Final Report FHWA-SA-10-016

# REVISED ASSESSMENT OF ECONOMIC IMPACTS OF IMPLEMENTING MINIMUM LEVELS OF PAVEMENT MARKING RETROREFLECTIVITY

**U.S. Department of Transportation**
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**16. Abstract**
The Federal Highway Administration's retroreflectivity team prepared a revised assessment of the economic impacts for a proposed rulemaking initiative that would revise the Manual on Uniform Traffic Control Devices (MUTCD) to include minimum maintained levels of retroreflectivity for pavement markings. The revised assessment represents an update of the preliminary analysis that was prepared before the team developed the proposed MUTCD language. The retroreflectivity team used the proposed MUTCD language, along with data from the preliminary analysis and a series of assumptions related to marking applications, to calculate the number of miles of markings on a national basis that would be subject to compliance with the minimum retroreflectivity values. The team then calculated the current annual maintenance costs for these markings. Next, the team calculated the annual national costs associated with maintaining the markings to the minimum levels by adjusting the service lives of the markings in accordance with the applicable minimum retroreflectivity level. Using an assumption that the distribution of marking materials on a national basis is 75 percent paint, 20 percent thermoplastic, and 5 percent epoxy, the team calculated the annual nationwide costs of implementing two alternative minimum pavement marking retroreflectivity standards, based on reported public preferences. The increased costs of the two options (less stringent and more stringent) were estimated as $64 million and $126 million, respectively, or 3.2 percent and 6.3 percent of the current costs of $2 billion, respectively. Although the evidence of potential safety improvements remains limited, there is some reason to believe that the more stringent option would not generate commensurate benefits. Therefore, the less costly alternative is recommended.

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# REVISED ASSESSMENT OF ECONOMIC IMPACTS OF MINIMUM PAVEMENT MARKING RETROREFLECTIVITY

In July 2008, the Federal Highway Administration (FHWA) published a preliminary analysis of the economic impacts of implementing minimum levels of pavement marking retroreflectivity (FHWA-SA-08-010[1]). That analysis provided an initial assessment of the potential economic impacts of including minimum levels of retroreflectivity in the Manual on Uniform Traffic Control Devices (MUTCD). However, that analysis was conducted prior to finalizing the proposed MUTCD language for minimum pavement marking retroreflectivity. Once the FHWA determined the initial proposed MUTCD language for minimum marking retroreflectivity, the FHWA retroreflectivity team prepared a revised analysis of the economic impacts of minimum marking retroreflectivity. This document describes the findings of that analysis.

## SUMMARY OF PREVIOUS ASSESSMENT

In December 2007, the FHWA published a final rule revising the MUTCD to address minimum levels of retroreflectivity for traffic signs. As that rulemaking effort was drawing to a conclusion, the FHWA began the preparation of a proposed rule for minimum levels of pavement marking retroreflectivity. As part of that effort, the FHWA sponsored an effort to conduct a preliminary assessment of the economic impacts of minimum levels of pavement marking retroreflectivity. This preliminary analysis was conducted before the completion of research to update the recommended minimum levels of retroreflectivity and before the FWHA had developed proposed MUTCD language for minimum marking retroreflectivity. As a result, the preliminary analysis was based on a general approach that assumed that the minimum retroreflectivity level would be based on speed and marking color.

To assess the economic impacts, researchers developed a spreadsheet-based analysis tool that calculates the costs associated with implementing minimum retroreflectivity levels. The spreadsheet considers the impacts of retroreflectivity levels, choice of materials, cost of materials, roadway types, and roadway mileage. The researchers used the analysis tool to assess the proposed minimum retroreflectivity levels and a more stringent alternative set of minimum levels. The analyses described in this report shows that the national economic impacts of implementing minimum levels of pavement marking retroreflectivity increase pavement marking maintenance by $64 million based on the less stringent levels, or $126 million based on the more stringent alternative.

## REVISED ASSESSMENT

In October 2007, the FHWA published a report that presented updated research recommendations for minimum levels of pavement marking retroreflectivity (FHWA-HRT-07-059[2]). This report contained the recommendations shown in Table 1 as the minimum levels of retroreflectivity. The research recommendations shown in this table define minimum levels of retroreflectivity on the basis of the type of roadway markings and on the presence of retroreflective raised pavement markers (RRPM). Because of the limited resources available for

[1] http://safety.fhwa.dot.gov/roadway_dept/night_visib/pavement_visib/fhwasa08010/fhwasa08010.pdf
[2] http://www.tfhrc.gov/safety/pubs/07059/07059.pdf

the research, the values in Table 1 can be considered a first cut and provide a starting point for the development of the values used in the proposed rule.

**Table 1. Research Recommended Minimum $R_L$ Values (mcd/m$^2$/lux).**

| Roadway Marking Configuration | Without RRPMs | | | With RRPMs |
|---|---|---|---|---|
| | ≤ 50 mi/h | 55–65 mi/h | ≥ 70 mi/h | |
| Fully marked roadways (with center line, lane lines, and/or edgeline, as needed)* | 40 | 60 | 90 | 40 |
| Roadways with center lines only | 90 | 250 | 575 | 50 |

* Applies to both yellow and white pavement markings.

In addition to the revised approach in defining minimum levels of retroreflectivity, the FHWA also began to develop the proposed MUTCD language for minimum levels of retroreflectivity. This language included provisions that excluded many pavement markings from complying with the minimum levels of pavement marking retroreflectivity. Appendix A presents the MUTCD language, including the minimum retroreflectivity levels presented in the proposed rule.

With both recommended minimum levels and proposed MUTCD language, the FHWA determined that the preliminary analysis did not adequately define the economic impacts of implementing minimum levels of retroreflectivity in the MUTCD. Therefore, the FHWA retroreflectivity team developed a revised assessment of the economic impacts.

## ANALYSIS PROCEDURE

The revised analysis began with the data that were assembled for the preliminary analysis and adapted it to the updated minimum retroreflectivity levels as adjusted by the FHWA retroreflectivity team for the proposed rulemaking, including both the MUTCD language and minimum retroreflectivity levels as presented in Appendix A.

The revised analysis procedure consisted of the following steps:

1. Determine the miles of roadway in each functional classification.
2. Determine the miles of roadway within each functional class of a given cross section (number of lanes).
3. Determine the typical longitudinal pavement marking pattern associated with each functional classification.
4. Determine the miles of roadway of a given cross section within each functional classification that are expected to comply with minimum retroreflectivity levels. Roadway miles could be excluded from compliance because the marking is not required or recommended, because the roadway speed is 30 mph or less, or where the roadway has continuous roadway lighting or RRPMs.
5. Calculate the miles of pavement marking within each functional class that are expected to comply with minimum retroreflectivity levels.
6. Calculate the current cost of maintaining the longitudinal pavement markings within each functional class based on typical marking replacement practices.

7. Calculate the cost of maintaining pavement markings to the minimum retroreflectivity levels based on the expected service life of the markings for the applicable minimum retroreflectivity level.
8. Determine the difference between the current costs and the costs associated with the minimum levels.
9. Calculate the cost of maintaining pavement markings to higher levels of minimum retroreflectivity to provide an alternate comparison.
10. The economic analysis calculates only the annual cost of replacing markings. It does not consider the administrative or logistical costs. Additional costs such as developing and implementing a maintenance method are not included under the assumption that the proposed 6-year implementation period is long enough to adjust currently planned maintenance activities. Specific costs not included in the analysis include:
    a. Cost to develop a maintenance method.
    b. Costs to implement a maintenance method (such as visual inspections).

## SUPPORTING DATA FOR REVISED ANALYSIS

The analysis procedure described in the previous section utilized the following data in determining the economic impacts of minimum pavement marking retroreflectivity:

1. Road mileage and cross section information from 2003 Highway Statistics. This is the data that was used in the preliminary analysis. The preliminary analysis report contains a description of this data (FHWA-SA-08-010[1]).
2. Pavement marking patterns for various cross sections were the same as used in the preliminary analysis.
3. The miles of roadway in each functional classification that were not subject to minimum retroreflectivity were determined on the basis of one or more of the following:
    a. The determination as to whether longitudinal markings were required or recommended was based on the roadway annual average daily traffic (AADT). The retroreflectivity team used FHWA data for the Federal-aid Highway System to determine the AADTs for a roadway cross section. The FHWA data had a single category for AADT values between 2000 and 5000. However, the AADT thresholds applicable for minimum retroreflectivity were 3000 for rural roads and 4000 for urban roads. The AADT values between 2000 and 5000 were equally divided into three ranges (2000-3000, 3000-4000, and 4000-5000) for use in the analysis. The percentage of roads above the applicable AADT criteria (3000 for rural roads and 4000 for urban roads) were applied to all functional classifications. Appendix B presents the data from the Federal-aid Highway System that the team used to develop percentages for roadway mileage above the threshold volumes.
    b. The percentage of roads within the applicable speed ranges were assumed based on the judgment of the FHWA retroreflectivity team. Table 2 shows the percentage of road mileage assumed within each speed range for each functional classification. Within a given speed range, the distribution of roadway mileage between 2 lane, 3 lane, and 4 or more lanes was based on FHWA data for the Federal-aid Highway System. This data is shown in Appendix C.

4. The costs ($/ft) for the pavement marking materials used in this report were obtained from a variety of sources, including NCHRP Synthesis 306 (Migletz, J., and J. Graham. *NCHRP Synthesis 306: Long-Term Pavement Marking Practices.* Washington, D.C.: TRB, National Research Council, 2002[3]), a 2005 unpublished FHWA report (Donnell, E.T., P.M. Garvey, D. Lee, S. Sathyanarayanan, and M.L. Patten. *Methods to Maintain Pavement Marking Retroreflectivity: Volume 1: Literature Review and Current State-of-the-Practice*. Federal Highway Administration, McLean, Virginia, December 2005. (unpublished[4])), a 2007 TxDOT report (Carlson, P.J., J.D. Miles, A.M. Pike, and E.S. Park. Evaluation of Wet-Weather and Contrast Pavement Marking Applications: Final Report. FHWA/TX-07/0-5008-2, Texas Transportation Institute, College Station, Texas, August, 2007[5]), and the 2007 FHWA workshops on minimum pavement marking retroreflectivity (Falk, K.W. and P.J. Carlson. Pavement Marking Retroreflectivity Workshops Summary Report. FHWA-SA-08-003, Federal Highway Administration, Washington, D.C., February 2008[6]). The cost values used in the analysis are shown in Table 3.
5. Service life data for various marking materials in a functional classification were obtained from an unpublished FHWA report (Migletz, J., J.L. Graham, D.W. Harwood, K.M. Bauer, and P.L. Sterner. *Evaluation of All-Weather Pavement Markings*. McLean, VA: FHWA, U.S. Department of Transportation, 2000. (unpublished[4])). This is the same marking material service life data used in the preliminary analysis. That report describes the service life data in greater detail. Table 4 presents the service life data used in the revised analysis. This report provided service life data for white and yellow markings separately. For the analysis, the team used the lowest service life reported for a given functional class and retroreflectivity level.
6. The alternate economic cost assessment was based on increasing selected minimum retroreflectivity levels. Minimum values of 50 were increased to 70 and minimum values of 100 were increased to 125. The minimum value of 250 remained the same.

[3] http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_306_1-14.pdf
[4] Report available from: Federal Highway Administration, Office of Safety Design - HSSD, Room E71-109, 1200 New Jersey Avenue, SE, Washington, DC 20590, Cathy Satterfield, P.E., 708-283-3552, cathy.satterfield@dot.gov or Greg Schertz, P.E., (720) 963-3764, greg.schertz@dot.gov.
[5] http://tti.tamu.edu/documents/0-5008-2.pdf
[6] http://safety.fhwa.dot.gov/roadway_dept/night_visib/pavement_visib/fhwasa08003/fhwasa08003.pdf

**Table 2. Percent of Road Mileage by Speed Category**

| Functional Classification | Speed Range for a Given Cross Section (number of lanes) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 lane | | | 3 lane | | | 4+ lanes | |
| | ≤ 30 mph | 35-50 mph | ≥ 55 mph | ≤ 30 mph | 35-50 mph | ≥ 55 mph | 35-50 mph | ≥ 55 mph |
| Rural Interstate | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 100% |
| Urban Interstate and Freeway/Expressway | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 100% |
| Rural Principal Arterial | 0% | 100% | 0% | 0% | 50% | 50% | 0% | 100% |
| Urban Principal Arterial | 0% | 100% | 0% | 0% | 50% | 50% | 0% | 100% |
| Rural Minor Arterial | 0% | 100% | 0% | 0% | 50% | 50% | 50% | 50% |
| Urban Minor Arterial | 0% | 100% | 0% | 0% | 100% | 0% | 100% | 0% |
| Rural Major Collector | 0% | 100% | 0% | 0% | 50% | 50% | 0% | 100% |
| Rural Minor Collector | 0% | 50% | 50% | 0% | 0% | 0% | 0% | 0% |
| Urban Collector | 75% | 25% | 0% | 50% | 50% | 0% | 0% | 0% |
| Rural Local | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Urban Local | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

**Table 3. Marking Material Costs-**

| Material- | Material Costs ($/LF) | |
|---|---|---|
| | Federal/State Agencies | City/County Agencies |
| Paint | 0.06 | 0.15 |
| Thermoplastic | 0.35 | 0.50 |
| Epoxy | 0.30 | 0.60 |

**Table 4. Pavement Marking Service Life Data**

| Type of Road | Marking Material | Current Practice | Expected Service Life (months) for a Given Retroreflectivity Level | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2 lane with Centerline only | | | All other roads | | | |
| | | | 100 | 125[C] | 250 | 50 | 70[C] | 100 | 125[C] |
| Freeway | paint | 12 | 12 | 12 | 4[B] | 12 | 12 | 12 | 12 |
| | thermo | 36 | 24.7 | 19 | 6[B] | 52.5 | 44.8 | 24.7 | 19 |
| | epoxy | 36 | 23.2 | 16.2 | 6[B] | 39.1 | 27.5 | 23.2 | 16.2 |
| Arterial[A] | paint | 12 | 12 | 12 | 4[B] | 12 | 12 | 12 | 12 |
| | thermo | 36 | 21.5 | 18 | 6[B] | 40.9 | 31.8 | 21.5 | 18 |
| | epoxy | 36 | 30.6 | 25.6 | 6[B] | 50.8 | 42.1 | 30.6 | 25.6 |

Notes:
[A]Values for arterial with speed of 45 mph and greater used for service life data.
[B]Data not available in FHWA report. Values shown were assumed for analysis.
[C]Retroreflectivity value used for alternate analysis.

## ASSUMPTIONS OF REVISED ANALYSIS

Beyond the actual data, the retroreflectivity team also had to make a number of assumptions in order to complete the revised analysis. These assumptions are listed below.

1. The percent of roadways with RRPMs or continuous lighting are shown in Table 5. These values were assumed based on the best judgment of the FHWA retroreflectivity team.
2. The percentage of roadway mileage in a given speed range for a specific functional classification was assumed as described previously and indicated in Table 2.
3. Various combinations of marking materials were assumed for the general analysis. Based on information gained through discussions with professionals in the pavement marking industry, the retroreflectivity team assumed a typical distribution of 75 percent paint, 20 percent thermoplastic, and 5 percent other materials (represented by epoxy in the analysis).
4. The FHWA report did not provide service life data for minimum retroreflectivity levels of 250 mcd/m$^2$/lux. As indicated in Table 4, the retroreflectivity team assumed service lives for this retroreflectivity level.
5. The typical practice for current marking maintenance was assumed based on common knowledge.
6. The marking patterns for a specific functional classification were based on engineering judgment.
    a. No edge lines are used on all urban roads at the arterial and lower classification.
    b. For roads with a centerline, a combination of no-way, one-way, and two-way passing configuration was used.

**Table 5. Percent of Road Mileage with Lighting or RRPMs**

| Functional Classification | Percent of Roadway Mileage with: | | | |
|---|---|---|---|---|
| | Lighting [A] | | RRPMs [B] | |
| | Rural | Urban | Rural | Urban |
| Interstate and Freeway/Expressway | 0% | 20% | 10% | 10% |
| Principal Arterial | 0% | 15% | 10% | 10% |
| Minor Arterial | 0% | 10% | 10% | 10% |
| Major Collector | 0% | N/A | 10% | N/A |
| Minor Collector | 0% | N/A | 0% | N/A |
| Collector | N/A | 0% | N/A | 0% |
| Local | Minimum retroreflectivity levels do not apply | | | |

[A] Continuous roadway lighting that meet the criteria in the MUTCD language to be exempted from minimum retroreflectivity levels.
[B] RRPMs present that meet the criteria in the MUTCD language to be exempted from minimum retroreflectivity levels.
N/A – functional classification not applicable.

## LIMITATIONS OF REVISED ANALYSIS

The approach used for the revised analysis had the following limitations associated with it:

1. The retroreflectivity team could not find data that indicated the total amount of marking mileage associated with any specific functional classification. This led to the need to assume a typical marking pattern for each functional classification.
2. There are some discrepancies in the service life data used for this analysis. In some cases, the discrepancies indicate yellow markings that have longer service lives than white markings. In other cases, the relative service lives for the different materials are not consistent.
3. The service life data for arterials are based on data for non-freeway with a speed of 45 mph or more. The analysis did not use the service life data for non-freeway with a speed of 40 mph or less. The 45+ mph data was used to represent the 35-50 mph speed group.
4. There is no service life data for retroreflectivity values of 250 or for the alternate analysis based on retroreflectivity values of 125.
5. The analysis assumes that if the service life for a specific retroreflectivity level is longer than the typical practice, then an agency will replace/maintain markings less often. This means that all roads that have minimum retroreflectivity levels of 50 will be maintained at a lower level than they are currently maintained.
6. The analysis addresses only the annual maintenance costs associated with minimum retroreflectivity for pavement markings. It does not address the benefits that would be achieved nor the administrative or logistical costs associated with implementing the management methods that would be associated with minimum retroreflectivity standards.

## FINDINGS OF REVISED ANALYSIS

Establishment of a uniform minimum level of nighttime pavement marking performance based on the visibility needs of drivers is expected to promote safety, enhance operations, and facilitate comfort and convenience for all drivers, especially older drivers. A report summarizing available information on the impacts of alternative retroreflectivity standards is "The Benefits of Pavement Markings: A Renewed Perspective Based on Recent and Ongoing Research" by Paul J. Carlson, Eun Sug Park, and Carl K. Andersen (Aug. 1, 2008)[7].

So far, neither experienced crash rates nor such proxies as speed, lateral position, and detection distance have generated reliable conclusions regarding the safety benefits of markings. Problems in the design of experiments have indicated a need for continued research in this area. Meanwhile, surveys of public attitudes have indicated a subjective preference for a minimum of 80 to 130 mcd/$m^2$/lx, more frequently in the upper part of the range. While driver reactions to retroreflectivity levels will certainly depend on weather, light conditions, speed, and roadway configuration, these factors require further study. Nevertheless, at this point, it is reasonable to accept the measured public preferences as the basis for a minimum standard.

Two alternatives have been considered. The lower represents a standard of 100 mcd/m2/lx for two-lane roads with centerline markings only and posted speeds of 35-50 mph and other roads with limits of 55 mph or more. A lower standard of 50 mcd/m2/lx is applicable to slower speeds on other roads, while a higher standard of 250 mcd/m2/lx is considered necessary for two-lane, high-speed roads. These figures are laid out in Table 3A-1 (Appendix A). The alternative

[7] http://safety.fhwa.dot.gov/roadway_dept/night_visib/pavement_visib/no090488/no090488.pdf

represents an approximation to the higher range of public preferences, with values of 70, 125, and 250 mcd/m2/lx as shown in Table 3A-1A (Appendix A).

The costs of the revised economic assessment are based on an informal survey of the largest industry suppliers, resulting in an estimate of material use on a national basis of 75 percent paint, 20 percent thermoplastic, and 5 percent epoxy applied across all functional classifications. This distribution of materials implies an estimated cost of the less stringent alternative of $64 million, while that of the more stringent alternative is almost twice as great at $126 million. These represent annual nationwide maintenance costs, above the current expenditure level estimated in the report by Carlson *et al.* at $2 billion. They exclude costs of delay due to potential maintenance disruptions and the administrative costs of implementing the proposed rule. The implied percentage increases are thus 3.2 percent and 6.3 percent.

In considering the two alternatives, FHWA regards it as justified to discount the potential benefits of the higher range of standards consistent with subjective preferences. Driver perceptions of an adequate marking are more demanding than what recent FHWA research presents as meeting drivers' visibility needs at night, based on a preview time of 2.2 seconds. Although the more stringent alternative would provide greater visibility, the incremental gains in safety and mobility would be impossible to quantify with any degree of accuracy. Therefore, FHWA believes that the less stringent standard of Table 3A-1 would establish an appropriate minimum level of nighttime pavement marking performance for the motoring public at a supportable cost of $64 million.

## APPENDIX A:
## PROPOSED MUTCD LANGUAGE AND MINIMUM RETROREFLECTIVITY LEVELS USED IN THE REVISED ECONOMIC ANALYSIS

### Section 3A.03 Maintaining Minimum Retroreflectivity of Longitudinal Pavement Markings [new section]

**Standard:**

**Public agencies or officials having jurisdiction shall use a method designed to maintain retroreflectivity of the following white and yellow longitudinal pavement markings, at or above the minimum levels in Table 3A-1:**

1. **Center line markings on roads where they are required or recommended by Section 3B.01. This shall include any no-passing zone markings, longitudinal two-way left-turn lane markings, and yellow markings used to form flush medians on such roads.**
2. **Lane line markings on roads where they are required or recommended by Section 3B.04. This shall include any dotted lane lines, lane drop markings, and longitudinal preferential lane markings on such roads.**
3. **Edge line markings on roads where they are required or recommended by Section 3B.07. This shall include any channelizing lines delineating gores, divergences, or obstructions on such roads.**
4. **Any optional edge line markings that are used to qualify for the lower minimum retroreflectivity values in the "All other roads" row of Table 3A-1.**

***Table 3A-1 Minimum Maintained Retroreflectivity Levels① for Longitudinal Pavement Markings***

| | Posted Speed (mph) | | |
|---|---|---|---|
| | ≤ 30 | 35 – 50 | ≥ 55 |
| Two-lane roads with centerline markings only ② | n/a | 100 | 250 |
| All other roads② | n/a | 50 | 100 |

① Measured at standard 30-m geometry in units of mcd/m$^2$/lux

② Exceptions:

A. When RRPMs supplement or substitute for a longitudinal line (see Section 3B.13 and 3B.14), minimum pavement marking retroreflectivity levels are not applicable as long as the RRPMs are maintained so that at least 3 are visible from any position along that line during nighttime conditions.

B. When continuous roadway lighting assures that the markings are visible, minimum pavement marking retroreflectivity levels are not applicable.

Support:

Compliance with the above Standard is achieved by having a method in place and using the method to maintain the minimum levels established in Table 3A-1. Provided that a method is being used, an agency or official having jurisdiction would be in compliance with the above Standard even if there are pavement markings that do not meet the minimum retroreflectivity levels at a particular location or at a particular point in time.

There are many factors for agencies to consider in developing a method of maintaining minimum pavement marking retroreflectivity including, but not limited to, winter weather, environmental conditions and pavement resurfacing.

*Guidance:*

*Except for those pavement markings specifically identified in the Option below, one or more of the following methods, as described in the 2010 Edition of FHWA's "Summary of the MUTCD Pavement Marking Retroreflectivity Standard (see Section 1A.11)," should be used to maintain retroreflectivity of longitudinal pavement markings at or above the levels identified in Table 3A-1:*

*A. Calibrated Visual Nighttime Inspection – Prior to conducting a nighttime inspection from a moving vehicle and in conditions similar to nighttime field conditions, a trained inspector calibrates his eyes to pavement markings with known retroreflectivity levels at or above those in Table 3A-1. Pavement markings identified by the inspector to have retroreflectivity below the minimum levels are replaced.*

*B. Consistent Parameters Visual Nighttime Inspection –A trained inspector at least 60 years old conducts a nighttime inspection from a moving vehicle under parameters consistent with the supporting research. Pavement markings identified by the inspector to have retroreflectivity below the minimum levels are replaced.*

*C. Measured Retroreflectivity – Pavement marking retroreflectivity is measured using a retroreflectometer. Pavement markings with retroreflectivity levels below the minimums are replaced.*

*D. Service Life Based on Monitored Markings – Markings are replaced based on the monitored performance of similar in-service markings with similar placement characteristics. All pavement markings in a group/area/corridor are replaced when those in the representative monitored control set are near or at minimum retroreflectivity levels. The control set markings are monitored on a regular basis by the visual nighttime inspection method, the measured retroreflectivity method, or both.*

*E. Blanket Replacement – All pavement markings in a group/area/corridor or of a given type are replaced at specific intervals. The replacement interval is based on when the shortest-life material in that group/area/corridor approaches the minimum retroreflectivity level. The interval is also based on historical retroreflectivity data for that group/area/corridor.*

*F. Other Methods – Other methods developed based on engineering studies that determine when markings are to be replaced based on the minimum levels in Table 3A-1.*

Option:

Public agencies or officials having jurisdiction may exclude the following markings from their minimum pavement marking retroreflectivity maintenance method(s) and the minimum maintained pavement marking retroreflectivity levels, but not from any requirements in Section 3A.02 to be retroreflective.

A. Words, symbols, and arrows,
B. Crosswalks and other transverse markings,
C. Black markings used to enhance the contrast of pavement markings on a light colored pavement,
D. Diagonal or chevron markings within a neutral area of a flush median, shoulder, gore, divergence, or approach to an obstruction,
E. Dotted extension lines that extend a longitudinal line through an intersection or interchange area,
F. Curb markings,
G. Parking space markings, and
H. Shared use path markings

***Table 3A-1A Minimum Maintained Retroreflectivity Levels① for Longitudinal Pavement Markings (Higher Retroreflectivity Values for Alternate Analysis)***

| | Posted Speed (mph) | | |
|---|---|---|---|
| | ≤ 30 | 35 – 50 | ≥ 55 |
| Two-lane roads with centerline markings only ② | n/a | 125 | 250 |
| All other roads② | n/a | 70 | 125 |

① Measured at standard 30-m geometry in units of mcd/m$^2$/lux

② Exceptions:

A. When RRPMs supplement or substitute for a longitudinal line (see Section 3B.13 and 3B.14), minimum pavement marking retroreflectivity levels are not applicable as long as the RRPMs are maintained so that at least 3 are visible from any position along that line during nighttime conditions.

B. When continuous roadway lighting assures that the markings are visible, minimum pavement marking retroreflectivity levels are not applicable.

## APPENDIX B:
## MILEAGE BY AADT AND NUMBER OF LANES

### Table 6. Mileage by AADT and Number of Lanes

| AADT group | Number of Thru Lanes | | | | | | | | | | | | | | | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| Under 500 | 41 | 184,360 | 50 | 131 | — | 6 | — | — | — | — | — | — | — | — | — | 184,589 |
| 500-1,999 | 218 | 269,132 | 605 | 1,671 | 3 | 3 | — | — | — | — | — | — | — | — | — | 271,633 |
| 2,000-4,999 | 145 | 209,301 | 2,090 | 10,861 | 30 | 72 | — | 8 | — | — | — | — | — | — | — | 222,507 |
| 5,000-9,999 | 58 | 100,108 | 2,183 | 27,794 | 34 | 494 | 2 | 4 | — | — | — | — | — | — | — | 130,677 |
| 10,000-19,999 | 19 | 39,658 | 1,679 | 50,841 | 440 | 1,213 | 6 | 27 | 0 | 6 | — | — | — | — | — | 93,889 |
| 20,000-34,999 | 3 | 4,672 | 590 | 37,450 | 707 | 3,743 | 15 | 95 | 7 | 3 | — | — | — | — | — | 47,286 |
| 35,000-54,999 | — | 183 | 77 | 13,730 | 372 | 4,486 | 63 | 205 | 1 | 3 | — | 2 | — | — | — | 19,120 |
| 55,000-84,999 | — | 5 | 4 | 3,781 | 192 | 3,481 | 66 | 462 | 1 | 15 | — | — | — | — | — | 8,008 |
| 85,000-124,999 | — | — | 3 | 572 | 72 | 2,761 | 107 | 619 | 23 | 48 | 2 | 22 | — | — | — | 4,228 |
| 125,000-174,999 | — | — | — | 37 | 8 | 1,373 | 93 | 899 | 62 | 172 | 4 | 45 | 3 | 1 | — | 2,697 |
| 175,000-249,999 | — | — | — | 4 | 0 | 131 | 23 | 697 | 75 | 293 | 17 | 84 | 1 | — | — | 1,325 |
| 250,000 and over | — | — | — | — | 3 | 3 | — | 67 | 18 | 191 | 1 | 54 | 4 | 20 | 1 | 363 |
| Totals | 485 | 807,420 | 7,280 | 146,873 | 1,861 | 17,766 | 375 | 3,083 | 186 | 731 | 24 | 206 | 8 | 21 | 1 | 986,322 |

Data from Federal-aid Highway System, 2007.

### Table 7. Mileage Summary AADT by Number of Lanes

| Volume Range | Mileage | | | Percentages | | |
|---|---|---|---|---|---|---|
| | 1 or 2 lanes | 3 lanes | 4 or more lanes | 1 or 2 lanes | 3 lanes | 4 or more lanes |
| 0-2999 | 523,567 | 1,352 | 5,472 | 64.81% | 18.56% | 3.20% |
| 3000+ | 284,338 | 5,928 | 165,665 | 35.19% | 81.44% | 96.80% |
| Total | 807,905 | 7,280 | 171,137 | 100% | 100% | 100% |

### Table 8. Rounded AADT Mileage Percentages Used in Analysis

| Volume Range | 1 or 2 lanes | 3 lanes | 4 or more lanes |
|---|---|---|---|
| 0-2999 | 65% | 20% | 3% |
| 3000+ | 35% | 80% | 97% |

## APPENDIX C:
## MILEAGE BY SPEED LIMIT AND NUMBER OF LANES

### Table 9. Mileage by Speed Limit and Number of Lanes

| Posted Speed Limit | Mileage of Federal-aid highways | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Through Lanes | | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | ALL |
| 5 | | 9 | | 1 | | | | | | | | | | | | 10 |
| 10 | | 26 | | 3 | | | | | | | | | | | | 29 |
| 15 | 1 | 552 | | | | | | | | | | | | | | 553 |
| 20 | 54 | 1,971 | 49 | 166 | 4 | 2 | 1 | | | | | | | | | 2,247 |
| 25 | 298 | 43,094 | 781 | 3,451 | 52 | 195 | 11 | 7 | | | | | | | | 47,888 |
| 30 | 86 | 46,902 | 1,119 | 6,832 | 97 | 320 | 5 | 48 | | 0 | | 1 | | | | 55,410 |
| 35 | 20 | 70,970 | 1,102 | 17,463 | 221 | 1,735 | 28 | 56 | | 2 | | | | | | 91,596 |
| 40 | 8 | 51,159 | 348 | 12,333 | 262 | 2,272 | 23 | 89 | 2 | | | | | | | 66,495 |
| 45 | 3 | 73,245 | 811 | 17,411 | 366 | 2,991 | 22 | 250 | 2 | | | 0 | | | | 95,101 |
| 50 | 1 | 43,458 | 430 | 5,379 | 114 | 1,168 | 24 | 120 | 4 | 7 | | 0 | | | | 50,706 |
| 55 | 14 | 364,136 | 1,953 | 26,552 | 277 | 2,851 | 107 | 682 | 55 | 153 | 8 | 39 | 4 | 4 | 1 | 396,835 |
| 60 | | 25,938 | 194 | 4,026 | 58 | 1,086 | 57 | 419 | 29 | 90 | 5 | 8 | 0 | | | 31,910 |
| 65 | | 49,589 | 359 | 24,047 | 348 | 3,505 | 89 | 1,148 | 90 | 474 | 12 | 152 | 4 | 17 | | 79,836 |
| 70 | | 35,627 | 108 | 20,145 | 62 | 1,561 | 8 | 266 | 4 | 4 | | 6 | | | | 57,789 |
| 75 | | 744 | 25 | 8,445 | | 81 | | | | | | | | | | 9,295 |
| 80 | | | | 620 | | | | | | | | | | | | 620 |
| All | 485 | 807,420 | 7,280 | 146,873 | 1,861 | 17,766 | 375 | 3,083 | 186 | 731 | 24 | 206 | 8 | 21 | 1 | 986,322 |

Data from Federal-aid Highway System, 2007.

### Table 10. Speed Limit Summary by Number of Lanes

| Speed Limit | Mileage | | | Percentages | | |
|---|---|---|---|---|---|---|
| | 1 or 2 lanes | 3 lanes | 4 or more lanes | 1 or 2 lanes | 3 lanes | 4 or more lanes |
| 0-30 | 92,994 | 1,949 | 11,195 | 11.51% | 26.77% | 6.54% |
| 35-50 | 238,864 | 2,692 | 62,344 | 29.57% | 36.97% | 36.43% |
| 55-80 | 476,048 | 2,639 | 97,599 | 58.92% | 36.26% | 57.03% |
| Totals | 807,905 | 7,280 | 171,137 | 100% | 100% | 100% |

### Table 11. Rounded Speed Limit Percentages Used in Analysis

| Speed Limit | 1 or 2 lanes | 3 lanes | 4 or more lanes |
|---|---|---|---|
| ≤ 30 mph | 11.5% | 26.8% | 6.5% |
| 35-50 mph | 29.5% | 37.0% | 36.4% |
| ≥ 55 mph | 59.0% | 36.3% | 57.0% |