



Methods for Maintaining Pavement Marking Retroreflectivity

FHWA-SA-22-028 | July 2022



U.S. Department of Transportation
Federal Highway Administration

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16. Abstract In response to a congressional directive, the Federal Highway Administration established a standard for minimum maintained pavement marking retroreflectivity levels that are incorporated in the <i>Manual on Uniform Traffic Control Devices</i> (MUTCD). This document, referenced in the MUTCD, describes retroreflectivity maintenance methods that, when implemented as intended, provide agencies with a flexible means of being in conformance with the standard. These methods were developed specifically for longitudinal pavement markings (i.e., center lines, lane lines, and edge lines) although some of the methods could also be applicable to other types of markings. Agencies can use the information in this report to help determine which retroreflectivity maintenance method or combination of methods best suits their needs.			
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in ²	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela/m ²	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AASHTO Guide	American Association of State Highway and Transportation Officials <i>Roadway Lighting Design Guide, 7th Edition</i>
ADT	average daily traffic
ANSI	American National Standards Institute
CFR	Code of Federal Regulations
FAQ	frequently asked question
FHWA	Federal Highway Administration
GIS	geographic information systems
IESNA	Illuminating Engineering Society of North American
LTAP	Local Technical Assistance Program
MUTCD	<i>Manual on Uniform Traffic Control Devices</i>
RRPM	raised retroreflective pavement marker

CHAPTER 1. INTRODUCTION

Purpose

On August 5, 2022, the Federal Highway Administration (FHWA) published a final rule that incorporated a standard for maintaining minimum retroreflectivity levels for pavement markings into Section 3A.03 of the *Manual on Uniform Traffic Control Devices* (MUTCD) (see figure 1 and Appendix A). This document, referenced in the MUTCD, describes retroreflectivity maintenance methods that, when implemented as intended, provide agencies with a flexible means of conforming to the standard. This document includes a number of potential methods because different agencies have varying levels of staffing, equipment, budgets, road systems, and expertise.

It is not the purpose of this report to provide information on the initial installation of markings and does not address initial retroreflectivity levels. The report provides information about methods to help agencies ensure pavement markings are replaced before they reach the end of their useful service life and no longer meet nighttime driving needs. This report also includes background information on pavement marking retroreflectivity.

Background

Reducing transportation-related fatalities and serious injuries across the transportation system is the first of four goals listed in FHWA's Strategic Plan.⁽¹⁾ In 2019, 36,096 people died in motor vehicle traffic crashes in the United States.⁽²⁾ While only a quarter of travel occurs at night,⁽³⁾ about one-half of traffic fatalities occur during nighttime hours.⁽⁴⁾ This translates to a nighttime fatality rate that is approximately three times greater than that of daytime. There are many reasons for this disparity, such as reduced visibility, impaired driving, and fatigue. One way to address the visibility of roadway delineation is to evaluate the retroreflectivity of in-service pavement markings and replace pavement markings that are no longer performing at their intended level by implementing effective retroreflectivity maintenance methods.

Retroreflection (more commonly referred to as *retroreflectivity*) is a special type of reflection where light reflecting off a surface is redirected back toward the source. For the case of pavement markings, light from vehicle headlamps is reflected from the markings back toward the vehicle, making the markings appear brighter to the driver than they would be otherwise. Pavement marking retroreflectivity can be measured and is a key indicator of the nighttime visibility of pavement markings. Maintaining pavement marking retroreflectivity to a level that meets nighttime driver needs is consistent with FHWA's goal of improving safety on the Nation's streets and highways. Many safety and operational strategies depend on pavement marking visibility that meets the needs of drivers. Furthermore, recent research shows reduction in both daylight and nighttime crashes with the presence of markings and increased probability of crashes for very low retroreflectivity values, thereby indicating there are nighttime safety benefits of maintaining longitudinal pavement marking retroreflectivity.⁽⁵⁻⁸⁾

Section 3A.03 Maintaining Minimum Retroreflectivity

Standard:

01 Except as provided in Paragraph 5, a method designed to maintain retroreflectivity at or above 50 mcd/m²/lx under dry conditions shall be used for longitudinal markings on roadways with speed limits of 35 mph or greater.

Guidance:

02 Except as provided in Paragraph 5, a method designed to maintain retroreflectivity at or above 100 mcd/m²/lx under dry conditions should be used for longitudinal markings on roadways with speed limits of 70 mph or greater.

03 The method used to maintain retroreflectivity should be one or more of those described in “Methods for Maintaining Pavement Marking Retroreflectivity” (see Section 1A.11) or developed from an engineering study based on the values in Paragraphs 1 and 2.

Support:

04 Retroreflectivity levels for pavement markings are measured with an entrance angle of 88.76 degrees and an observation angle of 1.05 degrees. This geometry is also referred to as 30-meter geometry. The units of pavement marking retroreflectivity are reported in mcd/m²/lx, which means millicandelas per square meter per lux.

Option:

05 The following markings may be excluded from the provisions established in Paragraphs 1 and 2:

- A. Markings where ambient illumination assures that the markings are adequately visible;
- B. Markings on streets or highways that have an ADT of less than 6,000 vehicles per day;
- C. Dotted extension lines that extend a longitudinal line through an intersection, major driveway, or interchange area (see Section 3B.08);
- D. Curb markings;
- E. Parking space markings; and
- F. Shared-use path markings.

Support:

06 The provisions of this section do not apply to non-longitudinal pavement markings including, but not limited to, the following:

- A. Transverse markings;
- B. Word, symbol, and arrow markings;
- C. Crosswalk markings; and
- D. Chevron, diagonal, and crosshatch markings.

07 Special circumstances will periodically cause pavement marking retroreflectivity to be below the minimum levels. These circumstances include, but are not limited to, the following:

- A. Isolated locations of abnormal degradation;
- B. Periods preceding imminent resurfacing or reconstruction;
- C. Unanticipated events such as equipment breakdowns, material shortages, and contracting problems; and
- D. Loss of retroreflectivity resulting from snow maintenance operations.

When such circumstances occur, compliance with Paragraphs 1 and 2 is still considered to be achieved if a reasonable course of action is taken to resume maintenance of minimum retroreflectivity in a timely manner according to the maintaining agency’s method(s), policies, and procedures.

Figure 1. Text. MUTCD maintaining minimum pavement marking retroreflectivity.

Improvements in pavement marking visibility will also support FHWA's efforts to be responsive to the needs of older drivers whose visual capabilities are declining. This is important because the number of older drivers is expected to increase significantly in the coming years. In 2019, 54.1 million drivers in the United States were at least 65 years old.⁽⁹⁾ The U.S. Department of Transportation estimates that there will be more than 72 million licensed drivers 65 years and older by 2030.⁽¹⁰⁾ In addition, there is an increased interest in pavement marking visibility for automated vehicle guidance.

When pavement markings were first used about 100 years ago, they were hand-painted along the center lines of dangerous curves and were not retroreflective. Since then, there have been many improvements in pavement markings, such as adding optics (typically glass beads) to provide nighttime visibility. Now pavement markings provide more safety benefits than ever. Recent studies, as well as those more than a half-century old, have continuously shown that adding edge lines to rural two-lane highways can reduce crashes and fatalities. More recent research findings demonstrate that benefits can be achieved using pavement marking edge lines with pavement widths as narrow as 18 feet and traffic volumes as low as 400 vehicles per day.⁽¹¹⁾ Other recent pavement marking research findings are included in a 2015 FHWA synthesis including topics such as the effects of pavement marking width and retroreflectivity.⁽¹²⁾

The opening statements of the MUTCD define the purpose of traffic control devices and the principles for their use. Traffic control devices, including pavement markings, are meant to promote highway safety and efficiency by providing for the orderly movement of all road users.⁽¹³⁾ (The MUTCD is incorporated by reference in 23 CFR 655.601 and is available on FHWA's website at <http://mutcd.fhwa.dot.gov>.)

To ensure consistent application, the MUTCD describes the characteristics of and warranting criteria for pavement markings.⁽¹³⁾ The Code of Federal Regulations (CFR) at 23 CFR 655 defines pavement marking colors. The MUTCD web page <http://mutcd.fhwa.dot.gov/kno-colorspec.htm> also references pavement marking colors. The importance of pavement marking retroreflectivity has been recognized in the current MUTCD, which states, "Markings that must be visible at night shall be retroreflective unless ambient illumination assures that the markings are adequately visible. All markings on Interstate highways shall be retroreflective."⁽¹³⁾

Maintaining Pavement Marking Retroreflectivity Performance

The most common way to specify retroreflectivity for markings is to use the international standard of 30-meter geometry, expressed in units of millicandelas per square meter per lux ($\text{mcd}/\text{m}^2/\text{lx}$). As the name indicates, this geometry represents the viewing scenario of a pavement marking 30 meters in front of a vehicle (specifically, a passenger sedan although vehicle size is not a critically sensitive parameter in nighttime pavement marking performance). Agencies often specify pavement marking retroreflectivity criteria for newly installed markings and less often for in-service pavement marking performance.

Generally, maintaining the daytime performance of pavement markings (i.e., presence and color) is less of an issue for agencies than maintaining nighttime performance (retroreflectivity). The nighttime performance of pavement markings can be more difficult to maintain for a variety of reasons, including wear due to traffic, roadway debris, and especially snowplowing activities.

Pavement markings generally use small glass beads to retroreflect light back toward the vehicle. The glass beads are applied to a variety of binder materials (e.g., water-based paints, solvent-based paints, thermoplastic, and epoxy) so that they are partially embedded but also exposed. If the beads get damaged or knocked out of the binder material, the retroreflectivity will degrade even though the marking may still be present. Generally, the retroreflectivity of pavement markings will fade faster than the presence of the marking, making the nighttime performance more difficult to maintain than the daytime performance. Another factor that comes into play with markings is that they are installed in varying field conditions (e.g., different contractors using different equipment applying the markings at different speeds during a variety of weather conditions), making their initial performance variable. Studies have also shown that it is difficult to accurately predict pavement marking retroreflectivity degradation, even if the initial retroreflectivity level is known.

As pavement markings degrade and become less retroreflective, their effectiveness for communicating the intended travel path and roadway alignment to nighttime road users diminishes. If left unattended, pavement marking retroreflectivity can diminish to the point that the markings cannot be seen in time for nighttime drivers to properly react. Thus, to maintain nighttime effectiveness, pavement markings must be replaced before they reach the end of their useful retroreflective life.

This report focuses on those methods that are most appropriate for monitoring pavement marking retroreflectivity to determine when they need to be replaced. Other techniques briefly described in chapter 2 may be appropriate for other purposes but were considered inadequate for the purposes of maintaining pavement marking retroreflectivity in accordance with the standard in the MUTCD.

Report Organization

This report outlines maintenance methods intended to provide agencies with a flexible means of maintaining conformance with the MUTCD standard for minimum retroreflectivity of pavement markings. Although mainly descriptive of the evaluation and monitoring processes, all methods described in chapters 3 through 7 are helpful in the decision process for replacing or restriping longitudinal markings.

Chapter 2 covers the objectives of the pavement marking retroreflectivity maintenance methods. The maintenance methods are introduced and defined. In addition, other inspection techniques that are not recommended to be used as maintenance methods are discussed.

Chapter 3 includes a description of the *measured retroreflectivity method*. This chapter includes information related to sampling and averaging pavement marking retroreflectivity with handheld and mobile equipment. This chapter identifies the link between the measurements and the MUTCD retroreflectivity levels. This chapter also identifies the advantages and potential concerns of this method.

Chapter 4 describes the *consistent parameters nighttime visual inspection method*. Background information on this method, instructions for conducting this inspection method, and how this

method links to specific retroreflectivity levels are described. Advantages and potential concerns are also included.

Chapter 5 describes the *calibrated pavement markings nighttime visual inspection method*. Background information, a description of the general procedures, details of applying this inspection method, and how this links to specific retroreflectivity levels are included. This chapter also identifies the advantages and potential concerns of this method.

Chapter 6 describes the *service life based on historical data method*. Procedures for conducting this method, current practices, and linking the service life to the MUTCD retroreflectivity levels are included. Advantages and potential concerns are also included.

Chapter 7 describes the *service life based on monitored markings method*. Procedures for conducting this method and linking the service life to the MUTCD retroreflectivity levels are included. This chapter also identifies the advantages and potential concerns of this method.

Chapter 8 includes a list of questions and answers to support the pavement marking retroreflectivity methods.

CHAPTER 2. OVERVIEW OF THE METHODS

Introduction

Traditionally, agencies have implemented different methods to ensure their pavement markings are maintained to meet drivers' needs in relation to local conditions, needs, and priorities. These maintenance methods are understood to incorporate both the process to determine when to re-mark roadways and a schedule to replace the markings. The methods in this report do not, however, cover the actual installation process, which varies significantly depending on the materials, specifications, and equipment used. This chapter introduces the objectives in implementing a retroreflectivity maintenance method and then briefly describes a number of potential methods that FHWA recommends would achieve the objectives. Each method is then described in detail in chapters 3 through 7. This chapter also describes other techniques that were considered and determined not appropriate to achieve the objectives.

The maintenance management process begins with agency policies and practices regarding the use of pavement marking materials. Agency policies have often been driven by the costs of the various marking materials and weighed against their durability. Agencies in the north that have consistent snow removal needs experience considerably different marking durability from agencies in the south that do not have these needs.

Once new pavement markings have been installed, there is a need to determine when the markings will reach the end of their useful life so they are replaced before they no longer provide the intended delineation in both daytime and nighttime conditions. By and large, the most common method used to trigger the replacement of pavement markings has been visual inspection. However, other retroreflectivity maintenance methods have also been tested and implemented, including measuring retroreflectivity and re-applying markings based on anticipated service life.

The MUTCD recommends agencies to use a method, which may include a single method or combination of methods described in this report, designed to maintain retroreflectivity at or above the minimum levels specified.

Objectives of the Methods

The intent of these maintenance methods is to provide a systematic means for agencies to ensure their longitudinal pavement marking retroreflectivity is continually at or above minimum maintained retroreflectivity requirements as established in the MUTCD. Use of the method implies not only determining when pavement markings need to be refreshed, but also scheduling the replacement of deficient markings in a timely manner. While the use of one or more of these methods will not guarantee that every inch of pavement marking will meet or exceed the MUTCD minimum levels at every point in time, these methods will help ensure that longitudinal pavement markings are typically replaced before they become inadequate in terms of their nighttime visibility.

Having a method in place to maintain retroreflectivity can help agencies prioritize how to spend limited resources, maximize the life of pavement markings, and ultimately contribute to

improved safety for the motoring public. While the use of a particular method does not guarantee that all markings will be visible at all times, such as during snow and rain events, the overall safety of the agency's roadway network will be improved by having such a maintenance method in place.

Regardless of how an agency chooses to ensure that pavement marking retroreflectivity is properly maintained, documentation of the process can be beneficial for many reasons. Written procedures help ensure that agency personnel properly follow the selected method, and maintenance records provide the agency with a systematic process for scheduling replacements and justification for the allocation of limited resources. For example, measurements of pavement marking retroreflectivity might show that certain markings are near or below the MUTCD levels earlier than expected based on service life predictions. The records provide documentation that an appropriate maintenance method was followed, and permit the agency to assess and revise the expected service life for a given type or group of markings, if necessary. If an agency has a method in place to manage or assess its markings and establishes a reasonable schedule for replacing markings as needed, the agency is better able to justify that it has met its performance goals. It is also quite possible that agencies will realize that they can achieve more life from their markings than previously expected. Documentation of the pavement marking retroreflectivity maintenance process can include a variety of information and levels of detail. The form and extent of documentation are up to the discretion of the individual agency. However, some items an agency might consider are described as follows:

- To prioritize and manage their programs, agencies may want to include a feature in their pavement marking retroreflectivity maintenance method that can adapt to changes in roadway volume and speed.
- Similarly, the maintenance management program could be flexible so that changes to pavement marking practices (i.e., binder material selection and retroreflective optics selection) can be easily accommodated.
- Because ambient illumination has an impact on the visibility of pavement markings, agencies may choose to place a lower priority on roadways where ambient illumination assures that the markings are adequately visible. A report from Alaska shows that when continuous lighting is used along stretches of highway with low pavement marking retroreflectivity, the pavement marking visibility can remain adequate.⁽¹⁴⁾ On its lighted sections of roadway, Alaska strives to maintain retroreflectivity, but knowing that presence, combined with lighting, provides adequate nighttime visibility, Alaska is free to allocate its resources to other priorities. This does not apply to intersection or safety lighting, where isolated areas of a roadway are lighted—those areas still need to be included in the agency's maintenance method.

In the United States, two primary documents describe roadway lighting criteria: the *Recommended Practice: Lighting Roadway and Parking Facilities* (ANSI/IES RP-8-21) and the American Association of State Highway and Transportation Officials (AASHTO) *Roadway Lighting Design Guide*, 7th Edition (known as the AASHTO Guide).^(15, 16) The *Recommended Practice for Lighting Roadway and Parking Facilities*, published by the Illuminating Engineering Society (IES), is commonly used by public agencies as the basis for establishing the appropriate lighting level design values for roadway lighting. This publication has been approved by the American National Standards Institute (ANSI) and is commonly referred to as RP-8. The

RP-8 lighting design criteria parallels the lighting criteria found in the AASHTO Guide, except for the general land-use parameter. The RP-8 criteria are based on an assessment of the roadway classification and pedestrian conflict area classification rather than the general land-use classification found in the AASHTO Guide.

A roadway or corridor may be planned for rehabilitation or resurfacing but have existing pavement markings with retroreflectivity approaching minimum levels. In such cases, a decision needs to be made about restriping the roadway, given that it will soon be resurfaced. In these cases, an agency could choose to set a maximum time frame between identification of potential inadequate pavement marking retroreflectivity and resurfacing. If more time than the maximum time frame is expected, an agency could decide to install a low-cost temporary pavement marking (e.g., conventional waterborne paint and AASHTO M247 Type I beads), issue a restriping contract, or include a provision within the resurfacing contract that conveys the maintenance of the markings, according to the MUTCD standard, to the contractor once the project is let for construction.

Resources will change over time, and unexpected events will occur. It will be important to establish documentation and make revisions as necessary. When extraordinary events occur, such as resource shortages or circumstances outside the control of the agency, documentation can be advantageous for justification of not meeting MUTCD levels. Repetitive instances of failure to maintain retroreflectivity may indicate a need to change resources or revise the documented method. Examples to address such occurrences could be:

- Revisions to standard operating procedures to accelerate replacement schedules in high-wear areas.
- Inclusion of new resources in lieu of or in combination with agency resources.
- Characterization of procurement rule changes that impact material deliveries.

Pavement Marking Visibility and Retroreflectivity

The ability to see a pavement marking at night is not solely a function of the retroreflective characteristics of the pavement marking, but is also dependent on several other factors such as:

- The amount and pattern of light produced by a vehicle's headlights.
- The amount of light reaching the pavement marking.
- The visual complexity of the scene (e.g., rural or urban).
- The weather (e.g., clear, rainy, or foggy).
- The visual capabilities of the observer.

A key factor in determining the visibility of a pavement marking is the contrast between the marking and the adjacent pavement surfaces. During daylight hours, ambient light provides pavement marking visibility by striking the marking surface. The reflected light scatters in all directions, but some of it reaches the driver's eyes. However, in dark environments (without roadway lighting), vehicle headlamps produce most of the light striking a pavement surface, and therefore the retroreflective properties of the pavement marking govern the amount of light that reaches the driver's eyes. While optics such as glass beads primarily provide the retroreflective performance of pavement markings, other factors also contribute to retroreflective performance.

These include the properties of the binder material (e.g., color, pigment type and amount, type, and thickness), pavement surface roughness, and amount of debris and dirt on the marking.

Acceptable Pavement Marking Retroreflectivity Maintenance Methods

The FHWA hosted a series of workshops around the country to solicit city, county, and State transportation agency input regarding issues about implementing a national standard on minimum pavement marking retroreflectivity levels.⁽¹⁷⁾ One of the most consistent comments was that a one-size-fits-all solution would not be practical, and that FHWA needed to provide flexibility in terms of meeting the minimum retroreflectivity levels. Therefore, this report includes several potential methods that agencies can choose from to maintain the retroreflectivity of their markings. Although mainly descriptive of the evaluation and monitoring processes, all methods listed here and described in detail in chapters 3 through 7 are helpful in the decision process of replacing or restriping longitudinal markings. Appendix B provides examples of how an agency might implement each of the maintenance methods.

Measured Retroreflectivity Method (See Chapter 3)

In this method, pavement marking retroreflectivity is measured and directly compared to the MUTCD minimum levels. The retroreflectivity measurements can be made with either handheld or mobile instruments using the standard 30-meter geometry. Inspectors must follow the instructions provided by the manufacturer to obtain reliable retroreflectivity readings, including periodically calibrating the equipment. Chapter 3 has more information about this method.

Nighttime Visual Inspection Methods

This report describes two types of nighttime visual inspections that can be implemented to maintain pavement marking retroreflectivity. Both methods are meant to be conducted during dry nighttime conditions. These two methods have common elements such as:

- The use of low-beam headlamp illumination.
- Inspections conducted at prevailing nighttime speeds.
- The use of trained inspectors.
- The dependence on subjective evaluations.

Consistent Parameters Nighttime Visual Inspection Method (See Chapter 4)

The consistent parameters inspection method is based on factors similar to those that were used in the research to develop a set of recommended minimum retroreflectivity levels. This method involves a nighttime review at highway speeds with low-beam headlamps by an inspector who is aged 60 years or older. The trained inspector judges the adequacy of the markings to meet his or her nighttime driving needs. Chapter 4 has more information about this method.

Calibrated Pavement Markings Nighttime Visual Inspection Method (See Chapter 5)

This method uses a trained inspector to view calibrated pavement markings at night prior to conducting a nighttime visual inspection. Calibrated pavement markings have known retroreflectivity at or above MUTCD levels. These pavement markings are set up where the

inspector can view them in a manner similar to the conditions of the nighttime visual inspections. The markings can be in a maintenance yard, along a service road or other such facility, or on a road open to public travel. The inspector uses the visual appearance of the calibrated pavement markings to establish evaluation thresholds for that night's inspection activities. Chapter 5 has more information about this method.

Service Life Based on Historical Data Method (See Chapter 6)

Using this method, an agency documents pavement marking installation dates and, using historical data or research results, establishes a schedule for replacing the markings. The schedule to replace the markings is designed to prevent the pavement marking retroreflectivity from falling below the MUTCD minimum levels. Pavement marking replacement schedules can be set for similar markings in similar conditions (considering factors such as pavement marking type, retroreflective optics, pavement type, pavement condition, and traffic volumes). Chapter 6 has more information about this method.

Service Life Based on Monitored Markings Method (See Chapter 7)

Using this method, an agency documents pavement marking installation dates and periodically monitors the retroreflectivity of a subset of the markings as a way to track their durability. The monitored markings represent a larger group of similar markings in similar conditions. When the monitored markings degrade and approach the MUTCD minimum levels, the entire group of markings (both monitored and the larger group they represent) are restriped. This is an alternative method for agencies that want to use a service life type of method but do not have historical data or specific research supporting service life estimates for their region and specific conditions. Chapter 7 has more information about this method.

Other Methods

An effective approach may be to combine one or more of these methods or to develop other methods based on engineering studies. If an agency develops a different method, however, it is important that the method be based on an engineering study and tied to the MUTCD minimum levels. An example of a combined method is performing one of the visual assessment methods to determine the quality of the markings: markings deemed as failing are replaced, markings deemed as adequate are left alone, and markings deemed as marginal are evaluated with a measured retroreflectivity method.

Techniques Not Recommended as Pavement Marking Retroreflectivity Maintenance Methods

FHWA identified several other pavement marking assessment techniques and considered but ultimately did not include these in the recommended methods, either because they could not be tied to a specific retroreflectivity level or due to other concerns. These techniques are described as follows. Future technologies and research may demonstrate that these techniques, or other innovative techniques, can be successfully used to maintain pavement marking retroreflectivity levels above the minimum levels in the MUTCD.

Sun-over-the-Shoulder Technique (Not a Recommended Method)

The sun-over-the-shoulder check is an evaluation of pavement marking retroreflectivity normally used to assess the general quality of freshly installed pavement markings. This quality control check is conducted during daylight hours. Contractors and agencies use this technique to check bead coverage during installation; it does not ensure specific retroreflectivity levels. The sun-over-the-shoulder technique is not considered a suitable pavement marking maintenance method to determine if and when longitudinal pavement markings have reached the end of their useful service life because it does not have a capability to tie the observation to a level of retroreflectivity at night.

Comparison Panel Technique (Not a Recommended Method)

The comparison panel technique involves placing a comparison panel with a known retroreflectivity level at or above a specific retroreflectivity level next to an in-service pavement marking. An inspector views the combination at a specified distance (e.g., 30 meters). If the comparison panel appears brighter than the pavement marking, the marking needs to be replaced. This technique needs to be conducted at night and with traffic control (for safety reasons). While this method is acceptable for the airfield markings for which it was developed, workshop participants deemed it unsafe for roadways because it entails too much risk for the inspectors.

Lane Line Count Technique (Not a Recommended Method)

To use this technique, inspectors count the number of lane lines visible from the driver's seat of a static test vehicle. This count of visible lane lines is multiplied by the lane line length and spacing to calculate visibility distances. While it is possible to tie a retroreflectivity level to a visibility distance, the need to have the inspection vehicle in a static position places the inspectors at risk. It is not feasible to accurately count the lane lines from a moving vehicle. In addition, this technique would not be possible on roadway sections without broken lines (e.g. two-lane roads with no passing allowed).

Windshield Marking Technique (Not a Recommended Method)

With this technique, a mark (using tape) is placed on the windshield at the line of sight for the inspector. This mark coincides with a visibility distance derived from a preview time of 2.2 seconds and the posted or prevailing nighttime speed of the roadway. The inspector then drives the roads at appropriate speed (the mark would need to be adjusted for speed) and disqualifies any segments where the pavement marking cannot be seen at the appropriate distance. This technique is not directly tied to specific pavement marking retroreflectivity levels. In addition, there is concern that minor changes in the driver position (e.g., slouching) would affect the accuracy of this system. Future research may determine an effective method using this technique.

Control Markings Technique (Not a Recommended Method)

A maintenance method described in the MUTCD for maintaining traffic sign retroreflectivity is called the control sign method and involves monitoring a subsample of traffic signs to determine their service life based on minimum sign retroreflectivity levels. As the control signs near the

end of their retroreflective life, they are scheduled for replacement along with the other in-service signs of the same age and materials. The control signs can be signs in a maintenance yard or in-service signs.

For pavement markings, this method is called the *service life based on monitored markings* method and is different in that the monitored markings must be in-service markings because the degradation of markings is so dependent on the wear they experience from traffic. Chapter 7 has more information about the service life based on monitored markings method.

Comparison Light Box (Not a Recommended Method)

A comparison light box is a handheld device that performs a daytime check of pavement marking retroreflectivity. The device is similar in size to a pavement marking retroreflectometer but is significantly less expensive. The device is composed of a box with a mirror and a light to show the appropriate geometry as the inspector looks directly down into the box. The image that the inspector sees is a side-by-side comparison of the in-service marking and a calibrated marking (placed within the device) that has a specific retroreflectivity level (at or above MUTCD levels). While this device provides a side-by-side comparison, it is not appropriate to use a comparison light box in a similar manner to a handheld pavement marking retroreflectometer. Both devices are used by placing them on the pavement marking to be inspected, but the retroreflectometer can be operated with a trigger pull and does not need the inspector to glance away from the roadway. With the comparison light box, on the other hand, the inspector needs to look down into the device, focus, and then make a decision, demanding the inspector look away from the roadway for a significant period. The comparison light box technique works, if it is used in a safe location such as with the appropriate traffic control. However, the handheld retroreflectometer provides a more objective measure of retroreflectivity and reduces user risk by allowing the user to scan traffic. The handheld retroreflectometer is more expensive but is preferred over the comparison light box.

CHAPTER 3. MEASURED RETROREFLECTIVITY METHOD

Introduction

In general, pavement marking retroreflectivity can be measured in the field in two ways: with handheld instruments or with mobile instruments. Handheld instruments must be placed on the pavement marking. Mobile instruments are attached to a vehicle and measure the pavement marking retroreflectivity as the instrumented vehicle is driven at typical roadway speeds. Both types of instruments provide objective retroreflectivity values that can be used in direct comparison to the MUTCD levels. The measurement method as an exclusive process to maintain pavement marking retroreflectivity has not historically appealed to agencies, as will be discussed in this chapter. However, when combined with a visual or service life method, the measured pavement marking retroreflectivity method adds an element of objectivity to the overall maintenance program. This combination of methods may enable agencies to more efficiently use their maintenance budgets.

Background

Pavement marking retroreflectivity levels are specified in the MUTCD at 30-meter geometry. Essentially, retroreflective measurements made under 30-meter geometry simulate the retroreflective performance of the pavement marking at a distance 30 meters in front of the vehicle (using entrance and observation angles of 88.76 and 1.05 degrees, respectively) (figure 2).

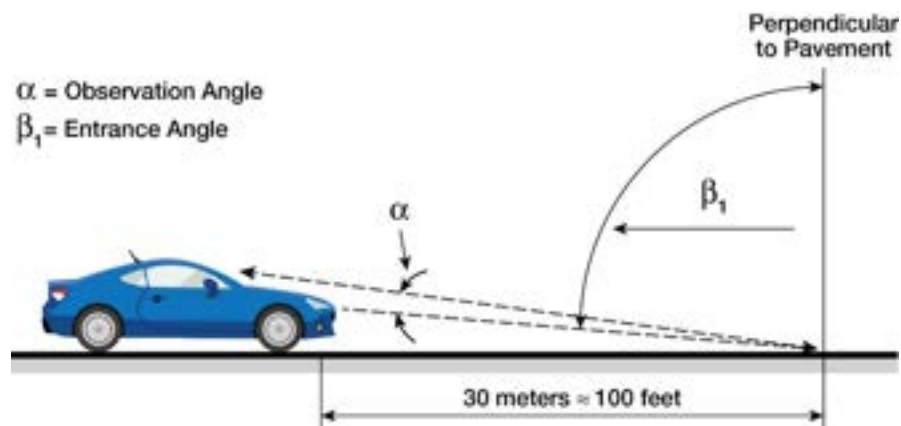


Figure 2. Diagram. 30-meter geometry.

For handheld retroreflectometer measurements, ASTM International has developed a standardized practice, *ASTM D7585/D7585M, Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments*.⁽¹⁸⁾ This standardized practice provides guidance on topics such as how many readings are needed. Currently, there is no national standard for mobile retroreflectometer measurements.

Several handheld retroreflectometers that can be used to measure pavement marking retroreflectivity are commercially available. While both the handheld measurement instruments and the mobile measurement instruments provide similar results related to measurement bias, repeatability, and reproducibility,⁽¹⁹⁾ using handheld instruments can be time consuming if many

roadways with miles of pavement markings are to be sampled. Mobile pavement marking retroreflectivity measurement instruments offer flexibility and efficiency for the measurement process. However, mobile measurement instruments necessitate a relatively high level of capital investment for those agencies interested in purchasing their own. Alternatively, some companies specialize in pavement marking measuring services using both handheld and mobile measurement instruments.

Inspector Training

The company selling the handheld or mobile retroreflectivity measurement instrument is best suited for providing training for proper use of the device. Specific calibration procedures and maintenance schedules for the equipment are important to follow in order to obtain accurate and repeatable measurements.

General Procedures

Measuring retroreflectivity using a handheld instrument is to be performed in safe conditions with appropriate traffic control. Measuring retroreflectivity using a mobile instrument provides relief from the need for traffic control. Using either type of instrument, the measurements must be made under dry conditions (pavement marking retroreflectivity can be measured under wet recovery and wet continuous conditions, but the minimum maintenance levels in the MUTCD pertain only to dry conditions). It is important to maintain a record of the measurements, when they were made, and other related information as deemed appropriate. If the measured retroreflectivity value approaches or is less than the MUTCD minimum level, the markings are scheduled for replacement.

Detailed Procedures

The basic procedure using a handheld retroreflectometer is to:

1. Calibrate the retroreflectometer each day before beginning measurements.
2. Select the segment of marking to be measured.
3. Take 16 or more measurements at regular intervals on that segment, ensuring the retroreflectometer is facing the direction of traffic appropriate to that line. If measuring a single center line, take measurements in both directions.
4. Document the individual readings and the average for the segment.
5. Move to the next line (e.g., if measuring center and edge lines) or the next segment.
6. Repeat steps 2 through 5.

See *ASTM D7585/D7585M*⁽¹⁸⁾ for further details.

The basic procedure for mobile measurements is similar to that for handheld measurements. Differences include no need for traffic control, additional efforts to verify accurate calibration, and the ability to collect larger amounts of data in a shorter time frame.

Examples of handheld and mobile pavement marking retroreflectometers are shown in figure 3 and figure 4, respectively. Handheld retroreflectometers are much less expensive than mobile units, are much easier to use, and require less training. However, handheld units are inconvenient

when a large number of measurements are needed or when measuring on roads with high traffic volumes. Safety issues are also related to the use of handheld units because workers are often exposed to traffic while measuring the retroreflectivity of a marking. Taking handheld measurements may also involve lane closures, increasing delay to motorists.



Figure 3. Photo. Measuring retroreflectivity with a handheld instrument.



Figure 4. Photo. Typical mobile pavement marking retroreflectivity measurement instrument.

Mobile units, on the other hand, are significantly more expensive than handheld units and require a significant amount of training and maintenance. However, mobile retroreflectometers produce a very large number of measurements (typically one measurement every inch) and allow for measurements to be taken at highway speeds without exposing personnel to traffic or lane closures. Some transportation agencies own mobile retroreflectometers, while others hire qualified contractors to perform mobile retroreflectivity measurements.

Linking Measurements to Retroreflectivity Levels

This method uses measured retroreflectivity as the basis for the decision of whether pavement markings meet the MUTCD minimum levels of retroreflectivity. The measured retroreflectivity values are compared to the minimum retroreflectivity levels specified in the MUTCD. Where measurements indicate pavement marking retroreflectivity is at or near the applicable level, the agency is expected to schedule marking replacement for these segments of roadway. This method provides the most direct comparison of in-service pavement marking retroreflectivity relative to the minimum maintained retroreflectivity levels.

Advantages

Retroreflectivity measurements can be made during the day. Measurements provide the most direct and objective means of monitoring pavement marking retroreflectivity levels.

Concerns

Measuring pavement markings can be time consuming and cost prohibitive, depending on the quantity of pavement markings to be measured and the measurement technique. However, agencies do not necessarily need to purchase their own instruments. Some agencies share devices, use loaners from Local Technology Assistance Program (LTAP) centers, or rent them from companies. For some agencies, measured retroreflectivity may be best used to support one of the other methods.

Using the retroreflectivity of pavement markings as the only indicator of whether markings need to be replaced could result in other attributes of the markings' overall appearance being neglected. Other factors to be considered include the daytime and nighttime color, the presence of the marking material, and the uniformity of the nighttime appearance. Agencies also need access to the measurement devices and trained personnel to use this method (or the measurement services of a third party).

The measurement bias, repeatability, and reproducibility limits of retroreflectivity measurements are also important considerations when using measurements to determine whether pavement markings meet the MUTCD minimum levels. ASTM has recently updated the repeatability and reproducibility limits for pavement marking retroreflectivity measured with a 30-meter geometry handheld instrument (see ASTM E1710).⁽²⁰⁾

CHAPTER 4. CONSISTENT PARAMETERS NIGHTTIME VISUAL INSPECTION METHOD

Introduction

Agencies can use the consistent parameters nighttime visual inspection method to conduct visual inspections at night without the need for specific calibrated markings or retroreflectivity measurements.¹ This method relies on the judgment of an inspector who is at least 60 years old. The minimum retroreflectivity levels outlined in the MUTCD are based on research that evaluated the visibility needs of 90 percent of drivers, which corresponds to a 62-year-old.⁽²¹⁾ The pavement marking visibility viewed by an inspector who is 60 years or older can be thought of as a surrogate for maintained retroreflectivity that meets the needs of drivers.

This method involves minimal resource investment on the part of the agency, although there is still a need for a record-keeping system for inspection data and the potential for higher labor costs where overtime pay at night is needed. While visual inspections reveal night visibility problems not discernable under any other method, they are subjective and therefore more difficult to tie to a specific retroreflectivity level. As a result, it is important for agencies using visual inspections to establish procedures that provide consistency in inspections. This implies the need for inspector training and possibly inspector certification.

Background

Probably the most common type of method used in the past to evaluate pavement marking retroreflectivity has been some form of the nighttime visual inspection method. Despite the subjectivity and reliability concerns of the method, research has shown visual assessment techniques can be used to assess the relative brightness of pavement markings, but not necessarily the retroreflectivity level of pavement markings.⁽¹²⁾ Therefore, it is important to have trained inspectors who follow the process outlined in this section when conducting nighttime visual inspections of pavement markings.

The consistent parameters method uses inspectors aged 60 years or older to observe pavement markings during the nighttime to assess the overall appearance of pavement markings and determine whether they need to be replaced. The observation is typically done through the windshield of the vehicle at or near the speed limit of the roadway.

Inspector Training

The key to this method is having trained inspectors. While there is no nationally recognized training course or certification for pavement marking inspectors, agencies are encouraged to provide inspector training before using this method. Elements of proper training include the purpose and objectives of the inspection, the types of markings to evaluate, when to conduct the

¹ The term *consistent parameters* is used to indicate the inspection method uses parameters that are consistent with those used during FHWA's research to develop recommended minimum retroreflectivity levels.⁽²¹⁾

inspection, documentation, safety, equipment, appropriate agency policies, and how to make a judgment on the adequate visibility of the markings.

General Procedures

The consistent parameters nighttime visual inspection method is typically conducted using a two-person crew. While the driver focuses on the driving task, the inspector (aged 60 years or more) evaluates the pavement markings and records the appropriate information. Those markings judged by the inspector to not meet his or her driving needs are noted as needing to be replaced (i.e., can the older driver see the markings far enough in advance to make appropriate decisions and maneuvers at normal driving speeds?). Although not preferred, an alternative to a two-person crew is to use one person with a tape recorder or mounted camcorder for recording notes. Retroreflectivity assessments need to be made at the time of the inspection by the inspector based on his or her nighttime visual needs. Video recordings are not to be used later for determining the condition of the markings. Video technology is not yet available that can provide the necessary quality to be used in assessing retroreflectivity.

Detailed Procedures

Agencies may find it helpful to develop inspector guidelines and procedures to ensure consistent inspections. The following are keys to a successful inspection:

1. Conduct inspections at normal speed and from the travel lane.
2. Conduct inspections using low-beam headlights while minimizing interior vehicle lighting.
3. Evaluate markings far enough in advance so that there is adequate time to respond to curves, changes in the number of lanes, or marking patterns.

Since inspections are only conducted with low-beam headlamps, it is important to verify the proper alignment of the inspection vehicle's low-beam headlamps (see figure 5).^(22, 23) The ambient conditions must be dark: at least 30 minutes beyond sunset. The condition of the pavement must be dry during the inspection. Unlike the calibration markings method, there is no equipment needed for this method. The only constraints are that the inspector be trained and be at least 60 years old, that the inspection take place at night, and that the inspection vehicle headlamps be properly aimed and set to low beams during the evaluation. The inspection vehicle can be any type of passenger vehicle, although a passenger car is preferred because it most closely matches the research parameters. The inspections are to be conducted at typical driving speeds and from the travel lanes immediately adjacent to the markings being evaluated.

It is helpful to plan the routes before the inspection begins. The frequency of inspections (e.g., once or twice per year) and the sampling procedures are part of the method. Documenting the process, including the inspection results, can help prioritize markings replacement schedules.

What you will need:

- A level area with a distance of approximately 7.625 meters (25 feet) plus the length of the vehicle from a flat, lightly colored wall.
- A tape measure.
- Masking tape.

Instructions:

1. Park the vehicle so that the headlamps are precisely 7.625 meters (25 feet) from a flat, lightly colored wall. The vehicle should have at least half a tank of gas and should be loaded as it would be when inspecting signs. This includes the weight of the driver (and passenger if present).
2. Measure the exact middle of both the windshield and rear window, and mark them with strips of tape, creating vertical centerlines, front and rear.
3. Standing behind the car, sight along the centerlines, and have an assistant mark the position of the vehicle centerline on the wall with a vertical strip of tape.
4. Measure the distance between the vehicle centerline and the headlamp lenses. Mark that distance to the right and left of the centerline on the wall with vertical strips of tape.
5. Measure the height of each headlamp from the ground (measuring to the center of the lens). Using those measurements, place horizontal strips of tape on the wall where the vertical strips have been applied. There should now be two crosses on the wall, with centers that correspond to the center of each headlamp lens.
6. For headlamps with a left-side cutoff, mark a horizontal line that is 53.34 millimeters (2.1 inches) below the headlamp centers with a horizontal strip of tape. For headlamps with a right-side cutoff, mark a horizontal line that runs through the headlamp centers.
7. Turn the vehicle headlamps on low beam. The left edge of the bright spots on the wall should just touch the vertical bars of the crosses. The top edge of the strongest gradient of light should just touch the horizontal line. Adjust the headlamp aim according to the manufacturer's instructions, if required.

Figure 5. Text. Headlamp aiming procedure.⁽²²⁾

Linking to Maintained Retroreflectivity Levels

This method links to the minimum retroreflectivity levels in the MUTCD by replicating the research conditions under which those levels were established. An objective of the MUTCD language is to establish minimum levels of nighttime pavement marking performance based on the visibility needs of nighttime drivers, especially older nighttime drivers. This procedure provides a technique to do just that.

Advantages

One of the major benefits of this method is that it has relatively low equipment, administrative, and fiscal burdens. Many agencies already perform some type of periodic pavement marking inspection although not all inspections are performed at night or with an older inspector. A

feature of this method is that the inspectors view the pavement markings in the context of their surroundings. Thus, an agency can assess the overall appearance of the pavement markings and the ability of the pavement markings to provide information to the driving public.

Using this method, it is possible to assess more than just the retroreflectivity of pavement markings. Inspectors may identify other damage, such as excessive wear from turning movements. In addition, they can examine current pavement markings to be sure they continue to meet MUTCD and other policy standards.

Concerns

This method relies on the judgment of the inspector. Therefore, it is the most subjective of all the recommended methods. It is good practice to occasionally conduct spot checks with a retroreflectometer to confirm the quality of the agency's visual inspections.

While it can be used effectively for the purpose of ensuring markings are replaced before the end of their useful service life, it is not feasible to use this method to enforce contracted retroreflectivity criteria that come with disincentives if the markings fail a specific level before a set period.

Pavement markings supplemented with raised retroreflective pavement markers (RRPMs) can be difficult to inspect visually. The brightness of the RRPMs can be much greater than that of the pavement markings, and therefore inspectors might find it difficult to judge the pavement marking retroreflectivity. Agencies using RRPMs may need to consider a different method.

Pavement markings on either side of the inspection vehicle can be evaluated during a visual inspection. However, pavement markings that are not adjacent to the inspection vehicle cannot be evaluated during a visual inspection. Therefore, for multilane highways, more than one pass (per direction) will be needed to inspect all longitudinal markings. This is not unique to this method.

CHAPTER 5. CALIBRATED PAVEMENT MARKINGS NIGHTTIME VISUAL INSPECTION METHOD

Introduction

Agencies can use the calibrated pavement markings nighttime visual inspection method as long as steps are taken to calibrate the inspector's perception of pavement marking retroreflectivity levels. While nighttime visual inspections will reveal the retroreflective condition of the markings, visual inspections are subjective and therefore more difficult than actual measurements to tie to a specific retroreflectivity level. Agencies using visual inspections need to establish procedures to provide consistency in inspections. This implies the need for training programs and possibly inspector certification.

This method entails only minor investment on the part of the agency, although there is a need for a record-keeping system for inspection data and the potential for higher labor costs where overtime pay is needed (because the inspection is performed at night). The significant up-front resource needed is a retroreflectometer to measure the calibrated pavement markings to ensure they are at the intended retroreflectivity levels. However, agencies do not necessarily need to purchase their own instruments. Some agencies share devices, use loaners from LTAP centers, or rent them from companies.

Background

Probably the most common type of method used to evaluate pavement marking retroreflectivity has been some form of the nighttime visual inspection method. Despite the subjectivity and reliability concerns of the nighttime visual inspection method, research has shown visual assessment techniques can be used to assess the relative brightness of pavement markings but not necessarily the actual retroreflectivity level of pavement markings.⁽¹²⁾ Therefore, it is important to have trained inspectors who follow the process outlined in this section when conducting nighttime visual inspections of pavement markings.

The calibrated markings method is a visual inspection method that shares some elements of the consistent parameters method. There are two primary differences:

- It does not restrict the inspector's age to 60 years or older.
- It requires calibration markings that have retroreflectivity levels at or above the minimum levels in the MUTCD.

With this method, the inspector views the calibration markings and then immediately proceeds to perform the nighttime inspection of in-service markings to determine whether they need to be replaced. The inspector typically observes the markings through the windshield of the vehicle at or near the speed limit of the roadway. The addition of a dedicated driver makes it possible for the inspector to concentrate on observing the markings at the appropriate distance.

Inspector Training

While there is no nationally recognized training course or certification for pavement marking inspectors, agencies are encouraged to provide some form of training for inspectors before they perform nighttime inspections.

Elements of the training include the purpose and objectives of the inspection, critical inspection techniques, cautions for improper techniques, the types of markings to evaluate, when to conduct the inspection, documentation, safety, equipment, appropriate agency policies and procedures, and how to make a judgment on the adequate visibility of the markings using this method. A necessary element of the training is to have the inspectors observe sample pavement markings at a variety of known retroreflectivity levels, including levels near the MUTCD levels, before conducting the inspections. This type of training is needed to help the inspector experience the differences between various retroreflectivity levels. Inspectors benefit from viewing the sample pavement markings at night under conditions similar to those under which they will perform inspections. This includes using the vehicle that will be used during the inspection, using low-beam headlamps, and locating the calibration pavement markings in positions that replicate most typical field applications.

General Procedures

This method uses trained personnel to observe pavement markings during nighttime conditions to assess the overall appearance of the markings and determine whether they meet the MUTCD retroreflectivity levels. This method is typically conducted using a two-person crew. While the driver focuses on the driving task, the inspector evaluates the pavement markings and records the appropriate information. Although the view of the pavement markings is not the same for the passenger as the driver, it is similar, and the safety of the inspection procedure is very important. Therefore, the use of a two-person crew is a practical and safe way to conduct an inspection using this method. The observation is made through the windshield of the vehicle at the normal travel speed of the roadway using low-beam headlamps. If the inspector finds a marking appears to be approaching or less bright than the calibration markings viewed earlier, then the markings are scheduled to be replaced.

An alternative to a two-person crew is to use one person with a tape recorder or mounted camcorder for recording notes. The retroreflectivity assessments need to be made by the inspector at the time of the inspection. Video recordings are not to be used later for determining the condition of the markings. Video technology is not yet proven to provide the necessary quality to be used in assessing retroreflectivity.

Detailed Procedures

To get started, it is helpful for an agency to develop a step-by-step set of instructions for consistency of inspections. This method requires a sample of pavement markings at or above the MUTCD-established retroreflectivity levels. These markings will be designated as the *calibration markings*. Depending on the agency specifications, the retroreflectivity levels of the calibration markings may be at the MUTCD-established levels, or they may be higher but not

lower than the appropriate level. The pavement marking retroreflectivity of the calibration markings will need to be measured and documented to ensure it is near the desired level.

Good practice includes both yellow and white calibration markings that are positioned accordingly (e.g., for a two-lane, two-way roadway, white on the right and yellow on the left). If the calibration pavement markings are installed specifically for this purpose, the contractor or installer will need to make special provisions to apply pavement markings near the desired levels. This will take some trial and error because the levels will be much lower than typical new pavement markings. However, it can generally be achieved by controlling truck speed and bead load rates. Retroreflectivity can also be lowered by applying a clear coat of polyurethane or other similar product.

It is important that the inspector evaluate the calibration markings from the vehicle to be used for the inspection before each night's inspection begins. The markings can be viewed in a static or dynamic condition. If the calibration markings are set up to be viewed in a static condition, then the calibration markings need to be at least 10 feet long and the inspection vehicle positioned 100 feet in advance of the calibration markings. This replicates the 30-meter geometry used in instrument measurements.

Calibration markings used in a dynamic condition (on an existing roadway) need to be long enough to provide the inspector at least 15 seconds of preview time to study the brightness of the marking. This means that the length of calibration markings to be used in dynamic conditions varies with the speed. The intended speed of the inspection vehicle during calibration can be used to calculate the length of calibration markings needed. If the agency has pavement markings on roads open to public travel that are known to be near the minimum levels, these markings may be used as calibration markings. However, in this case, the calibration process is performed at the posted or operating speed, which necessitates a significant length of calibration marking. For example, at 60 mph, calibrated markings at least one-quarter mile long are needed to provide enough viewing time for the inspector to calibrate his or her eyes.

When viewing the calibrated markings, the inspector tries to focus about 100 feet in front of the vehicle and commit to memory the appearance (or brightness) of the calibrated markings. The inspector uses the appearance of the calibrated markings as a benchmark to determine if in-service markings are brighter or less bright than the calibrated markings. Those that are less bright and those at about the same brightness level are scheduled for replacement.

Once a set of pavement markings that are at or near the level(s) set by the agency has been installed or identified for use as calibration markings, it is a good practice to measure and document the retroreflectivity levels as part of the process. ASTM Test Method D7585⁽¹⁸⁾ includes a description of the appropriate test method for handheld pavement marking retroreflectometers.

Any type of vehicle can be used for the calibrated pavement markings visual inspection method. Since inspections are conducted only with low-beam headlamps, it is important to verify the alignment of the low-beam headlamps of the inspection vehicle (see figure 5 in chapter 4). The ambient conditions must be dark: at least 30 minutes beyond sunset. The condition of the pavement must be dry during the calibration and during the inspection. If calibration markings

are viewed in a dynamic condition, at least one pass of the calibration markings must be made, but more than one can be beneficial.

Linking to Retroreflectivity Maintenance Levels

Retroreflectivity levels are incorporated into this method by training the inspectors and using procedures that allow them to correlate their inspection observations with known retroreflectivity levels through the use of calibrated pavement markings (at or above the MUTCD levels). It is important that inspectors observe the calibrated markings prior to each night's inspection. It is good practice for inspectors to observe the calibrated pavement markings intermittently throughout each nighttime inspection. Therefore, it is helpful to locate the calibrated pavement markings in a centralized area and plan the night inspection route so that the calibrated markings can be observed several times throughout the night.

Advantages

One of the major benefits of using this method is that it has relatively low administrative and fiscal burdens. Many agencies already perform some type of periodic pavement marking inspection, although not all inspections are performed at night, and few are actually linked to retroreflectivity levels. A feature of this method is that the pavement markings are viewed in their natural surroundings. Thus, the overall appearance of the pavement marking and the ability of the pavement markings to provide information to the driving public can be assessed.

Using this method, it is possible to assess more than just the retroreflectivity of pavement markings. Other damage can be identified such as excessive wear on the inside of curves or loss of presence (i.e., when some of the pavement marking material is missing), which might not be identified with spot retroreflective measurements alone.

Concerns

This method is somewhat subjective. However, research has shown that inspectors can make subjective ratings of pavement marking visibility that can be used as surrogates for retroreflectivity (i.e., using qualitative ratings such as *poor*, *marginal*, and *desired* rather than specific retroreflectivity levels such as 80 or 115 mcd/m²/lx). There is some safety concern involved while performing these inspections, particularly if the driver is also the evaluator and recorder. For safety reasons, it is best for two people to conduct nighttime inspections. Including additional inspections by different inspectors has been shown to increase the reliability of visual inspections. It is also good practice to occasionally conduct spot checks with a retroreflectometer to confirm the quality of the agency's findings.

Agencies using this method will need to establish a protocol that fits their conditions, including the frequency of inspections and the establishment of calibrated markings. Part of that protocol could be route planning to separate higher-speed roads which need higher retroreflectivity from lower-speed roads so that the inspector's eyes are calibrated for the correct retroreflectivity level of the route. Since pavement markings tend to lose their retroreflective performance over time, it is important to measure the calibrated markings periodically to ensure that they are at or above the appropriate levels.

Visual inspections of pavement markings supplemented with RRPMs can be difficult. The brightness of the RRPMs is usually much greater than that of the pavement markings, and therefore it can be difficult to judge the pavement marking retroreflectivity. Agencies using RRPMs may need to consider a different method.

Pavement markings on either side of the inspection vehicle can be evaluated during a visual inspection. However, pavement markings that are not adjacent to the inspection vehicle cannot be evaluated during a visual inspection. As a result, for multilane highways, more than one pass is needed (per direction) to inspect all longitudinal markings. This is not unique to this method.

CHAPTER 6. SERVICE LIFE BASED ON HISTORICAL DATA METHOD

Introduction

With this method, an agency documents pavement marking installation dates and, using historical retroreflectivity data or research results, develops a schedule for replacing the markings. This schedule is designed to prevent the pavement marking retroreflectivity from falling below the MUTCD retroreflectivity level. Using this method, agencies can set pavement marking replacement schedules for similar markings in similar conditions.

Procedures

Research shows that the most pertinent factors in determining the service life of pavement marking retroreflectivity are pavement marking type (e.g., binder, thickness, and optics), pavement surface, snowplow operations, traffic volumes, and climate.^(24, 25) Therefore, it is appropriate for agencies using this method to consider these factors when determining the service life of their markings. Without the support data on how long pavement markings last before reaching a predetermined retroreflectivity level, an agency may find it best to use an alternative maintenance method, such as service life based on monitored markings (chapter 7).

To track and schedule replacement of specific markings, the agency can use a computerized documentation technique, such as a spreadsheet listing the factors. Alternatively, fully featured geographic information systems (GIS) can be developed. Either way, pavement markings of similar type can be grouped with roadways under similar conditions. Merging the different factors along with an agency's historical retroreflectivity data enables an agency to use this method.

Current Practice

A literature review and agency surveys have shown that the expected service life of pavement markings varies considerably across the United States.⁽²⁶⁾ Table 1 shows the range of values for assorted pavement marking types. The large ranges demonstrate the need to use historical retroreflectivity data based on your agency's or your state's own conditions.

Table 1. Range of pavement marking service life estimates.⁽²⁶⁾

Pavement Marking Material Type	Range of Service Life (Years)
Water-based paints	0.5 to 3.0
Alkyl-based paints	0.25 to 3.0
Epoxy	2.0 to 5.0
Thermoplastics	1.0 to 7.0
Preformed tapes	2.0 to 8.0
Methyl methacrylate	2.0 to 7.0
Polyurea	3.0 to 4.0

Linking Service Life to Retroreflectivity Maintenance Levels

Either historical retroreflectivity data or research results can be used with this method. Regardless of which is used, the expected service life period must be based on the MUTCD minimum levels or higher levels established by the agency with jurisdiction of the roadway. The markings are scheduled for replacement before they reach this point.

Advantages

The major benefit of using this method is that, in theory, there is no need to conduct field inspections once the service life estimates are generated. However, realizing the differences in weather from year to year and the differences in quality of pavement marking applications, it is advisable to conduct periodic retroreflectivity checks. It will be necessary to establish a management system so that the installation and replacement cycles can be properly administered.

For agencies with heavy winter maintenance activities that make annual or more frequent striping of their entire network a necessity, this method can be quite effective. Many northern agencies currently practice this maintenance method—restriping certain highway systems each year with water-based paint. However, these agencies might need to prioritize their restriping programs so that they replace their markings as soon as practical after winter conditions and consider which roadways may also warrant remarking in the fall. Analyzing historical data might also trigger consideration for using durable marking materials to keep marking retroreflectivity above the MUTCD levels for more of an entire year or even for multiple years at a time.

Concerns

One of the issues with this method is that the replacement times can vary depending on many factors. Having reliable service life numbers is important for obtaining the maximum benefit from this method. In addition, regional climate plays a critical role in the expected service life. Having local or regional service life data is important.

To use this method with durable markings, an agency needs several years of in-service pavement marking retroreflectivity data available to estimate the life of the markings. Many agencies have established in-house test decks or have contracted with researchers to design and monitor test decks. These activities are time consuming but essential in order to properly estimate the service life of durable pavement markings.

CHAPTER 7. SERVICE LIFE BASED ON MONITORED MARKINGS METHOD

Introduction

With this method, an agency documents pavement marking installation dates and periodically monitors the retroreflectivity of a representative sample of those markings as a way to track their durability. The agency uses these monitored markings to represent a larger group of similar markings in similar conditions. When the monitored markings degrade and approach the MUTCD minimum levels, the entire group of markings (both monitored and the larger group they represent) are restriped. This is an alternative method for agencies that want to use a service life method but do not have historical data or specific research supporting service life estimates for their region's specific conditions (i.e., their in-service life before falling below the MUTCD minimum levels).

Procedures

Because markings perform differently depending on several key factors, it is important to have monitored markings that represent a reasonable range of these key factors. Considering factors such as pavement marking type, binder material, retroreflective optics, pavement surface, snowplow operations, climate, and traffic volumes is appropriate because research shows that many of these are important factors for the service life of pavement marking retroreflectivity.^(25, 26) The key assumption with this method is that markings of similar type in similar conditions deteriorate at the same rate. Once an agency determines how to stratify the markings, it can monitor some of the markings in each of the stratified levels (rather than monitoring all markings).

To track the retroreflectivity of the monitored markings, the agency can use a computerized documentation technique, such as a spreadsheet listing the factors. Fully featured GIS systems can also be used. Either way, pavement markings of a similar type are grouped with roadways having similar conditions. Then, using a specific monitored roadway section or sections representing other roadway sections with similar characteristics, the agency tracks the retroreflectivity of that specific roadway section. The selected monitored representative section of roadway should include as many features and characteristics of the larger common group as feasible. When the monitored markings deteriorate and approach the MUTCD-established retroreflectivity level, the entire group of markings (both monitored and the larger group they represent) are restriped.

The preferred way to monitor markings is the measured retroreflectivity method. However, an agency may instead assess the monitored markings using either the calibrated pavement markings nighttime visual inspection method or the consistent parameters nighttime visual inspection method. The length of the roadway section(s) with the monitored markings needs to be long enough to provide a statistical representation of the larger group of markings they are meant to represent.

Linking Service Life to Retroreflectivity Maintenance Levels

When pavement marking service life is determined by monitoring in-service markings, they must be assessed at specified intervals to determine how they are performing with respect to the retroreflectivity levels set by the MUTCD. The trending retroreflectivity levels from the monitored markings can be used to schedule pavement marking replacement.

Advantages

This method involves the inspection of a subset of markings in the field that represent a larger group of markings. Agencies must track when each group of pavement markings was installed. Using this method, agencies can develop a thorough understanding of pavement marking retroreflectivity durability and adjust their policies as field data and pavement marking costs indicate. Compared to measuring pavement marking retroreflectivity for all longitudinal markings, this method minimizes the need to expose the inspector to traffic and reduces both data collection costs and data management needs.

After a period, an agency can use these data to develop service life values. When an agency determines the service life values for its pavement markings, it may transition to the service life based on historical data method (chapter 6).

Concerns

Agencies need to understand what factors or conditions to consider to group their markings appropriately and select a representative sample for each group of markings to determine when to replace the group of markings.

While this method has advantages, agencies need to determine how to group similar pavement markings and other key factors (such as those listed). In addition, agencies need to determine the sampling procedures for the monitored markings (such as those outlined in ASTM D7585^[18]) and the frequency of inspections. An important aspect of this method is that the pavement markings selected to be monitored must be installed on roadways representative of the agency's jurisdiction. Markings cannot be installed in the maintenance yard or another convenient area without traffic. Because pavement marking retroreflectivity is so closely tied to pavement surface types and traffic volumes, the control method as described for maintenance of traffic sign retroreflectivity is not an appropriate method for maintaining pavement marking retroreflectivity.

CHAPTER 8. FREQUENTLY ASKED QUESTIONS

This chapter provides some frequently asked questions (FAQs) and the corresponding answers. FHWA maintains visibility-related FAQs on the FHWA Office of Safety roadway departure nighttime visibility page, https://safety.fhwa.dot.gov/roadway_dept/night_visib/. The web page will be updated as additional FAQs are generated.

What Markings Are Subject to the Minimum Maintained Retroreflectivity Levels?

The minimum maintained retroreflectivity applies to all longitudinal pavement markings (i.e., center lines, lane lines, and edge lines) on roadways with posted speed limits of 35 mph or greater. This includes both temporary and permanent pavement markings. Agencies have the option to exclude markings where ambient illumination assures markings are adequately visible from their method. Also, markings on streets or highways that have an average daily traffic (ADT) of less than 6,000 vehicles per day may be excluded. In addition, dotted extension lines (per MUTCD Section 3B.08), curve markings, parking space markings, and shared-use path markings may be excluded from an agency's method.

Is a Retroreflectometer Required to Use the Pavement Marking Retroreflectivity Maintenance Methods Described in This Report?

Not necessarily. This report includes methods that do not require retroreflectivity measurements. Some methods only need access to a retroreflectometer for a short time to establish the retroreflectivity levels of reference markings. Alternatives to purchasing retroreflectometers include borrowing devices from LTAP centers or other agencies. Devices are also available for rent from some manufacturers. Additional information on handheld and mobile pavement marking retroreflectometers can be found in the FAQs on the FHWA Office of Safety roadway departure nighttime visibility page, https://safety.fhwa.dot.gov/roadway_dept/night_visib/.

Is an Inventory Necessary?

No. However, the benefits of having an inventory are described for each method in chapters 3 through 7 of this report.

Does an Inspector Need to Be at Least 60 Years Old?

Only for one method, the *consistent parameters nighttime visual inspection method*. This report includes several other methods that have no age requirements for inspectors.

Can I Use Any Vehicle for the Nighttime Inspection Methods?

No, the vehicle must be a passenger vehicle. It is also important to use low-beam headlamps during the inspections. For the consistent parameters method, a sedan is preferred because it most closely matches the research parameters. However, other passenger vehicles are acceptable, such as a sports utility vehicle or light truck.

Are Annual Inspections Frequent Enough?

Typically, yes, if an agency already has data showing rates of deterioration, although it might depend on the amount of traffic, snowplow operations, and durability of the marking materials. A good practice is to inspect more frequently until a database is built showing rates of deterioration to know if markings are providing adequate retroreflectivity throughout much of the year. Inspecting at a time of year when markings are typically near the end of their expected service life might assist in decisions regarding upgrading to longer-life marking materials.

Is Documentation of My Inspections Required?

No. Although it is not required, it is a good practice. Agencies that document their maintenance method and maintenance activities may realize benefits in terms of budgeting resources, defense against litigation, etc.

What If I Cannot Restore All Markings According to the Replacement Schedule?

The MUTCD requires the use of “a method designed to maintain retroreflectivity at or above...” If your implementation of the maintenance method is designed to maintain your markings above the minimum values, you would be considered to be in compliance with the standard. Unanticipated events may occur that cause delays in reapplication. If unanticipated events occur, compliance with the standard is still considered to be achieved as long as a reasonable course of action is taken to resume maintenance of minimum retroreflectivity in a timely manner according to your agency’s method(s), policies, and procedures. See paragraph 8 of 2009 MUTCD Section 3A.03.

Am I Allowed to Use Resources or Take Actions outside My Written or Documented Method and Still Be Considered in Compliance?

An agency is responsible for maintaining pavement markings regardless of whether the method is documented. While detailed documentation is useful for business practices and consistency, it is unlikely to address every event or circumstance. For example, an agency would be prudent to schedule reapplication of markings on sections of abnormal wear that are discovered during inspections or routine maintenance, even if that is not part of its written procedure or typical practice.

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APPENDIX A: FINAL RULE—PAVEMENT MARKING RETROREFLECTIVITY MUTCD TEXT

Add a row to Table I-2, Target Compliance Dates Established by FHWA:

2009 MUTCD Section Number(s)	2009 MUTCD Section Title	Specific Provision	Compliance Date
3A.03	Maintaining Minimum Retroreflectivity	Implementation and continued use of a method that is designed to maintain retroreflectivity of longitudinal pavement markings (see Paragraph 1)	4 years from the effective date of this revision of the MUTCD

Add a new reference document to Section 1A.11, Relation to Other Publications:

Section 1A.11

“Methods for Maintaining Pavement Marking Retroreflectivity,” (FHWA-SA-22-028), 2020 Edition (FHWA)

Revise Section 3A.03 as follows:

Section 3A.03 Maintaining Minimum Retroreflectivity

Standard:

01 Except as provided in Paragraph 5, a method designed to maintain retroreflectivity at or above 50 mcd/m²/lx under dry conditions shall be used for longitudinal markings on roadways with speed limits of 35 mph or greater.

Guidance:

02 Except as provided in Paragraph 5, a method designed to maintain retroreflectivity at or above 100 mcd/m²/lx under dry conditions should be used for longitudinal markings on roadways with speed limits of 70 mph or greater.

03 The method used to maintain retroreflectivity should be one or more of those described in “Methods for Maintaining Pavement Marking Retroreflectivity” (see Section 1A.11) or developed from an engineering study based on the values in Paragraphs 1 and 2.

Support:

04 Retroreflectivity levels for pavement markings are measured with an entrance angle of 88.76 degrees and an observation angle of 1.05 degrees. This geometry is also referred to as 30-meter geometry. The units of pavement marking retroreflectivity are reported in mcd/m²/lx, which means millicandelas per square meter per lux.

Option:

05 The following markings may be excluded from the provisions established in Paragraphs 1 and 2:

- A. Markings where ambient illumination assures that the markings are adequately visible;

- B. Markings on streets or highways that have an ADT of less than 6,000 vehicles per day;
- C. Dotted extension lines that extend a longitudinal line through an intersection, major driveway, or interchange area (see Section 3B.08);
- D. Curb markings;
- E. Parking space markings; and
- F. Shared-use path markings.

Support:

06 The provisions of this Section do not apply to non-longitudinal pavement markings including, but not limited to, the following:

- A. Transverse markings;
- B. Word, symbol, and arrow markings;
- C. Crosswalk markings; and
- D. Chevron, diagonal, and crosshatch markings.

07 Special circumstances will periodically cause pavement marking retroreflectivity to be below the minimum levels. These circumstances include, but are not limited to, the following:

- A. Isolated locations of abnormal degradation;
- B. Periods preceding imminent resurfacing or reconstruction;
- C. Unanticipated events such as equipment breakdowns, material shortages, and contracting problems; and
- D. Loss of retroreflectivity resulting from snow maintenance operations.

When such circumstances occur, compliance with Paragraphs 1 and 2 is still considered to be achieved if a reasonable course of action is taken to resume maintenance of minimum retroreflectivity in a timely manner according to the maintaining agency's method(s), policies, and procedures.

APPENDIX B: METHOD DEVELOPMENT

Getting Started

This appendix provides examples of how an agency might implement each of the maintenance methods described in the main body of this report. The method development examples provided here are geared toward smaller local agencies with limited expertise in developing and implementing a method.

Maintenance Methods

The *Manual on Uniform Traffic Control Devices* (MUTCD) requires agencies to use a method and recommends one or a combination of the methods described in the main body of this report. These methods are designed to help agencies continually maintain retroreflectivity of longitudinal pavement markings at or above the MUTCD specified minimum levels (i.e., the required minimum of 50 mcd/m²/lux and the recommended minimum of 100 mcd/m²/lux for higher speed roads). The primary outcome of each of these methods is the timely scheduling and replacing of all deficient markings whether measured, visually inspected, or scheduled based on service life. See Chapter 2 for a brief summary of the methods, and chapters 3 through 7 for more detail on each method.

Agencies will need to personalize the basic method they choose to make it work for their specific situation. The examples shown here are included to help agencies work through this process to document their agency-specific method. These examples refer to retroreflectivity thresholds that an individual agency can set higher than the appropriate minimum level in the MUTCD to assist in scheduling markings for replacement *before* they become deficient for nighttime driving visibility.

Regardless of how an agency chooses to maintain pavement marking retroreflectivity, documentation of the process can be beneficial for many reasons. Written procedures help ensure that agency personnel properly follow the selected method, and maintenance records provide the agency with a systematic process for scheduling replacements and justification for the allocation of limited resources.

Deciding Which Roads and Markings to Include in the Method

The first step for each agency is to determine if they have pavement markings that meet the criteria to which the standard in the MUTCD applies. Some agencies may not be required to have a method if they only own and maintain very low speed roads. Some may choose not to implement a method if all their roadways have adequate lighting or low volumes that allow for exclusion under the option. Check the MUTCD to determine whether your agency is required to implement a method, keeping in mind future changes such as growth in traffic volumes.

Markings to which the standard does not apply (e.g. roads with speed limit less than 35 mph) must still be retroreflective (see 2009 MUTCD Section 3A.02), but they can be excluded from an agency's pavement marking retroreflectivity maintenance method (Section 3A.03). To maintain adequate marking visibility on all roads open to public travel, agencies are encouraged to think

about and plan for the maintenance of markings that are not required by the MUTCD to be included in the maintenance method.

If an agency that does have pavement markings requiring a maintenance method decides to limit their method to certain roads and markings based on the flexibility in the standard, guidance, and option statements in the MUTCD, they will need to determine which roads and markings will not be included in the method. The following questions can help an agency decide which to include:

- Will roads with speed limits less than 35 mph be included?
- Will other longitudinal markings beyond center lines, edge lines, and lane lines be included (e.g. curb markings)?
- Will any non-longitudinal markings be included (e.g. crosswalks)?
- Will an average daily traffic (ADT) threshold be used to reduce the amount of roadway covered by the method? If so, will the threshold be lower than the 6,000 vpd allowed by the MUTCD option to account for future growth or based on crash data?
- Are there roadway segments that will be excluded because they have roadway lighting?

The various maintenance methods have different information needs, costs, and level of effort to implement. However, regardless of the method, agencies might find it beneficial to create an inventory (e.g., an electronic database is helpful) of the roadways and markings to be included in the maintenance method. Such an inventory could include, but not be limited to, the following:

- Road name/number.
- Section beginning and endpoint (e.g., milepost, section number, etc.).
- Roadway classification.
- Volume range or ADT.
- Speed limit.
- Pavement surface type.
- Winter maintenance activity level (e.g. frequency of plowing).
- Pavement marking material (i.e., substrate and retroreflective elements).
- Color and type of markings.
- Installation date.
- Installation method (i.e. applied to surface or inlaid).
- Limits of installation.

The inventory and some of the items listed above are more important to certain maintenance methods. That will be discussed under the examples for each method.

Table B1 provides a summary of the information and data needs for each maintenance method.

Table B1. Maintenance method information and data needs.

Information/Data Needs	METHOD				
	Measured Retroreflectivity	Consistent Parameters Nighttime Visual Inspection	Calibrated Pavement Markings Nighttime Visual Inspection	Service Life Based on Historical Data	Service Life Based on Monitored Markings
Roadway Sections and Markings to Include in the Maintenance Method	✓	✓	✓	✓	✓
Retroreflectivity Measurements	✓				+
Nighttime Visual Evaluation		✓	✓		*
Inspector 60 Years or Older		✓			*
Markings of Known Retroreflectivity (at or above minimum level)			✓		*
Historic Retroreflectivity Degradation Data or Marking Service Life Data				✓	
Database or Records of Marking Installation Information	+	+	+	✓	✓
Database or Records of Roadways/Markings with Similar Conditions and Characteristics	+	+	+	+	✓
Database or Records of Inspection Data and/or Findings	+	+	+		+

✓ = Essential

+ = Suggested

* = Alternative to suggested

Method Development: Measured Retroreflectivity

Method Definition

In this method, pavement marking retroreflectivity is measured and directly compared to the minimum levels in the MUTCD. The retroreflectivity measurements can be made with either handheld or mobile instruments (i.e., retroreflectometers) using the standard 30-meter geometry.

Measured Retroreflectivity Method

Inspectors should follow the instructions provided by the manufacturer to obtain reliable retroreflectivity readings, including periodically calibrating the equipment. Handheld retroreflectometers are placed on the pavement marking, while mobile retroreflectometers are attached to a vehicle and measure the pavement marking retroreflectivity as the instrumented vehicle is driven at typical roadway speeds. Both types of retroreflectometers provide objective retroreflectivity values that can be used in direct comparison to the MUTCD levels.

This example only covers the measured retroreflectivity method using a handheld retroreflectometer.

Method Needs

To successfully implement a measured retroreflectivity maintenance method that uses a handheld retroreflectometer, the following will be needed:

- Roadways and markings to be included in the maintenance method.
- Handheld retroreflectometer to use for measuring retroreflectivity.
- Marking retroreflectivity measurement plan.
- Trained inspector.

Method Implementation

This example includes potential steps for an agency to consider when establishing a measured retroreflectivity maintenance method for pavement marking retroreflectivity using a handheld retroreflectometer. Agencies are encouraged to customize the method to local conditions and agency practices.

1. Using the MUTCD and the information in the “Getting Started” section of this appendix, determine which markings will be included in your agency’s method. If the agency chooses to develop an inventory, specific information on the pavement marking materials, pavement type, and volume is not critical for the measured retroreflectivity method because all markings included in this maintenance method are measured. However, agencies might find it useful to gather such information to use in projecting when the markings will reach the minimum levels, so they can plan to have the markings replaced before that time. This information will also be valuable for evaluating the cost effectiveness of various marking materials and for future planning purposes. With this type of information, an agency can potentially reduce the number of miles to measure by measuring a representative sample of the markings included in the method or reducing the frequency of measurements on newer durable markings known to have retroreflectivity well above the appropriate minimum level.
2. Purchase or arrange to borrow a handheld retroreflectometer to use for measuring retroreflectivity if your agency does not have one.
3. Select a documentation procedure to record pavement marking retroreflectivity values and schedule the replacement of specific markings. This documentation and scheduling of replacement markings could be a list, spreadsheet, or database and might also include maps or geographic information system (GIS) components. Some retroreflectometers will

retain data such as measurements and averages, as well as latitude/longitude, however, the agency will likely want to keep records that are tied to specific markings and roads for use in making decisions about replacement schedules.

4. Provide inspector training or contract out the work. The company selling the retroreflectometer is best suited to provide training for proper use of the device. Specific calibration procedures and maintenance schedules for the equipment are important to follow to obtain accurate and repeatable measurements.
5. Establish a plan for conducting retroreflectivity measurements per *ASTM D7585/D7585M, Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments*.² Consider the following in your plan:
 - a. Establish the number of evaluation sections needed within each roadway segment to be measured. For example, in a 20-mile segment with similar markings and traffic volume, an agency might randomly select five individual miles that will be measured in a particular year.
 - b. Plan to take measurements at a time when the pavement will be dry.
 - c. Select the specific location of each evaluation section to be measured (e.g. the Milepost 1–2, 4–5, etc.). To reduce traffic control, it will likely be most efficient to use the same sections for edge lines as center lines.
6. Conduct field measurements using the following steps for each roadway section being evaluated.
 - a. Calibrate the retroreflectometer each day before beginning measurements and periodically check the calibration throughout the day.
 - b. Set-up appropriate MUTCD Part 6 compliant traffic control measures to provide safe conditions for inspectors.
 - c. Take 16 or more measurements at regular intervals within the evaluation section, ensuring the retroreflectometer is aligned with the direction of traffic appropriate to that line. If measuring a single center line, take measurements in both directions.
 - d. Document the individual readings and the average for the section.
 - e. Move to the next line (e.g., if measuring center and edge lines) or the next evaluation section.
7. Compare the average measurements with retroreflectivity thresholds chosen by your agency. Typically, thresholds are set above the MUTCD minimum levels so that markings are replaced *before* they reach the minimum level.
8. Schedule markings to be replaced as needed. Determine how best to prioritize replacement based on retroreflectivity levels, upcoming projects, and weather conditions that limit striping seasons.

² ASTM International. ASTM D7585/D7585M, Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments, 2015 is the current version and is available for purchase at <https://www.astm.org/Standards/D7585.htm>

Measured Retroreflectivity Method

9. Update the marking inventory as needed after restriping activities have occurred (e.g. if using a new type of material and tracking service life).
10. Assess and update the maintenance method and supporting information as necessary. Consider if additional roadways and their markings need to be added.

Examples

Figure B1 shows an example of a map that could be developed by a local agency to depict the roadway segments (dashed black lines) with markings that need to be included in the maintenance method. Figure B2 shows all of the roadway segments (short dashed green lines) that are being evaluated with retroreflectivity measurements within the next year. In this example the remaining roadway segments will not be evaluated this year because they are already scheduled for restriping or are not planned for retroreflectivity evaluation for at least another year (due to the use of durable pavement markings that were recently installed and retroreflectivity verified). These maps could be produced in conjunction with a spreadsheet database. The results of the retroreflectivity evaluations would be compared to the appropriate MUTCD minimum level or agency threshold and scheduled for restriping as necessary.

An inventory example is shown in Table B2. Each roadway to which the method applies would be included, although the example only shows a small sample. The data collected in the field, such as inspection dates and corresponding retroreflectivity measurements, are used to update the inventory. Planned restriping activities or the next anticipated inspection date would be helpful to include as well. The inventory can group similar roadway types or be organized according to a planned inspection route to make implementing the method easier. The spreadsheet could be supplemented or replaced with a GIS database or map system.



Figure B1. Diagram. Roadways to be included in the method.

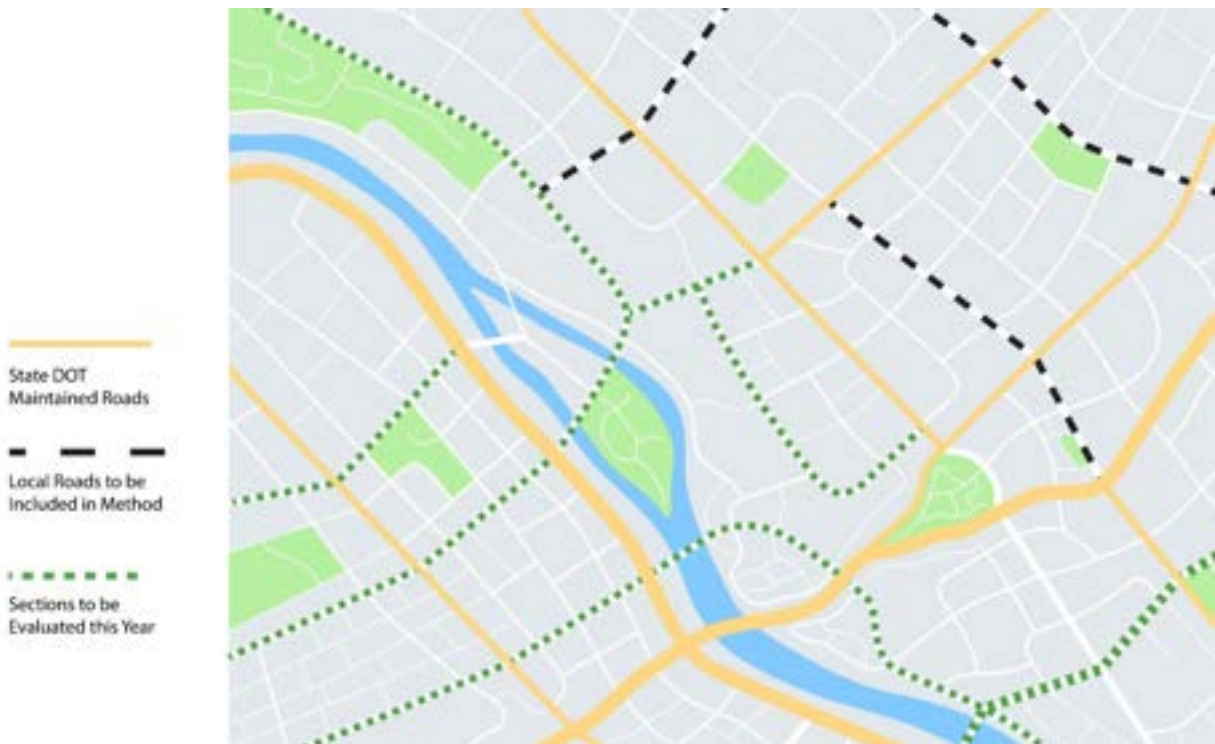


Figure B2. Diagram. Roadways included in method and evaluated this year.

Table B2. Spreadsheet example of roadway database for measured retroreflectivity.

Road Name (Segment Identification ³)	Segment Length and Limits	Functional Classification	Traffic Volume (ADT)	Speed Limit (mph)	Pavement Surface	Pavement Marking Material ⁴	Winter Maintenance	Line Type(s)	Installation Date	Previous Retroreflectivity Measurement and Date Evaluated	Next Retroreflectivity Measurement Date	Scheduled for Restriping ⁵	Notes ⁶
Main St., Upshaw County	0.8 miles (Bambino Ln to Rt 30)	Local	9,500	45	asphalt	water-based paint, 15 mils, AASHTO M247 Type I beads	None	edge lines, center lines, lane lines	4/14/19	March 2020, white = 85, yellow = 60	None, schedule for restripe	Yes	
Route 202 (Control Section 1-66)	7.6 miles (US 28 to Jansen Dr.)	Minor Arterial	10,000	50	asphalt	spray thermoplastic	None	edge lines, lane lines	5/17/19	None	Fall 2020	No	Expected service life over 2 years
Jansen Drive, Upshaw County	3 miles (Main St. to Ret 202)	Local	6,000	40	asphalt	water-based paint	None	edge lines, center lines	4/15/19	March 2020, white = 120, yellow = 105	Late 2020	No	Has overhead lighting, keep on retro monitoring program
...
...

³ Unique road segment identifier (if used by agency).

⁴ Marking binder and reflective optic types, material thickness, application methods, etc.

⁵ Has the section been scheduled for restriping?

⁶ Include notable site characteristics and other notes.

Method Development: Consistent Parameters Nighttime Visual Inspection

Method Definition

In this method, an agency conducts nighttime visual inspections without the need for specific calibrated markings or retroreflectivity measurements. This method relies on the judgment of a trained inspector who is at least 60 years old. The minimum retroreflectivity levels outlined in the MUTCD are based on research that evaluated the visibility needs of 90 percent of drivers, which corresponds to a 62-year-old. The pavement marking visibility viewed by an inspector who is 60 years or older can be thought of as a surrogate for maintained retroreflectivity that meets the needs of drivers.

Method Needs

To successfully implement a consistent parameters nighttime visual inspection method, the following will be needed:

- Roadways and markings to be included in the method.
- Inspection vehicle with properly aligned low-beam headlamps.
- Trained inspector (age 60 years or over).
- Driver.

Method Implementation

This example includes potential steps for an agency to consider when establishing a consistent parameters nighttime visual inspection method for pavement marking retroreflectivity. Agencies are encouraged to customize the method to local conditions and agency practices.

1. Using the MUTCD and the information in the “Getting Started” section of this appendix, determine which markings will be included in your agency’s method. If your agency chooses to create an inventory, the most critical information will be the location identifier and the type of markings (i.e., edge line, center line, and lane line) so that your inspector can document which markings need to be replaced. It is worth noting the presence of raised reflective pavement markers (RRPMs) since visual inspections of pavement markings supplemented with RRPMs can be difficult. The brightness of RRPMs in good condition is usually much greater than that of the pavement markings, and therefore it can be difficult to judge the pavement marking retroreflectivity. Other information, such as the type of pavement marking material, can be useful if your agency is using the information from the inspections for future planning.
2. Select a documentation technique to track/schedule the replacement of specific markings. This tracking and scheduling of replacement markings can be a list, spreadsheet, or database and might also include maps or GIS components.
3. Select the vehicle to be used for inspection. The inspection vehicle can be any type of passenger vehicle, although a passenger car is preferred because it most closely matches the research parameters. Check the vehicle to ensure that the low-beam headlamps are

properly aligned prior to performing inspections (see Figure 5 in the main body of this report).

4. Select the inspection crew. This method is typically conducted using a two-person crew. While the driver (of any age) focuses on the driving task, the inspector (age 60 or older) evaluates the pavement markings and records the appropriate information. Although the view of the pavement markings is not the same for the passenger as the driver, it is similar, and the safety of the inspection process is important. Therefore, the use of a two-person crew is a practical and safe way to conduct an inspection using this method. The observation is made through the windshield of the vehicle at the normal travel speed of the roadway using low-beam headlamps.
 - Note: An alternative to a two-person crew is to use one person with a tape recorder or mounted camcorder for recording notes. The retroreflectivity assessments need to be made by the inspector at the time of the inspection. Video recordings are not to be used later for determining the condition of the markings because video technology is not yet proven to provide the necessary quality to be used in assessing retroreflectivity.
5. Conduct inspector training. Agency specific inspector guidelines and procedures can help to ensure consistent inspections. While there is currently no nationally recognized training course or certification for pavement marking inspectors, agencies are encouraged to provide some form of training for inspectors before they perform nighttime inspections. Elements of the training might include:
 - a. Purpose and objectives of the inspection.
 - b. Critical inspection techniques and cautions for improper techniques.
 - c. Types of markings to evaluate.
 - d. When to conduct the inspection.
 - e. Documentation.
 - f. Safety.
 - g. Equipment.
 - h. Appropriate agency policies and procedures.
 - i. How to rate in-service markings to provide adequate information to determine scheduling for markings (e.g. need immediate replacement, replace before winter).
6. Develop the route plan, considering pavement markings that are not adjacent to the inspection vehicle cannot be evaluated during a visual inspection. As a result, one pass in each direction is needed for two-lane roads and more than one pass is needed per direction to inspect all longitudinal markings on multilane roads.
7. Perform the nighttime visual inspection.
 - a. The ambient conditions must be dark—at least 30 minutes beyond sunset—and the condition of the pavement must be dry during the inspection.
 - b. The inspector observes the pavement markings through the windshield of the vehicle at the normal travel speed of the roadway using low-beam headlamps.

Consistent Parameters Nighttime Visual Inspection Method

- c. The inspector rates each marking adjacent to the vehicle, considering whether it can be seen far enough in advance to make appropriate decisions and maneuvers at normal driving speeds. The inspector uses a dimmed⁷ light or a computer dimmed for nighttime viewing to take notes to avoid corrupting the inspection process by in-vehicle illumination that would impact proper viewing of the roadway and pavement markings.
8. Schedule markings to be replaced, as needed, based on the inspector's rating. Determine how best to prioritize replacement based on ratings, upcoming projects, and weather conditions that limit striping seasons.
9. Update the marking inventory as needed after restriping activities have occurred (e.g. to indicate date markings were replaced and type of material used).
10. Assess and update the maintenance method and supporting information as needed. Consider if additional roadways and their markings need to be added.

Examples

Table B3 shows a hypothetical example of an inspection data collection sheet that could be used by inspectors. The sheet indicates the general location of the nighttime inspection, who conducted the inspection, what vehicle was used, and when the inspection occurred. Each row indicates a homogeneous roadway section in a specific travel direction. The inspector indicates the rating for markings and records notes on each section as appropriate.

An inventory example is shown in Table B4. Each roadway to which the method applies would be included, although the example only shows a small sample. Field data such as evaluation dates and corresponding inspection ratings are used to update the inventory. Planned restriping activities or the next anticipated evaluation date would be helpful to include as well. The inventory can be organized according to planned inspection routes or similar roadway types to make implementing the method easier. The spreadsheet could be supplemented or replaced with a GIS database or map system.

⁷ A red dimmed light is preferable over a white light to reduce the impact on the observer's night vision.

Table B3. Example inspection data collection sheet for consistent parameters nighttime visual inspection.

Pavement Marking Retroreflectivity Inspection Report							
Inspector Name: J. Garcia			Inspector Age: 62		Agency/Location: Washington County, central section		
Driver: A. Smith			Vehicle Number: 24		Date: 3/25/2021		Time: 8:30 pm to 11:00 pm
Roadway	Section Identifier	Section Limits	Travel Direction	MARKING RATING ⁸			Notes
				Center Line or Left Edge Line (yellow)	Lane Line (white)	Right Edge Line (white)	
CR 11	3A	CL to MP4	EB	A	N/A ⁹	A	
CR 11	3B	MP4 to MP7	EB	B	N/A	A	
CR 11	3C	MP7 to MP12	EB	B	N/A	B	
CR 11	3D	MP12 to I-11	EB	A	N/A	B	RPMs present
Main St.	N/A	All	NB	D	D	D	Right edge captured on 2nd pass
Main St.	N/A	All	SB	F	F	D	Right edge captured on 2nd pass
Green Ln.	N/A	All	NB	C	N/A	B	
Green Ln.	N/A	All	SB	C	N/A	B	Contrast with pavement is not good
CR 6	N/A	All	SB	C	N/A	N/A	Yellow marking color is fading
CR 6	N/A	All	NB	D	N/A	N/A	Close to failing

⁸ Ratings: A = Excellent, B= Very good, C= Acceptable, D = Marginal, F = Fail.

⁹ Not applicable because marking type was not present (e.g. no lane lines on two-lane, two-way road or no edge lines on two-lane road).

Table B4. Spreadsheet example of roadway database for consistent parameters nighttime visual inspection.

Road Name (Segment Identification ¹⁰)	Segment Length and Limits	Functional Classification	Traffic Volume (ADT)	Speed Limit (mph)	Pavement Surface	Pavement Marking Material	Marking Thickness	Reflective Optics	Winter Maintenance	Line Type(s) ¹¹	Installation Date	Scheduled for Restriping?	Previous Inspection Rating ¹² and Date Evaluated	Notes ¹³
Main Street	2.6 miles (Justin Blvd to 14 th Ave)	Minor Arterial	11,000	50	asphalt	water-based paint	15 mils	AASHTO M247 Type I	Low	EL, CL, LL	4/14/19	No	All Very Good, March 2020	
Main Street	1.7 miles (14 th Ave to city limit)	Minor Arterial	7,200	50	asphalt	water-based paint	15 mils	AASHTO M247 Type I	Low	EL, CL, LL	4/14/20	No	None	
University Drive	4.2 miles (Rte 1 to Rte 18)	Major Arterial	17,000	40	asphalt	spray thermoplastic	90 mils	Double Drop Type II and III	Low	EL, CL, LL	5/18/19	Spring 2021	White Marginal, Yellow Fail March 2020	Has overhead lighting, keep on retro monitoring program.
14 th Ave	0.5 miles (Main St to Jay St)	Local	5,500	35	asphalt	water-based paint	15 mils	AASHTO M247 Type I	None	CL	8/14/19	No	White Acceptable, Yellow Marginal March 2020	Include in method due to expected increase in ADT
...
...
...

¹⁰ Unique road segment identifier (if used by agency).

¹¹ CL = center line, EL = edge line, LL = lane line.

¹² Ratings: Excellent, Very Good, Acceptable, Marginal, Fail.

¹³ Include notable site characteristics or other notes.

Method Development: Calibrated Pavement Markings Nighttime Visual Inspection

Method Definition

In this method, an agency conducts nighttime visual inspections using a trained inspector's perception of pavement marking retroreflectivity levels in the field. With this method, the trained inspector views calibrated pavement markings of known retroreflectivity at night prior to conducting a nighttime visual inspection. The calibrated pavement markings are set up where the inspector can view them in a manner similar to the conditions of the nighttime visual inspections. The inspector uses the appearance of the calibrated markings as a benchmark to rate in-service markings.

Method Needs

To successfully implement a nighttime visual inspection method that uses calibrated markings, the following will be needed:

- Roadways and markings to be included in the method.
- Calibration markings at or above the MUTCD minimum level(s) or agency threshold(s).
- Inspection vehicle (any type) with properly aligned low-beam headlamps.
- Trained inspector (a specific age is not required).
- Driver.

Method Implementation

This example includes potential steps for an agency to consider when establishing a calibrated pavement markings nighttime visual inspection method. Agencies are encouraged to customize the plan to local conditions and agency practices.

1. Using the MUTCD and the information in the "Getting Started" section of this appendix, determine which markings will be included in your agency's method. If the agency chooses to create an inventory, the most critical information will be the location identifier and the type of markings (i.e., edge line, center line, and lane line) so that the inspector can document which markings need to be replaced. It is worth noting the presence of RRPMS since visual inspections of pavement markings supplemented with RRPMS can be difficult. The brightness of RRPMS in good condition is usually much greater than that of the pavement markings, and therefore it can be difficult to judge the pavement marking retroreflectivity. Other information, such as the type of pavement marking material, can be useful if the agency is using the information from the inspections for future planning.
2. Select a documentation technique to track/schedule replacement of specific markings. This tracking and scheduling of replacement markings can be a list, spreadsheet, or database and might also include maps or GIS components.
3. Establish calibration markings.
 - a. The retroreflectivity levels of the calibration markings are checked before each cycle of inspections. Typically, calibration markings are higher than the MUTCD

minimum level to allow time to schedule needed replacement of markings identified in the inspection *before* they reach the minimum level.

- b. The calibration markings include both yellow and white markings and are positioned accordingly (e.g., for a two-lane, two-way roadway, white on the right and yellow on the left).
 - c. The calibration markings are located in an area without significant external ambient lighting (e.g. street or parking lot lighting) so that the visual calibration is not impacted by these light sources. A location central to the markings being inspected (especially the first night of a cycle of inspections) is helpful so that the inspector can come back and visually recalibrate during the night's inspection if needed.
 - d. If the calibration pavement markings are installed specifically for this purpose, the contractor or installer will need to make special provisions to apply pavement markings near the desired levels. This will take some trial and error because the levels will be much lower than typical new pavement markings. However, it can generally be achieved by controlling truck speed and bead load rates. If needed, retroreflectivity can be lowered by applying a clear coat of polyurethane, acrylic, or other similar product.
 - e. The calibration markings can be viewed in a static or dynamic condition.
 - i. If the calibration markings are set up to be viewed in a static condition, the calibration markings should be at least 10 feet long and the inspection vehicle positioned 100 feet in advance of the calibration markings. This replicates the 30-meter geometry used in retroreflectometer measurements.
 - ii. If the calibration markings are to be used in a dynamic condition, they should be long enough to provide the inspector at least 15 seconds of viewing time to study the brightness of the marking. This means that the length of calibration markings to be used in dynamic conditions varies with the speed. The intended speed of the inspection vehicle during calibration can be used to calculate the length of calibration markings needed. If the agency has pavement markings on roads open to public travel that are known to be at or above the MUTCD specified minimum levels, these markings can be used as calibration markings. However, in this case, the calibration process is performed at the posted or operating speed, which might necessitate a significant length of calibration marking. For example, at 60 mph, calibrated markings at least one-quarter mile long are needed to provide enough viewing time for the inspector to calibrate his or her eyes.
4. Select the vehicle to be used for inspection. Any size vehicle can be used as long as it is also used in the calibration process. Check the vehicle to ensure that the low-beam headlamps are properly aligned prior to performing calibration or inspections (see Figure 5 in the main body of this report).
 5. Select inspection crew. This method is typically conducted using a two-person crew. While the driver focuses on the driving task, the inspector evaluates the pavement

markings and records the appropriate information. Although the view of the pavement markings is not the same for the passenger as the driver, it is similar, and the safety of the inspection procedure is important. Therefore, the use of a two-person crew is a practical and safe way to conduct an inspection using this method. The observation is made through the windshield of the vehicle at the normal travel speed of the roadway using low-beam headlamps.

- Note: An alternative to a two-person crew is to use one person with a tape recorder or mounted camcorder for recording notes. The retroreflectivity assessments need to be made by the inspector at the time of the inspection. Video recordings are not to be used later for determining the condition of the markings because video technology is not yet proven to provide the necessary quality to be used in assessing retroreflectivity.
6. Conduct inspector training. Agencies are encouraged to provide some form of training for pavement marking inspectors before they perform nighttime inspections despite the current lack of recognized training or certifications. Elements of the training might include:
 - a. Purpose and objectives of the inspection.
 - b. Critical inspection techniques and cautions for improper techniques.
 - c. Types of markings to evaluate.
 - d. When to conduct the inspection.
 - e. Documentation.
 - f. Safety.
 - g. Equipment.
 - h. Appropriate agency policies and procedures.
 - i. How to rate in-service markings using this method.

A helpful element of the training for this method is to have inspectors observe sample pavement markings at a variety of known retroreflectivity levels, including levels near the MUTCD minimum levels. This type of training provides the inspector experience recognizing differences between various retroreflectivity levels. Inspectors benefit from training at night using the vehicle that will be used during the inspection.

7. Establish inspection routes. Where multiple retroreflectivity thresholds are used (e.g. for roads with speed limits 70 mph or higher), plan routes by separating higher-speed roads from lower-speed roads so that the inspector's eyes are calibrated for the correct retroreflectivity threshold for the route.
8. Perform the nighttime visual inspection.
 - a. The ambient conditions must be dark—at least 30 minutes beyond sunset—and the condition of the pavement must be dry during the calibration and during the inspection.
 - b. The inspector views the calibration markings from the vehicle to be used for the inspection before each night's inspection begins.
 - iii. For a static calibration, the inspector parks the inspection vehicle about 100 feet in front of a designated part of the calibration markings (e.g. a

- specific broken line of an existing lane line or the center of a 10 foot portion) and commits to memory the appearance (i.e., brightness) of the calibrated markings from the seat he/she will be inspecting the markings.
- iv. For a dynamic calibration, the inspector determines an appropriate speed or range of speeds for the night's inspection, calculates a 15 second viewing distance at that speed (e.g. $15 \text{ seconds} \div 3600 \text{ second/hr} \times 50 \text{ mph} \times 5280 \text{ ft/mile} = 1100 \text{ ft}$), and finds an appropriate reference point in the vehicle to assist in maintaining his/her focus at that distance. The driver then navigates the calibration markings at the appropriate speed while the inspector commits to memory the appearance (i.e., brightness) of the calibrated markings while focused at that distance. More than one pass of the calibration markings can be beneficial.
 - c. The driver navigates the planned inspection route while the inspector rates in-service markings adjacent to the vehicle, considering whether markings appear brighter than the calibration markings, nearly the same, or less bright. The inspector uses a dimmed¹⁴ light or a computer dimmed for nighttime viewing to take notes to avoid corrupting the inspection process by in-vehicle illumination that would impact proper viewing of the roadway and pavement markings.
9. Schedule markings to be replaced as needed using the inspector's ratings. Determine how best to prioritize replacement based on ratings, upcoming projects, and weather conditions that limit striping seasons.
 10. Update the marking inventory as needed after restriping activities have occurred.
 11. Assess and update the calibration and inspection process as needed (e.g. recommended timeframe to borrow retroreflector so that calibrated markings can be measured and refreshed, if necessary, before the next inspection cycle). Consider if additional roadways and their markings need to be added.

Examples

Table B5 shows a hypothetical example of an inspection data collection sheet that could be used by inspectors. The sheet indicates the general location of the nighttime visual inspection, who conducted the inspection, what vehicle was used, and when the inspection occurred. Each row indicates a homogeneous roadway section in a specific travel direction. The inspector rates each section and records notes on each section as appropriate.

An inventory example is shown in Table B6. Each roadway to which the method applies would be included, although the example only shows a small sample. Field data such as evaluation dates and corresponding inspection ratings are used to update the inventory. Planned restriping activities or the next anticipated evaluation date would be helpful to include as well. The inventory can be organized according to a planned inspection route to make implementing the

¹⁴ A red dimmed light is preferable over a white light to reduce the impact on the observer's night vision.

Calibrated Pavement Markings Nighttime Visual Inspection Method

method easier. The spreadsheet could be supplemented or replaced with a GIS database or map system.

Table B5. Example survey data collection sheet for calibrated pavement markings nighttime visual inspection.

Pavement Marking Retroreflectivity Inspection Report							
Inspection Date: 4/11/2021				Agency/Location: Lincoln County, north of Rum River			
Calibration Time: 9:00 pm		Inspection Time: 9:45 pm–1:00 am		Calibration Marking Measurement Date: 4/1/2021			
Inspector: L. Nguyen			Inspector Age: 48		Calibration Marking Levels ¹⁵ :		White: 113 mcd/m ² /lux
Driver: D. Wright			Vehicle Number: 11				Yellow: 106 mcd/m ² /lux
Roadway	Section Identifier	Limits	Travel Direction	MARKING RATING ¹⁶			Notes
				Center Line or Left Edge Line (yellow)	Lane Line (white)	Right Edge Line (white)	
CR 11	3A	CL to MP4	EB	P	N/A ¹⁷	P	
CR 11	3B	MP4 to MP7	EB	P	N/A	P	
CR 11	3C	MP7 to MP12	EB	M	N/A	M	
CR 11	3D	MP12 to I-35	EB	P	N/A	M	RPMs present on center line
CR 11	3A	CL to MP4	WB	M	N/A	P	
CR 11	3B	MP4 to MP7	WB	M	N/A	P	
CR 11	3C	MP7 to MP12	WB	M	N/A	M	
CR 11	3D	MP12 to I-35	WB	P	N/A	M	RPMs present on center line
Main St.	N/A	All	NB	F	F	F	Right edge captured on 2nd pass
Main St.	N/A	All	SB	F	F	F	Right edge captured on 2nd pass
Green Ln.	N/A	All	NB	M	N/A	M	Markings are dirty
Green Ln.	N/A	All	SB	M	N/A	M	Markings are dirty
CR 6	N/A	All	SB	M	N/A	N/A	Yellow marking color is fading
CR 6	N/A	All	NB	M	N/A	N/A	Close to failing

¹⁵ Measured retroreflectivity of calibration markings.

¹⁶ Ratings: P = Pass, M = Marginal, F = Fail.

¹⁷ Not applicable because marking type was not present (e.g. no lane lines on two-lane, two-way road or no edge lines on two-lane road).

Table B6. Spreadsheet example of roadway database for calibrated pavement markings nighttime visual inspection.

Road Name (Segment Identification ¹⁸)	Segment Length and Limits	Functional Classification	Traffic Volume (ADT)	Speed Limit (mph)	Pavement Surface	Pavement Marking Material	Marking Thickness	Reflective Optics	Winter Maintenance	Line Type(s) ¹⁹	Installation Date	Scheduled for Restriping?	Previous Inspection Rating ²⁰ and Date Evaluated ²¹	Notes ²²
Main Street	2.6 miles (Justin Blvd to 14 th Ave)	Minor Arterial	11,000	50	asphalt	water-based paint	15 mils	AASHTO M247 Type I	Low	EL, CL, LL	4/14/20	Yes	All Very Good, March 2020	
Main Street	1.7 miles (14 th Ave to city limit)	Minor Arterial	7,200	50	asphalt	water-based paint	15 mils	AASHTO M247 Type I	Low	EL, CL	4/14/20	May 2021	None	
University Drive	4.2 miles (Rte 1 to Rte 18)	Major Arterial	17,000	40	asphalt	spray thermoplastic	90 mils	Double Drop Type II and III	Low	EL, CL, LL	5/18/19	No	White Marginal, Yellow Fail March 2020	Has overhead lighting, but keep on monitoring program
14 th Ave	0.5 miles (Main St to Jay St)	Local	5,500	35	asphalt	water-based paint	15 mils	AASHTO M247 Type I	None	CL	8/14/20	Yes	White Acceptable, Yellow Marginal March 2020	Include in method due to expected increase in ADT Replace before winter
...
...
...

¹⁸ Unique road segment identifier (if used by agency).

¹⁹ CL = center line, EL = edge line, LL = lane line.

²⁰ Ratings: Excellent, Very good, Acceptable, Marginal, Fail.

²¹ Link inspection data sheets to the database.

²² Include notable site characteristics and other notes.

Method Development: Service Life Based on Historical Data

Method Definition

In this method, an agency documents pavement marking installation dates and, using historical retroreflectivity data and/or research results, develops a schedule for replacing the markings before they reach their end of service life. This schedule is designed to maintain the pavement marking retroreflectivity at or above the MUTCD minimum retroreflectivity levels. Using this method, agencies can set pavement marking replacement schedules for markings with similar characteristics in similar conditions.

Method Needs

To successfully implement a maintenance method that uses marking service life based on historical data, the following will be needed:

- Roadway sections and markings to be included in the maintenance method.
- Historical (or research) data on how long pavement markings materials used by the agency last under similar weather and traffic conditions before reaching a predetermined retroreflectivity level.
- Pavement marking information.

The historic service life data is unique to this maintenance method. Having reliable service life information applicable to local conditions and the material type and thickness used might be a concern when selecting this method. Variations in weather and marking installation quality also impact the expected service life of the markings and need to be taken into consideration. Potential sources of this data include state or other agency databases, marking guidance, or research reports. Another way to obtain accurate service life data is to use the monitored markings service life method or the measured markings method for a few years, then switch to the historical service life method when enough data has been collected to accurately predict service life. However, if the agency changes marking materials, another round of monitoring or measuring might be needed to obtain historical service life for the new materials.

Method Implementation

This example includes potential steps for an agency to consider when establishing a service life based on the historical data maintenance method for pavement marking retroreflectivity. Agencies are encouraged to customize the method to local conditions and agency practices.

1. Using the MUTCD and the information in the “Getting Started” section of this appendix, determine which markings will be included in your agency’s method. Regardless of whether or not the agency chooses to develop an inventory, for this method, it is essential to have records of when specific markings were installed. Particularly useful information in an inventory would include installation location, date, marking type, pavement surface, traffic volume, and expected weather conditions. Other pavement marking and roadway specific information will also be important to determining the appropriate service life. Marking service life is generally dependent on:
 - a. Pavement marking type (e.g., binder, thickness, inlay, and optics).
 - b. Pavement surface.

Service Life Based on Historical Data Method

- c. Use/frequency of snowplow operations.
 - d. Traffic volumes.
 - e. Climate.
2. Select a documentation technique to track and schedule the replacement of specific markings. This tracking and scheduling of replacement markings can be a list, spreadsheet, or database and might also include maps or GIS components.
3. Document historical or research data on retroreflectivity levels and marking service life for conditions and materials similar to those under your agency's jurisdiction.
 - a. Use marking and roadway characteristic data to estimate the marking service life as accurately as possible for the marking materials used and roadway conditions.
 - b. Use the expected service life from the historical or research data to determine when markings of each type, color, etc. will likely reach the appropriate MUTCD minimum level or higher threshold established by the agency. Chapter 6 of this report provides some general ranges of expected marking service life; however, local conditions will determine expected service life in your method. If adequate expected service life data are not available for local conditions, consider using another maintenance method until adequate data are established.
4. Develop groupings that have the same marking materials on roadways with similar characteristics. These groupings will all use the same expected service life and will be restriped at the same intervals. That does not necessarily mean all roadways with markings in the same grouping will be striped the same year. The installation of the markings could be staggered initially to spread out initial and subsequent restriping costs.
5. Review installation dates to determine the age of each group of markings and compare to the expected service life determined based on historical or research data.
6. Schedule markings to be replaced *before* they reach the end of their service life. Determine how best to prioritize replacement based on years in service, upcoming projects, and weather conditions that limit striping seasons.
7. Update the marking inventory as needed after restriping activities have occurred (e.g. to indicate date markings were replaced and type of material used). Update roadway groupings if new marking materials were used or if conditions have changed.
8. Assess and update the maintenance method and supporting information, as necessary. Consider if additional roadways and their markings will be added. Revise service life information and restriping schedules as new historical/research information becomes available.

Examples

Table B7 shows a hypothetical example of the type of historical data an agency could use in developing a catalog of pavement marking service life data for use with this method. The data provided are hypothetical; please do not use for purposes beyond this example. The service life for a particular marking under your local conditions might be longer or shorter than the times listed in the table for the conditions described.

An inventory example is shown in Table B8. Each roadway to which the method applies would be included, although the example only shows a small sample. Roadways with similar

Service Life Based on Historical Data Method

characteristics and similar markings can be grouped together to make identifying the expected service life easier. Planned restriping activities are included to update the inventory. The spreadsheet could be supplemented or replaced with a GIS database or map system.

Table B7. Hypothetical example of expected pavement marking service life (Do not use these values—example only).

Historical Data for Pavement Marking Service Life (Clay County)							
Service Life Grouping	Pavement Marking Type	Pavement Surface	ADT range	Use/Frequency of Snowplow Operations	Service Life to reach R _L 50 mcd/m ² /lux	Data Source/ Date	Notes
Paint, Asphalt 1	Water-based paint, 15 mil, Type I beads	Asphalt	3,000–5,000	None	Yellow—18 months	Route 5 Test Area, Clay County: 5/2017	No data for white, expected to be equal to or greater than yellow. Source data from local testing.
Paint, Asphalt 2	Water-based paint, 15 mil, Type I beads	Asphalt	5,000–8,000	None	White—16 months Yellow—16 months	Route 5 Test Area, Clay County: 5/2017	Source data from local testing.
Paint, Asphalt 3	Water-based paint, 15 mil, Type I beads	Asphalt	10,000–20,000	None	White—14 months Yellow—12 months	Durango Parkway Monitored Markings, Clay County: 7/2016	Source data from past monitored markings area.
Paint, Asphalt 4	Water-based paint, 15 mil, Type I beads	Asphalt	5,000–8,000	Medium, 5-10 times/year	White—12 months Yellow—12 months	Mountain Pass Test Area, Union County: 5/2018	Adjacent county with results on snow plowed roads.
Paint, Concrete 1	Water-based paint, 15 mil, Type I beads	Concrete	15,000–25,000	None	White—12 months Yellow—12 months	Northern Blvd Monitored Markings, Clay County: 9/2016	Source data from past monitored markings area.
Thermoplastic, Asphalt 1	Thermoplastic, 90 mil, double drop Type II and III beads	Asphalt	6,000–8,000	None	White—48 months Yellow—44 months	Main Street Monitored Markings, Clay County: 8/2019	Source data from past monitored markings area.
Thermoplastic, Asphalt 2	Thermoplastic, 90 mil, double drop Type II and III beads	Asphalt	10,000–20,000	None	White—42 months Yellow—40 months	State Research Report B-1141: 8/2017	Apply state level data to local roads with similar markings and traffic conditions.
Thermoplastic, Asphalt 3	Thermoplastic, 90 mil, double drop Type II and III beads	Asphalt	20,000–30,000	Low, 3-5 times/year	White—36 months Yellow—36 months	State Research Report B-1141: 8/2017	Apply state level data to local roads with similar markings and traffic conditions.
Thermoplastic, Concrete 1	Thermoplastic, 90 mil, double drop Type II and III beads	Concrete	30,000–40,000	None	White—36 months Yellow—36 months	State Research Report B-1141: 8/2017	Apply state level data to local roads with similar markings and traffic conditions.

Table B8. Spreadsheet example of roadway database for service life based on historical data (hypothetical data).

Road Name (Segment Identification ²³)	Segment Length and Limits	Functional Classification	Traffic Volume (ADT)	Speed Limit (mph)	Pavement Surface	Pavement Marking Material	Marking Thickness	Reflective Optics	Winter Maintenance	Line Type(s) ²⁴	Installation Date	Expected Service Life ²⁵ (Service Life Grouping)	Expected Replace by Date ²⁶	Scheduled for Restriping ²⁷	Notes ²⁸
Main Street	2.6 miles (Justin Blvd to 14 th Ave)	Minor Arterial	11,000	50	asphalt	water-based paint	15 mils	AASHTO M247 Type I	Low	EL, CL, LL	4/14/20	W ²⁹ —12 months, Y—12 months Paint Asphalt 3	4/14/21	Spring contract	
Main Street	1.7 miles (14 th Ave to city limit)	Minor Arterial	7,200	50	asphalt	water-based paint	15 mils	AASHTO M247 Type I	Low	EL, CL	4/14/20	W—12 months, Y—12 months Paint Asphalt 4	4/14/21	Spring contract	
University Drive	4.2 miles (Rte 1 to Rte 18)	Major Arterial	17,000	40	asphalt	spray thermoplastic	90 mils	Double Drop Type II and III	Low	EL, CL, LL	5/18/19	W—36 months, Y—36 months Thermoplastic Asphalt 3	5/18/22	No	Has overhead lighting, but keep on monitoring program
14th Ave	0.5 miles (Main St to Jay St)	Local	5,500	35	asphalt	water-based paint	15 mils	AASHTO M247 Type I	None	CL	8/14/20	Y—16 months Paint Asphalt 2	12/14/21	Fall contract	Include in method due to expected increase in ADT Replace before winter
...
...

²³ Unique road segment identifier (if used by agency).

²⁴ CL = center line, EL = edge line, LL = lane line.

²⁵ Expected service life based off historic data of similar markings on similar road type and which service life grouping category (see Table B2).

²⁶ When are the markings expected to be replaced based on installation date and expected service life?

²⁷ Has the section been scheduled for restriping?

²⁸ Include notable site characteristics, if section is being used to gather future expected service life data, and other notes.

²⁹ W indicates white marking (i.e. lane line or right edge line), and Y indicates yellow marking (i.e. center line or left edge line on divided road).

Method Development: Service Life Based on Monitored Markings

Method Definition

In this method, an agency documents pavement marking installation dates and periodically monitors the retroreflectivity of a representative sample of those markings to track their durability. The agency uses these monitored markings to represent a larger group of markings with similar characteristics in similar conditions. When each group of the monitored markings degrade and approach the MUTCD minimum levels, the markings have reached their end of service life, and the entire group of markings (both the monitored markings and the larger group of pavement markings they represent) are scheduled for replacement before they are expected to reach the minimum retroreflectivity levels. This is an alternative method for agencies that want to use a service life method but do not have historical data or research supporting service life estimates for their region's specific conditions (i.e., their in-service life before reaching the appropriate MUTCD minimum level or higher agency established threshold).

Method Needs

To successfully implement a maintenance method that uses service life based on monitored markings, the following will be needed:

- Roadway sections and markings to be included in the maintenance method.
- Sets of markings to serve as the monitored markings that include a reasonable range of key factors for the larger group they represent.
- Pavement marking information.

Having a representative sample of markings is critical to this method. Considering material type and thickness, as well as roadway conditions, will be important to determining appropriate factors for grouping the markings. Variations in weather and marking installation quality also impact the expected service life but are typically not an issue unless they are significantly different between the monitored markings and the larger sample they represent (e.g. markings on a mountain pass are likely subjected to more snow plow passes than those in a valley).

Method Implementation

This example includes potential steps for an agency to consider when establishing a service life based on the monitored markings maintenance method for pavement marking retroreflectivity. Agencies are encouraged to customize the method to local conditions and agency practices.

1. Using the MUTCD and the information in the “Getting Started” section of this appendix, determine which markings will be included in your agency's method. Whether or not the agency has an inventory, it is essential to be able to associate each marking within the method to the similar monitored markings that represent it. An inventory is particularly useful to assist in this association. For this method, key information includes:
 - a. Pavement marking type (e.g., binder, thickness, inlay, and optics).
 - b. Pavement surface.
 - c. Use/frequency of snowplow operations.

- d. Climate.
 - e. Traffic volumes.
 - f. Installation date.
2. Select a documentation technique to track and schedule the replacement of specific markings. This tracking and scheduling of replacement markings can be a list, spreadsheet, or database and might also include maps or GIS components.
 3. Develop groupings that have the same marking materials on roadways with similar characteristics. These groupings will all use the same monitored markings against which to compare. The trending retroreflectivity levels from the monitored markings will be used to schedule pavement marking replacements.
 4. Establish the sets of markings to use as the monitored markings and record their retroreflectivity levels.
 - a. The preferred way to monitor markings is the measured retroreflectivity method. However, an agency could instead assess the monitored markings using either the calibrated pavement markings nighttime visual inspection method or the consistent parameters nighttime visual inspection method. Please refer to the specific chapters of the report and other sections of this appendix for more information on those methods.
 - b. Ensure the length of the roadway sections with the monitored markings is long enough and in enough different locations to provide a statistical representation of the larger group of markings they are meant to represent. A larger sample of monitored markings might be appropriate if one of the nighttime visual inspection methods are used, due to the less precise nature of this method.
 - c. Determine how frequently the retroreflectivity levels of the monitored markings need to be assessed to ensure the markings are scheduled to be replaced prior to reaching the MUTCD minimum levels.
 - d. Determine the sampling procedure for the monitored marking evaluation. Collect and record an adequate number of retroreflectivity readings (see ASTM D 7578) if measuring retroreflectivity. If using a nighttime visual inspection method, consider multiple recorded observations along the length of the monitored section to achieve a representative sample.
 - e. Conduct the inspection of the monitored markings.
 5. Schedule markings in both the monitored sections and the larger group of markings they represent to be replaced *before* the associated monitored markings reach the appropriate MUTCD minimum level or the higher agency established threshold. Determine how best to prioritize replacement based on years in service, upcoming projects, and weather conditions that limit striping seasons.
 6. Update the marking inventory as needed after restriping activities have occurred (e.g. to indicate date markings were replaced and type of material used). Update roadway groupings if new marking materials were used or if conditions have changed.
 7. Assess and update the maintenance method and supporting information, as necessary. Consider if additional roadways and their markings need to be added.

Examples

Figure B3 shows an example of a map that could be developed by an agency to depict the location of the monitored markings and the larger group of markings with similar conditions that the monitored markings represent. It depicts a single pavement marking type (paint) and multiple installation years (2019 and 2020). Each year has its own set of installations and monitored markings. Based on retroreflectivity of the monitored markings, the entire group of markings (i.e., both monitored and the larger group they represent) are restriped *before* the monitored markings reach the appropriate MUTCD minimum level or the higher agency threshold. Additional maps or different colors or patterns on the map would be needed to represent other marking types, installation years, or different conditions.



Figure B3. Diagram. Example of monitored markings map.

An inventory example is shown in Table B9. The example only includes one group with similar pavement, marking, and volume considerations. Consider additional groups with separate monitored marking sections for different volumes, pavement types, marking material properties, or winter maintenance conditions. The other groups could be listed in separate tables with their own sets of monitored marking sections. All roadway sections within a group need to have similar characteristics and are restriped at the same time based on the retroreflectivity of the monitored markings so planned restriping activities can be done for each group rather than each segment. Evaluation is only required for the monitored markings, so that column will only be needed for the monitored segments. The spreadsheet could be supplemented or replaced with a GIS database or map system. Each roadway with markings that meet the requirements of the rule needs to be included.

Table B9. Spreadsheet example of roadway database for service life based on monitored markings.

Group 1: Waterborne Paint on Bituminous Surface with Traffic Volumes between 5,000 and 15,000 ADT and Speed Limits under 60 mph (Agency threshold = 75).									Restriping Scheduled? No, measurements in monitored segments indicate this group will last until Spring.				
Road/Segment Identification ³⁰	Segment Length and Limits	Monitored segment? (if so, date measured)	Functional Classification	Traffic Volume (ADT)	Speed Limit (mph)	Winter Maintenance	Binder Thickness (mils)	Reflective Optics (AASHTO M247)	Installation Date	Line Type(s) ³¹	Monitoring Results ³²	Next Date to Monitor	Notes ³³
Main St. Extension, Clay County	2.5 miles (June Ln to Green County Line)	Yes 11/18/19	Local	9,500	45	None	15	Type I	5/14/19	CL EL LL	94 (Y ³⁴) 114 (W) 103 (W)	3/18/20	Monitored Marking Section
Route 45 (Control Section 1-66)	6.2 miles (Grand Blvd to US 50)	No	Minor Arterial	11,000	50	None	15	Type I	5/17/19	CL EL			
Route 45	11.4 miles (US 50 to Mason County Line)	No	Minor Arterial	7,000	55	None	15	Type I	5/17/19	CL EL			
Balcones Drive, Clay County	4.2 miles (Rte 45 to Rte 66)	No	Local	12,000	40	None	15	Type I	4/28/19	EL LL			Overhead lighting, but keep on retro monitoring program
Grand Blvd	3.7 miles (Main St to Foothills Rd)	Yes 11/18/19	Minor Arterial	12,000	40	None	15	Type I	5/14/19	EL LL	97 (Y) 127 (W)	3/18/20	Monitored Marking Section Divided by raised median
...
...

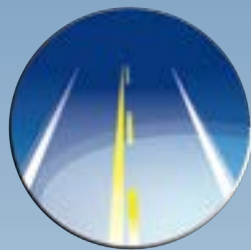
³⁰ Unique road segment identifier (if used by agency).

³¹ CL = center line, EL = edge line, LL = lane line.

³² Average of measured retroreflectivity for each line type. Only applies to monitored segments—leave other segments blank.

³³ Include notable site characteristics, if section is being used to gather future expected service life data, and other notes.

³⁴ Y indicates yellow marking (i.e. center line or left edge line on divided road), and W indicates white marking (i.e. lane line or right edge line).



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