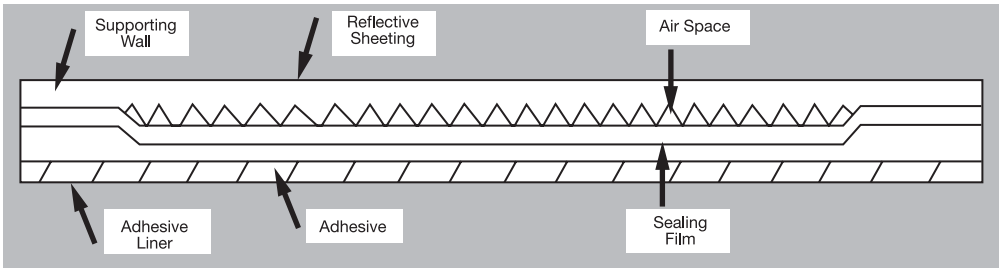
Encapsulated Lens Sheeting



Type IV Sheeting Material

A high-intensity retroreflective sheeting, which is typically a non-metallized, microprismatic, retroreflective material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators. Stimsonite produces a Type IV sheeting material (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs,* pp. 6-8).

Microprismatic Sheeting



Type V Sheeting Material

A high-intensity retroreflective sheeting, that is commonly made up of metallized microprismatic retroreflective material. This sheeting is typically used for delineators (*ASTM D 4956 Standard Specification for Retroreflective Sheeting for Traffic Control – Ballot p. 3)*.

Type VI Sheeting Material

An elastomeric retroreflective sheeting without adhesive. This sheeting is sometimes referred to as "high intensity grade" and is commonly a vinyl microprismatic retroreflective material. This sheeting is typically used for temporary roll-up signs, traffic cone collars, and post bands (*ASTM D 4956 Standard Specification for Retroreflective Sheeting for Traffic Control – Ballot p. 3)*.

Proposed Type VII Sheeting Material – (Not an Official Type as of 11/1999)

A non-metallized, microprismatic, retroreflective material. Typical applications for this material are permanent highway signing, construction zone devices and delineators. This material may also be known as Stimsonite 6200 *(ASTM D 4956 Standard Specifications for Retroreflective Sheeting for Traffic Control – Ballot p. 3)*.

Proposed Type VIII Sheeting Material – (Not an Official Type as of 11/1999)

A non-metallized, microprismatic, retroreflective material. This material is commonly referred to as "diamond grade" or "LDP – long distance performance". LDP is a wide-angle retroreflective sheeting that has optimized performance at narrow observation angles and has extended entrance angle performance. The material is opaque (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs,* pp. 6-8).

Proposed Type IX Sheeting Material – (Not an Official Type as of 11/1999)

A non-metallized microprismatic retroreflective sheeting material. It is a wide-angle retroreflective sheeting with optimized performance over a broad range of observation angles. It is commonly referred to as "VIP – Visual Impact Performance". VIP is translucent in white and yellow (*An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs,* pp. 6-8).

CHAPTER 3
SIGN RETROREFLECTIVITY AND THE AGING PROBLEM

Driving at night has always posed a challenge for drivers. In addition to drowsiness or fatigue, the inability of drivers to see objects clearly can hamper their ability to safely operate a motor vehicle. Older drivers have a more difficult time seeing at night than younger drivers do. As the population ages, a higher percentage of drivers are finding it increasingly difficult to identify, read and comprehend traffic control devices at night or inclement weather.

Traffic signs are the principal means to convey information to drivers. Safety problems can arise when the signs fail to communicate the necessary information. Several studies have been conducted to evaluate the effect that age plays in a driver's ability to detect, comprehend and react to traffic signs. A majority of the studies revealed that older drivers have more difficulty identifying traffic signs at night than do younger drivers (*Minimum Highway Sign Luminance Requirements for Older Drivers*). Additionally, it has been noted in at least one of the studies that older drivers have more difficulty identifying traffic signs during the day as well (*Relative Visibility of Increased Legend Size vs. Brighter Materials for Traffic Signs*).

Several hypotheses have been suggested for the failure of traffic signs to adequately meet the needs of older drivers. One hypothesis proposes that the letters on the traffic signs are not tall enough or wide enough for older drivers to identify and comprehend at distances at which younger drivers can (*Ibid*). Other hypotheses center on the type of sheeting material used (*Minimum Highway Sign Luminance Requirements for Older Drivers* and *Retroreflective Sheeting Materials on Highway Signs*). Although this report focuses on the latter hypothesis, it should be noted that the letter series on the sign impacts the driver's ability to read and comprehend the sign.

The different grades of sign sheeting materials produce varying levels of retroreflectivity. The differences in the levels of retroreflectivity between sheeting types are a result of the elements used to prepare the material. Experiments with older drivers suggest that the higher-grade or prismatic sheetings are more retroreflective, and therefore easier for older drivers to detect (*Minimum Highway Sign Luminance Requirements for Older Drivers* and *Retroreflective Sheeting Materials on Highway Signs*).

For example, a yellow sign made of Type I sheeting has a reflectivity of about 50 cd/fc/ft^2. A yellow sign made out of Type VII sheeting has a reflectivity of about 660 cd/fc/ft^2, or over 13 times brighter than the Type I sheeting. More information on the retroreflectivity of the various sheeting materials can be found in the matrix on page 9.The federal government has recognized the importance of retroreflectivity and the difficulties that older drivers can experience when signs are not performing as they were intended. In April of 1998, the Federal Highway Administration released a report indicating guidelines for the minimum retroreflectivity levels for different types of traffic signs. At the same time, the report listed the minimum retroreflectivity levels for the various sheeting types. Tables A-1 through A-4 in Appendix A list the minimum retroreflective guidelines for the different types and colors of traffic signs.

CHAPTER 4
SIGNING MATERIALS

While there are a few ways to manufacture a sign, the focus of this report is on sign sheeting. However, the subcommittee working on this report wanted to ensure that the reader was aware of concerns with the types of inks that are used when signs are screened. When using screened signs make sure that the proper inks are used. Most fabricated signs are comprised of two components, the reflective sheeting and the screening inks that are used to apply the message to the background. Breakdown of one or both of these components hinders the drivers' ability to recognize and adequately respond to the sign. If screened signs are used, the inks used should correspond to the sheeting material. For example, 3M provides inks that are to be used with its sheeting material. If low-quality inks are used with high-quality sheeting, the sign may fade and become difficult for drivers to comprehend.

As mentioned above, the focus of this report is on sign sheeting material and its ability to address the needs of the driving public. This section of the report describes the sign sheeting materials that are available to local agencies for permanent highway signing. In order to simplify the information for the various sheeting types, a matrix was created. Included in the matrix is information on the cost of the material, the anticipated life of the material, the initial retroreflectivity of the material, and advantages and disadvantages of the sheeting material.

It should be noted that all dollar values used in the matrix are 1999 dollars and are subject to change depending upon the quantities of material ordered. Lower volume purchases are subject to higher prices than higher volume purchases.

New materials are constantly introduced to the market. As a result, agencies should continue to monitor new products. Recently Stimsonite was purchased by Avery Dennison. As a result, some product names will be changed and new products will be introduced. Additionally, ASTM is in the process of reviewing new sheeting types. It is likely that there will be nine sheeting types in the near future.

TABLE 4.1 - MATRIX OF MATERIALS

Sheeting Material	Material Type	Material Cost[1]	Sign Face Cost[2]	Anticipated Life[3]	Life-cycle Costs[4]	Initial Retroreflectivity[5] (white)	Advantages	Disadvantages
Type I Engineering Grade	Enclosed Lens	$0.85	$3.00 - $3.50	5 - 7	$108	70	▪ Low initial cost per square foot.	▪ Needs to be replaced approximately every six years. ▪ Workers have higher exposure to traffic. ▪ There is no warranty. ▪ Materials used to make the sheeting have changed over the years due to environmental concerns – the result is that the material is not as durable. ▪ Suffers damage from cold cracking. ▪ Not as bright as other sheeting materials, making it difficult for older drivers to identify.
Type II Super Engineering Grade	Enclosed Lens	Not Available – this material is generally not used in Minnesota	Not Available	5 - 7	Not Available	Twice as bright as Type I	▪ Relatively low initial cost per square foot.	▪ Needs to be replaced approximately every six years. ▪ Workers have higher exposure to traffic. ▪ Not as bright as the high-intensity sheeting materials – it is still difficult for older drivers to identify and respond to quickly. ▪ Warranty is only for one year.
Type III High Intensity	Encapsulated Lens	$3.51	$5.40 - $5.90	14	$78	3.5 times brighter than Type I	▪ Moderate cost per square foot. ▪ Has a ten-year warranty. ▪ Expected life is 14 years. ▪ More visible to older drivers than the Type I and Type II sheetings. ▪ Lower life-cycle costs than Type I and Type II sheetings because it does not have to be replaced as often. ▪ Workers have less exposure to traffic.	▪ Not as bright as the Type VII sheeting for older drivers. ▪ Higher initial costs versus Type I or Type II sheetings.

TABLE 4.1 - MATRIX OF MATERIALS (continued)

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Proposed Type VII Stimsonite 6200	Non-metallized Microprismatic Retroreflective Material	Not Available	Not Available	Not Available	Not Available	3.5 times brighter than Type I	▪ Has a seven-year plus three-year warranty. ▪ More visible to older drivers.	▪ Higher initial costs.
Proposed Type VIII LDP	Non-metallized Microprismatic Retroreflective Material	$4.25	$7.10 - $7.60	15 - 20	$84	6 times brighter than Type I	▪ Has a ten-year warranty. ▪ Expected life is 15-20 years. ▪ Highly visible to older drivers. ▪ Low life-cycle costs. ▪ Workers have less exposure to traffic.	▪ Higher initial costs.
Proposed Type IX VIP	Non-metallized Microprismatic Retroreflective Material	$4.25	$7.10 - $7.60	15 - 20	$84	11 times brighter than Type I	▪ Has a ten-year warranty. ▪ Expected life is 15-20 years. ▪ Most visible to older drivers. ▪ Low life-cycle costs. ▪ Workers have less exposure to traffic.	▪ Higher initial costs. ▪ Material is transparent, allowing defects in sign backing material to show through.

(6) Material costs are per square foot and are in 1999 dollars.

(7) Sign face costs include the sheeting material and the sign backing material for a typical 30" x 30" stop sign. Costs are per square foot and are in 1999 dollars. A minimum order of 25 signs was assumed for the prices – costs will vary depending upon the number of signs ordered.

(8) Anticipated life for materials with a range was the midpoint. For Type I and Type II, this was six years; for Proposed Types VIII and IX, the midpoint was 18 years.

(9) Life-cycle costs include initial cost of installation and replacement costs needed to maintain a 18-year life cycle. The values are discounted using a 5 percent rate. For a more detailed analysis, please refer to Section 4. 1999 dollars are used.

(10) Measures the retroreflectivity for the different sheeting types. Improvements in performance are fairly consistent across most colors: (i.e., a Type II sheeting material is 2 times brighter than Type I sheeting material for white signs, yellow signs, green signs red signs and blue signs). Measures of retroreflectivity are in $cd/fc/ft^2$.

CHAPTER 5
LIFE CYCLE COST ANALYSIS

Agencies should consider the initial material and installation costs as well as overall life cycle costs and safety benefits when evaluating sign sheeting materials. Many agencies may fail to perceive that the sheeting material on the sign is only a portion of the overall cost of placing the sign in the field. If the life of the sign material, as well as installation costs is considered, a less expensive lower quality sheeting may not be the long-term low-cost alternative.

The Minnesota Department of Transportation recently completed a life cycle cost analysis associated with switching from Type III (high-intensity) sheeting to Proposed Type IX (VIP) sheeting for all of their permanent, regulatory, warning and guide signs. The analysis found that the sign sheeting material accounted for a small percentage of the total installation cost. In addition, it determined that the higher initial sheeting cost was more cost-effective in the long-term due to the additional sign life of the higher priced sheeting materials. As a result, Mn/DOT has decided to switch to all VIP sheeting.

An example of a life cycle analysis is shown in Table 2. The results indicate that the more expensive Proposed Type VIII and Proposed Type IX sheetings become more cost-competitive with lower cost sheeting material when the sheeting life and the installation costs are calculated. The Type I material typically lasts five to seven years, whereas the Proposed Type VIII and Proposed Type IX typically last over 18 years. As a result, signs using Type I sheeting will need to be replaced three times as often as a sign using Proposed Type VIII or Proposed Type IX sheeting.

TABLE 5.2
LIFE CYCLE COST EXAMPLE[1]

Material Type	Initial Sheeting Material Costs[2]	Initial Sign Face Costs[3]	Initial Sign Costs[4]	Expected Life (Years)	Replacement Costs[5]	Total Costs	Material as a percentage of initial sign face costs	Material as a percentage of initial sign costs
Type I	$5.31	$20.31	$58.31	5-7	$49.92	$108.23	26%	9%
Type II	Not Available	Not Available	Not Available	5-7	Not Available	Not Available	Not Available	Not Available
Type III	$21.94	$35.31	$73.31	14	$4.78	$78.09	62%	30%
Type IV	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available
Proposed Type VII	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available
Proposed Type VIII	$26.56	$45.94	$83.94	18	$0	$83.94	58%	32%
Proposed Type IX	$26.56	$45.94	$83.94	18	$0	$83.94	58%	32%

(1) Based on a 18-year sign life for a 30" X 30" sign.

(2) Sheeting material cost were calculated by multiplying the cost of the material per square foot by 6.25 feet, the size of a 30" X 30" sign.

(3) Initial sign face costs include the sheeting material and the aluminum sign backing. Costs were calculated by using the midpoint of the price ranges listed in Table 1 and multiplying by 6.25 square feet – the size of a 30" X 30" sign.

(4) Initial sign costs include the sign face, the posts, staff time and equipment costs. Estimated costs for posts and hardware are $20 per sign and cost for staff and equipment is estimated at $18 per sign.

(5) Additional replacement costs incurred due to shorter sheeting life. Items calculated in replacement costs included the sign face and labor and equipment costs. In performing the lifecycle analysis a 5 percent discount rate was used. Replacement costs were based on an 18-year life.

Additional Benefits of Higher Grade Sheetings

Additional safety benefits of more visible signs are not factored into the analysis but bear consideration when selecting sheeting materials. A higher grade sheeting that is more visible to drivers at a longer distance can improve driver reactions and result in better and more timely decision-making.

Additionally, sign replacements require personnel to be exposed to traffic and other environmental risks. Signs made out of lower grade sheeting materials have to be replaced more frequently due to their shorter life. As a result, workers have greater exposure than they would if a higher grade sheeting material, with a longer life, was used.

Economies of Scale

The theory of economies of scale states that as more goods are produced, the production costs decrease. As agencies increase their use of the higher-grade sheetings the costs per square foot will decrease. When costs are decreased, the higher-grade sheetings will become even more attractive for local agencies to use. Orders for signs by local agencies in rural Minnesota indicated that currently 60 percent of the signs purchased are made out of engineering grade sheeting material, while 30 percent are made out of high intensity and 10 percent are made out of the VIP. In part, because the volumes purchased favor the engineering grade sheeting, its prices are lower than the other sheeting materials. If the numbers were switched, and 60 percent of the signs ordered were made out of high intensity or VIP, the prices of those materials should drop.

CHAPTER 6
BEST MANAGEMENT PRACTICES

There are several measures an organization can undertake in order to ensure that it is getting the most for its money in terms of signing. This section of the report highlights some of those measures that can be used to ensure a cost-effective sign budget.

1. Develop a sign inventory or a sign management system. A sign inventory can be used by agencies to develop a listing of signs that will need to be replaced within a certain timeframe. The inventory can be a useful tool for planning and budgeting improvements.

2. Consider purchasing sign sheeting off of Mn/DOT's contract or other agency contracts. Bulk purchasing can sometimes result in a better price than direct bids.

3. Consider placing larger and brighter signs in urban areas where there are other activities competing for the driver's attention.

4. Use higher-grade reflective sheeting on the more critical regulatory and warning signs such as stop, yield, stop ahead, yield ahead and curves.

5. Consider increasing the size of signs at intersections or locations where there have been safety problems or there are conditions that limit visibility.

6. Consider the use of VIP sheeting at locations where signs are at angles to traffic, signs are further from the roadway due to wider radii at intersections or have other limitations. VIP has a broad range of observation angles from which it can be easily identified.

CHAPTER 7
WORKS CONSULTED

Bissell, Howard. *Minimum Sign Retroreflective Guidelines*, Publication No. FHWA-RD-97-074, Federal Highway Administration, Washington, D.C. May 1997.

King, Ellis, Johnny Graham, Anwar Fazal, and Thad Duncan. *Minimum Highway Sign Luminance Requirements for Older Drivers*. Raleigh, N.C. August 1996.

Mace, Douglas, Philip Garvey, and Robert Heckard. *Relative Visibility of Increased Legend Size vs. Brighter Materials for Traffic Signs*, Report No. FHWA-RD-94-035, Federal Highway Administration, Washington D.C. December 1994.

McGee, Hugh and Jeffrey Paniati. *An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs*, Report No. FHWA-RD-97-052, Federal Highway Administration, Washington D.C. April 1998.

McGee, Hugh and Sunil Taori. *Impacts on State and Local Agencies for Maintaining Traffic Signs within Minimum Retroreflectivity Guidelines*, Report No. FHWA-RD-97-053, Federal Highway Administration, Washington D.C. April 1998.

Tranchida, Donna, Erik Arthur, and Stirling Stackhouse. *Retroreflective Sheeting Materials on Highway Signs*. St. Paul, MN. February 1996.

APPENDIX A

MINIMUM RETROREFLECTIVE GUIDELINES

TABLE A-1
GUIDELINES FOR BLACK-ON-YELLOW OR BLACK-ON-ORANGE WARNING SIGNS

	Material Type	Sign Size (inches)		
		>=48	36	<=30
Bold Symbol	All	15	20	25
Fine Symbol and Word	I	20	30	35
	II	25	35	45
	III	30	45	55
	IV and VII	40	60	70

All table values are in cd/lx/m^2

TABLE A-2
GUIDELINES FOR BLACK- OR BLACK AND RED-ON-WHITE REGULATORY/GUIDE SIGNS

	Traffic Speed (miles per hour)					
	45 mph or greater			40 mph or less		
	Sign Size (inches)					
Material Type	>=48	30-36	<=24	>=48	30-36	<=24
I	25	35	45	20	25	30
II	30	45	55	25	30	35
III	40	55	70	30	40	45
IV and VII	50	70	90	40	50	60

All table values are in cd/lx/m^2

TABLE A-3
GUIDELINES FOR WHITE-ON-RED REGULATORY SIGNS

	Traffic Speed (miles per hour)					
	45 mph or greater			40 mph or less		
	Sign Size (inches)					
Sheeting Color	**>=48**	**36**	**<=30**	**>=48**	**36**	**<=30**
White (legend)	35	45	50	25	30	35
Red (background)	8	8	8	5	5	5

All table values are in cd/lx/m^2

TABLE A-4
GUIDELINE FOR WHITE-ON-GREEN GUIDE SIGNS

	Sheeting Color	Traffic Speed (miles per hour)	
		45 or greater	**40 or less**
Ground Mounted	White (legend)	35	25
	Green (background)	7	5

All table values are in cd/lx/m^2

APPENDIX B
SIGN MANAGEMENT SYSTEM

Reasonable care must be taken to ensure that traffic signs are in place and in good repair. An effective traffic sign management system can help engineers and officials serve the needs of the driving community.

The Federal Highway Administration released a report entitled "An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs" in April of 1998. The report, which describes what a sign management system is, the components of a system, how to develop a system and the importance of maintaining a system, was used to develop this section of the report.

Sign Management Systems

A sign management system is a coordinated program of policies and procedures that assists agencies in tracking the location and characteristics of all sign installations. The following elements should be incorporated into any management system:

- Use materials (sheeting, substrate, bracing, etc.) that conform to agency specifications. Select the appropriate material based on cost, service life and drivers' needs. The ability to monitor the cost and service life of various materials will ensure that the agency is using the most cost-effective material.

- Provide the ability to forecast sign replacements. This aids in budgeting and scheduling of sign material or fabricated sign replacements.

- An inventory of stockpiled fabricated signs. Having prefabricated signs on hand enables timely replacement.

- An inventory of signs on the road that is updated when new information is received or repairs or replacements are made.
- Periodic inspections to ensure that signs are maintained at a serviceable level and continue to meet the users' and the community's needs. A management system can be effective in

scheduling inspections, recording the results and determining when the signs may need to be replaced. Inspections will also identify maintenance needs such as sign cleaning, post repair, graffiti removal and foliage/brush removal.

- Listing of sign materials that can be recycled and used for future sign requirements.

Components of the System

An effective sign management system is built around four key factors: a thorough inventory, regular daytime and nighttime inspection of signs, proper maintenance and replacement of signs that have fulfilled their useful life.

Sign Inventory

One of the most important components of the sign management system is the sign inventory. It is extremely difficult to oversee an agency's signage needs if there is not a comprehensive inventory of the signs in the system. A complete sign inventory can provide many benefits, including:

- Targeting signs for replacement. Monitoring installation and repair dates of signs enables the user to detect signs that are likely to be in need of repair or replacement. When combined with an inspection program, an inventory facilitates the removal of signs that have fulfilled their useful life.

- Identifying problem locations. Tracking installation and repair dates makes it possible for the user to identify areas that are prone to vandalism and safety problems. A comprehensive inventory is important for identifying and replacing missing or vandalized signs.

- Minimizing tort liability. A comprehensive sign inventory can prove to be a useful tool in litigation. An inventory can prove the existence of a specific sign at a specific location and provide the inspection and maintenance associated with the sign. (Some insurers have recognized the value of sign inventories in reducing liability. For example, the Utah Risk Management Association offers a three percent discount on insurance premiums to jurisdictions with a sign inventory.)

- Planning and budgeting for sign replacement. Knowing how many signs one manages, as well as how old those signs are, allows the user to develop a regular sign replacement program. The inventory assists the user in making informed decisions on how to budget resources most effectively.

- Maximizing productivity. Combining a sign inventory with work orders allows the user to track the productivity of signing activities and to schedule regular and emergency maintenance activities.

There are a number of variables that can be gathered and incorporated into a sign inventory. The user needs to decide how useful the data is versus the cost of acquiring and maintaining the data. At a minimum, some basic data needs to be collected. Data regarding the location of the sign, its condition and any maintenance activities that have been conducted are necessary for identifying signs that need replacement. The information is also useful in legal proceedings. Table B-1 lists the basic requirements. However, if the user wants to refine the estimates on replacement dates or wants to build a sign replacement and budget plan, more data will need to be gathered. Information regarding the installation date and characteristics of the sign and its supports provides the user with greater insight and enables better decision-making regarding sign replacement and budgets. Table B-2 lists additional data that may be of value to the user. Additionally, Table B-3 provides a list of data that may be included if more information on sign installation is desired. It is important to remember that data needs to be maintained and updated. If staffing is limited, a well-maintained inventory of basic information is more desirable than a poorly maintained inventory with numerous data variables.

TABLE B-1
BASIC DATA ELEMENTS

DATA	DESCRIPTION
Location	Includes several variables such as route name, route number, distance from measuring point, etc., depending on the location reference system that is used.
Position	Location of the sign relative to the road (i.e., left, right, overhead, in the median, etc.).
Sign Code	Usually based on the Manual on Uniform Traffic Control Devices designations, it may be supplemented or modified based on state or local sign designations.
Sign Condition	An assessment of the quality of the sign based on daytime and nighttime visual inspections.
Maintenance Activity	Lists and describes the maintenance activity associated with a particular sign.
Inspection/Maintenance Date	Date when the sign was inspected or maintained

TABLE B-2
ADDITIONAL DATA ELEMENTS

DATA	DESCRIPTION
Installation Date	The date when the sign face was installed.
Sign Size	The width and height of the sign.
Sheeting Type	The grade of retroreflective sheeting used on the sign face.
Backing Type	The type of sign blank material.
Post/Support Type	The type of sign support used; may also include breakaway characteristics.
Post/Support Condition	An assessment of the quality of the sign support.
Sign Orientation	The Cardinal direction the sign is facing.
Traffic Speed	The speed limit of the roadway where the sign is located.

TABLE B-3
COMPLETE DATA ELEMENTS

DATA	DESCRIPTION
Offset	The distance of the sign from the edge of the pavement.
Height	The height of the sign above the level of the road at the edge of the pavement.
Retroreflectivity	An objective measure of the nighttime quality of the sign. The measurement is usually taken visually or with some sort of retroreflectometer.
Inspector	The name or initials of the individual who inspected or maintained the sign.
Sign Identification Number	A unique number identifying the sign.
Images	Visual images of the sign, either digitally located or linked to a videodisc-based photo log.
Comments	Any notes or information about the sign and its installation.
Other Reference Numbers	Numbers of maintenance districts, contract numbers, plan numbers, etc.

The data collected for the sign inventory can be maintained on paper or computer; however, for most jurisdictions, it is more efficient to use a computer software package.

Sign Inspection

Another important component of a sign management system is the sign inspection program. Regular and routine inspection of signs can help ensure their visibility and effectiveness to drivers. Periodic inspections of signs should be part of the agency's operations.

Traffic signs can be defective in a number of ways; therefore, any inspection should look for all of the following deficiencies:

- Major cracking, delaminating, peeling or blistering of the retroreflective sheeting material. If major damage has occurred, the face will have to be replaced.

- Missing messages from the sign face. The sign will likely need to be repaired or replaced.

- Visibility of the sign is hampered due to vegetation or structures. The vegetation may have to be trimmed or the sign may need to be moved.

- Dirt or other materials on the face of the sign. The sign may need to be washed.

- Graffiti or vandalism. The face may need to be cleaned, repaired or replaced depending upon the extent of the damage.

- Orientation and structural stability of the support system. The sign should be facing in the correct direction and its supports should be sound.

- Poor retroreflectivity. If the sign cannot be seen at night due to poor retroreflectivity, its face may need replacing.

- Usefulness. Some signs may no longer be needed; they should be removed if they are no longer useful.

A trained staff person can easily identify most of the deficiencies described above through a daytime visual inspection. If staff is properly trained, problems can be identified on a daily basis as people travel the routes. Nonetheless, it is still important to conduct a formal inspection on an annual basis. Procedures for conducting sign inspections can be found in "Maintenance Management of Street and Highway Signs" and in the Institute of Transportation Engineers' publication "Traffic Sign Handbook."

Poor retroreflectivity is one of the few deficiencies that cannot always be readily identified through a daytime visual inspection. Loss in retroreflectivity can occur as a result of exposure to ultraviolet light, moisture, temperature fluctuation, pollution, vandalism and chemical reactions. This loss may not be noticeable during the day; however, it can be noticeable at night. Communities trying to assess the retroreflectivity can do visual inspections at night (which is easier to do, but is hazardous and may be expensive) or they can use a retroreflectometer (a device that measures retroreflectivity) or a hand-held high-intensity light beam during the day. It is up to the individual department to decide which method of is most appropriate for their needs.

Sign Maintenance

Adequate and regular maintenance is important to extending the life of any sign. The following maintenance activities help keep a sign effective:

- Cleaning the sign face to remove normal dirt accumulation.
- Removal of spray paint and other vandalism.
- Removal of vegetation blocking the visibility of a sign.
- Reorientation of the sign.
- Replacement of signposts or braces damaged by a knock down.

It is good practice to document all of the sign maintenance activities that occur as part of a sign inventory. Most computer inventory programs provide space for maintenance activities.

Replacement

Signs will need to be replaced when they have fulfilled their useful life. Communities need to plan and budget for sign replacement on an annual basis. As explained earlier in this report, minimum reflective values have been established for four groups of signs. These values only marginally meet the retroreflectivity needs of most drivers. Older drivers find it especially difficult to identify, comprehend and react to signs that marginally meet minimum retroreflectivity guidelines.

Because replacing signs before their use life has expired can be expensive, communities have a tendency to prolong the life of the sign beyond the minimum retroreflective guidelines. This can lead to an increase in nighttime accidents, an increase in driver delay, an increase in motorist irritation and a possible increase in tort claims. Therefore, agencies should have a sign replacement program that cost-effectively identifies and replaces the signs that are approaching the minimum retroreflective values. Table B-4 shows options an agency can use to ensure that its signs will meet the minimum retroreflective requirements, the tools needed to carry out those options and the effectiveness of the options.

TABLE B-4
MEETING MINIMUM RETROREFLECTIVE REQUIREMENTS

OPTION	REQUIREMENTS	COMMENTS
Visual Assessment	• Nighttime inspection. • Minimum retroreflective reference panel (a small square of a sign at minimum retroreflectivity can be placed on the sign you are evaluating to compare the two retroreflectivities). • Can be done with or without an inventory. • No special equipment is needed.	• Marginally acceptable method of gauging retroreflectivity. • High potential for errors. • May not be cost-effective (signs may not be replaced soon enough or they may be replaced too quickly).
Maximum Sign Life	• Signs are dated. • Signs are part of an inventory that has the installation date denoted. • The retroreflectivity is gauged by the life of the sign. • No special equipment is needed.	• Acceptable method of gauging retroreflectivity. • Eliminates nighttime inspections. • Potential for error. • May not be cost-effective.
Maximum Sign Life with Visual Assessment Verification	• Same as above. • Additional nighttime inspection.	• Acceptable method of gauging retroreflectivity. • Will increase the cost of inspection. • May be more cost-effective than the option listed above.
Measured Retroreflectivity Compared to Required Retroreflectivity	• Inventory • Sign dating • Reflectometer	• Desirable method of gauging retroreflectivity. • Higher inspection costs. • Highest assurance that signs are replaced when they need to be. • Maximum life of the sign is received.

APPENDIX A

MINIMUM RETROREFLECTIVE GUIDELINE

APPENDIX B

SIGN MANAGEMENT SYSTEM