NCHRP SYNTHESIS 431

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Practices to Manage Traffic Sign Retroreflectivity

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSPORTATION RESEARCH BOARD 2012 EXECUTIVE COMMITTEE*

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*Membership as of February 2012.

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Practices to Manage Traffic Sign Retroreflectivity

A Synthesis of Highway Practice

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

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Cover figure: Research Associate Dan Walker collecting retro values of a typical stop sign. Photo by TTI staff Fan Ye.

FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Jon M. Williams
Program Director
Transportation Research Board

"Traffic sign retroreflectivity" is a sign property which, during nighttime, causes light from a vehicle's headlamps to be reflected back to the driver, giving the sign an illuminated appearance. The federal government has established guidance to ensure that agencies responsible for traffic signs will bring their signs up to an acceptable standard of retroreflectivity. The objective of this study is to provide examples of effective practices that illustrate how different types of agencies can meet the retroreflectivity requirements. Information was gathered through a literature review and telephone surveys.

Jonathan M. Ré and Paul J. Carlson of the Texas Transportation Institute collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

PRACTICES TO MANAGE TRAFFIC SIGN RETROREFLECTIVITY

SUMMARY

Roadway traffic signs are a primary means of conveying critical information to roadway users. The *Manual on Uniform Traffic Control Devices* (*MUTCD*) provides the basic principles that govern the design and use of traffic control devices for all roadways open to public travel. In 1993, the U.S. Congress required that the Secretary of Transportation revise the *MUTCD* to include "a standard for a minimum level of retroreflectivity for pavement markings and signs which apply to all roads open to public travel." It was meant to ensure that drivers, especially the elderly, be able to detect, comprehend, and react to traffic signs accordingly and help to facilitate safe, uniform, and efficient travel. To satisfy the congressional directive, FHWA added a table containing minimum sign retroreflectivity values (section 2A.08 of the 2009 *MUTCD*). In addition, several methods are identified that agencies can implement to maintain traffic signs at or above the minimum retroreflectivity requirements.

The objective of this synthesis study was to provide examples of effective and advantageous practices that illustrate how different types of agencies can meet the retroreflectivity requirements. The aim of this study was to document the state of the practice and identify content that will assist other agencies that are exploring different methods for maintaining sign retroreflectivity. Information for this synthesis study was gathered from three distinct sources: published research, existing guidance and policy, and telephone surveys.

The telephone surveys comprised the majority of the information in this report. The goal of the surveys was to identify what methods have been implemented and which have shown the most promise. The survey included 14 main questions and was designed to facilitate an open-ended conversation about sign retroreflectivity and general maintenance practices. Survey participants were public agencies with active programs for maintaining sign retroreflectivity. They were located and contacted through professional society e-mail lists, meeting announcements, professional contacts, agency websites, past presentation materials, and referrals; in some cases, it was the participants who expressed an interest and in other cases their participation was requested. Overall, 48 agencies participated, 40 that operate roadways open to the public that selected a method found in the *MUTCD.* The questions were e-mailed to the participants prior to scheduling a time for the interview, so that individuals had time to prepare their responses. During the telephone survey, the questions served as a guide for a general discussion about traffic sign issues and practices between the surveyor and the participant.

Table 1 shows the distribution of the 40 agencies that have selected a method for replacing and maintaining a sign population. Within participant responses, it was determined that the expected sign life method was the most selected primary and secondary method for replacing and managing signs; the second most common was visual nighttime inspection; however, agencies were somewhat conflicted about this method. Survey participants were typically divided into two groups: agencies that have used nighttime inspection and agencies that rejected it. The primary reason for ending nighttime inspection was that agencies were concerned about staffing and did not want to add another activity to an already demanding maintenance schedule.

The blanket replacement method was the third most selected method and agencies employing this approached generally praised it for its ease and straightforward application. Finally, a few agencies were implementing the measured retroreflectivity or control signs

TABLE 1
DISTRIBUTION OF METHOD SELECTION

MUTCD Assessment and Management Methods	Primary Sign Replacement Method		Secondary or Support Method	
	Local Agencies*	State DOTs	Local Agencies	State DOTs
Nighttime Inspection	6	7	0	2
Measured Retroreflectivity	2	0	0	0
Expected Sign Life	11	4	11	5
Blanket Replacement	3	5	4	0
Control Signs	2	0	5	5

*Local agencies include towns, cities, counties, and one toll road agency. The sum of the Primary Sign Replacement Method columns numbers 40. The Secondary or Support Method columns add to a lesser number because there is no requirement that there be a secondary method and agencies may have multiple support methods.

methods. The cost for a retroreflectometer and time requirements for the measurements were the deciding factors.

The survey responses identified several strategies and techniques that were labeled as effective practices. For the visual nighttime inspection, the most noteworthy practice was the implementation of training programs to ensure inspector proficiency. Resource management tools were the most acclaimed benefit for the expected sign life method and it is important that agencies utilize sign information for planning, scheduling, and budgeting. Simplicity and ease were valued in the blanket replacement method; an effective practice to evenly and consistently blanket replace signs from year to year. A retroreflectometer can be expensive; however, its measurements can be very valuable, particularly in support of other methods. It is an effective practice to use the control signs method to justify the extension of sign warranty periods so that agencies can expand sign service life and maximize potential resources. Lastly, replacing signs based solely on retroreflectivity measurements can be time-consuming. If an agency has access to a retroreflectometer, it can be used in conjunction with routine daily maintenance; however, the readings should not detract from or eclipse other important activities.

This synthesis also includes case studies of four agencies of various sizes that participated in the survey: the town of Clifton Park, New York; St. Louis County, Minnesota; the city of Phoenix, Arizona; and the Missouri Department of Transportation. Each case study dealt with different geographical and climatic conditions. Each case study provides detailed information about the agencies' sign replacement and management practices. These agencies have implemented effective combinations of methods and it was believed that providing additional detail to the readers was beneficial.

Areas where survey participants thought there was a lack of guidance or information were also noted and compiled in this synthesis. Some of the areas suggested for further research included sheeting material color deterioration and the effects of nighttime inspection intervals on different sign populations. The need for monitoring the development of retroreflectivity measurement technology and creating a national database that would contain important information about the sign service life information of different sheeting materials from across the county is also discussed.

This report concluded that survey participants were implementing a variety of primary and secondary methods for maintaining signs and ensuring retroreflectivity compliance. The expected sign life method was the most often selected followed by the visual nighttime inspection and blanket replacement methods. Selection ranking aside, participant responses showed that each method exhibited distinctive advantages and operational benefits. Each of the methods listed in the *MUTCD* were being used by at least one agency. Overall, each agency's approach for maintaining adequate signs was practical, versatile, and effective.

CHAPTER ONE

INTRODUCTION

Roadway traffic signs are a primary means of communicating critical information to roadway users. The *Manual on Uniform Traffic Control Devices* (*MUTCD*) provides the basic principles that govern the design and use of traffic control devices for all roadways open to the public (*1*). There are five main principles in the *MUTCD* that traffic control devices must follow:

1. Fulfill a need,
2. Command attention,
3. Convey a clear simple meaning,
4. Command respect from road users, and
5. Give adequate time for proper response.

Traffic signs are also classified into three primary designations: regulatory, warning, and guide signs. Each classification serves a distinct purpose and adheres to strict and uniform design standards. Regulatory signs inform of traffic laws or regulations, warning signs give notice of a situation that might not be readily apparent, and guide signs provide destination information such as directions, distances, and points of interest. Sign information can be conveyed through the legend, which can be comprised of words, symbols, and arrows. Road users can also extract information from a sign's unique appearance, with size, color, and shape critical components. In addition to the specialized design criteria, road users need to detect signs and comprehend the message content in a timely manner in both daytime and nighttime. At night, signs not internally illuminated must be fabricated with retroreflective materials. Light from a vehicle's headlamps is reflected from the sign's surface back to the driver giving the sign an illuminated appearance.

BACKGROUND

In 1993, the Secretary of Transportation was required by Congress to revise the *MUTCD* to include "a standard for a minimum level of retroreflectivity for pavement markings and signs which apply to all roads open to public travel" (*2*). The goal of the new minimum retroreflectivity requirements was to improve safety on our nation's streets and highways, and was meant to ensure that drivers, especially the elderly, would be able to detect, comprehend, and react to traffic signs accordingly and help to facilitate safe, uniform, and efficient travel. To satisfy the congressional directive, FHWA added a table containing minimum sign retroreflectivity values to the *Manual* (section 2A.08 of the 2009 *MUTCD*). In addition, several methods are identified that agencies can implement to maintain traffic signs at or above the minimum retroreflectivity requirements. The next section expands on both the requirements and approved maintenance methods.

Establishing sufficient and acceptable minimum retroreflectivity levels has been an ongoing collaboration of several different studies. In 1993, Paniati and Mace (*3*) established minimum requirements for regulatory, warning, and guide signs. The researchers developed a computer analysis program that incorporated various driver, vehicle, and roadway parameters. The program computed the minimum required visibility distance for various inputs, which ultimately generate minimum retroreflective values. In 1995, Mercier et al. (*4*) confirmed that Paniati and Mace's minimum requirements would sufficiently meet the needs of an aging driving population. This research team measured the luminance thresholds for various traffic signs in a laboratory setting and determined that the minimum levels would meet the needs of 85% or more of all drivers. In 2004, Carlson and Hawkins (*5*) established the final FHWA minimum retroreflectivity requirements, those that are used today. Their research utilized methods from the Paniati and Mace study, but incorporated new inputs to reflect recent developments in vehicle headlamps, changes in fonts, vehicle types and sizes, drivers' nighttime needs, and the latest sheeting materials. Carlson and Hawkins also employed a new analysis tool that computed retroreflectivity requirements for traffic signs in various positions (right, left, and overhead) on the roadway. The final minimum levels were adopted by FHWA and are contained in Table 2A-3 of the 2009 *MUTCD* (*1*). The requirements exclude blue and brown signs and also parking, walking/hitchhiking/crossing, pedestrian, adopt-a-highway, and bike signs. Also restricted are the uses of specific retroreflective materials in certain sign applications.

Merely establishing and documenting minimum retroreflectivity levels was not the sole objective. The key element in the standards is maintaining sign retroreflectivity at or above the minimums. To establish a level of compliance, FHWA established three important compliance dates (on August 31, 2011, a notice of proposed amendments was published in the *Federal Register* recommending that the compliance dates for sign retroreflectivity be modified. As of March 2012, FHWA has not responded to the comments. For the latest information, see http://mutcd.fhwa.dot.gov/):

- January 2012: Implementation and continued use of an assessment or management method that is designed to maintain traffic sign retroreflectivity at or above the established minimum levels.
- January 2015: Replacement of regulatory, warning, and post-mounted guide (except street name) signs that are identified as failing.
- January 2018: Replacement of street name signs and overhead guide signs that are identified as failing.

With regard to the first compliance date, the 2009 *MUTCD* states “Public agencies or officials having jurisdiction shall use an assessment or management method that is designed to maintain sign retroreflectivity at or above the minimum levels” (*1*). Traditionally, each agency manages and maintains its traffic signs in a manner that best accommodates their specific conditions, resources, and priorities. For this reason, the *MUTCD* allows for the flexibility to select and modify one or more methods to best fit the needs of each entity.

The second and third compliance dates deal with the replacement of existing signs that are below the minimum levels. Each agency will encounter different circumstances when addressing these two compliance dates. Some proactive agencies may have few signs to replace, while others may have to replace a large portion of their sign population. A recent study by Opiela and Andersen (2007) estimated that the two compliance mandates will cost the nation approximately $37.5 million (*6*). It is estimated that the 2015 compliance will cost state and local agencies $5 and $11.5 million, respectively, and the 2018 compliance requirements will cost $6.8 and $14.2 million, respectively. At a more focused level, the Indiana Local Technical Assistance Program (LTAP) Center conducted a similar study, which calculated that the state would need $14.2 million to bring all public roadway signs into compliance (*7*).

Initial findings concerning the benefits of upgrading signs appear to justify the costs. A demonstration project was carried out recently in Mendocino County, California (*8, 9*). The county is located in Northern California and the transportation authority at the time was responsible for maintaining approximately 1,000 centerlines. Over a three-year period, the county improved the current sign inventory by using two different approaches. The first approach addressed sign placement and uniformity by conforming to state standards. The county targeted signing at locations with safety concerns and eliminated all nonstandard signing. The second approach upgraded all ASTM D4956 Type I signs with Type III signs. The combination of more uniform signing practices and brighter sheeting materials has reduced traffic crashes. The county analyzed 19 different roadways over a six-month period. County roadways with enhanced signing saw a 42% reduction in crashes, whereas nearby control roads experienced an increase in crashes of 27%. The sign enhancement program cost the county about $79,000 and it was estimated that the crash reduction savings ranged from $12.6 to $23.7 million.

SYNTHESIS OBJECTIVE

An agency will essentially be in compliance with the new *MUTCD* minimum sign retroreflectivity standard if they have a method in place and can demonstrate that they are acting in good faith to implement that method. FHWA acknowledges that an agency would be in compliance even if there are some individual signs that do not meet the minimum retroreflectivity levels at a particular point in time (*1*). For the most part, the key element is selecting and implementing a suitable method to maintain traffic sign retroreflectivity. Many public agencies have been aware of the approaching compliance dates for some time. There are proactive state and local entities that have acceptable methods in place and already meet one or more of the mandates, whereas others are just beginning to identify a suitable sign replacement method. There is a great deal of knowledge and expertise that can be derived from such proactive agencies and it is important to assess how certain methods have been implemented and to what degree of success.

The objective of this synthesis study was to provide examples of effective practices that illustrate how agencies can meet the retroreflectivity requirements, and also to document the state of the practice and make the results available to assist other agencies that are exploring different methods for maintaining sign retroreflectivity. Key issues will also uncover gaps in knowledge, determine future needs, and identify new areas of research.

STUDY APPROACH

Information for this synthesis study was acquired from three distinct sources: published research, existing guidance and policy, and telephone surveys. Initially, a literature review of research was conducted. Most of the research dealt with scientific and structured studies, and most of these research studies had definitive results and clear recommendations, such as documenting vandalism rates or evaluating retroreflectivity technology. The second source of information included Internet websites, agency newsletters, or past PowerPoint presentations. Two examples were the Washington State Department of Transportation’s (DOT) Traffic Sign Retroreflectivity website and Minnesota DOT’s *Traffic Sign Maintenance/Management Handbook.* Although the research and existing guidelines were vital components for this synthesis study, the majority of the information came from telephone surveys. Appendix A contains a list of useful resources for agencies just starting to acquire a familiarity with the sign retroreflectivity requirements.

Survey Design

The primary focus of this synthesis study was conducting telephone surveys. The goal of the surveys was to identify what methods have been implemented and which have shown promise. The survey questions were designed to facilitate and engage the study participants in a more structured discussion of sign practices at his or her agency. The survey questionnaire included 14 main questions most of which were open-ended. In some situations there were follow-up bullets points if obtaining additional information was pertinent. The major issues the survey addressed were to identify:

- The size and scale of the agency's traffic sign activities,
- How proactive the agency has been with sign replacement,
- General opinions and apprehensions about the *MUTCD* retroreflectivity requirements,
- How their method complies with the *MUTCD* and why it was selected,
- How their method functions and the major operational advantages, and
- Challenges encountered in the implementation process and lessons learned.

Appendix B contains a copy of the survey questions and the telephone script that was read to the participants about the purpose of the survey. One goal of the survey was to obtain a wide range of participants. The survey participants needed to reflect various situations throughout the country such as differing agency size, regional climate, population density, and environmental conditions. Targeted survey participants included local agencies (cities, towns, and counties), state DOTs, LTAP centers, and private organizations. At the onset of the study, a list of possible survey candidates was established, some of which came from Topic Panel recommendations and from personal contacts; however, the majority came from specific requests. Presentations were also made at different meetings, such as National Committee on Uniform Traffic Control Devices, TRB, and American Traffic Safety Services Association to generate interest in the project. Ultimately, surveys were e-mailed to different list groups and municipal organizations to solicit participants. Candidate response rate and survey participants are discussed later in the report.

The survey questions were e-mailed to participants prior to scheduling a time for an interview; therefore, individuals had time to prepare their responses. During the telephone survey, the questions served as a guide for a general discussion about traffic sign issues and practices. The discussion could periodically deviate from the question list if the participant had important information to share or if there was any additional follow-up inquiry. Notes obtained from the survey participants were compiled and beneficial information was documented.

Organization of Report

The first chapter lays the foundation for the succeeding material by describing the purpose of the study, states overall objectives, and explains the methodology to achieve its goals. Chapter two presents basic information on the different assessment and management sign methods outlined in the *MUTCD*. The majority of the survey participants' information is contained in chapter three, and chapter four includes four selected Case Studies that expand on useful strategies. Chapter five summarizes the effective practices and chapter six describes areas where information is needed and suggestions for possible future research. Finally, chapter seven concludes by summarizing key findings from chapters two through six.

CHAPTER TWO

DESCRIPTION OF SIGN RETROREFLECTIVITY MAINTENANCE METHODS

The 2009 *MUTCD* states that an agency "shall use an assessment or management method" (*1*) to maintain sign retroreflectivity. The manual does not dictate the method, but provides agencies the flexibility to implement one or more methods that best fit their needs, expertise, and level of resources. The intent of the methods and guidance outlined in the *MUTCD* is to provide support to the agencies and offer them systematic procedures to maintain traffic sign retroreflectivity. Again, compliance is achieved by having a method in place and being able to document active implementation. Conformance does not require or guarantee that every individual sign will meet or exceed the minimum retroreflectivity levels at every point in time. This chapter describes each method and concludes with a section on sign service life for different sheeting materials.

SIGN RETROREFLECTIVITY MAINTENANCE METHODS

Section 2A.08 in the *MUTCD* offers five traffic sign methods for maintaining nighttime sign visibility and an "Other" method, which must be supported by an engineering study (*1*). The five methods are categorized as either assessment or management. Assessment methods evaluate the retroreflectivity of individual signs and include visual nighttime inspection and measured sign retroreflectivity. Management methods incorporate an expected retroreflective life period of individual sheeting materials within the sign inventory. The retroreflective life of signs can originate from manufacturers' warranties, demonstrated performance, or control sign assessments. The management methods include expected sign life, blanket replacement, and control signs. Assessment and management methods may be combined in many different ways to accommodate an agency's needs and objectives. The *MUTCD* description of each method is provided here and additional details of each method are provided in this chapter.

- Visual Nighttime Inspection—The retroreflectivity of an existing sign is assessed by a trained sign inspector conducting a visual inspection from a moving vehicle during nighttime conditions. Signs that are visually identified by the inspector to have retroreflectivity below the minimum levels are to be replaced.
- Measured Sign Retroreflectivity—Sign retroreflectivity is measured using a retroreflectometer. Signs with retroreflectivity below the minimum levels are to be replaced.
- Expected Sign Life—When signs are installed, the installation date is labeled or recorded so that the age of a sign is known. The age of the sign is compared with the expected sign life. The expected sign life is based on the experience of sign retroreflectivity degradation in a geographic area compared with the minimum levels. Signs older than the expected life need to be replaced.
- Blanket Replacement—All signs in an area or corridor, or of a given type, are replaced at specified intervals. This eliminates the need to assess retroreflectivity or track the life of individual signs. The replacement interval is based on the expected sign life, compared with the minimum levels, for the shortest-life material used on the affected signs.
- Control Signs—Replacement of signs in the field is based on the performance of a sample of control signs. The control signs might be a small sample located in a maintenance yard or a sample of signs in the field. The control signs are monitored to determine the end of retroreflective life for the associated signs. It is important that all field signs represented by the control sample be replaced before the retroreflectivity levels of the control sample reach the minimum levels.

It can also be pointed out that FHWA has a full report detailing each of the sign retroreflectivity methods listed in the *MUTCD*. The FHWA report also includes a useful description of how to conduct the assessment methods. Finally, it also specifies the advantages and disadvantages of each of the sign retroreflectivity methods listed in the *MUTCD*. The FHWA report can be found at the following web address: http://safety.fhwa.dot.gov/roadway_dept/night_visib/policy_guide/fhwahrt08026/.

Visual Nighttime Inspection

Visual nighttime inspection is a common method for maintaining traffic sign retroreflectivity and guidelines for the inspection procedure have been documented for approximately 50 years (*10*). The method is simple and requires a trained or experienced inspector to view traffic signs from a moving vehicle during nighttime conditions. The inspector subjectively concludes if a given sign passes or fails. This is a broad overview, but effective implementation does require expertise and attention to detail.

Visual nighttime inspection requires one individual, but is more effective with two; a dedicated inspector monitoring and recording sign failures and a focused driver following a predetermined inspection route. It is important that visual inspection take place during typical nighttime conditions and that viewing not be affected by adverse or inclement weather such as fog or rain. Interior vehicle lighting should be minimized so that the inspector's vision is not affected. The inspection can emulate how a normal driver would view a typical sign: at normal roadway speeds, from an appropriate travel lane, and at an adequate viewing distance. Sign failures and noteworthy comments are to be documented in a standardized procedure. The inspector can document his or her evaluations by means of written notes on an agency form, audio recording, or laptop computer. The duration of a nighttime inspection session must not exceed a period where inspector fatigue becomes an issue or where roadway conditions change, such as frost forming on a sign. Throughout the inspections, it is important to be consistent with agency procedures and be able to document when the nighttime sign inspections have been completed.

There have been several research studies that have evaluated the visual nighttime inspection method. One of the first research studies to assess and document the accuracy of visual sign inspection was conducted in the state of Washington in 1987 (*11*). The first part of the study surveyed state DOTs and determined that 35 of 44 responding states used some type of visual inspections in the daytime and/or nighttime. The practices varied between DOTs, but all states replaced signs if there were visual physical defects or inadequate retroreflectivity. The second part of the Washington study evaluated the accuracy of 17 trained sign observers (*11*). The researchers trained the observers to rate STOP and warning signs in two environmental settings: a controlled gymnasium and a stationary car on a simulated road. After training, the observers were driven on two highway courses where they rated a total of 130 traffic signs. Overall, the observers made correct ratings for 75% of the signs. Within the total incorrect responses, observers were more likely to replace an adequate sign than to accept a sign with insufficient retroreflectivity. Despite the incorrect responses, replacing signs that are questionable or borderline is a more cautious but preferable approach for drivers. The researchers concluded that "trained observers can make accurate and reliable decisions to replace traffic signs" (*11*).

In 1996, Hawkins et al. (*12*) conducted a similar study that built on the Washington study's survey. In a statewide survey of Texas DOT (TxDOT) district sign maintenance offices, the researchers found that 80% of the districts conducted nighttime visual inspections and 65% also performed daytime inspections. Approximately 83% of the districts would implement visual inspection training when the proposed FHWA requirements took effect. The researchers also conducted a cost–benefit analysis of several different sign maintenance methods and determined that at that time visual inspection was one of the least expensive methods.

In 2001, to build on the previous studies findings, Hawkins and Carlson evaluated the accuracy of experienced TxDOT sign personnel (*10*). In this study, TxDOT staff subjectively assessed 49 test signs during nighttime conditions and rated them as "Acceptable," "Marginal," or "Unacceptable." TxDOT observers viewed test signs on a closed-course track at speeds of 30 to 40 mph. Only one test sign within the sample failed to meet the *MUTCD* minimums; however, the TxDOT observers rejected a total of 26 signs. The researchers determined that for sign assessment the overall appearance and uniformity of the sign face were as important as the retroreflectivity levels. The TxDOT observers identified sign inconsistencies and blemishes that rendered the sign unacceptable despite meeting the retroreflective minimums. The researchers concluded that "visual nighttime sign inspections should be a critical component of any process that evaluates the nighttime visibility of traffic signs" (*10*).

Another visual sign inspection study was conducted in North Carolina in 2006. Rasdorf et al. (*13*) evaluated the accuracy of North Carolina DOT (NCDOT) staff evaluations by comparing the visual nighttime inspection pass or fail decisions with retroreflectivity measurements. The study collected retroreflectometer measurements of 1,057 inspected signs on various types of state roadways in five different counties. Overall, the analysis determined that the NCDOT sign inspectors were effective in identifying and removing signs that were below the minimum values, and that accuracy levels ranged from 54% to 83%. The incorrect inspection decisions included a mix of both type I errors (failing adequate signs) and type II (passing inadequate signs). Despite the wide accuracy range, the researchers concluded that the NCDOT inspectors were proficient and that nighttime visual inspection was reliable.

Finally, Kilgour et al. (*7*) at the Indiana LTAP Center completed a study similar to the North Carolina study during the same time period. Again, researchers compared the pass or fail decisions of sign inspectors with the infield retroreflectometer measurements. There were 1,743 signs measured on roadways that were recently inspected by local agency personnel throughout different counties, cities, and towns in Indiana. Overall, the study determined that the inspectors were accurate in 88% of the pass or fail decisions. Within the type I errors, inspectors failed 1.2% of the signs despite adequate retroreflectivity values. Type I errors were most common for signs with red sheeting material. The red color in the sign would fade before the retroreflectivity resulting in inspectors failing the signs as a result of poor appearance. The overall type II error rate was 10.8% and the highest occurrence of this type of error was observed for yellow warning signs. Ultimately, the study acknowledged that visual nighttime inspection was a "reasonably accurate" method with "minimally trained personnel" (*7*).

Despite the high accuracy nighttime retroreflectivity inspection rates noted previously, the visual nighttime inspection method is still a subjective process and dependent on the experience and knowledge of the sign inspectors. FHWA offers three different sign inspection procedures to assist inspectors, reduce the subjective nature of inspections, and develop a link to the minimum retroreflectivity requirements. The details are contained in the 2007 publication *Maintaining Traffic Sign Retroreflectivity* (*14*), which is referenced in the *MUTCD* and contained in Appendix A. The procedures are a recommended practice to comply with the *MUTCD* standard. If an agency chooses not to use at least one of the supportive techniques, it is important that they be able to justify the deviation with an engineering study that describes another procedure linked to the minimum *MUTCD* levels. One or more of the following procedures can be used to support visual inspections:

- Calibration Signs: An inspector views a calibration sign each time before conducting a nighttime field review. The calibration signs have known retroreflectivity levels at or above the specified minimums. The calibration signs are set up in a maintenance yard where the inspector can view the signs in a manner similar to nighttime field inspections. The inspector uses the visual appearance of the calibration sign to establish the evaluation threshold for that night's inspection activities.
- Comparison Panels Procedure: This procedure involves assembling a set of comparison panels that represent retroreflectivity levels above the specified minimums. Inspectors then conduct a nighttime field review and when a marginal sign is found a comparison panel is attached and the sign/panel combination is viewed. Signs found to be less bright than the panel would then be scheduled for replacement.
- Consistent Parameters Procedure: The nighttime inspections are conducted under conditions similar to those used in the research to develop the minimum retroreflectivity levels. These factors include:
  - Using a sport utility vehicle or pick-up truck to conduct the inspection.
  - Using a model year 2000 or newer vehicle for the inspection.
  - Using an inspector who is at least 60 years old with 20/20 vision (corrected).

With the aid of one or more of these techniques, visual nighttime inspection can be an effective method for maintaining sign retroreflectivity and monitoring sign quality. When an agency is considering strategies, this is one method that might be closely examined. Before making a decision, there are some advantages and issues to consider:

- Advantages:
  - Evaluates more than sign retroreflectivity, such as face uniformity, message legibility, sign support integrity, damage, knockdowns, vandalism, obscuring vegetation, genera sign visibility, etc.
  - Provides the opportunity to observe other roadway items such as raised pavement markers, pavement striping, delineators, and object markers.
  - Does not require advanced equipment or sophisticated computer programs.
  - Limits the low amount of waste because only failed signs are targeted for replacement.
- Issues to consider:
  - Sign evaluation is subjective.
  - Inspectors need to be properly trained and one of the three supportive techniques be used correctly.
  - Because nighttime inspection occurs during non-regular work hours, overtime and next-day scheduling may be a concern.
  - There are outside aspects that are difficult to control such as weather, moisture in the air, and oncoming vehicles headlights.
  - Agency procedures need to be followed consistently.

Measured Retroreflectivity

The measured sign retroreflectivity method directly obtains retroreflectivity values with specialized equipment. Sign measurements remove the subjective nature by acquiring a specific retroreflectivity value. Repeatable and adequate measurements require both a calibrated instrument and a knowledgeable operator. As with the visual nighttime inspection method, standard operating procedures need to be established.

There are two types of devices that measure sign retroreflectivity in the field: contact instruments, which require the operator to place the device in direct contact with the sign face, and noncontact instruments, which can measure sign retroreflectivity from a distance and where devices can be either hand-held or vehicle-based systems. Noncontact instruments can expedite the sign measurement process and offer a significant amount of flexibility; however, the trade-off is higher levels of uncertainty. The current technology of vehicle-based systems is not yet at the level of practical implementation; therefore, agencies must use hand-held contact units.

There are two common types of hand-held retroreflectometers and both instruments express measurements, the coefficient of retroreflection (R_A), in units of candelas per lux per meters squared (cd/lx/m^2). Measurements need to be taken at an observation angle of 0.2 degrees and an entrance angle of –4.0 degrees to be comparable to the minimum levels in the *MUTCD*.

Sign retroreflectivity measurement procedures are relatively straightforward; however, it is important that procedures be followed consistently. ASTM Standard Test Method E1709 outlines the procedures for operating and taking measurements with a retroreflectometer (*15*); it specifies that a retroreflectometer operator acquire a minimum of four retroreflectivity measurements per retroreflective sign color. The measurement locations are in different parts of the sign and the readings can be averaged when compared with the *MUTCD* minimum levels.

The measured sign retroreflectivity method can be expensive and time-consuming. Individual retroreflectometer units can cost between $10,000 and $12,000; therefore, assigning one to each sign technician is typically not feasible. Also, some measurements can be difficult to obtain because the lower edge of many signs is 7 ft above the road surface. Readings may require the use of a ladder, and overhead signs may call for a truck with a boom lift. The readings may also expose sign technicians to more potential roadway hazards and place them in undesirable locations. Widespread implementation of this method at a large agency may not be practical because of the cost, time requirements, and roadway exposure. The advantages and issues to consider are:

- Advantages:
  - Readings can be directly compared with *MUTCD* minimum levels.
  - A retroreflectometer removes the subjective nature of the visual nighttime inspection.
  - Data collected throughout the years can provide sheeting material deterioration rates for localized conditions.
  - Sign compliance can be thoroughly documented and there is a minimal amount of waste because only failed signs are targeted for replacement.
  - The *MUTCD* minimum contrast ratios for red/white signs can be obtained.
  - Measurements can be obtained during normal daytime work hours.
- Issues to consider:
  - Retroreflectometers can cost between $10,000 and $12,000.
  - Signs may be difficult to access because of physical barriers, sign height, and certain roadway conditions. Obtaining some measurements with hand-held contact units can be difficult and time-consuming.
  - Dew, light rain, and moisture on a sign can impede the data collection process.
  - Agencies must decide if sign measurements are to be collected when the signs are washed or unwashed.
  - Units only account for retroreflectivity readings and this method does not consider overall sign appearance and uniformity.
  - Obtaining measurements may expose sign technicians to potential roadway hazards and place them in undesirable locations.

In general, sign retroreflectivity measurements appear to be best suited to complement another method.

Expected Sign Life

The expected sign life method is the first of the three different management methods. The main aspect of the expected sign life method is that it documents and tracks individual signs to be replaced before the service life period expires. Sign service life represents the length of time that a certain sign sheeting material will be used in the field while remaining in compliance with the minimum retroreflective requirements. Sign service life can be based on sign sheeting warranties, test deck or field measurements, or empirical data from other regional studies.

The key is being able to identify the age of individual signs, which may be accomplished through a scientific system and/or advanced technology. The level of complexity and sophistication depends on an agency's needs and available resources. Implementation of the expected sign life method can vary significantly; however, there are three main components to most successful systems. These components, in a hierarchical order, are establishing sign installation dates, identifying signs for replacement, and organizing sign data.

The first component is establishing a sign's installation dates, which is the foundational base to the expected sign life method. The majority of the agencies employing this method use installation date stickers to track sign age (*16*). An installation date sticker may contain the fabrication and/or installation dates, sheeting type, unique sign identification number, and/or other agency specific information. The stickers are typically placed on the back of signs in a visible area. Figure 1 shows several examples of sign installation date stickers. Barcode labels can also be used and serve the simple purpose of linking important information physically to the sign. Another simple technique to establish sign age is through digital images. Most digital cameras record the date and time stamp noting when a picture was taken, and some cameras can also associate latitude and longitude coordinates with the image, which transitions into the next component.

The second component is identifying and locating individual signs that require replacement. Large agencies with sizeable sign inventories need to be able to identify the locations of signs slated for replacement. Two effective forms of sign location information are spatial data and benchmark-based data. Spatial coordinates could be collected with a hand-held Global Positioning System (GPS) unit and benchmark-based data could be measured with a Distance Measurement Instrument from the nearest cross street or mileage marker.

The third component deals with organizing and managing the sign data. A large sign inventory may generate a significant amount of data and agencies need to be able to access information in a timely and efficient manner to schedule sign replacement. The sign location and installation data can be linked and stored in either a spreadsheet form or a geographic information system (GIS)-based platform. Microsoft Excel is one type of spreadsheet software and Google Earth and ArcGIS are two examples of spatial mapping platforms. A small agency could use Google Earth and the latitude and longitude coordinates from the images of a digital camera to populate an expect sign life system.

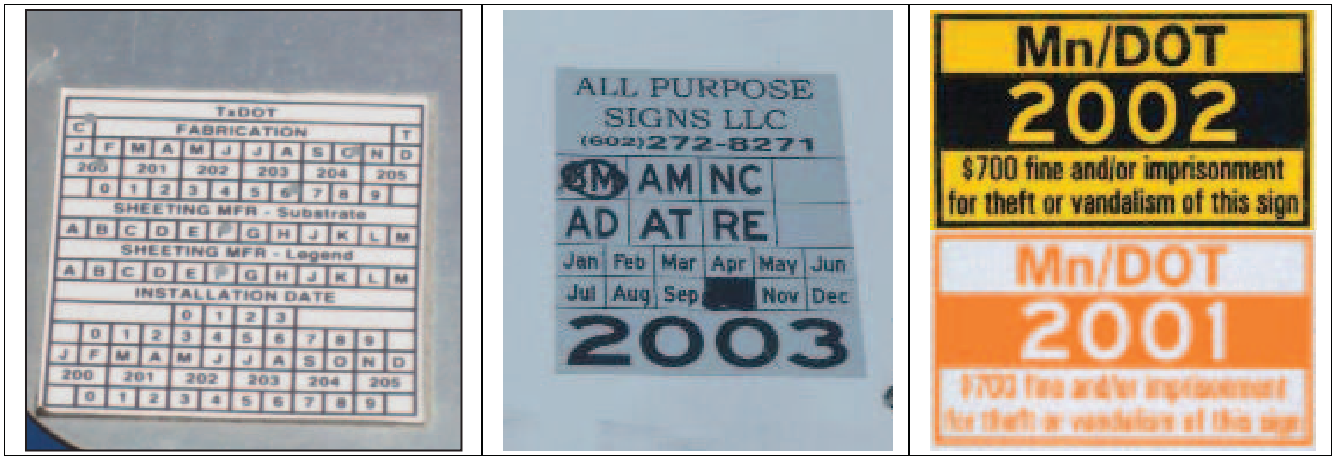

FIGURE 1 Images of sign installation date stickers.

Agency needs and objectives vary considerably and there are many different options and levels of sophistication for expected sign life systems. These systems may have a sign inventory component that allows agencies to query specific sign information or asset management features that allow for enhanced planning, work scheduling, and budgeting capabilities. In all systems, the overall objective is to expedite and streamline maintenance operations through the effective organization and management of the sign data. Expected sign life systems or inventory programs could be developed in-house or acquired through an outside vendor. Several LTAP centers offer systems at a reasonable cost and there are many commercial companies that have developed packages that include data-gathering equipment and sophisticated software.

Agencies considering this method need to thoroughly research the many different options available before selecting a system or program. An agency could take into consideration its level of resources, funding, staff demands, and technical expertise. A system is selected that is compatible with both short- and long-term agency goals. There also needs to be general acceptance from all involved users and parties. If users are not willing to fully support the system and keep the sign information up-to-date and accurate, then the investment into the system could be wasted. The advantages and issues to consider are:

- Advantages:
  - Sign replacement can be thoroughly documented.
  - There may be only a small amount of waste because only those signs near the service life period are targeted for replacement.
  - This method can expedite and streamline signing operations.
  - This method keeps accurate records of the sign inventory and is easily able to access specific sign information.
  - This method provides asset management capabilities and enhanced tools for planning, scheduling, and budgeting purposes.
- Issues to consider:
  - Service life periods need to account for the different types of sheeting materials and environmental conditions that may affect retroreflectivity.
  - This method relies on accurate and up-to-date information of individual signs.
  - Sophisticated and advanced systems may require a high level of technical support and expertise.
  - Collecting sign inventory data and initially creating an expected sign life system can be an expensive and time-consuming process.
  - Administrative, maintenance, and upkeep cost can be high.
  - Computer-based systems are susceptible to technical problems and information loss.

Blanket Replacement

The blanket replacement method uses service life periods and is similar to the expected sign life method; the fundamental difference derives from targeting a large group of signs as opposed to identifying individual signs. The replaced signs can be based on either spatial or strategic data. The spatial sign replacement removes all signs in a certain geographic area. The scale of the spatial area can vary widely between agencies. The area could be limited to a single road or corridor or as large as all signs in a county. The strategic approach replaces all signs of a common characteristic such as sheeting type, sign classification, and sign content. Upgrading sign sheeting from Type I to Type III is an example of strategic replacement. STOP signs are a major concern and may have a strategic priority for replacement over warning and guide signs. Blanket replacement could incorporate both spatial and strategic characteristics by removing specific sign types in a certain area.

The major advantage of the blanket replacement method is that it is relatively easy and straightforward to implement. Operations and resources are minimal; it does not require advanced personnel training, high administrative cost, or time-consuming maintenance procedures. A computer-based sign inventory and management system may not be a requirement, but it could greatly benefit this approach. When implemented, agencies typically stagger the blanket replacement schedule to simplify planning and budgeting.

Consider an agency using Type III High-Intensity Beaded Sheeting, which has a warranty period of 10 years. The agency divides its jurisdiction into ten different areas. Each year, that agency will replace all the signs in one of the ten different areas and the replacement rate for each area is based on a regular 10-year cycle. Planning, scheduling, and budgeting can be simplified when an agency knows that it will have to replace around 10% of the sign population each year. Figure 2 is a map of a blanket replacement schedule and the divided areas.

The blanket replacement method documentation is simple and an agency can draft a short policy memo justifying the service life period, defining the area boundaries, and outlining the yearly sign replacement procedures. Because all of the signs in a specific area are replaced on a regular cycle, the chances of having signs that are below the *MUTCD* minimum requirements are small. An agency can easily show that it is implementing its method and working toward compliance through work orders and sign replacement schedules. Overall, the blanket replacement method has simple procedures, removes subjectivity, and can simplify sign replacement documentation.

Conversely, the blanket replacement method can lead to premature sign replacement and waste. Signs are sometimes replaced before the retroreflectivity falls below the minimum levels and reasons could be attributed to vandalism, vehicle knockdowns, road reconstruction, and changes in standards. As a result, signs in a specific blanket replacement area will not always have the same installation period. When the replacement cycle is reached, there may be many signs with adequate retroreflectivity that are removed. Not only do signs not reach full potential in the field, but maintenance costs for replacing adequate signs in the long term may be a substantial drain on agency resources. The advantages and issues to consider are:

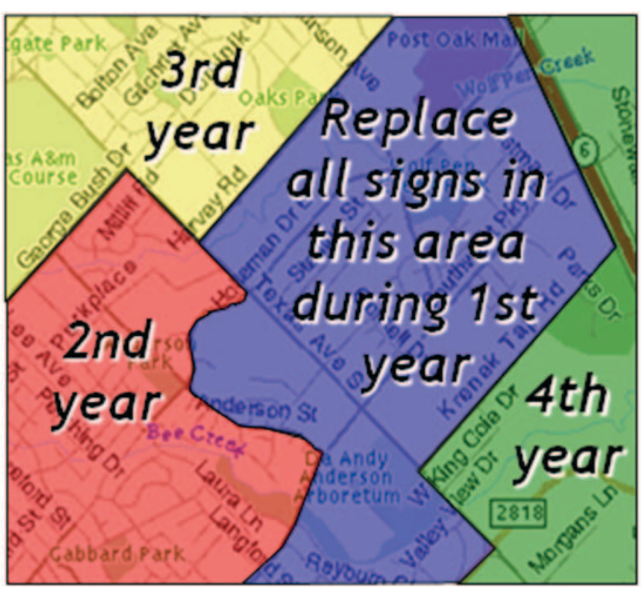

FIGURE 2 Blanket replacement map and schedule.

- Advantages:
  - Identifying signs and formulating the replacement schedule is simple and straightforward.
  - Administrative costs are low.
  - Regular replacement cycles can help with planning, scheduling, and budgeting.
  - There is the capacity to target certain sign types such as placing a greater priority on STOP signs or removing all Type I signs from the roadway.
  - Sign inventory and management systems may not be necessary; however, they could provide support.
- Issues to consider:
  - There is a high possibility of premature sign replacements.
  - There remains the need to determine the replacement cycles.
  - Routine daily inspection and maintenance is still needed.
  - Operating costs and additional sign installation labor could be higher than with other methods.

Control Signs

The control signs method is the third sign management strategy and it may utilize both sign assessment and management techniques to maintain sign compliance. The *MUTCD* states that sign replacement in the field is based on the performance of a sample set of control signs (*1*). Specific sheeting types in the controlled sample set represent the retroreflective values of a sign population in the field. The control signs may be a sample in a secure maintenance yard or selected signs on the roadway. Control signs are monitored and assessed to determine retroreflective performance. When the control signs approach the retroreflective minimums, all corresponding signs in the field are replaced. The control signs method requires a means of establishing a creditable sample set, sign evaluation techniques, and a system to locate corresponding signs in the field.

The first step is to establish an acceptable and effective sample size. An agency should select a sample size that it determines is appropriate and justifiable. The National Transportation Product Evaluation Program conducts sign deterioration studies for new sheeting products for AASHTO. It tests two panels for each new sheeting type in an accelerated experiment to determine minimum levels of outdoor durability (*16*). Carlson and Lupes recommend testing a minimum of three signs per sheeting type continually installed at strategic intervals (*17*).

Another aspect of the control signs method is determining adequate sign sample locations and arrangements. The unprotected signs on an open roadway are exposed to vandalism, knockdowns, and other forms of premature damage. A protected facility greatly lessens the likelihood of the control signs being harmed, and may provide a limited and biased sample that does not fully represent roadway conditions. Unprotected sample signs can encompass a large geographic area and cover a wide range of roadway conditions. It is important that the unprotected sample size is large enough to compensate for signs that are removed or damaged during the evaluation period. It may be an effective strategy to establish control signs in both a protected area and on the open road.

Unlike the previous two management methods, this approach requires the periodic use of a retroreflectometer. Measuring the retroreflectivity of control signs should follow the same procedures outlined in ASTM Standard E1709-00e1 (*15*). An average of four readings per retroreflective sign color is recorded to document the retroreflectivity levels throughout the life of the sign. The time intervals between consecutive measurements depend on an agency's objectives and desired level of precision. Carlson and Lupes (*17*) rationalized that too little time between measurements of control signs may lead to the misuse of labor and resources, whereas long periods between readings may lead to inaccuracies in predicting service life in the field. This method not only indicates when corresponding signs in the field require replacement, but can also help to establish regional specific service life periods for different sheeting materials. The control signs method allows an agency to document and verify the extension of service life periods past the manufacturer's warranty.

The control signs method is a desirable option for agencies that want to monitor regional sign performance, but do not want to spend the time and resources to measure every sign in the field. This approach could be used when an agency wants to extend or examine service life of a specific sign sheeting material. Because sign measurements are periodic, an agency may be able to borrow a retroreflectometer from a LTAP center or rent a unit from a vendor once per year instead of spending between $10,000 and $12,000 to purchase one. The advantages and issues to consider are:

- Advantages:
  - The ability to monitor regional specific year-to-year sign retroreflectivity performance without having to measure every sign in the field.
  - A means to validate the extension of service life for a specific sign sheeting material past the manufacturer's warranty with the purpose of minimizing cost and resources.
- Issues to consider:
  - Agencies need to purchase or obtain a retroreflectometer.
  - Installing control signs, collecting measurements, and analyzing the data can be time-consuming and costly.
  - This method requires continuous monitoring of control signs and regular upkeep.

SIGN SERVICE LIFE

The sign retroreflectivity management methods have a common theme of being based on knowledge of the sign service life, or the length of time that a certain sign sheeting material will remain compliant with the minimum retroreflective requirements (without being subjected to bullet holes, graffiti, or other sources of damage that would result in premature removal). The retroreflectivity of a sign will degrade and deteriorate over time as it is exposed to regional environmental conditions. When a sign reaches or approaches the end of its service life, it is then replaced. Different sheeting materials, regional conditions, and maintenance practices are some of the major factors that can significantly affect service life periods.

The sign service life that an agency selects can be based on several different options such as sign sheeting warranties, test deck or field measurements, or empirical data from other regional studies. The most basic and rudimentary approach would be using sign sheeting manufacturers' warranty periods as a substitute for service life for one of the management methods. A typical manufacturer's warranty period guarantees that a sign will retain 80% of the original retroreflectivity levels within a certain time period and does not necessarily represent a sign's true service life. Most warranty periods are fairly conservative because the same warranty period needs to cover all signs whether they are in Arizona or Alaska. Some signs may fail before the end of the warranty period, but most will surpass it.

Table 2 provides an example of how conservative warranty periods can be for certain sign sheeting types. The last column in the table shows the difference between the manufacturers' warranty values and the *MUTCD* minimum maintained retroreflectivity level for black on white regulatory signs. The table contains the typical manufacturers' warranty values, which are 80% of the ASTM new sheeting values. It can be noted that the 80% threshold in new sheeting retroreflectivity is typical. Besides the Type I and Type II sheeting, it may be inferred that most of the sheeting types' service lives may extend well past the typical warranty periods.

Manufacturers' warranty retroreflectivity values may deviate from the typical 80% thresholds, which mean that the warranty service periods may also vary. Typical and common warranty periods are seven years for Type I and ten years for Type II and Type III sheeting materials. There is a wider range for prismatic materials, which include Type IV,

TABLE 2
BLACK ON WHITE REGULATORY SIGNS COMPARISON

ASTM Retroreflective Sheeting Type*	ASTM New Sheeting R_A Values*	Typical Manufacturers' Warranty R_A Values	*MUTCD* Minimum R_A Level	Difference in Warranty and Minimum R_A
I	70	56	50	6
II	140	112	50	62
III	250	200	50	150
IV	360	288	50	238
VIII	700	560	50	510
IX	380	304	50	254
XI	580	464	50	414

Note: All retroreflectivity R_A values are in units of cd/lx/m^2 for an observation angle of 0.2° and an entrance angle of −4.0°.

*ASTM information originated from ASTM D4956-11a (*18*).

Type VIII, Type IX, and Type XI. The warranty periods for these prismatic materials may range from 10 to 12 years depending on the sheeting type, color, and signing application. These warranty periods may be different, but the periods mentioned previously were common industry lengths at the time. Besides warranty periods, service life may be ascertained from past regional studies.

One of the first studies to assess sign service life and deterioration rates was conducted in 1992 by Black et al. for FHWA (*19*). The objective of the study was to determine factors that contributed to sign retroreflective degradation and to formulate models based on significant factors to accurately estimate retroreflectivity. The researchers collected retroreflective readings from 5,722 signs in 18 different locations throughout the United States. In addition to the measurements, the collection process identified sheeting color, type, contrast ratio, sign direction, ground elevation, area type, and sheeting age. The measurements revealed that Type III signs performed adequately for up to 12 years. The analysis determined that sheeting age, ground elevation, and temperature were significant factors in sign deterioration. It also showed that the sign direction and solar radiation variables were not acceptable predictors of in-service sign retroreflectivity. The researchers also created deterioration models for projecting service life periods in certain conditions. Despite weak correlation in some of the models, the deterioration equations predicted that most Type III sign sheeting could last well past the manufacturers' warranty periods.

Ten years later, the Louisiana Department of Transportation and Development produced a study that generated retroreflectivity deterioration models (*20*). The objectives of the Wolshon et al. study were to assess current compliance rates, determine influential factors, and create statistical models to predict retroreflectivity relative to age. The data collection measured 237 signs in Louisiana and identified key environmental factors that might affect sign deterioration. The results showed that 92% of the signs under the 10-year warranty were above the minimum requirements. Of those signs past the warranty period, 43% were in compliance.

A study at Purdue University by Bischoff and Bullock (*21*) applied a similar approach; however, their primary objective was to determine if Indiana's current Type III 10-year service life needed to be shortened or could be extended. A total of 1,341 Type III roadway sign retroreflectivity measurements were recorded, and sheeting colors included red, yellow, and white. Many of the signs exceeded the 10-year warranty period and installation ages were as high as 16 years. Overall, the analysis found that only seven signs were not in compliance with the minimum requirements and signs past 10 years were performing adequately. Linear prediction models were created that showed that red Type III sheeting produced the highest R-squared value at 0.32, and white Type III sheeting displayed the lowest at 0.02. There was a great deal of disparity in the regression models and differences became more evident as sign age increased. Ultimately, researchers could not fully support the prediction models, but did recommend that the service life of white and yellow Type III sheeting be extended to 12 years and that the service life of red Type III sheeting remain at 10 years.

The last and most recent expected service life study was conducted in 2006 by Rasdorf et al. for the North Carolina DOT (*13*). There were similar objectives and a comparable approach to the earlier studies. Measurements were compiled from 1,057 Type I and Type III signs in North Carolina and included the four different colors. Models were generated from linear, logarithmic, polynomial, power, and exponential functions. The majority of the models exhibited poor correlation and the R-squared values ranged from 0.01 to 0.48. Within the sign sheeting types, white had the weakest relationship, while red showed the strongest, which was similar to the Bischoff and Bullock study (*21*). Despite the poor correlation, the majority of the Type III signs performed well and the models projected long-term retroreflective compliance beyond 10 years.

CHAPTER THREE

RANGE OF PRACTICES

This chapter summarizes the general material from survey responses and includes valuable practices, trends, and guidance. The first section covers the survey results, and the following sections are comprised of noteworthy information for each of the five different assessment and management methods.

SURVEY RESULTS

The survey participants were identified from agency websites, past presentation materials, and referrals and contacted through professional society e-mail lists, meeting announcements, and professional contacts. In some cases, they notified the consultants that they were interested in participating; in other cases, it was the consultants who requested participation. Most of the surveys were conducted by telephone and typically lasted 30 minutes. A few participants forwarded written survey responses or detailed e-mails owing to time constraints. In total, this study received responses from 49 different agencies and organizations. Figure 3 contains a map of the survey participants and a list of the different agencies can be found in Appendix C.

The survey included a broad sample and the participants came from all time zones in the contiguous 48 states. Geographic and climatic conditions were diverse. The local agencies were located in different demographic areas from both urban and rural conditions, with population densities ranging from 30 to approximately 3,800 residents per square mile. Agency sign inventories ranged from fewer than 4,000 to an estimated 1.3 million. Survey participants came from 24 local agencies, 16 state DOTs, and 8 others. Local agency respondents were from 2 towns, 7 cities, 14 counties, and 1 toll road agency. The others category included survey participants that did not manage public roads and were not in a position to implement a *MUTCD* method for maintaining sign retroreflectivity, and consisted of LTAP centers, private consultants, and a product vendor.

Table 3 contains the distribution of the 40 agencies that have selected a method for replacing and maintaining a sign population. For clarification, the total survey participant count was 48; however, the agencies that operated roadways open to the public numbered 40. The difference was a result of the "other" category. The table shows the five *MUTCD* methods and the number of agencies that have selected it as a primary and secondary method. The primary method was defined as the agency's principal approach for identifying and replacing signs. The secondary or support methods were strategies that supplemented the primary method and helped to ensure sign compliance. Each agency is represented in the primary method column, but this was not always the case for secondary methods. Some agencies did not employ a secondary method and others combined two or three. For example, one agency used visual nighttime inspection as the primary means for identifying inadequate signs; however, it also had a sign inventory system to better manage resources and collected control sign measurements to monitor sheeting material longevity.

VISUAL NIGHTTIME INSPECTION

The visual nighttime inspection method was the second most selected method. Thirteen agencies employed this as their primary method and two agencies used it as a secondary or support method. Despite its common use, it was determined that most of these agencies could be divided into two distinct groups: agencies that have implemented nighttime inspection in the past and agencies that quickly rejected it. A few agencies selected the method when they had no previous inspection experience; however, the majority of the participants were could be placed in the two distinct groups. In addition, it was noted that many agencies believed that they were in compliance with the *MUTCD* because they were routinely inspecting their signs at night. However, during the interviews it was discovered that they were not actually following the three procedures FHWA has outlined for nighttime visual inspections.

Those agencies that did not use nighttime visual inspection were most concerned with the potential of increased tort lawsuits because of the subjectivity of this method. Two agencies in urban areas were dissuaded from using visual nighttime inspection because sign inspector safety could not be guaranteed in certain high crime areas. However, the most common concerns regarding nighttime inspection regarded staffing, overtime pay, and schedule modification. Some of the survey agencies were downsizing and it would have been difficult to expand maintenance activities with existing limitations. Generally, the rejection group believed that visual inspection required too much time and resources.

All survey participants with visual nighttime experience gave it positive remarks. With regard to staff demands and

FIGURE 3 Map of survey participant locations. *Note:* The gray shading indicates the participating state DOTs. The "Local Agencies" (•) include towns, cities, counties, and a toll road agency. The "Other Agencies" (∆) include LTAPs, private businesses, and other survey participants that did not select a *MUTCD* method.

scheduling, the agencies noted that there were challenges, but none were insurmountable. The scheduling of nighttime inspection sessions differed among agencies; some in the north conducted inspection sessions in either early fall or late spring, whereas others in the south preferred the winter months. The common key is conducting sign inspections during the time of the year when there is less daylight. Nighttime inspections were also typically scheduled when there were less frequent maintenance activities. In rural areas, a night session would last approximately 3 to 5 hours and cover about 100 miles of one direction of a roadway. Inspectors would stop if dew or frost started to form on the signs. Most agencies employed a team of two that consisted of a dedicated driver and a sign inspector; however, there were some agencies that completed inspections with just one employee, but it was not common. Visual sign inspection was usually documented on a specialized form or a notepad, whereas some agencies used audio recording devices.

A few survey participants elected to complete all of the nighttime inspection sessions during a period of one or two weeks, whereas others completed them over several months when there were periods of downtime. One agency preferred to use all of the maintenance staff and a few office personnel to complete all roadway inspections in one night. This way the inspections are quickly out of the way and the maintenance staff can move on to other items. One agency has multiple sign crews; when one sign crew conducts nighttime inspections, the other sign crews compensate by assuming a larger share of the routine daytime sign maintenance. Most agencies have their maintenance staff adjust their work schedules to complete inspections within an 8-hour shift.

TABLE 3
DISTRIBUTION OF METHOD SELECTION

MUTCD Assessment and Management Methods	Primary Sign Replacement Method		Secondary or Support Method	
	Local Agencies*	State DOTs	Local Agencies	State DOTs
Nighttime Inspection	6	7	0	2
Measured Retroreflectivity	2	0	0	0
Expected Sign Life	11	4	11	5
Blanket Replacement	3	5	4	0
Control Signs	2	0	5	5

*The local agencies include towns, cities, counties, and the one toll road agency. The sum of the Primary Sign Replacement Method columns adds up to 40. The Secondary or Support Method columns add to a different total because it is not required to have a secondary method and agencies may have multiple support methods.

There may be overtime or shift differential pay for some of the inspections; however, it was not queried in the survey.

Another important aspect of this method concerns the inspection intervals or frequencies. The *MUTCD* does not state how frequently signs should be inspected, whether once per year or once every two years. There were several agencies that consistently inspected all roadway signs each year; however, inspection intervals ranged from four per year to once every five years. The agency with a five-year interval was conservative with inspections and more likely to remove any questionable signs. One respondent expressed the opinion that when the inspection interval was longer, there was a higher possibility of having inadequate signs on the roadway. Conducting nighttime inspections once per year appears reasonable, but this study did not identify any optimal inspection interval.

Visual nighttime inspection can also be used as a secondary or temporary support method. One agency needed to conduct a quick assessment of the overall sign population and utilized nighttime inspection to sample various roadways in the county to better understand the quality of the existing signs for a cost analysis. The nighttime inspection of sampled roadways revealed that approximately one-third of the signs were inadequate. Consequently, the agency elected to implement an expected sign life method in an attempt to save adequate signs as opposed to wasting resources in a countywide blanket replacement. One of the benefits of visual nighttime inspection cited most often was maximizing sign service life. One participant mentioned that Type III signs between 10 and 15 years old would typically look fine during inspections. One DOT noted that this method can extend the use of some signs for up to 20 years.

The *MUTCD* does state that "the retroreflectivity of an existing sign is assessed by a trained sign inspector" (*1*). Some of the DOTs had established training programs that consisted of field demonstrations and/or instructional materials. One DOT placed signs of various retroreflectivity levels along a local racetrack and maintenance personnel were trained to find the substandard signs. Another DOT had a computer-based training course that provided examples and descriptions of failed signs and an inspector would complete a short test that was kept on record. It was mentioned that certain LTAP centers also provided training courses, but the majority of the participants relied on past experience and on-the-job training. It was common to hear that many inspectors had between 10 to 20 years of job experience.

For additional resources on visual nighttime inspection, the *MUTCD* refers readers to 2007 FHWA publication *Maintaining Traffic Sign Retroreflectivity* (FHWA-SA-07-020) (*14*). In that publication, FHWA recommends that an agency use one or more supportive techniques for nighttime visual assessments, including consistent parameters, calibration signs, and comparison panels. Apart from training, most agencies had not decided which supportive technique(s) they plan to implement. Several of the DOTs were exploring calibration signs, but have not formalized procedures. One DOT was using a retroreflectometer to measure signs that were recently replaced to find signs that were at or near the minimum levels to be used in the calibration procedures. There was one sign sheeting manufacturer that began producing comparison panels; however, there were no respondents that were aware of the manufacturer's product before the surveys were conducted. There was some confusion with the supportive technique requirements and this was one area where participants thought more guidance would be helpful.

MEASURED RETROREFLECTIVITY

Measured retroreflectivity was the least selected method and most agencies did not consider it as a primary method for maintaining minimum sign retroreflectivity. The LTAP centers surveyed strongly recommended other methods because of the high cost for a retroreflectometer and for the considerable demand on labor and time. Again, there were two different types of retroreflectometers and each cost approximately $10,000 to $12,000 per unit. Most agencies are currently trying to do more with less and the purchase of a retroreflectometer was not a cost-effective option. Along with the initial cost, measuring a large sign population can be a substantial drain on manpower. Some of the surveyed DOTs possessed a retroreflectometer and used it for periodic sampling; a few local agencies also own a retroreflectometer and several had the ability to borrow a unit from an LTAP center.

The Minnesota DOT's *Traffic Sign Maintenance/Management Handbook* (*22*) states that data collectors following the ASTM E1709-00e1 standard can measure approximately 20 signs per hour, although a lower rate of 10 to 15 unwashed signs per hour was documented in a 2011 TRB publication (*23*). In this study, the data collection process measured between 80 and 120 signs per day. The higher rate was only achieved once and was the result of continuous favorable shoulder conditions and signs that were spaced close together. Measurements take time and can be a tiring process if readings are collected over prolonged periods of multiple hours. The measurement rate is also heavily dependent on the roadway conditions and the location of the sign.

Based on past data collection experience, some measurements may be difficult and time-consuming to obtain as a result of physical barriers, sign height, and shoulder conditions. Some retroreflectivity measurements may require that technicians use a ladder or a truck with a boom lift. Bridges, guardrails, unstable roadway shoulders, limited sight distance, overhead mast arms, and nearby railroad tracks are just a few examples of difficult measurement conditions. High-speed and high-volume roadways may also place sign technicians in undesirable locations where it would be prudent to have additional traffic control. There are ample opportunities to measure signs on a roadway for a control sign sample or study; however, some sign measurements may not be worth the time and effort.

In the survey, two agencies were exploring the use of the measured retroreflectivity method as their primary approach for replacing signs. The first agency was a county with a population of approximately 114,000 residents in mostly rural areas. The engineer estimated that there are approximately 80,000 signs on 2,600 centerline-miles. The county attorney was concerned about tort liability and believed that measured retroreflectivity would be the best method to verify sign compliance. The sign measurements would also be recorded and tracked in a sign inventory system. The county engineer would like to purchase several retroreflectometers for maintenance staff. The agency already inspects each sign and sign support once per year during daytime hours. The engineer envisioned that the maintenance staff would collect and record retroreflectivity measurements as they perform their yearly inspections. Signs would be replaced primarily when the readings were near or below the minimum levels to extend sign use. This participant reported that the method was still being developed. Overall, the county planned on combining existing maintenance activities with an additional step to ensure sign compliance and maximize service life.

The other agency using the measured retroreflectivity method was a toll road organization that operates a prominent bridge, multiple transit facilities, and approximately six miles of roadway. The participant estimated that they currently manage about 400 signs. The agency used Type III sheeting and wanted to maximize the service life of existing signs. A few years before, a student intern created a basic sign inventory system in Excel; however, the sign information had not been kept up to date. The initial plan was to borrow a retroreflectometer from the local LTAP center for up to two weeks. A team of maintenance technicians would collect retroreflectivity readings for all signs. They would also have a chance to update and verify information in the existing sign inventory system. The measurements would help to prioritize immediate sign replacements and the updated information would be used when establishing an expected sign life system where future replacements are based on service life periods.

EXPECTED SIGN LIFE

Of all the sign retroreflectivity maintenance methods listed in the *MUTCD,* the expected sign life method was found to be used the most often. Several of the LTAP centers recommended that agencies strongly consider some type of expected sign life system to better manage resources and track sign data. When asked if they had any advice to provide to other agencies, the most common response from participants was "know how many signs you have on the roadway." Although this method is based on individual sign replacements, the practical implementation is centered on effective management and organization of sign data. With the pending compliance dates on sign retroreflectivity, it appears that agencies finally have the justification to build a sign inventory, assess the signs' condition (specifically retroreflectivity but other characteristics as well, such as hardware, placement, and necessity) of the sheeting, and predict the remaining life using expected sign life.

Among the survey participants, 17 of 41 agencies utilized this method as their primary means for replacing signs. Of the participants that selected alternative sign methods, 16 of the 24 agencies implemented some type assessment method system as a secondary method. Regardless of being a primary or secondary method, there were many common aspects between both approaches. For this section, primary and secondary methods that manage and track sign information were broadly referred to as an expected sign life system.

There were two basic ways that the expected sign life method was used. One way was to build an inventory, assess the signs' condition (especially retroreflectivity), and then develop an estimate for the remaining number of years that the signs could be in service. The second way to implement the expected sign life method without building an inventory is to start installing date stickers on the signs.

Regardless, agencies still need to have an estimate of their signs' service life. Some agencies used the manufacturer's warranty periods as a default service life and replacement period. A manufacturer's warranty period guarantees that a sign will retain 80% of the original retroreflectivity levels over a certain time period and does not represent a sign's service life. A sheeting material can last significantly longer than the warranty period. One city used a replacement period of 7 years for Type I sheeting. Others reported that their service life replacement periods were based on past experience and field observations. A few participants conducted formal studies to justify the extension of the previous replacement period with the purpose of maximizing resources. A Midwestern DOT's formal study extended the replacement period from 14 to 18 years for Type III signs and they hope to achieve 20 years of service life for signs on overhead sign panels (*24*). Service life replacement periods varied substantially; however, 10, 12, and 15 years were common. Some of the literature relevant to sign life was included earlier in this report.

Apart from service life, most survey respondents acknowledged that they were able to identify sign age from the date stickers that were placed on the backs of signs. The stickers by themselves had little effect on maintenance; however, it was generally agreed that this was a good practice.

Beyond the installation of date stickers, an agency needs some type of structured and systematic approach for managing information and replacing signs such as in a sign inventory system. One basic method would be maintaining a collection of photographs that depict roadway signs and document the installation date. An additional step would be to maintain a formal written list of sign information; however, when dealing with large quantities of constantly evolving sign data, it is better to have a more robust system. Sign inventories are described further later in this report.

BLANKET REPLACEMENT

Blanket replacement was the third most selected method by survey participants. Seven agencies use this method as their primary means for sign replacement and two agencies use it as a secondary approach. Agencies that employed blanket replacement often described it as simple and easy to implement, although this method did have its detractors.

The most common concern was the potential waste of labor and materials that came from replacing adequate signs. A research report in 2006 examined past NCDOT sign budgets and determined that the agency replaced 4.7% of the sign population as a result of vandalism or damage (*13*). One of the DOT participants tracked and monitored sign activities throughout the state and estimated that for any given year 10% of all signs were knockdowns. Another agency tracked the installation of 3,000 signs from 1995 and found that approximately one-third remained on the roadway 16 years after installation. These examples illustrate that many signs will not last to the end of the blanket replacement cycles and there will always be replacements resulting from routine attrition. Regardless, many survey participants have been able to successfully address the waste issue.

Agencies using the blanket replacement method curtailed sign waste by setting certain sign tolerance periods and trying to reuse adequate signs. For example, one of the surveyed DOTs implemented a corridor blanket replacement method with a replacement cycle of 15 years. That DOT has gathered empirical data and collected regional sign measurements to determine that certain sheeting materials can last up to 15 years and sometimes longer. During corridor replacements, it would salvage and not remove any sign in the roadway that was less than three years old. Most signs in that state were replaced after 15 years; however, some could have a maximum installation age of 18 years. In this instance, the blanket replacement cycle and tolerance period were based on the DOT's experience and a certain level of comfort.

Another DOT implemented a different approach to reducing waste and salvaging adequate signs. This DOT set the blanket replacement cycle for roadway corridors at the 10-year warranty period. The participant acknowledged that most signs would be adequate after the warranty period, but they did not have a formal study to verify that the replacement cycle could be systematically extended. In the absence of such a study, the DOT utilized the visual nighttime inspection as a secondary method to extend sign longevity and to ensure retroreflectivity compliance. Basically, the DOT set the blanket replacement cycle at 10 years, but would not replace any sign that had been installed for six years or less. With the combined methods, the maximum installation of a sign was 16 years, and the nighttime inspection helped to extend the use of a sign in lieu of a formal study.

On a smaller scale, a participant from a midsize county salvaged signs during blanket replacement, which would be removed from the roadway and used as backups or in reserve. Based on the county's experience, signs would typically last between 10 and 15 years. The county resurfaces or reconstructs certain roadways each year and during that time all signs on the resurfaced roadways would be replaced. One advantage to this approach of combining roadway resurfacing and sign replacement was that the funding would come from the construction budget as opposed to the maintenance budget. In certain cases, there may be more funding and flexibility when dealing with the construction budget. To reduce waste, the county borrowed a retroreflectometer from the state LTAP center and measured signs that they perceived to be salvageable. The salvageable signs were stored at the maintenance office and used as backup or in reserve. For example, if a STOP sign was knocked down during the weekend, a maintenance technician would use one of the salvaged signs as a quick and adequate replacement.

One county selected the blanket replacement method because sign replacement could be easily documented. The survey participant was concerned about liability and a possible increase in tort lawsuits. The county attorney believed that blanket replacement was the easiest method to document and defend in court. For this agency, waste and removing adequate signs from the roadway were not major issues. Its approach was to divide the county into different regions and sign replacements were staggered for a 10-year cycle, which was based on the warranty period. When a region was scheduled for replacement, all of the signs were removed regardless of installation age and nothing was salvaged. The county kept records of work orders and sign replacements to verify that all signs were under warranty and within compliance. The agency acknowledged that signs could last longer than the warranty periods; however, it was more important to the agency to reduce liability than try to extend sign service life.

CONTROL SIGNS

The control signs method was another approach that few agencies considered and only two agencies selected it as a primary means of replacing signs. One of the agencies was actively implementing the method and the other was in the preliminary phases of determining formal procedures. Many participants did not thoroughly investigate this method because it requires both a retroreflectometer for collecting measurements and a system for managing sign data. This method may take time to implement but it does have advantages.

The agency implementing the control sign method established it in 2007 and maintains approximately 32,000 signs. The county owned a retroreflectometer and had setup a sign inventory system that was developed in-house to manage and track individual signs. Each year, maintenance technicians measured the retroreflectivity of 150 of the oldest signs for each sign color. These signs are in the field and are unprotected. The sign inventory system was utilized to determine the locations of the oldest signs on the roadway. The oldest signs served as the control sample and it was believed that if these signs were still meeting the minimum levels, then the newer signs should also be adequate. The estimated time requirement for a team to complete all measurements was approximately 40 hours. The yearly retroreflective readings were analyzed to identify sign failures and failing contrast ratios. The new readings were compiled with the past measurements to determine retroreflective deterioration rates for different sheeting types. In theory, control sign failures would identify the regional service life periods and all signs with a similar installation age would be targeted for replacement. The county started using Type III sheeting in 1995 and switched to Type IV a few years ago. Sixteen years after installation, there had not been any measurements that were below the *MUTCD* minimum levels; therefore, there had not been any targeted replacements.

The county was pleased with the control signs method and has presented material on the strategy in several conferences and meetings. The agency plans to continue the same control signs procedures and they have expressed interest in purchasing a second retroreflectometer. As stated earlier, this was the only agency implementing control signs as the primary sign replacement method; however, there are several that have used a similar strategy as a secondary or support method.

Of the surveyed DOTs, 6 of the 16 state agencies possessed retroreflectometers. In 2007, one state completed a sign service life study. This DOT collected retroreflectivity and chromaticity measurements from 211 Type III control signs in the field. The control signs were located in two different parts of the state, and the sample varied in color and type. The results helped the agency to justify the extension of the blanket replacement cycle from 14 to 18 years. The control sign measurements also determined that some of the red STOP signs failed to meet some of the color requirements in ASTM Standard D4956-09. The agency believed it had been being too conservative with blanket replacements and the control sign measurements helped it to ascertain a more appropriate cycle length. In 2009, that DOT officially changed sign sheeting from Type III to Type IV and planned on continuing control sign measurements to establish a suitable cycle length for the new sheeting.

Another DOT using this method set up a control signs test deck to establish regional service life periods for existing sheeting materials and to evaluate new products as they are introduced into the market. The control signs test deck consisted of 56 signs that varied in color and material type. It was located in a protected maintenance yard office in the state capital. The DOT positioned the signs to face south and tilted them at a 45 degree angle to accelerate the deterioration process. Retroreflectivity measurements were collected every six months and readings were compiled to analyze sign deterioration rates. The control signs test deck helped to establish an appropriate service life period for the DOT's expected sign life method.

In a different approach, one county planned to utilize control sign measurements to monitor failed signs and evaluate visual nighttime inspectors. The county arranged to borrow a retroreflectometer from the state LTAP center with the purpose of collecting measurements of failed signs that were removed and replaced. The participant stated that the readings could help to identify if signs with high retroreflectivity levels were being removed prematurely or if sign inspectors needed to remove certain signs sooner. In this case, the control signs method was not only used to monitor sign retroreflectivity, but it was also implemented to help reevaluate and improve existing maintenance practices.

SIGN INVENTORIES

The new minimum sign retroreflectivity standards in the *MUTCD* do not require agencies to build and/or maintain sign inventories. However, it was evident that many of the agencies contacted during this study believed that the new minimum sign retroreflectivity standards gave them the final justification they needed to build a sign inventory so that they could best manage their signs.

Sign inventories varied in functionality and complexity, but many were relatively simple and developed in-house. One of the simplest computer-based systems was developed by a student intern as a summer project for one of the surveyed agencies. The intern formatted an Excel spreadsheet to include the desired sign attributes and it was found to work well for a sign population of fewer than 1,000. Another participant also used Excel and it worked satisfactorily for a much larger sign population. In a similar approach, one agency created an Access database that interfaced with ArcView to manage both sign and spatial data. That system was developed in 2001 by in-house staff and the system included attributes, pictures, and GPS coordinates for more than 10,000 signs. One of the DOTs was operating a system that was developed in the 1980s by agency staff from a DOS program. The system was a somewhat cumbersome and the participant needed replacement; however, it still served a valuable purpose.

Another county used an in-house system for tracking sign replacements and work orders that started as paper records. An employee took the paper record format and expanded it into a computer-based program. The program started with modest origins; however, it had evolved to include pull-down menus, advanced data filters, and mapping capabilities.

Nonprofit agencies and private businesses offer a wide range of software packages and products to manage sign inventories. In the nonprofit category, systems have been created by LTAP centers or university-based organizations. These programs are sometimes free or can be purchased at a reasonable cost. Two examples include Transportation Asset Management Software from the Utah LTAP center and Roadsoft from the Center for Technology & Training at Michigan

Tech University. Two of the surveyed agencies used one of the programs and both expressed positive opinions. Survey participants also used a variety of commercially available off-the-shelf systems, several of which were spoken of highly. Essentially, the key was selecting a system that fits an agency's requirements, which was easier said than done.

One participant acknowledged that finding existing software packages was not difficult; however, it was determining which one best accommodates an agency's needs and desires that was. Another survey participant was evaluating different programs at the time of this report and was preparing to solicit vendors to present the system to the agency. Expected sign life systems are long-term strategies, but a large part of that investment comes at the beginning during the initial sign data collection process.

Each agency has created its initial sign inventory and gathered the data differently. One DOT in the north started the process during the winter when there was downtime. The staff reviewed roadway video-logging files and aerial images at the beginning of the initial data collection. In the spring, staff traveled the roadways to gather additional data and to confirm the accuracy of the initial collection. One surveyed county collected sign data and GPS coordinates for approximately 24,000 signs during the summer. A team of one full-time employee and one student intern absorbed the data collection tasks in with their regular summer maintenance activities. The county engineer described the data collection process as manageable and indicated that the student intern was a significant help in the creation of the sign inventory.

A surveyed private consultant shared his experience with inventorying sign data for nine U.S. military installations. One of the challenges for the consultant was estimating time demands and he determined that a team of two could collect data for 220 signs each day. The consultant advised that an agency should determine what sign attribute information is needed before starting the collection process. He also recommended that it was easier to gather inessential sign data in the initial collection than in a secondary effort. One participant acknowledged that the data collection process helped to identify where additional signs were needed and where unnecessary signs could be removed.

In addition to traffic signs, many of the participants inventoried and incorporated other roadway items into the same system. For example, one of the LTAP software packages included modules to manage signs, culverts, guardrails, and roadway pavement conditions. Participants mentioned that they also include pavement striping, roadway no-passing zones, and sidewalk data into the same system. One agency started with a program that was originally purchased to manage bridge information. Once the staff gained proficiency with administrating bridge data, the system was expanded to manage other roadway items such as signs and culverts. Another participant recognized that it was more important to implement one system that can encompass multiple roadway items than to have multiple systems that manage one asset each.

One of the advantages to sign inventory is the ability to quickly access sign data. One participant reported that its system was frequently used when there was an inquiry from a concerned resident. Staff could promptly access specific sign information and promptly address the issue. Another example involved missing signs; a technician in the field would report any missing signs to the main office. The office would directly identify the missing sign and process the work order. In this way, the field technician would not be required to spend much time investigating and the replacement process could be accelerated.

The last example deals with knockdown signs. Before creating a sign inventory, one agency made two separate trips to handle such incidents. The first trip would ascertain the sign type, dimensions, and necessary hardware and the second trip was for the actual replacement or repair of the sign. Having a sign inventory eliminates the first trip, because a technician can determine all of the sign information from an office computer. Quickly accessing sign information is valuable and particularly beneficial when time is an issue.

Agencies have also been incorporating new technologies into their sign inventories with the goal of streamlining maintenance. Several of the surveyed DOTs were in the process of transitioning their current systems to web-based platforms. Uploading large quantities of sign data has been time-consuming and a new platform can significantly reduce the data processing time. One large city was expediting activities by implementing a paperless maintenance system; work orders would be received and completed digitally. Another agency was implementing a similar strategy, but with tablet computers that maintenance technicians could use in the field. It is possible that in the future maintenance staff will be able to receive work orders, query sign information, and upload GPS coordinates with smartphones or other similar devices from the side of the road.

Of all the advantages of the sign inventory, most of the agencies touted the planning and management capabilities. Participants consistently noted the benefits of knowing the number of signs on the roadway for future planning, scheduling work orders, tracking replacements, and budgeting yearly sign expenses. One DOT was able to budget sign replacements three years in advance, allowing them to address any funding concerns with DOT administrators. When switching from Type III to Type IV sheeting, one participant was able to quickly prioritize and budget Type III sign replacements. A city utilized sign data to estimate the cost of bringing its sign inventory into compliance for the 2015 and 2018 deadlines. Similarly, a DOT was able to predict that the minimum retroreflectivity requirements would cost an additional $2.5 million per year to meet the 2015 deadline. In both cases, the agencies were better able to seek additional funding sources because they provided detailed information and were able to express a clear need.

Despite the potential advantages of a sign inventory, a system is only useful if the sign information is accurate. One individual remarked that the most difficult task of sign management activities was keeping the sign inventory up-to-date. Another DOT transitioning to a new and more advanced system, reported a gap in time when sign information and replacements could not be updated. This period of inactivity resulted in some difficulties for maintenance staff and impeded the initial progress of the new system. Along with keeping the sign information current, it was also critical to keep staff proficient and trained.

One of the participants shared experiences with a new program and initial training. It was acknowledged that many of the maintenance technicians have limited experienced with computer programs. Many had concerns about the new system and believed that maintenance practices were fine without adding further responsibilities. The solution was to quickly create a support group that could address the technician's initial concerns. The support group also gathered technician feedback to help customize the program and make it more user-friendly. The agency brought in a vendor to provide training and initial technical support. The technicians were able to gain a sense of ownership for the system when they were involved from the onset of the project. The participant indicated that the sign inventory system was now a large part of the technicians' routine tasks and there have not been any major concerns.

Based on the responses from this effort, it is clear that there are many advantages of developing and using a sign inventory system that go beyond simply managing sign retroreflectivity. Most agencies use their systems for the potential planning and resource management capabilities. One participant stressed that it took a great deal of time and troubleshooting before benefits could be achieved, and that other agencies considering this method should stay committed, exercise patience, and continue to make incremental improvements.

CHAPTER FOUR

CASE STUDIES

This chapter includes the case studies of four different agencies that participated in the survey. Each case study provides detailed information about the agencies' sign replacement and management practices. These agencies have implemented effective combinations of methods and it was believed that providing additional detail to the readers could be beneficial. Each case study deals with different geographical and climatic conditions and the agencies were of different sizes and types.

CLIFTON PARK, NEW YORK

Background

The town of Clifton Park, New York, is in Saratoga County and is a small suburban community that lies just north of the Albany and Schenectady metropolitan areas. The town has about 37,000 residents and the municipal government maintains approximately 200 miles of centerline roadway miles within a 50 square mile area. For the regional climate, average summer high temperatures are in the 80°F range and winter average lows are in the teens (*25, 26*). The annual cumulative snowfall is approximately 60 in. per year and the annual cumulative rainfall is about 38 in. At the time of this report, it was estimated that the town maintained approximately 6,000 traffic signs.

Sign Replacement Methods

Clifton Park has been diligent with routine sign maintenance and day-to-day sign replacements, but the area has grown significantly within the last decade and the town has annexed many outlying residential developments, presenting some challenges for the small community. First, some signs and posts within the newly incorporated areas differ from the town's standards, and it was necessary that the signs and equipment be uniform and compliant. The other main challenge was the difficulty in budgeting and planning, because the town did not have an accurate estimate of the number of signs in existing and new areas.

In 2007, the town began to address its signing issues and the *MUTCD* minimum retroreflectivity levels. Despite routine maintenance, some of the signs did not meet the minimum requirements. The changes and sign replacement were viewed as an opportunity to improve overall quality; however, the revisions involved additional labor and expertise. The few Clifton Park staff members were proficient and knowledgeable about basic routine maintenance activities; however, minimum retroreflectivity requirements were a new issue. Minimum values contained in *MUTCD* Table 2A.3 were new and terms such as observation angle and contrast ratio had not been commonly used. To resolve this situation, the town sought outside assistance, by soliciting technical advice from regional experts. The Albany and Schenectady area contains many government agencies and Clifton Park staff was able to consult with professionals from the departments of transportation and public safety. After investigating the issues and consulting with regional experts, the town was able to obtain 402 safety improvement funding and set a course of action.

When evaluating the different signing methods offered in the *MUTCD,* the town gravitated toward approaches that fit its resources and expertise. Measured retroreflectivity was not an option for a small agency such as theirs owing to the high price of a retroreflectometer and limited staff hours. Similarly, the visual nighttime inspection method was also deemed to be too time-consuming, and nighttime work would detract from important daytime activities. The town had experience with GIS and GPS technologies and already possessed the necessary equipment. Therefore, the town opted to pursue a management approach where sign inventory and asset management tools would be utilized.

Staff first reviewed several different software products and packages. They found that several commercial systems offered too many features that would not be used. On the other hand, some of the LTAP programs were not equipped to handle all of the town's needs. Ultimately, the town selected a local consulting company to help customize a computer-based system that would fit its needs. The consultants created a program that was similar to the town's existing storm water management system. The program was designed to be very user-friendly with simple drop-down menus and buttons. Throughout the creation process, the consultants solicited advice and feedback from its intended users.

Clifton Park planned to use the computer-based system to manage its sign data for a combined expected sign life and blanket replacement approach. The town was divided into 12 separate regions and signs would be replaced in one of the regions each year as part of a 12-year replacement cycle. The town was installing traffic signs with Type IV or higher sheeting materials. It was acknowledged that such sheeting may last longer than 12 years; therefore, signs less than three years old in an area scheduled for blanket replacement would remain and be monitored periodically to ensure compliance. Signs between the installation age of four and five years would be removed, but would be used as temporary replacements if a sign was damaged or knocked down.

Method Review

The town of Clifton Park acknowledged that many of the issues that small agencies encounter such as fiscal restraints and vandalism were similar to challenges faced by larger agencies. One major difference that a small agency would have to contend with is the limited number of staff. This small agency needed personnel during daytime hours and experienced difficulties with rearranging work schedules. It was desirable to select a method that could easily be added to their already tight work schedules. Also, the staff at Clifton Park was informed about but not experienced with the minimum retroreflectivity requirements. As a result, they sought outside assistance and advice from local professionals who were more knowledgeable.

Ultimately, the town emphasized the importance of continuing education and participation in professional societies. Through interacting and networking with other professionals, the town was able to acquire additional funding, select an appropriate course of action, and customize a computer-based system that would address their current and future needs. By sharing knowledge and expertise, this small agency was able to address the problems presented by limited staff size and gain the benefits that a larger agency may possess. Town officials hope to share their experiences and knowledge with other small agencies at upcoming conferences.

ST. LOUIS COUNTY, MINNESOTA

Background

St. Louis County is a large rural county in northern Minnesota that covers approximately 7,000 square miles. The 2010 census population was approximately 200,000 residents and the largest city is Duluth. The area is accustomed to dealing with long winters and the average low temperature for the winter and spring is about 15°F (*25, 26*). Average annual precipitation is approximately 31 in. and the average annual snowfall is approximately 78 in. The yearly average possibility of sunshine is 52% and the average number of cloudy days per year is 186. At the time of this report, the public works department employed seven full-time maintenance technicians who were engaged in traffic signing activities. The resident engineer estimated that the county maintains approximately 40,000 signs and approximately 3,000 centerline-miles.

Sign Replacement Methods

The county was familiar with the *MUTCD* retroreflectivity requirements and took proactive steps to meet the compliance dates. The county had a combination of Type I, Type III, and Type IV sheeting materials. Based on their experience and field observations, most of the Type III and Type IV signs lasted from 10 to 12 years. The agency had been committed to regular sign replacement, but admitted that there were some Type I signs that had been on the roadway for 15 to 20 years. The first step the engineer took was to continue to use durable and adequate sign sheeting materials. It was believed that some of the newer Type III and Type IV sheeting still performed adequately; however, the Type I and many of the older signs needed to be replaced. The engineer believed that replacing them with new Type XI signs would be more noticeable to for drivers during adverse weather conditions.

St. Louis County previously implemented a blanket replacement method with adequate results. The county was divided up by townships and all signs on a segment of roadway were typically replaced at the end of the replacement cycle based on material warranty periods. The engineer simply modified and accelerated the existing blanket replacement schedules to meet both the 2015 and 2018 compliance dates. Along with this method, the county maintained a sign inventory system that helped with maintenance activities and resource management.

The sign inventory started as an Access database that simply documented sign information and blanket replacements. By 2005, maintenance demands quickly exceeded the capabilities of this system and the agency transitioned to a new program. The engineer acknowledged that their needs and requirements continued to expand and the county changed programs again in 2010. The new system was relatively inexpensive and was able to track and manage other roadway items. Each sign inventory system transition progressed smoothly and there were no major issues or loss of information. The engineer reported that individual sign information was checked for accuracy during the course of each system change allowing the agency to identify missing and unnecessary signs.

St. Louis County elected to continue blanket replacement because it was well-established and staff was accustomed to the routine replacement cycles. The visual nighttime inspection method was considered; however, it was decided that the county was not properly staffed to inspect such a large amount of roadway. The measured retroreflectivity method was also quickly rejected for a similar reason.

Method Review

One of the keys to St. Louis County's approach was that the staff was familiar with the routine blanket replacement cycles and the sign inventory system. The primary and secondary methods had worked effectively and the engineer did not need to implement any sizeable or hasty changes to meet the *MUTCD* compliance dates. Procedures were kept straightforward and consistent, which has allowed the county to be thorough in maintenance activities and not neglect any areas. With the blanket replacement method, the engineer was not overly concerned about premature sign replacement and no signs were reused. It was acknowledged that being able to document sign compliance and follow a routine schedule were acceptable tradeoffs. Routine blanket replacements were staggered, which allowed the engineer to better plan budgets and work schedules. Overall, the county's consistent and diligent approach has enabled it to maintain a high level of sign quality, which will allow them to easily meet the *MUTCD* requirements.

Another key to the county's approach was reducing the number of unnecessary signs. When St. Louis County changed sign inventory systems in 2010, it checked the accuracy and location of most of the roadway signs. During this period, the engineer made it a priority to remove any unnecessary signs. The county received guidance from the Minnesota DOT's *Traffic Sign Maintenance/Management Handbook* (*22*), which reported that over-signing was a critical issue and a substantial drain on resources. The engineer stressed that signs should be installed when there was a clear need. Plans included removing special Warning signs that were deemed unnecessary, such as Deer Crossing symbol signs or Watch for Children signs. The engineer reasoned that the reduction in unnecessary signs could help drivers to focus on more critical driving tasks and allow the county to conserve valuable resources.

PHOENIX, ARIZONA

Background

Phoenix is the capital of Arizona and the sixth largest city in the United States. It encompasses 500 square miles and is comprised mostly of developed urban areas. The city's nickname is the "Valley of the Sun" and it is well-deserved. High temperatures in the summer routinely reach 110°F and the annual possible sunshine rate is 85% (*25, 26*). Phoenix experiences an average annual precipitation rate of 8 in. and the average wind speed is 6 mph. At the time of this report, the city maintained an estimated 800,000 signs and 5,500 centerline-miles. Maintenance responsibilities were divided into six different regions and each region had its own sign crews who were responsible for daily maintenance and sign replacement.

Sign Replacement Method

In Phoenix, the two issues that continuously affected the sign inventory were the harsh climate and urban vandalism. First, the constant sun and the high temperatures can cause some materials to deteriorate faster. Type III signs in some parts of the country may last from 10 to 15 years; however, Phoenix reported that its Type III signs remained adequate for only 8 to 10 years. The city recently changed to Type IV sign sheeting and hopes to extend the service life past 10 years; however, as yet they have not conducted any formal studies on sign longevity. From its experience, red STOP signs and yellow–green fluorescent School Zone signs have a tendency to fade in color at a faster rate than other types of signs. Previously, the city requested that sign crews monitor these signs and replace any signs when the color appears to have faded. Legend peeling on Regulatory and Warning signs was another problem. To address these issues, the city switched from using black vinyl to acrylic materials, which has reduced the peeling and legend shrinking issues. Because of the harsh climate engineers continuously need to monitor sign quality and make small adjustments to extend service life.

Concerning vandalism, there were high rates of spray paint-damaged signs in certain areas of the city. Phoenix has responded to this problem by applying anti-graffiti film to all signs. Maintenance staff can now wipe off or wash a sign to remove spray paint and not have to replace the entire sign. The engineers were concerned about maintaining adequate retroreflectivity levels; however, they have expressed more concern about other issues that affect sign appearance and message content such as color fading.

The engineers previously used the blanket replacement method as its primary means for replacing signs. Blanket replacement cycles were based on the city's experience with sign deterioration, because some materials would fail earlier than the specified in warranty periods. Because of the high vandalism rates and attrition, many of the signs on a given roadway that were scheduled for blanket replacement would differ in age. Maintenance staff would try to salvage and reuse adequate signs if they were one or two years old.

Phoenix has acknowledged that it has been diligent in sign maintenance and management; however, there have been difficulties with dealing with such a large urban area with a harsh climate. Despite proactive measures, many city signs would not meet the *MUTCD* minimum retroreflectivity requirements. It was agreed that the city needed to take additional action if it was going to meet the 2015 and 2018 compliance dates. At the time, the city did not have a functioning sign inventory system, but it did have detailed records of blanket replacements in each of the six regions. Engineers used these records to prioritize sign replacements and complete a cost estimate. It was estimated that to bring street name signs alone up to compliance would cost $11.5 million.

The engineers used the detailed cost information to secure stimulus money to fund blanket replacement of STOP and YIELD signs throughout the city. Additionally, they received a grant from a large sheeting manufacturing company to inventory and collect sign data for 14 major roadways. The initial inventory covered only approximately 250 centerline-miles of the total 5,500; however, it allowed the city to better manage resources on the more heavily traveled roadways. Using the aforementioned grant, the engineers planned to utilize an expected life sign approach and replace individual signs. The engineers wanted to expand the initial data collection to cover more roadways, but funding was limited and replacing inadequate signs was a higher priority. Until additional funding was secured, the city used expected sign life for the 14 roadways and blanket replacement for all other areas.

Other methods were considered, but none were determined to be practical. It was also decided that purchasing a retroreflectometer was not feasible and borrowing one from an LTAP center not beneficial. Visual nighttime inspection was also considered, but staffing was an issue. Staff demands were already high with existing maintenance and overtime was a concern. If staff was going to conduct sign inspections, the engineers preferred such inspections during routine daily maintenance, because vandalism, sign discoloration, and legend peeling were also major issues.

Method Review

Overall, Phoenix has developed a viable plan and is working toward the goal of sign compliance despite the constraints and challenges. The detailed blanket replacement records allow the city to evaluate the current state of the sign inventory and helps them to prioritize sign replacements. Engineers have completed a detailed cost estimate that provides the total expenditures for bringing the sign population into compliance for the 2015 and 2018 deadlines. With the cost estimate, they were able to secure stimulus funding and the previously mentioned grant. These additional funding sources were limited, but they helped to address some of the higher priorities, which were STOP and YIELD signs and high-volume roadways.

When asked at the end of the survey to provide advice for other agencies, the engineers acknowledged that it was to "start small and expand." Given the constraints and funding limitations, the city was not able to complete a sign inventory for all of the roadways or replace all of the signs at once. A careful review of their resources and capabilities was undertaken to create a detailed plan that prioritized short- and long-term sign inventory management. Critical issues were addressed first and future expansion of the service life system planned for when resources became available. For a few roadways it was not ideal to implement an expected sign life method and blanket replacement for other areas; however, it was practical and feasible at the time.

MISSOURI DEPARTMENT OF TRANSPORTATION

Background

The state of Missouri is situated in the middle of the country and experiences a wide range of climatic conditions. The yearly temperature can vary from 90°F in the summer to below freezing in the winter (*25, 26*). The average annual snowfall ranges from 20 in. in the northern portion to 10 in. in the south. The yearly average possibility of sunshine for four major cities within the state ranges from 56% to 61%. The land type includes gently rolling hills, dense forest, and agricultural flatland. The state has a mix of urban and rural areas and mirrors the demographics of many other states across the country. The Missouri DOT (MoDOT) roadway system is comprised of approximately 32,000 centerline-miles, which include several major Interstates and a significant number of two-lane rural highways. It was estimated that the state maintains between 700,000 and 1 million signs.

Sign Replacement Method

MoDOT has been proactive with replacing signs resulting from inadequate retroreflectivity. Rural areas experience more vandalism and knockdowns were an issue in urban areas; however, inadequate retroreflectivity was the primary reason for sign replacement. MoDOT engineers have been aware of the *MUTCD* requirements for some time and did not have any major concerns about the upcoming 2015 and 2018 compliance dates. It believes that the overall sign population is in satisfactory condition and that existing methods for maintaining and managing signs required only minor modifications.

Prior to the minimum retroreflectivity ruling, MoDOT used an alternating annual day/night inspection of its highway signs. These inspections were conducted by both engineering staff and field crews. These individuals were not officially trained, but simply learned by observing those they inspected with. This process was somewhat effective, but did result in some variation in inspection results from one part of the state to another. When the new retroreflectivity rules became official, MoDOT originally implemented a blanket replacement method as a means to address compliance. However, the department switched to visual nighttime inspections in late 2009/early 2010 because of the possible waste from early sign replacement that could occur and the desire to extend the sign service life of the signs as long as possible. After 2010, nighttime inspections in the state were conducted at least once per year and it was recommended that a team of two conduct inspections during the fall or spring. All inspectors followed the same basic procedures, but each of the 10 different districts in the state implemented slightly different inspection techniques. The participant responded that the primary concern with the current strategy was that inspections varied too greatly throughout the state and MoDOT needed a more consistent approach.

MoDOT first developed written guidelines for all districts to follow. The guidelines standardized the visual nighttime inspection procedures and documented the basic steps. The second part of the guidelines provided descriptions for adequate and failing signs. Because of the subjective nature of the inspection process, some districts were more likely to remove adequate signs prematurely. State engineers requested more consistent sign evaluations and sign performance descriptions to help remove some of the variability. Along with the guidelines, MoDOT implemented statewide training for sign inspectors. The training procedures were still being developed, but it was envisioned that inspectors would view a mix of adequate and failed signs to train their eyes. Quality assurance checks were initiated to monitor the inspectors. An engineer would use a retroreflectometer to spot-check certain signs on randomly selected roadways. The quality assurance checks were a way to assess inspection consistency and to provide inspectors with feedback.

To supplement the visual nighttime inspections, MoDOT created an advanced expected sign life system. The state previously operated a program developed by a former employee; however, this system was now outdated and had become difficult to maintain. When this employee retired, there was a considerable loss of expertise and changes to the program were complicated. Also, the old system did not integrate well with new technology and a work order required several steps before it was included in the system. These complications negated many of the expected sign life system benefits and changes were required.

The new system offers the agency more interconnectivity and features that are more versatile. It was developed inhouse and was a web-based Oracle product. It greatly reduces unnecessary paperwork, and the web-based platform allows users to quickly search, upload, or change sign data. The transition from the old system to the new system was reasonably straightforward and well-organized. The new system is compatible with touch-screen and smartphone devices, and it was anticipated that technicians would be able to create or complete a work order in the field, which would then automatically update the sign inventory information. The new system helps to expedite maintenance operations and streamline the flow of data.

Method Review

MoDOT has used both assessment and management methods to maintain its sign population. The visual nighttime inspection assesses sign retroreflectivity and confirms compliance with the *MUTCD* minimum levels. The new system documents if a sign has either passed or failed the visual nighttime inspection and ultimately offers a wide range of management capabilities to make maintenance operations more efficient. It is believed that this is a well-rounded approach that ensures both high sign quality and effective use of resources.

The state agency has proactively addressed the subjective nature of visual inspections and implemented a program to achieve more consistent sign evaluations. The guidelines and formal training help to refresh the knowledge of veteran inspectors and provides guidance to new staff members. Quality assurance checks monitor the sign inspections and the results provide feedback to the inspectors. As a result, MoDOT has created a cyclical process that continues to improve the quality and consistency of its sign inspection method.

The new system offers a large number of management and organizational capabilities. It helps track vandalism and monitor sign quality to extend the life of valuable resources. The engineers can use the planning, scheduling, and budgeting tools to improve maintenance operations. Technicians in the field are able to quickly access a considerable amount of information to accelerate and simplify their tasks. The agency is enthusiastic about all of the new systems potential, but still was most concerned with two very mundane issues; signs being knocked down by mowing crews and leaning posts. This new sophisticated system by itself will not ensure that a sign is straight, but it will expedite and simplify the basic maintenance needed to fix it.

This is an excellent example of an agency not concentrating exclusively on retroreflectivity and neglecting routine daily maintenance. A newly installed sign with high retroreflectivity values does not necessarily ensure driver visibility and comprehension. Routine daily maintenance can fix a twisted sign, right a leaning post, and trim trees limbs that would otherwise obscure a sign's message content. Focusing just on retroreflectivity is not a substitute for daily maintenance and vice versa. Maintaining adequate retroreflectivity and continuing daily sign maintenance are vital components and there needs to be an appropriate balance of both.

CHAPTER FIVE

EFFECTIVE PRACTICES

The effective practices identified by this study are presented here. They are presented as general sign practices and then for each sign retroreflectivity maintenance method. In addition, Appendix D contains common questions, myths, and answers associated with the new minimum sign retroreflectivity standards in the *MUTCD*.

GENERAL SIGN PRACTICES

- Type I sheeting material can still be used in certain situations; however, it is more cost-effective to install Type III or Type IV as a minimum standard.
- Explore sheeting materials and products that have a long service life. The higher cost of materials may be offset by reduced labor and fewer sign replacements.
- Stress the importance of sign assessment to staff during routine daily maintenance. It is also important to monitor such issues as sheeting color, vandalism, and damaged sign posts.
- Keep yearly sign maintenance and management practices consistent. Routine schedules and operations help to set a basic level of quality and prevent periods of neglect.
- Prioritize current and future sign replacement if resources are limited. Create a list of priorities and address items on the list in descending order such as targeting STOP and regulatory signs first, replacing warning signs, and so on.
- Unnecessary signs may be a substantial drain on agency resources and are not to be installed for political reasons. During sign inspections, assess whether each sign is still needed.
- Continue to seek maintenance information from outside sources such as FHWA, LTAP centers, surrounding agencies, conferences, workshops, journal articles, professional societies, etc.
- Identify sign assessment and management strategies that your agency could implement in a practical and efficient manner.
- Create a comprehensive sign plan that addresses existing and long-term goals.
- Document your sign assessment and management strategies and be able to demonstrate that you are actively implementing your approach in a consistent manner.
- Consider providing routine training for employees who deal with sign management and maintenance activities.
- Continue to reexamine your approach and long-term goals. Methods and strategies can be modified to improve operations and to better manage resources.

VISUAL NIGHTTIME INSPECTION

- FHWA intends for agencies to use one or more of the sign inspection procedures documented in *Maintaining Traffic Sign Retroreflectivity* (FHWA-SA-07-020) (*14*). If none of these procedures are used, an agency must be able to justify the deviation with an engineering study.
- For the calibration signs technique, commercial grade or Type I signs could be used. Signs removed from the roadway with known retroreflectivity levels at or slightly above the *MUTCD* minimums could also be used.
- It is more effective for inspections to be completed with a team of two, if possible, and during favorable weather conditions.
- It is best to perform nighttime inspections when there is flexibility or downtime in a staff's schedules. Inspections must not detract from daily activities and ideally the method would supplement and support routine maintenance.
- Inspection intervals or frequencies depend on an agency's capabilities and resources.
- Provide written expectations and guidelines for inspectors to follow. Handout materials can document the agency's procedures and offer descriptions and examples of adequate and failed signs.
- Implement training for both new and experienced sign inspectors. Agencies may create their own programs or participate in courses that are provided by the LTAP center or the state DOT. Having done visual nighttime inspections does not necessarily equate to training.
- Require a visual nighttime inspection form that an agency can utilize to document the sign inspection process. The forms can document such information as the roadway, inspector, date, and signs identified for replacement.
- Inspection teams monitor and report any other maintenance issues that are observed during nighttime inspections. The primary focus is on signs; however, the team might also be able to observe pavement markings, delineators, and other retroreflective items.
- Quality assurance checks can help to improve the inspection process and provide feedback to sign inspectors. Such checks can be completed with a retroreflectometer or by another impartial sign inspector.

MEASURED RETROREFLECTIVITY

- Measurements should follow ASTM Standard E1709 with four or more readings per sign color.
- The measured retroreflectivity method is best suited for agencies with smaller sign populations.
- It is important that collecting readings be completed within a manageable timeframe. The measurement process need not consume excessive amounts of time that could result in other maintenance activities being neglected.
- Measurements are to be combined with other routine maintenance activities. For example, staff can collect readings when examining sign supports or when repairing knockdown signs.

EXPECTED SIGN LIFE

- Resources for service life values for sign sheeting materials are available from FHWA, sign manufacturers, LTAP centers, DOTs, nearby agencies, and research reports.
- Expected sign life systems can be used to extend sign service life, expedite maintenance operations, and help manage resources.
- When selecting or developing a system, agencies should consider both existing and future needs and necessities.
- Systems should be able to expand and evolve over time. An agency must also be aware that systems may become obsolete or experience technical difficulties. There needs to be contingency plans for salvaging important data or transitioning to a new system.
- It is best to gather a wide range of sign data in the initial collection process to avoid having to collect additional information in a secondary effort.
- During the data collection process, it is beneficial to reexamine signs on the roadway to identify where additional signs are needed, where changes need to be made to comply with the *MUTCD,* and where unnecessary signs could be removed.
- It may be desirable to use the same or a similar system for multiple roadway items such as culverts, guardrails, roadway pavement, striping, no-passing zones, and sidewalks.
- Agencies need to be committed to the long-term use and support of this method. The system is only valuable if the data are kept up-to-date and accurate.

BLANKET REPLACEMENT

- Replacement cycles need to be regular and staggered evenly from year to year to help with planning, scheduling, and budgeting.
- Agencies need to document blanket replacement details such as cycle length, procedures, and segmented roadways/areas.
- Salvaging or reusing adequate signs could be considered if resources are limited.
- Records and work orders could be used to demonstrate that signs are replaced within a reasonable and acceptable time period.

CONTROL SIGNS

- Temporarily borrowing or renting a retroreflectometer might be considered if purchasing a unit is not feasible.
- Agencies should be able to justify their control signs' sampling procedures. It is important to establish an acceptable number of control signs and set appropriate measurement intervals.
- It is important that measurement data be accumulated and analyzed throughout the years to identify trends in sheeting performance and sign deterioration.
- Control sign data could be used to establish regional service life periods for certain sheeting materials. The regional data could then be used to extend service life for signs in the blanket replacement or expected sign life methods.

CHAPTER SIX

RESEARCH IN PROGRESS AND RESEARCH NEEDS

This chapter describes research in progress and identifies research needs. Aspects and issues where study participants thought there was a lack of guidance or information were noted and compiled. These areas are summarized here.

- Explore sheeting material color deterioration by collecting chromaticity measurements. Participants indicated that color appeared to fade more quickly in certain sign materials, orientations to the sun, and in different parts of the country. It is possible that color deteriorates sooner than retroreflectivity in certain situations. A presentation at the 2011 TRB Annual Meeting identified some early work on this issue (*27*).
- Identify the effects of nighttime inspection intervals on different sign populations. The nighttime inspection intervals in this survey ranged from four inspections per year to one inspection every five years. It may be helpful to discover if there is a nighttime inspection interval that optimizes resources while maintaining a high level of quality.
- Explore the feasibility for creating a national database that would contain important information with regard to traffic signing. Such a database could include sign service life information of different sheeting materials from across the county. The service life information could be comprised of past research, agency control signs measurements, and/or data from LTAP centers. The database could also document tort cases and help agencies comply with the *MUTCD* requirements. Important conceptual questions with creating the national database would be what information should be included, who would maintain and keep the information current, what media and platform would be used to distribute the information, and how to best service the targeted users. Future maintenance methods could also be documented and evaluated so that other agencies are aware of the options.
- Monitor the development of retroreflectivity measurement technology. The measured retroreflectivity method was the least selected method by the survey respondents owing to the high cost of a unit and the time required to collect data. For this to be a viable option for most agencies there needs to be a substantial reduction in the cost of a hand-held retroreflectometer or the noncontact mobile units need to gain proficiency.
- Analyze the maintenance benefits and cost savings of new digital devices and web-based platforms. It is now possible for maintenance technicians to search, upload, and change sign information from a smartphone or tablet computer while in the field. It would be beneficial to study agencies that are employing some variation of this technology and conduct a before-and-after cost analysis. Determine the areas and operations where technology can have the largest impact and try to quantify the savings in time, resources, and cost.
- Evaluate the supportive techniques for the visual nighttime inspection method in greater detail. Most sign inspectors acquire expertise from agency training or on-the-job experience. Some veteran sign inspectors were concerned about the different support techniques and thought they may be superfluous in some cases. It may be beneficial to further investigate the benefits of the calibration signs and comparison panels. For instance, are they most beneficial for junior-level staff and are comparison panels effective during daytime conditions?
- How does an agency properly evaluate contrast ratio on red/white signs when they are doing the nighttime visual assessment?

CHAPTER SEVEN

CONCLUSIONS

The objective of this synthesis study was to provide examples of effective and advantageous practices that illustrate how different types of agencies can meet the *Manual on Uniform Traffic Control Devices* (*MUTCD*) retroreflectivity requirements. The aim of this study was to document the state of the practice and identify content that could assist other agencies exploring different methods for maintaining sign retroreflectivity. Information was obtained from past research, existing guidance and policy, and telephone surveys. The surveys comprised the majority of the information in this report. The survey questionnaire included 14 main questions and was designed to facilitate an open-ended conversation about sign retroreflectivity and general maintenance practices.

Surveys were conducted with participants from different parts of the country. Overall, 48 agencies participated and 40 operate roadways open to the public that selected a sign retroreflectivity method from the *MUTCD.* From participant responses it was determined that the expected sign life method was the most selected primary and secondary method for replacing and managing signs. The second most frequently reported was visual nighttime inspection; however, agencies were somewhat conflicted about this method. Survey participants were typically separated into two groups; agencies that have used nighttime inspection and agencies that do not. The primary reason for rejecting nighttime inspection was that agencies were concerned about staffing and did not want to add another activity to an already demanding maintenance schedule. The blanket replacement method was the third most selected method and agencies employing this approach praised it for its ease and straightforward application. Finally, a few agencies were implementing the measured retroreflectivity or control signs methods. The cost for a retroreflectometer and time requirements for the measurements were the deciding factors.

The survey findings identified several strategies and techniques that were considered as effective practices. The effective practices are described in chapter five and varied for each *MUTCD* method. The most noteworthy practice for the visual nighttime inspection was the implementation of training programs to ensure inspector proficiency. Resource management tools were the most prominent benefit for the expected sign life method and agencies can utilize sign information for planning, scheduling, and budgeting. Simplicity and ease were the most valued benefits in the blanket replacement method. It is an effective practice to evenly and consistently blanket replace signs within an agency from year to year. Purchasing a retroreflectometer can be expensive; however, such measurements could be valuable, particularly in support of other methods. It is an effective practice to utilize the control signs method to justify the extension of sign warranty periods so that agencies can expand sign service life and maximize potential resources. Lastly, replacing signs based solely on retroreflectivity measurements can be time-consuming. If an agency has access to a retroreflectometer, it is most beneficial when used in conjunction with routine daily maintenance; however, the readings should not detract or eclipse other important activities.

This synthesis study revealed that survey participants were implementing a variety of primary and secondary methods for maintaining signs and ensuring retroreflectivity compliance. Selection ranking aside, participant responses showed that each method exhibited distinct advantages and operational benefits.

It should also be pointed out that FHWA has a report detailing each of the sign retroreflectivity methods listed in the *MUTCD.* The FHWA report also includes a useful description of how to conduct the assessment methods. Finally, it also outlines the advantages and disadvantages of each of the sign retroreflectivity methods listed in the *MUTCD,* and can be found at: http://safety.fhwa.dot.gov/roadway_dept/night_visib/policy_guide/fhwahrt08026/.

One final note, FHWA has started rule making that may potentially change the *MUTCD* language regarding sign retroreflectivity (see *Federal Register,* Vol. 76, Volume 169, pp. 54156–54162). A final rule has not yet been issued and is not expected to be issued until the summer of 2012 (after the current January 2012 compliance date to select and implement a sign retroreflectivity maintenance method). Although these on-going rule-making activities may change the specifics of the minimum retroreflectivity regulations in the *MUTCD,* it is still considered good practice to maintain sign retroreflectivity for nighttime drivers.

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APPENDIX A

Minimum Maintained Retroreflectivity Levels Resources

The first document is reprinted here in its entirety because of its importance. This document is referenced in the *MUTCD* and contains the basic information of the visual inspection method that outlines the three specific procedures that FHWA intends to be used if the visual inspection method is selected. Other valuable sign retroreflectivity resources are included in this Appendix.

NEW MUTCD SIGN

U.S. Department of Transportation
Federal Highway Administration

RETROREFLECTIVITY REQUIREMENTS

Maintaining Traffic Sign Retroreflectivity *FHWA-SA-07-020*

Traffic signs provide important information to drivers at all times, both day and night. To be effective, their visibility must be maintained. The 2003 *Manual on Uniform Traffic Control Devices* (MUTCD) addresses sign visibility in several places, including Sections 1A.03, 1A.04, 1A.05, 2A.06, 2A.08, and 2A.22. These sections address factors such as uniformity, design, placement, operation, and maintenance. Previously, the MUTCD did not specify minimum retroreflectivity levels.

The second revision of the 2003 MUTCD introduces new language establishing minimum retroreflectivity levels that must be maintained for traffic signs. **Agencies have until January 2012, to establish and implement a sign assessment or management method to maintain minimum levels of sign retroreflectivity.** The compliance date for regulatory, warning, and ground-mounted guide signs is January 2015. For overhead guide signs and street name signs, the compliance date is January 2018. The new MUTCD language is shown on page 2 and 3 of this document.

The new standard in Section 2A.09 requires that agencies maintain traffic signs to a minimum level of retroreflectivity outlined in Table 2A-3 of the MUTCD. The Federal Highway Administration (FHWA) believes that this proposed change will promote safety while providing sufficient flexibility for agencies to choose a maintenance method that best matches their specific conditions.

Including Table 2A-3 in the MUTCD does not imply that an agency must measure the retroreflectivity of every sign. Rather, the new MUTCD language describes five methods that agencies can use to maintain traffic sign retroreflectivity at or above the minimum levels. Agencies can choose from these methods or combine them. Agencies are allowed to develop other appropriate methods based on engineering studies. However, agencies should adopt a consistent method that produces results that correspond to the values in Table 2A-3.

The new MUTCD language recognizes that there may be some individual signs that do not meet the minimum retroreflectivity levels at a particular point in time. As long as the agency with jurisdiction is maintaining signs in accordance with Section 2A.09 of the MUTCD, the agency will be considered to be in compliance. This document describes methods that can be used to maintain sign retroreflectivity at or above the MUTCD's minimum maintained retroreflectivity levels.

RETROREFLECTIVITY MAINTENANCE

The MUTCD describes two basic types of methods that agencies can use to maintain sign retroreflectivity at or above the MUTCD minimum maintained retroreflectivity levels — assessment methods and management methods. The FHWA has identified and listed assessment and management methods for maintaining sign retroreflectivity in accordance with Section 2A.09. These methods are described on page four. A full report on these methods can be found at *www.fhwa.dot.gov/retro*.

New MUTCD Minimum Retroreflectivity Compliance Periods

- Four years for implementation and continued use of an assessment or management method that is designed to maintain traffic sign retroreflectivity at or above the established minimum levels;
- Seven years for replacement of regulatory, warning, and ground-mounted guide (except street name) signs that are identified using the assessment or management methods as failing to meet the established minimum levels; and
- Ten years for replacement of street name signs and overhead guide signs that are identified using the assessment or management method as failing to meet the established minimum levels.

New MUTCD Section 2A.09 Maintaining Minimum Retroreflectivity

Support:

Retroreflectivity is one of several factors associated with maintaining nighttime sign visibility (see Section 2A.22).

Standard:

Public agencies or officials having jurisdiction shall use an assessment or management method that is designed to maintain sign retroreflectivity at or above the minimum levels in Table 2A-3.

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 2A-3. Provided that an assessment or management method is being used, an agency or official having jurisdiction would be in compliance with the above Standard even if there are some individual signs that do not meet the minimum retroreflectivity levels at a particular point in time.

Guidance:

Except for those signs specifically identified in the Option portion of this Section, one or more of the following assessment or management methods should be used to maintain sign retroreflectivity:

A. **Visual Nighttime Inspection** – The retroreflectivity of an existing sign is assessed by a trained sign inspector conducting a visual inspection from a moving vehicle during nighttime conditions. Signs that are visually identified by the inspector to have retroreflectivity below the minimum levels should be replaced.

B. **Measured Sign Retroreflectivity** – Retroreflectivity is measured using a retroreflectometer. Signs with retroreflectivity below the minimum levels should be replaced.

C. **Expected Sign Life** – When signs are installed, the installation date is labeled or recorded so that the age of a sign is known. The age of the sign is compared to the expected sign life. The expected sign life is based on the experience of sign retroreflectivity degradation in a geographic area compared to the minimum levels. Signs older than the expected life should be replaced.

D. **Blanket Replacement** – All signs in an area/corridor, or of a given type, should be replaced at specified intervals. This eliminates the need to assess retroreflectivity or track the life of individual signs. The replacement interval is based on the expected sign life, compared to the minimum levels, for the shortest-life material used on the affected signs.

E. **Control Signs** – Replacement of signs in the field is based on the performance of a sample of control signs. The control signs might be a small sample located in a maintenance yard or a sample of signs in the field. The control signs are monitored to determine the end of retroreflective life for the associated signs. All field signs represented by the control sample should be replaced before the retroreflectivity levels of the control sample reach the minimum levels.

F. **Other Methods** – Other methods developed based on engineering studies can be used.

Support:

Additional information about these methods is contained in the 2007 Edition of FHWA's *"Maintaining Traffic Sign Retroreflectivity"* (see Section 1A.11).

Option:

Highway agencies may exclude the following signs from the retroreflectivity maintenance guidelines described in this Section:

A. Parking, Standing, and Stopping signs (R7 and R8 series)

B. Walking/Hitchhiking/Crossing signs (R9 series, R10-1 through R10-4b)

C. Adopt-A-Highway signs

D. All signs with blue or brown backgrounds

E. Bikeway signs that are intended for exclusive use by bicyclists or pedestrians www.fhwa.dot.gov/retro — *Maintaining Traffic Sign Retroreflectivity (2007)* Page 3

New MUTCD Table 2A-3. Minimum Maintained Retroreflectivity Levels ①

SIGN COLOR	SHEETING TYPE (ASTM D4956-04)				ADDITIONAL CRITERIA
	Beaded Sheeting			Prismatic Sheeting	
	I	II	III	III, IV, VI, VII, VIII, IX, X	
White on Green	W*; G ≥ 7	W*; G ≥ 15	W*; G ≥ 25	W ≥ 250; G ≥ 25	Overhead
White on Green	W*; G ≥ 7	W ≥ 120; G ≥ 15			Ground-mounted
Black on Yellow or Black on Orange	Y*; O*	Y ≥ 50; O ≥ 50			②
Black on Yellow or Black on Orange	Y*; O*	Y ≥ 75; O ≥ 75			③
White on Red	W ≥ 35; R ≥ 7				④
Black on White	W ≥ 50				—

① The minimum maintained retroreflectivity levels shown in this table are in units of cd/lx/m² measured at an observation angle of 0.2° and an entrance angle of -4.0°.
② For text and fine symbol signs measuring at least 1200 mm (48 in) and for all sizes of bold symbol signs
③ For text and fine symbol signs measuring less than 1200 mm (48 in)
④ Minimum Sign Contrast Ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity)
* This sheeting type should not be used for this color for this application.

BOLD SYMBOL SIGNS

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

FINE SYMBOL SIGNS – Symbol Signs Not Listed As Bold Symbol Signs

SPECIAL CASES

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

ASSESSMENT METHODS

Assessment methods require evaluation of individual signs within an agency's jurisdiction. There are two basic assessment methods — visual assessment and measured sign retroreflectivity.

1. VISUAL ASSESSMENT

Nighttime Inspection

In the visual nighttime inspection method, on-the-fly assessments of retroreflectivity are made by an inspector during nighttime conditions. The following recommendations provide general guidance for the inspections:

- Develop guidelines and procedures for inspectors to use in conducting the nighttime inspections and train inspectors in the use of these procedures.
- Conduct inspections at normal speed from the travel lane(s).
- Conduct inspections using low-beam headlights while minimizing interior vehicle lighting.
- Evaluate signs at typical viewing distances so that adequate time is available for an appropriate driving response.

One or more of the following procedures should be used to support visual inspections.

Calibration Signs Procedure

In this procedure, an inspector views a "calibration sign" prior to conducting the nighttime inspection described above. Calibration signs have known retroreflectivity levels at or above minimum levels. These signs are set up where the inspector can view the calibration signs in a manner similar to nighttime field inspections. The inspector uses the visual appearance of the calibration sign to establish the evaluation threshold for that night's inspection activities. The following factors provide additional information on the use of this procedure:

- Calibration signs are needed for each color of sign in Table 2A-3.
- Calibration signs are viewed at typical viewing distances using the inspection vehicle.
- Calibration signs need to be properly stored between inspections so that their retroreflectivity does not deteriorate over time.
- Calibration sign retroreflectivity should be verified periodically.

Comparison Panels Procedure

Comparison panels are used to assess signs that have marginal retroreflectivity. The comparison panels are fabricated at retroreflectivity levels at or above the minimum levels. When the visual inspection identifies the retroreflectivity of a sign as marginal, a comparison panel is attached to the sign and the sign/panel combination is viewed and compared by the inspector.

Consistent Parameters Procedure

Nighttime inspections are conducted under similar factors that were used in the research to develop the minimum retroreflectivity levels. These factors include:

- Using a sport utility vehicle or pick-up truck to conduct the inspection.
- Using a model year 2000 or newer vehicle for the inspection.
- Using an inspector who is at least 60 years old.

2. MEASURED SIGN RETROREFLECTIVITY

In this method the retroreflectivity of a sign is measured and directly compared to the minimum level appropriate for that sign. ASTM E1709, Standard Test Method for Measurement of Retroreflective Signs Using a Portable Retroreflectometer, provides a standard method for measuring sign retroreflectivity.

> An agency can choose to use either an assessment method or a management method, or a combination of the two. Agencies may develop other methods as long as they are documented in an engineering study and correspond to the values in Table 2A.3.

MANAGEMENT METHODS

Management methods provide an agency with the ability to maintain sign retroreflectivity without having to assess individual signs. There are three basic management methods — sign replacement based on expected sign life, blanket replacement of large numbers of signs at appropriate intervals, and use of control signs.

1. EXPECTED SIGN LIFE

In this method, individual signs are replaced before they reach the end of their expected service life, which is the time anticipated for the retroreflective material to degrade to the appropriate minimum level. Expected service life can be based on sign sheeting warranties, weathering deck results, measurements of field signs, or other criteria.

This method requires a system for tracking sign age. A common approach for identifying the age of individual signs uses a label on the sign to mark the year of fabrication or installation. Sign management systems can also be used to track the age of individual signs.

2. BLANKET REPLACEMENT

With this method, an agency replaces all signs in an area, or of a given type, at specified time intervals based on the relevant expected sign life. This method typically requires that all of the designated signs within a replacement area, or of the particular sign type, be replaced even if a sign was recently installed.

3. CONTROL SIGNS

In this method, a control sample of signs is used to represent all of an agency's signs. The retroreflectivity of the control signs is monitored and sign replacement is based on the performance of the control signs.

- Agencies should develop a sampling plan to determine the appropriate number and type of control signs needed to represent the agency's signs.
- Control signs may be actual signs in the field or signs in a maintenance yard (for convenience).
- The retroreflectivity of the control signs should be monitored using an assessment method.

Other sign retroreflectivity resources:

MUTCD
http://mutcd.fhwa.dot.gov/

FHWA Nighttime Visibility Resources
http://safety.fhwa.dot.gov/roadway_dept/night_visib/

FHWA Nighttime Visibility Policy Guidance
http://safety.fhwa.dot.gov/roadway_dept/night_visib/policy_guide/

FHWA 2011 *Traffic Sign Retroreflective Sheeting Identification Guide*
http://safety.fhwa.dot.gov/roadway_dept/night_visib/sign_visib/sheetguide/

FHWA Rumors, Myths, and the Straight Facts
http://www.rocal.com/DOCS/FINAL%20myth%20brochure%20april%2011%20(4).pdf

FHWA Presentation: Conducting Sign Retroreflectivity Inspections
http://safety.fhwa.dot.gov/roadway_dept/night_visib/sign_visib/pps_signinsp0708/

The National Work Zone Safety Information Clearinghouse
http://www.workzonesafety.org/

ATSSA Retroreflectivity Clearinghouse
http://www.atssa.com/Retroreflectivity.aspx

Washington State DOT Traffic Sign Retroreflectivity website
http://www.wsdot.wa.gov/LocalPrograms/Traffic/SignRetro.htm

Minnesota DOT resources
http://www.dot.state.mn.us/stateaid/trafficsafety/retro-reflectivity/SignRetroreflectivity_AMinnesotaToolkit.pdf
http://www.lrrb.org/PDF/2010RIC10.pdf

National LTAP and TTAP website
http://www.ltap.org/centers/

Utah LTAP Center Software resources
http://www2.utahltap.org/software/

Ohio LTAP Center resources
http://www.dot.state.oh.us/Divisions/Quality/LTAP/Sign%20Retroreflectivity%20Implementation%20Guide/GSfile5%20-%20Template%201%20-%20Calibration%20Signs%20Procedure.pdf

The Technology Transfer Program, Institute of Transportation Studies at University of California–Berkeley
http://www.techtransfer.berkeley.edu/newsletter/08-1/retroreflectivity.php

Center for Technology & Training at the Michigan Tech Transportation Institute
http://ctt.mtu.edu/SignRetroPresentations.html

APPENDIX B

Telephone Survey

My name is _________ and I work for the Texas Transportation Institute (TTI). We are currently investigating different methods for maintaining traffic sign retroreflectivity at or above the new *MUTCD* minimum requirements for the National Cooperative Highway Research Program (NCHRP). The goal of this questionnaire is to learn more about your agency's traffic sign retro maintenance program. We will be developing a report that documents successful practices so that other agencies can learn and quickly adopt techniques that fit their specific situation.

The questionnaire consists of questions designed to spark discussion and identify common information for reporting purposes; however, we can deviate from the questions as needed. The questionnaire should take about a half an hour to complete. Your participation is voluntary and you have the option to pass on any question.

Along with writing down your responses, we would also like to audio record this telephone survey so that we can verify the accuracy of the written notes. Your audio recorded responses will be deleted immediately after we have completed verification and/or prior to the completion of this project. As your participation is voluntary, it is also your option to decline the audio recording.

We appreciate your time and any assistance may help other agencies. Do you have any questions or comments at this time? Please let us know if we have your verbal consent to continue with the survey.

(*If yes, continue.*)

Do you disallow the use of audio recording equipment so that your responses to this telephone questionnaire are only documented through written notes and not audio recorded?

(*If yes, then do not activate the audio recording equipment and document the response in the General Information section.*)

(*If no, then activate the audio recording equipment and document the audio recording information in the General Information section.*)

General Information:

Name ____________________

Agency Name ____________________

Position ____________________

Telephone ____________________

E-mail ____________________

Audio Recording Info ____________________

Survey Questions

- Can you provide information on the size and scale of your agency's traffic sign activities?
  a. Do you know how many signs are in your jurisdiction?
  b. Do you know how many centerline miles are in your jurisdiction?

- Based on experience and not warranties, what would you say is the expected service life for signs in your area?
  a. Does this depend on the type of sheeting material or direction the sign is facing?
  b. Are there other factors you consider?

- Please provide some background on the major causes and reasons for traffic sign replacement at your agency.
  a. Inadequate retroreflectivity,
  b. Vandalism (stolen, graffiti, bullet holes, paintballs),
  c. Damage/knockdowns (traffic crashes, mowing),
  d. Change in standards (size, legend, material), and
  e. Other.

- Just to confirm, please indicate that you are familiar with the minimum retroreflectivity requirements for traffic signs in the 2009 *MUTCD?* And the pending January 2012, 2015, and 2018 dates?

- What concerns or apprehensions do you have with the upcoming *MUTCD* retroreflectivity requirements?
  a. Increased tort claim lawsuits,
  b. Personnel training,
  c. Acquiring additional resources and funding,
  d. Sign compliance documentation,
  e. Managing a sign inventory system, or
  f. Other.

- What traffic sign replacement method is your agency utilizing to comply with the *MUTCD* retroreflectivity requirements? Please provide detail. Is the method described in an internal memo or policy? Can you send us a copy?

- How did your agency choose to use this method?
  a. What factors were at play and what factors were most important?
  b. Did you consider other methods?
  c. What information sources did you use or review in helping make your decision?

- How are you documenting the continuous use of your method and sign replacement?

- If an inventory is being built, how was that decision made?
  a. What other benefits do you expect to get out of the inventory?
  b. How do you plan to develop the inventory?
  c. How do you plan to maintain the inventory?
  d. What platform is the inventory (Excel, vendor, in-house, etc)?

- Is your agency employing any special equipment or innovative technologies or applications to meet *MUTCD* compliance?

- Were there any funding issues with meeting the *MUTCD* minimum retroreflectivity requirements?
  a. How did you secure additional funding for your maintenance method?
  b. How did you get approval from administrators or decision makers?
  c. Did you complete a life cycle cost analysis of your sign replacement method?
  d. Do you have an expected cost associated with bringing your sign inventory into compliance?

- Can you describe your personnel training requirements and how did your agency establish them?

- Are there any other major sign assessment or management challenges that your agency has dealt with or is currently encountering?

- What advice or suggestions would you have for other agencies just starting to determine the best method to manage their sign retroreflectivity? Is there anything they must do or must avoid?

Finally, would it be OK if we were to follow up with a few additional questions?

APPENDIX C

Survey Participants

TABLE C1
LIST OF STATE SURVEY PARTICIPANTS

Agencies	Primary Method	Population	Total Area (sft^2)	Estimated Centerline Miles	Contact Number
Alabama DOT	Nighttime Inspection	4,780,000	51,000	11,800	334-242-6275
Colorado DOT	Blanket Replacement	5,030,000	104,000	9,100	303-757-9280
Florida DOT	Nighttime Inspection	18,800,000	54,000	12,000	850-410-5600
Idaho TD	Nighttime Inspection	1,570,000	83,000	5,000	208-334-4458
Illinois DOT	Blanket Replacement	12,830,000	56,000	16,000	217-782-7820
Indiana DOT	Blanket Replacement	6,480,000	36,000	11,000	317-233-4688
Kansas DOT	Blanket Replacement	2,850,000	82,000	10,000	785-296-3756
Michigan DOT	Blanket Replacement	9,880,000	57,000	9,600	517-373-2625
Missouri DOT	Nighttime Inspection	5,990,000	69,000	32,000	573-751-2551
New Hampshire DOT	Nighttime Inspection	1,320,000	9,000	4,100	603-271-2291
New Jersey DOT	Expected Sign Life	8,790,000	7,000	2,400	732-697-7360
North Carolina DOT	Nighttime Inspection	9,540,000	49,000	80,000	919-773-2800
Pennsylvania DOT	Expected Sign Life	12,700,000	45,000	39,900	717-787-3620
Texas DOT	Nighttime Inspection	25,150,000	262,000	80,000	512-416-3134
Vermont AOT	Expected Sign Life	630,000	9,000	3,000	802-828-2651
Wisconsin DOT	Expected Sign Life	5,690,000	54,000	13,000	414-227-2166

TABLE C1
(*continued*)

Agencies	Primary Method	Area Type	Population	Total Area (sft^2)	Estimated Centerline Miles	Contact Number
Town of Clifton Park, NY	Expected Sign Life	Rural	33,000	50	200	518-371-6651
Town of Manchester, CT	Expected Sign Life	Rural	58,000	30	210	860-647-3152
City of Austin, TX	Expected Sign Life	Urban	790,000	300	2,400	512-974-1551
City of College Station, TX	Nighttime Inspection	Urban/Rural	94,000	40	600	979-764-3690
City of Lakeland, FL	Nighttime Inspection	Urban	94,000	70	350	863-834-6001
City of Norfolk, VA	Expected Sign Life	Urban	242,000	100	2,000	757-664-7300
City of Palm Bay	Expected Sign Life	Urban	100,000	70	N/A	321-952-3437
City of Philadelphia, PA	Control Signs	Urban	1,526,000	140	2,200	215-686-5560
City of Phoenix, AZ	Expected Sign Life	Urban	1,445,000	520	5,500	602-262-4659
Golden Gate Bridge Hwy. & Trans. District	Measured Retro.	Urban	N/A	N/A	6	415-455-2000
Barton County, KS	Nighttime Inspection	Rural	27,000	900	400	620-793-1800
Brevard County, FL	Nighttime Inspection	Urban/Rural	543,000	1,560	1,140	321-255-4313
Charlotte County, FL	Measured Retro.	Urban/Rural	159,000	860	2,600	941-575-3600
Hancock County, IN	Expected Sign Life	Rural	70,000	310	670	706-444-5746
Hillsborough County, FL	Nighttime Inspection	Urban	1,229,000	1,300	3,200	813-635-5400
Kent County, MI	Nighttime Inspection	Urban/Rural	602,000	870	1,900	616-336-3694
Mercer County, NJ	Blanket Replacement	Urban/Rural	366,000	230	180	609-989-6600
Mercer County, OH	Expected Sign Life	Rural	40,000	470	790	419-586-7759
Montgomery County, OH	Blanket Replacement	Urban/Rural	559,000	460	320	937-225-6040
Orange County, CA	Expected Sign Life	Urban	3,010,000	950	310	714-955-0200

(*continued on next page*)

TABLE C1
(*continued*)

Agencies	Primary Method	Area Type	Population	Total Area (sft^2)	Estimated Centerline Miles	Contact Number
Pierce County, WA	Control Signs	Urban/Rural	795,000	1,800	1,800	253-798-7253
St. Louis County, MN	Blanket Replacement	Rural	200,000	6,900	3,000	218-625-3830
Tippecanoe County, IN	Expected Sign Life	Urban/Rural	172,000	500	850	765-423-9210
Yolo County, CA	Expected Sign Life	Rural	200,000	1,000	760	530-666-8775

TABLE C2
LIST OF OTHER SURVEY PARTICIPANTS

Agencies	Type	Contact Number
Cornell Local Roads Program	LTAP Center	607-255-8033
DLZ Indiana LLC	Consulting Engineering Firm	574-236-4400
Gannett Fleming, Inc.	Consulting Engineering Firm	717-763-7211
Michigan LTAP	LTAP Center	906-487-2102
Mn/DOT Research Services Section	State Research Department	651-366-3680
PennDOT LTAP	LTAP Center	1-800-FOR-LTAP
Professional Pavement Products, Inc.	Product Vendor	888-717-7771
Indiana LTAP	LTAP Center	765-494-2164

APPENDIX D
Myths and Other Frequently Asked Questions

During this project it became obvious that there were a variety of questions about the new minimum sign retroreflectivity requirements that were unanswered and the amount of misinformation was growing. FHWA has a document addressing some of the questions here: http://www.rocal.com/DOCS/FINAL%20myth%20brochure%20april%2011%20(4).pdf. Other myths or frequently asked questions are listed here with brief answers.

On-the-job experience is a substitute for training for nighttime inspection. This is not true. FHWA has provided LTAP with training slides that describe the importance of nighttime sign visibility, the basics of retroreflection, the methods listed in the *MUTCD,* a link between the methods in the *MUTCD* and the minimum retroreflectivity levels, and how to perform each of the assessment methods.

A hand-held retroreflectometer is required to meet the new *MUTCD* requirements. This is not true for all methods. However, there are methods that do require the use of a retroreflectometer. There are alternatives to purchasing retroreflectometers. For instance, retroreflectometers are available through LTAPs and are also available for rent.

All signs have to be replaced by a certain date. By January 2015, only the shoulder-mounted signs (except street name signs) listed in Table 2A-3 that fail to meet the minimum retroreflectivity levels need to be replaced. By January 2018, all overhead signs and street name signs need to be in compliance with the minimum retroreflectivity levels. Right now there are no minimum retroreflectivity levels for blue and brown signs. (On August 31, 2011, a notice of proposed amendments was published in the *Federal Register* proposing to modify the compliance dates for sign retroreflectivity. As of January 2012, FHWA have not responded to the comments. For the latest information, see http://mutcd.fhwa.dot.gov/.)

Warranty is the same as service life or minimum retro value. As described in the this report, the warranty period of sign sheeting is generally much less than the in-service life based on minimum retroreflectivity levels.

The cheapest sheeting is the most cost-effective. Many life-cycle cost analyses have shown that the cheapest sheeting is not the most cost-effective when the life-cycle cost is considered.

The most expensive sheeting is the best. Again, life-cycle cost analyses show that the most expensive sheeting materials are not the most cost-effective. Agencies must weigh the initial cost of the sheeting materials versus their expected life, which can vary in different regions of the country and is typically much longer than the warranty period that sign sheeting manufacturers provide.

Engineering grade material is not allowed now. For some sign types, this is true. Engineering grade sheeting (or ASTM Type I material) is not allowed for yellow or orange warning signs and for the legend on guide signs and street name signs.

A computer inventory is required. No sign inventory is required. However, there are many benefits of having a sign inventory as described in the report.

You must have a 60-year old for nighttime inspection. There are three different visual nighttime inspection procedures that can be used. The procedure that FHWA calls "consistent parameters" does require an inspector to be at least 60 years of age. The other two visual nighttime inspection procedures do not have set criteria on the age of the inspector.

All nighttime inspections are alike. There are actually three specific visual nighttime inspection procedures that FHWA has spelled out. A description of the procedures can be found in Appendix A.

If you implement the blanket replacement method you can forgo routine maintenance. This is not true. There are many other aspects of signing that need to be maintained besides retroreflectivity. For examples, there are knockdowns, vandalism, and vegetation that all need constant maintenance to ensure that the signs perform as intended.

Sign retroreflectivity can be assessed during a daytime inspection. While it may be possible to judge the relative age of a sign during daytime inspections (mostly based on the color), it is less than reasonable to judge retroreflectivity. Some agencies have tried using a spotlight during the day or flashing their high beam lights. However, there is too much subjectivity in these methods to be considered reasonable.

Frost or dew does not affect retroreflectivity. When frost or dew is detected during sign inspections, the inspections should stop and be scheduled for another night. The ability for a sign to properly retroreflect light in conditions of frost or dew is significantly diminished.

Retroreflectivity can be assessed by nighttime photos. As FHWA explains in its literature, using photographs of signs is not an acceptable method to judge retroreflectivity. The amount of light and the proximity of the light to the camera can make a perfectly good sign look bad or vice versa. This is why FHWA does not publish photographs of traffic signs with retroreflective levels printed next to the sign.

Retroreflectometers are precision instruments that produce perfect results with no variation. The ASTM committee is working on the development of a precision and bias statement for the handheld retroreflectometers for Test Method E1709. Recently a research report from Indiana used 22 stop signs and three different retroreflectometers in a laboratory test to determine the range of median bias for Type I and Type III sheeting for both the legend and background (white and red). Here is what they found:

- Type I background ranged from 1 to 3 cd/lx/m^2;
- Type III background ranged from 2 to 4 cd/lx/m^2;
- Type I legend ranged from 3 to 12 cd/lx/m^2; and
- Type III legend ranged from 15 to 40 cd/lx/m^2.

They also made field measurements with the handhelds. They concluded that it is reasonable to assume that the coefficient of variation for an individual sign will be between 4% and 14% when using a handheld device. The paper was published in the *ITE Journal of Transportation* (March 2011).

The Highway Innovative Technology Evaluation Center funded a study in 2004 to investigate the bias of retroreflectivity measurements. The draft final report shows measurement bias of some prismatic sheeting materials as much as 25%. This is similar to statements in ASTM E1709 concerning differences in measurements using different types of handheld retroreflectometers.

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation