DEPARTMENT OF TRANSPORTATION

TRANSPORTATION RESEARCH SYNTHESIS

Minnesota Department of Transportation
Office of Transportation System Management
Research Services & Library
651-366-3780
www.mndot.gov/research

TRS 1707

October 2017

Sign Life-Cycle Policies and Practices

Prepared by CTC & Associates LLC

MnDOT Metro District Traffic Engineering is reviewing its practices for determining traffic sign life expectancy and replacement. The Metro District is interested in understanding the state of the practice regarding traffic sign colors, life cycles and management, specifically whether signs are selected for replacement based on a specific age or characteristics such as color fade, reduced retroreflectivity levels and loss of fluorescence. In addition, the Metro District would like to know the role that sign sheeting types and fabrication methods play in sign color selection and sign life expectations and replacement.

To determine the state of the practice, a survey was sent to representatives of all state departments of transportation, several metropolitan area agencies and select Canadian provinces. This Transportation Research Synthesis includes findings from the survey along with the results of a literature search regarding sign life expectancy and replacement.

Technical Advisory Panel

Josie Tayse, Technical Liaison
MnDOT Metro District

Matt Mullins, Principal Investigator
CTC & Associates LLC

Mark Linsenmayer, Principal Investigator
CTC & Associates LLC

Dan Warzala, Project Coordinator
MnDOT Research Services & Library

Sheila M. Johnson, Panelist
MnDOT Metro District

Steve Misgen, Panelist
MnDOT Metro District

Sign Life-Cycle Policies and Practices

Introduction

MnDOT Metro District Traffic Engineering is interested in the practices that other state departments of transportation (DOTs) use to determine traffic sign life expectancy and replacement. Of particular interest is the state of the practice regarding traffic sign colors, life cycles and management, specifically whether signs are selected for replacement based on a specific age or characteristics such as color fade, reduced retroreflectivity levels and loss of fluorescence. The Metro District would also like to learn about the role that sign sheeting types and fabrication methods play in sign color selection and sign life expectations and replacement.

The results of a survey of practice sent to representatives of all state DOTs, several metropolitan area agencies and select Canadian provinces significantly expand on findings from the preliminary literature review. While the literature search failed to find strong correlation in state and national resources between sign performance, sign characteristics and life expectancy, survey respondents showed a strong sense that color and retroreflectivity degradation can be linked to sign color, sheeting type, age and facing direction. Literature and survey findings converge to suggest that signs retain above-minimum retroreflectivity values past expected and programmatically replaced service lives. Survey commentary suggested that replacement decisions are significantly accelerated for vandalized and accident-damaged signage, a facet of sign replacement not otherwise a focus of this investigation.

Summary of Findings

This Transportation Research Synthesis is divided into two sections:

- Survey of Practice.
    - Sign Replacement.
    - Sign Color.
    - Retroreflectivity.
    - Fluorescence.
    - Regional Variation.
    - General Information.
- Related Resources.
    - Minnesota Research.
    - Retroreflectivity and Service Life.
    - Color and Service Life.
    - Management Methods for Replacement.
    - Research in Progress.

Survey of Practice

An online survey was distributed to representatives from all state DOTs and selected municipal and Canadian transportation agencies to investigate their experiences with traffic sign life expectancy and replacement along with agency policies and practices toward sign replacement, sign color, retroreflectivity and fluorescence.

Representatives from 25 state agencies, the City of Philadelphia and a Nova Scotia, Canada, transportation agency responded to the survey. Every agency uses sign sheeting from 3M, and 74 percent also draw on Avery Dennison for sheeting. Three DOT respondents—Indiana, Pennsylvania and Vermont—provided relevant research documents along with their responses, and Florida provided a citation. Other agencies provided contact information for county, municipal and other transportation representatives who might provide relevant insight. Below are highlights of the survey results.

Sign Replacement

Sign inspection and retroreflectivity levels proved to be widely used for determining service life termination for signs, but expected service life was nearly as common a standard. All three standards were mentioned in 59 percent or more of responses. Sign life expectancy is connected to arterial type, sign type and even sign function (signs for warning were in one case differentiated from other sign functions in terms of a blanket age replacement program). Corridor and age-based blanket replacement strategies seem typically to be conservative; retroreflectivity values may yet meet minimum standards at the time of blanket replacement. Inspected retroreflectivity standards mostly follow recommendations in the Federal Highway Administration's Manual on Uniform Traffic Control Devices, a widely cited standard.

Sign Color

Color and sign type showed strong correlations across survey responses. Type IV sheeting is used extensively for yellow and white signs, Type IX is used mostly for white and fluorescent signs, and Type XI is used for 40 to 44 percent of white, yellow, fluorescent yellow and yellow-green fluorescent signs. While 56 percent of agencies use ElectroCut film fabrication for red color backgrounds, 74 percent or more use it for brown, green and blue backgrounds. Fully 85 percent use silk screen ink printing for red background signs, and just under half use silk screening for brown and blue backgrounds. Silk screening edges out the use of ElectroCut film for legend fabrication; 85 percent of agencies use silk screening for black and red legends, 67 percent use ElectroCut for black legends and 70 percent for red legends.

Virtually every agency noticed color degradation in signs; half also noticed it in sign legends. Agencies associated color degradation most with sign age, facing direction and sign color. Only one-quarter of respondents identified pollution and particulates as factors in color fade. Responses on expected sign life by color indicated that the majority of respondents expect 13 to 15 years of signs of every color.

Retroreflectivity

While agencies showed confidence in linking color degradation to various sign characteristics, that confidence wavered in linking retroreflective degradation to sign characteristics. While all but two respondents noticed color degradation in agency signs, 63 percent noticed degradation in retroreflectivity in agency signs. Those that noticed retroreflective fade linked it to sign fabrication type and sign age, but the distribution was nearly uniform across all categories. Two-thirds of respondents associated loss of retroreflectivity with sign facing direction.

Fluorescence

Associations of degradation of fluorescent sign quality with sign types, ages and environments were more ambivalent than with sign color and retroreflectivity. Half of respondents noticed fade in fluorescence, and half noticed color fade on fluorescent signs. Degradation in color and fluorescence on fluorescent signs, when recognized, was most commonly seen in signs that had been in service for six to 10 years. Color and fluorescence degradation were linked to sign facing direction in one-third or more of responses, and cracking of fluorescent signs was not linked heavily to fluorescence loss and was not often considered a replacement-level flaw. Forty percent of respondents associated color change with fluorescence degradation in fluorescent signs, and less than one-third associated retroreflectivity degradation with fluorescence degradation. Respondents clearly favored fluorescent yellow signs over standard yellow signs, largely due to higher visibility in low-light conditions like overcast skies, fog, dusk and dawn.

Regional Variation

All but two respondents recognized color degradation in signs, and the majority of these agencies consider sign facing direction a factor in color fade, though correlation was unanimous in agencies from the Southern region of the United States, stood at about 77 percent in the upper Midwest, and was about 75 percent in the West. While many agencies also recognize fading in retroreflectivity, the correlation with sign facing direction was less obvious to respondents on regional and individual levels. Fade in fluorescence and color on fluorescent signs drew even less certainty from agencies.

Related Resources

The literature review uncovered limited research regarding traffic sign life-cycle and replacement policies or practices. Highlights include the following:

- A 2014 MnDOT study about national and state practices concerning specific elements of sign maintenance.
- Several journal articles and conference papers reporting on studies of retroreflectivity and traffic sign service life. These resources suggest that sign damage is the most important factor in sign replacement practices.
- A 2012 New Hampshire DOT study that suggests replacement decisions based on nighttime visual inspections may be more cost-effective as a sign management method.
- Ongoing research projects on sign color, sheeting, retroreflectivity and deterioration, as well as on sign management strategies for service life assessment and replacement.

Next Steps

MnDOT may wish to extend the survey to some of the counties and metropolitan areas identified in Appendix B, although none of those contacts encompass an area as large as Philadelphia, which provided survey responses.

The Florida respondent’s experience with ultraviolet (UV) damage to sign facing could be explored further. The respondent noted regional differences within the state due to increased UV exposure in the southern half of Florida. He also indicated the use of a wider range of sign sheeting types than MnDOT has inquired about in the survey.

Commentary in survey results was fairly wide ranging with regard to sign ages based on sign characteristics and sign types put to use. Both topics could be expanded upon based on comments and, if MnDOT wishes upon review of the full survey results, further inquiry.

The role of retroreflectivity in replacement standards suggests that signs remain at least adequately retroreflective at the time of retirement. It may be of value to compare the relative value of retroreflectivity to sign color degradation and sign readability in sign performance, particularly for consideration of blanket replacement strategies.

Loss of fluorescent properties in fluorescent signs was the least recognized characteristic explored in the survey and may warrant further study. Yellow fluorescent signs were prized for their low-light visibility, but the relationships between fluorescence degradation and degradation in color and retroreflectivity remained uncertain to most survey respondents.

MnDOT should next conduct research projects on sign life cycles and human factor evaluation testing. A life sign cycle study would create an ongoing test site to determine the life cycle of various sign types through testing of retroreflectivity, color, fluorescence and ink over time. Human factor evaluation testing would look at retroreflectivity, color, fluorescence and readability subject to driver age, vehicle type, time of day and light levels to determine what sheeting types and sign properties are best perceived by drivers over the life of the sign. This research need (513a) is on the list for the Transportation Research Innovation Group (TRIG) board member selection fiscal year 2019 research proposals.

Detailed Findings

Survey of Practice

Representatives from all state departments of transportation (DOTs) and selected metropolitan and Canadian transportation agencies were contacted to investigate their experiences with sign life expectancy and replacement. Agency representatives were surveyed about four areas of traffic sign management—sign replacement requirements, sign color, retroreflectivity and fluorescence—and general sign practices.

Representatives from 27 agencies responded to the survey. These respondents represented the City of Philadelphia, the province of Nova Scotia, Canada, and transportation agencies from the following 25 states:

- Alabama.
- Arkansas.
- Delaware.
- Florida.
- Idaho.
- Illinois.
- Indiana.
- Iowa.
- Kentucky.
- Maryland.
- Massachusetts.
- Michigan.
- Mississippi.
- Nebraska.
- New Hampshire.
- New Mexico.
- Ohio.
- Oregon.
- Pennsylvania.
- South Carolina.
- South Dakota.
- Texas.
- Vermont.
- Wisconsin.
- Wyoming.

Appendix A provides the full text of the survey questions. Appendix B lists the contact information for survey respondents and other individuals who might provide relevant insight for this report. The full survey results are provided in a separate document as an Excel spreadsheet. Below are highlights of the subject areas addressed in the survey.

Sign Replacement

Respondents were asked to assess how their agency identifies when to replace signs. The four most common standards used were:

- Inspection failure (19 responses, or 70 percent).
- Retroreflectivity degradation (18 responses, or 67 percent).
- Age (16 responses, or 59 percent).
- Color degradation (14 responses, or 52 percent).

Other standards included vandalism and accident damage to signs as well as corridor replacement strategies.

Agencies were then asked to identify or describe the failure or degradation level at which they replace signs. Open-ended answers suggested that nighttime visual assessments (eight responses) were common, as were meeting Federal Highway Administration (FHWA)/Manual on Uniform Traffic Control Devices (MUTCD) standards (eight responses) for retroreflectivity or contrast ratios. Four responses mentioned retroreflectivity levels without identifying the assessment approach.

Ages to replacement varied from five to 20 years, usually with multiple life expectancies for signs depending on certain characteristics. Life spans were correlated to characteristics such as specific sign functions (regulatory or warning signs); arterial types (one agency replaces signs on Interstates in 18 to 20 years, but on secondary arterials based on retroreflectivity levels being assessed as poor); measured behavior (one agency favors a 12-year sign life expectancy with calibration testing that may extend the sign life to 15 years); or sign type. For example, one agency used a 15-year cycle for retroreflective sheeting sign replacement. Another agency replaces sheet signs at 18 years of life and panel signs at 20 years; another gives flat sheet signs 15 years and extruded signs 20 years.

Based on survey responses, inspection and determination of retroreflectivity are probably the most widely adopted assessment methods, but age is still used to manage signs in various levels of distinction based on sign material, function or placement. The Arkansas DOT respondent noted that Arkansas replaces signs in a blanket program based on a life expectancy of 15 years, but adds that Arkansas tested about 10,000 signs of 15-plus years of age for retroreflectivity and found that 86 percent still met minimum MUTCD standards for retroreflectivity.

Sign Color

Respondents were asked about sign color and its relationship to sign material, life expectancy and field performance.

In terms of sign color and sign type, 27 respondents answered:

- White signs: 74 percent of respondents use Type IV sheeting, and 56 percent use Type IX.
- Yellow signs: 64 percent of respondents use Type IV sheeting.
- Fluorescent yellow: 58 percent use Type IX sheeting, and 42 percent use Type XI.
- Fluorescent yellow-green: 52 percent use Type IX, and 44 percent use Type XI.

Four respondents use Type III for many colors, and three favor Type VIII for many colors. Type VII was mentioned once for fluorescent orange signs, and Illinois does not use ASTM type.

For signs of four different background colors, the survey asked what sign manufacturing method agencies favor. The 27 responses identified that ElectroCut film has become predominant in sign fabrication, followed by silk screen ink printing:

- Red background: 85 percent of respondents use silk screen ink printing, and 56 percent use ElectroCut film.
- Brown background: 78 percent use ElectroCut film, and 44 percent use silk screen ink printing.
- Green background: 81 percent use ElectroCut film, and 41 percent referred to “other” manufacturing methods for this color.
- Blue background: 74 percent use ElectroCut film, 48 percent use silk screen, and 44 percent referred to “other” manufacturing methods for this color.

Fabrication methods were also queried for signs with black or red legends, and showed that silk screen remains the favored approach to coloring legends:

- Black legend: 85 percent of respondents used silk screen, and 67 percent used ElectroCut film.
- Red legend: 85 percent used silk screen, and 70 percent used ElectroCut film.

Life expectancies for signs of various colors all heavily favored 13 to 15 years, as shown in the table below.

Sign Life Expectancy						
Color	**0 10 Years**	**11 12 Years**	**13 15 Years**	**16 20 Years**	**21+ Years**	**Total**
Red	4	5	12	6	0	27
Brown	7	2	10	7	1	27
Green	5	4	10	4	4	27
Yellow	5	4	11	5	2	27
Fluorescent Yellow	7	5	9	5	0	26
Fluorescent Yellow-Green	6	7	9	5	0	27
White	4	5	10	4	4	27
Blue	6	3	10	6	2	27

Degradation of color was reported by 93 percent of the 27 respondents. All of the agencies that noticed color fade in signs identified it in the color background, and 50 percent also notice degradation in sign legends, as well. Red legends and red and brown backgrounds were the most cited colors that show noticeable degradation. Agencies that noticed color degradation associated the degradation with sign age (81 percent of responses), facing direction (77 percent, most of which describe south-facing signs) and the color itself (65 percent) rather than with pollution and particulates (27 percent).

Of note from the Florida experience is that agency officials note extensive degradation from ultraviolet exposure that noticeably increases in the south half of the state.

Retroreflectivity

Responses to questions about retroreflectivity and signs suggest that agency representatives view the relationship between retroreflectivity and sign characteristics with a little less certainty than they do relationships between sign colors and sign characteristics.

Most respondents have noticed degradation of retroreflectivity in their signs, but not all. Of 27 respondents, 17 answered yes, five answered no, and five responded N/A. From the yes answers, 15 respondents associated the beginning of retroreflectivity degradation with sign type and age ranges, as reported in the table below.

When Retroreflectivity Begins to Degrade						
Fabrication Type	**0 10 Years**	**11 12 Years**	**13 15 Years**	**16 20 Years**	**21+ Years**	**Total**
Type IV	4	3	2	2	3	14
Type IX	3	2	2	2	2	11
Type XI	2	2	3	1	2	10

With almost as high a certainty as with degradation in sign color, respondents associated retroreflectivity degradation with sign facing direction; 16 of 24 respondents affirmed facing direction as a factor in retroreflectivity degradation. Six respondents selected N/A, and two answered no.

Fluorescence

The bulk of the survey focused on properties and characteristics of fluorescent signage. Respondents were almost evenly split on whether they noticed fluorescent properties fading on their fluorescent signs: 13 of 26 indicated they had noticed fluorescence fade, 12 indicated they had not, and one selected N/A. An identical split echoed in noticeability of color fade in fluorescent signs: 13 of 26 answered that they had noticed color fade on fluorescent signs, 12 that they had not, and one responded N/A.

Of respondents who had noticed fade in fluorescence, seven saw it in yellow fluorescent signs in the six- to 10-year range, two in the 13- to 15-year range, and one in three to five years. Seven noticed similar degradation in yellow-green fluorescence in six to 10 years, two in 13 to 15 years, two in three to five years, and one other in 11 to 12 years.

Of respondents who had noticed color fade on fluorescent signs, five noticed it on fluorescent yellow signs at six to 10 years, three at 13 to 15 years, and one at three to five years. With fluorescent yellow-green signs, two noticed color fade at three to five years, five at six to 10 years, one at 11 to 12 years, and three at 13 to 15 years.

Facing direction was a little more tentatively linked to loss of fluorescence in fluorescent signs than it was to color and retroreflectivity degradation. Nine of 25 respondents did consider facing direction a factor in fluorescence loss, eight did not, and eight answered N/A. Facing direction and color loss in fluorescent signs showed a similar split: Eight of 24 answered yes, eight answered no, and eight selected N/A.

Four questions explored the impact of cracking on fluorescent signs. Eleven of 25 respondents notice cracked sheeting on fluorescent signs, but 14 did not. Those who had noticed cracking were less sure of when cracking appears in terms of fluorescence degradation, with three respondents noticing cracks before fluorescence is lost on the sign, three noticing it after fluorescence is lost, and 10 respondents answering N/A. Almost half of survey respondents do not see cracking as a significant cause of replacement in fluorescent signs. Seven of 25 answered yes, there is a level of cracking that requires repair or replacement of fluorescent signs, while 11 answered that there is not, and seven selected N/A. Only seven of 24 respondents believe that cracking affects a sheet sign's retroreflectivity; nine believe cracking impacts readability; nine selected N/A; and another five associated cracking with other sign functions such as reduction in both retroreflectivity and readability, though two of these five believe sign function is not impeded by cracking.

Agencies also display a lack of consensus on whether colors change when fluorescence begins to degrade. Ten of 25 respondents assert that color changes as fluorescence changes, but eight responded that color does not change with retroreflectivity degradation, and another seven answered N/A. Of the agencies that identify color change with loss of fluorescence, five of nine see this change within three to five years of the noticeable loss in fluorescence for both yellow and yellow-green fluorescent signs, three see it in six to 10 years for both colors, and one sees it in 13-to 15 years.

Loss of fluorescent properties does not appear to impact retroreflectivity; 13 of 19 respondents answered that retroreflectivity did not fail when fluorescence failed. However, 15 of 23 respondents replace fluorescent signs when fluorescent noticeably fades.

Agencies clearly favor fluorescent yellow signs over standard yellow signs. Seventeen of 23 agencies find fluorescent yellow more visible at night than regular yellow, 16 of 22 find the fluorescent sign more retroreflective, and even agencies that do not affirm the retroreflectivity and nighttime visibility of fluorescent over standard yellow signs prefer the fluorescent version. Ten of 15 respondents argue that fluorescent yellow offers benefit over standard yellow, mostly in improved visibility in daytime and low-light conditions such as fog, cloudy skies, dusk and dawn.

Regional Variation

Southern agencies seem to identify sign facing direction, especially southward or toward water, as a factor in color, retroreflectivity and even fluorescence loss, but this tendency is not much stronger than in other regions. Regional perceptions of sign performance with respect to facing direction showed no strong trends. While 25 of 27 responding agencies notice color fade, 21 recognize sign facing direction as a factor in color fade, as can be seen in the table below.

All six Southern states considered facing direction a factor in color loss, seven of nine states in the Upper Midwest also identify a correlation, as do five of eight in the Northeast, and three of four in the West.

Regional Variation in Degradation

Agency	Color fade factor in retire and replace	Notice color fade	Facing direction factor in color fade	Notice retro reflectivity fade	Facing direction factor in retro reflectivity fade	Notice fluores cence fade	Facing direction factor in fluores cence fade	Notice color fade on fluores cence signs	Facing direction factor in color loss on fluores cence signs
South									
Alabama	✔	✔	✔	✔	✔				
Arkansas		✔	✔	✔		✔		✔	
Florida		✔	✔	✔	✔	✔	✔	✔	✔
Mississippi	✔		✔						
South Carolina		✔	✔						
Texas	✔	✔	✔	✔	✔	✔	✔	✔	✔
Upper Midwest									
Illinois		✔	✔						
Indiana		✔	✔		✔				
Iowa	✔	✔	✔	✔	✔	✔	✔	✔	
Kentucky		✔		✔	✔				
Michigan	✔	✔		✔		✔		✔	
Nebraska	✔	✔	✔		✔				

Ohio	✔	✔	✔	✔	✔	✔	✔	✔	✔
South Dakota		✔	✔						
Wisconsin		✔	✔			✔			
Northeast									
Delaware				✔	✔	✔	✔	✔	✔
Maryland	✔	✔		✔		✔		✔	
Massachusetts		✔	✔	✔	✔				
New Hampshire		✔		✔					
Nova Scotia, Canada	✔	✔	✔	✔	✔			✔	✔
Pennsylvania		✔	✔	✔	✔	✔	✔	✔	✔
Philadelphia	✔	✔	✔	✔	✔	✔	✔		
Vermont	✔	✔	✔					✔	
West									
Idaho	✔	✔	✔	✔	✔	✔	✔	✔	✔
New Mexico		✔			✔				
Oregon	✔	✔	✔	✔	✔				
Wyoming	✔	✔	✔			✔	✔	✔	✔

Retroreflectivity loss was not quite as strongly connected with facing direction for respondents. Four of six Southern agencies recognize retroreflectivity fade, and three of these four associate it with facing direction. Seven of eight agencies in the Northeast recognize retroreflectivity degradation, and five of those associate the degradation with sign facing direction. Upper Midwest and Western numbers seem less certain. While only four of nine Midwest states recognize retroreflectivity fade, five of nine associate retroreflectivity loss with facing direction. In the West, two of four recognize retroreflective degradation, but three associate retroreflectivity loss with sign facing direction. Facing direction is almost always south, though in some instances agencies identify the facing direction as toward traffic or toward water.

Half the Southern states recognize color and fluorescence fade on fluorescent signs, and two of three that notice such degradation consider facing direction a factor. Five of eight agencies in the Northeast notice such degradation on fluorescent signs, and three of those five associate these fades with facing direction. Half the Western states notice such color and fluorescence fade, and both of these link it to facing direction. The Midwest shows the least certainty about degradation of color and fluorescence on fluorescent signs. Only three of the nine Upper Midwest states recognize color and fluorescence degradation on fluorescent signs, and only one of these associates it with facing direction.

General Information

In terms of sheeting manufacturer preference, all 27 respondent agencies use 3M as a sign sheeting source, and 20 of 27 use Avery Dennison as well. Eleven use Orafol, and five identify Nippon Carbide as another source.

Additional research was provided by some survey respondents about sign life cycle based on sign color, retroreflectivity or fluorescence. Four of those studies are attached to this report as Appendix C, Appendix D, Appendix E and Appendix F.

Related Resources

Minnesota Research

Recently MnDOT and the Local Road Research Board funded research on traffic sign life expectancy and the factors that influence sign life. While some sheeting materials were identified as having strong service lives, the literature search and fieldwork in Minnesota identified few clear correlations between sign life and factors such as age, facing direction, color and sheeting materials.

Traffic Sign Life Expectancy, Minnesota Department of Transportation, June 2014
http://www.dot.state.mn.us/research/TS/2014/201420.pdf
This study includes a detailed literature search of national and state practices and documents on elements of sign maintenance, including sign life expectancy, materials, sign facing direction, color, color fading and failure rates. Key findings of the literature review were that sign orientation and weather did not play substantial roles in retroreflectivity degradation, except possibly in the case of south-facing red signs. Color fade may be a more limiting parameter than retroreflectivity, which typically outlasts predicted sign service life. However, studies have not tracked retroreflectivity degradation over a long enough time to justify changes to sign life parameters.

A study of Minnesota signs found no conclusive relationships between sign life expectancy, sign material, sign facing direction, color, color facing and failure rates. Beaded sheeting signs should have a performance life of 12 to 20 years, and prismatic sheeting should have a performance life of 15 to 30 years. South-facing red signs may be more vulnerable to degradation than other color–direction combinations.

Retroreflectivity and Service Life

Studies of retroreflectivity and service life clearly suggest that sign damage is the most important factor in sign replacement strategies. The studies described in this section suggest that sign life does not correlate well with in-field retroreflective performance, and that retroreflectivity usually outlasts project sign life. Damage to signs, even if the damage doesn't impact retroreflective measures, makes signs less visible. Investigators suggest that damaged signs should be replaced promptly. Based on retroreflectivity, Type IV signs will last much longer than 15 years, if undamaged.

"The Effects of Damage on Sign Visibility: An Assist in Traffic Sign Replacement," Majid Khalilikhah and Kevin Heaslip, *Journal of Traffic and Transportation Engineering*, Vol. 3, Issue 6, pages 571-581, December 2016.
http://www.sciencedirect.com/science/article/pii/S2095756416300423?via percent3Dihub
Researchers found that expected sign life remains the most commonly used method in sign management for replacement decisions. A study of 1,683 signs in Utah showed that while sign age impacts retroreflectivity, sign damage and other factors significantly affect retroreflectivity.

"Evaluation of Sign Sheeting Service Life in Wyoming," Adam Pike and Paul Carlson, *TRB 93rd Annual Meeting Compendium of Papers*, Paper #14-0758, 2014.
http://docs.trb.org/prp/14-0758.pdf
Researchers studied 525 retroreflective signs, mostly made with Type III or Type IV materials. Research shows that life expectancy is impacted by retroreflective degradation, sheeting color, sheeting orientation and minimum retroreflectivity levels required by the Manual on Uniform Traffic Control Devices (MUTCD). However,

Type IV sheeting has a service life of at least 15 years and no clear end of service life based on retroreflectivity, suggesting that replacement should be determined on a property other than retroreflectivity.

“**Simulation-Based Evaluation of Traffic Sign Retroreflectivity Maintenance Practices,”** Joseph Hummer, Elizabeth Harris and William Rasdorf, *Journal of Transportation Engineering*, Vol. 139, Issue 6, pages 556-564, June 2013.
Citation at https://trid.trb.org/View/1250212
Investigators evaluated sign management based on nighttime visual inspection, blanket replacement and expected sign life in terms of sign damage and sign replacement. They concluded that sign managers should make replacing damaged signs a priority. Nighttime visual inspections are more cost-effective than blanket replacement practices, and expected sign life methods are nearly as cost-effective as visual inspections. Researchers offer five best practices for sign management.

“Analysis of Sign Damage and Failure: Utah Case Study,” Wesley Boggs, Kevin Heaslip and Chuck Louisell, *Transportation Research Record 2337*, pages 83-89, 2013.
Citation at https://trid.trb.org/View/1242349
Retroreflectivity ensures visibility, but does not necessarily identify sign legibility. In a study of 1,716 signs in Utah, researchers found that 93 percent were compliant with retroreflectivity standards, but 28 percent were so damaged that they were illegible, even if retroreflectively compliant. Researchers determined that higher damage rates could be contributed to average annual precipitation, elevation, seasonal temperature swings and exposure.

“Research of In-Service Regulatory Signs Sheeting, Retro-Reflectivity, and Deterioration Characteristics,” Ming Jiang and Rui Zhou, 12th COTA International Conference of Transportation Professionals, pages 1087-1095, August 2012.
Citation at https://trid.trb.org/View/1274299
In this 12-year study of 120 signs, researchers evaluated various mathematical models for assessing deterioration and life cycles of sign sheeting materials. Using the data gathered during the study, they developed a deterioration curve of the coefficient of retroreflection.

Development of Assessment Strategies for Sign Retroreflectivity, Travis Evans, Utah State University, 2012.
http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=2222&context=etd
This paper examines sign damage and its impacts on retroreflectivity and sign performance in Utah. Study results suggest that damage control may be an effective way to maintain sufficient sign retroreflectivity over its life cycle.

Color and Service Life

These citations indicate that research on color and sign life is sparse and highly valued. Each of the key Federal Highway Administration (FHWA) approved colors performs well in terms of retroreflectivity, but damage from pollution may limit signs of certain color or color-contrast combinations. While no color shows poor performance, red signs and red/orange and orange/yellow color contrasts may be less visible than other colors and color combinations. In terms of retroreflectivity, the limited research suggests all colors will exceed 15-year life expectancies.

"Analysis of the Effects of Coarse Particulate Matter (PM10) on Traffic Sign Retroreflectivity," Majid Khalilikhah, Kevin Heaslip and Chuck Louisell, *TRB 94th Annual Meeting Compendium of Papers*, Paper #15-6064, 2015.
Citation at https://trid.trb.org/View/1339560
In this study, researchers surveyed Utah DOT's sign database and measured the retroreflectivity of more than 1,700 signs based on sheeting color and material. The performance of Type IX and Type XI signs, particularly red signs, varied more than other evaluated types based on particulate matter adherence levels. Research also indicated that other factors impact retroreflective performance.

Daytime Color Appearance of Retroreflective Traffic Control Sign Materials, John Molino, Jason Kennedy, Pascal Beuse, C. Cameron Miller, Wendy Davis and Carl Andersen, Federal Highway Administration, April 2013.
https://www.fhwa.dot.gov/publications/research/safety/13018/13018.pdf
This research evaluated the hue, saturation and brightness of six colors used on various types of sign sheeting materials. White, green and blue color areas in signs proved distinct in retroreflective materials. Red, orange and yellow areas proved less distinct. While FHWA standards appear effective for daytime perception of retroreflectivity, revisions may be considered for red/orange and orange/yellow color boundaries.

"The Current State of Research on the Long-Term Deterioration of Traffic Signs," Bradford Brimley and Paul Carlson, *TRB 92nd Annual Meeting Compendium of Papers*, Paper #13-0033, 2013.
Citation at https://trid.trb.org/View/1240351
A review of research on long-term deterioration of traffic signs suggests that some signs have "unrealistically long expected lifespan[s]." Based on the state of the research, researchers suggest that a long-term study of sign deterioration should focus on retroreflectivity and color.

Retroreflectivity of Existing Signs in Pennsylvania, Pennsylvania Department of Transportation, April 2012.
http://www.dot7.state.pa.us/BPR_PDF_FILES/Documents/Research/Complete percent20Projects/Operations/Retroreflectivity percent20of percent20Existing percent20Signs.pdf
Pennsylvania DOT examined retroreflectivity in terms of its sign management program and compliance with MUTCD standards. For post-mounted signs, the agency relies on Type III and Type IV sheeting. Based on research, including a retroreflectivity measure of 1,000 signs, Pennsylvania DOT recommends setting a 15-year service life on red, yellow, white and green signs.

Management Methods for Replacement

While most agencies rely on life expectancy methods for sign replacement, research suggests replacement decisions based on nighttime visual inspections may be more cost-effective as a sign management method. The New Hampshire DOT study described below echoes the findings of the journal article "Simulation-Based Evaluation of Traffic Sign Retroreflectivity Maintenance Practices" (see the **Retroreflectivity and Service Life** section of this TRS). In the study, researchers examined the MUTCD-approved methods for evaluating retroreflectivity compliance and found that based on the DOT's management system and available data, nighttime visual inspection is the most cost-effective method for the agency.

Determining a Strategy for Efficiently Managing Sign Retroreflectivity in New Hampshire, New Hampshire Department of Transportation, May 2012.
http://www.nh.gov/dot/org/projectdevelopment/materials/research/projects/documents/FHWA-NH-RD-14282V.pdf
New Hampshire DOT looked at sign assessment and management methods for meeting retroreflectivity requirements from the MUTCD. Researchers evaluated visual nighttime inspection, measured sign retroreflectivity, expected sign life, blanket replacement and control sign approaches in sign assessment and

management. They determined that a visual nighttime inspection of signs was the most economical way for the agency to assess and manage its sign system for compliance with MUTCD retroreflectivity levels. New Hampshire DOT currently lacks a statewide sign inventory; if an inventory were in place, another sign assessment and management method may prove to better suit the agency's sign management needs.

Research in Progress

The citations below present current research projects on sign color, sheeting, retroreflectivity and deterioration, as well as on sign management strategies for service life assessment and replacement.

Development of a Sign Sheeting Sampling Protocol for the Determination of Service Life of Traffic Signs, Florida Department of Transportation, Contract BDV24 977-13, completion date: February 28, 2017.
https://trid.trb.org/View/1357040
From the project description:

> The objective of this project is to conduct a statewide review of sign appearance, color and color contrast ratio, and retroreflectivity to identify the deterioration rate of sign sheeting colors and types. Study will cover street and traffic signs for Rural, State and Federal streets. Colors considered for this study will be Red, White, Green and Blue signs. With this information, the project will develop a Predictive Model for Sign Sheeting service life based on its location, type, color and other parameters identified in the study. Based on findings, propose specification and Maintenance Rating Program (MRP) evaluation modifications to maximize cost effectiveness.

Sign Life Expectancy, South Carolina Department of Transportation, SPR 727, expected completion date: November 2017.
Project summary available from the 2016 Annual Report, SCDOT State Planning & Research Program, Part II: Research, page 20, 2016. http://www.scdot.scltap.org/wp-content/uploads/2017/02/SPR2016-final_web.pdf
From the project summary:

> The main objective of this study is to provide SCDOT [South Carolina Department of Transportation] with a well-researched sign management plan based on actual expected sign life that will extend the life of signs over the current method and at the same time be in compliance with the Manual on Uniform Traffic Control Devices (MUTCD) specified minimum retroreflectivity levels. SCDOT maintains approximately 750,000 signs. Prolonging the life of these assets will result in direct cost savings. The benefits of having a more accurate sign management program will also improve roadway safety and support the SCDOT's Target Zero initiative and commitment to eliminating traffic fatalities and severe injuries over time.

Sign Replacement Strategy, North Carolina Department of Transportation, Research Project Number 2018-25, expected completion date: December 2018.
https://connect.ncdot.gov/projects/planning/Pages/ProjDetails.aspx?ProjectID=2018-25
From the executive summary:

> The purpose of this research is to assess alternate NCDOT [North Carolina Department of Transportation] roadway sign replacement strategies and to benchmark their costs so that sign performance is maintained or enhanced while lowering costs. This study answers the question "is there an implementable lower cost sign replacement strategy that meets or exceeds current performance levels?" This study will explore whether or not this strategy could consist of a systematic sign replacement strategy that can be used by any division within North Carolina. We will analyze sign replacement strategies on primary and secondary roads, develop and use a simulation model (validated with actual NCDOT data) to predict future sign replacement needs, and estimate budgets based on sign condition, sign replacement rate, and operations costs. These estimates will then be used by NCDOT to improve cost efficiency and facilitate more informed sign management decisions for maintaining the required level of sign condition and performance.

Appendix A

Sign Life-Cycle Policies and Practices: Survey Questions

The following survey was distributed to representatives from all state departments of transportation and selected municipal and Canadian transportation agencies to investigate their experiences with traffic sign life expectancy and replacement.

Sign Replacement

1. Which of the following factors determine retirement and replacement of signs for your agency?
    - Age
    - Color degradation
    - Retroreflectivity
    - Inspection failure
    - Other
2. Please identify or describe the failure or degradation level or measure at which your agency retires and replaces signs.

Sign Color

3. Which sign sheeting types do you use for signs of the following colors?
    - White
        - Type IV
        - Type IX
        - Type XI
        - Other
    - Yellow
        - Type IV
        - Type IX
        - Type XI
        - Other
    - Fluorescent yellow
        - Type IV
        - Type IX
        - Type XI
        - Other

- Fluorescent yellow-green
    - Type IV
    - Type IX
    - Type XI
    - Other

4. For signs of the following colors, which fabrication methods do you use?
    - Red background
        - Digital printing
        - Silk screen ink printing
        - ElectroCut film
        - Other
    - Brown background
        - Digital printing
        - Silk screen ink printing
        - ElectroCut film
        - Other
    - Green background
        - Digital printing
        - Silk screen ink printing
        - ElectroCut film
        - Other
    - Blue background
        - Digital printing
        - Silk screen ink printing
        - ElectroCut film
        - Other
    - Other
5. For signs with the following legend colors, which fabrication methods do you use?
    - Black legend
        - Digital printing
        - Silk screen ink printing
        - ElectroCut film
        - Other

- Red legend
    - Digital printing
    - Silk screen ink printing
    - ElectroCut film
    - Other

6. Please indicate the service life your agency expects of signs of each of the following colors:
    - Red
    - Brown
    - Green
    - Yellow
    - Fluorescent yellow
    - Fluorescent yellow-green
    - White
    - Blue
7. Have you noticed color degradation of signs?

7A. If Yes, please describe the colors for backgrounds or legends in which you notice color degradation:

- Color background
- Legend

7B. If you have noticed color degradation of signs, which of the following characteristics or conditions do you believe to be a contributing factor in color degradation? Please describe.

- The color itself
- Facing direction
- Accumulation of particulates on sign face (deicing, soot, pollution, etc.)
- Sign age
- Other

Retroflectivity

8. Have you noticed retroreflectivity degradation on your agency's signs?
    - Type IV
    - Type IX
    - Type XI
9. In your experience, is sign facing direction a factor in retroreflectivity fading? If yes, please describe the facing direction(s) that causes or accelerates retroreflectivity fade, and when the loss becomes noticeable (3-5, 6-10, 11-12, 13-15, 16-20 years).

Fluorescence

10. In your experience, do fluorescent properties noticeably fade on your agency's fluorescent signs? If yes, please indicate when fluorescence noticeably fades on signs of the following colors:
    - Fluorescent yellow
    - Fluorescent yellow-green
11. In your experience, do colors noticeably fade on your agency's fluorescent signs? If yes, please indicate when color noticeably fades on signs of the following colors:
    - Fluorescent yellow
    - Fluorescent yellow-green
12. In your experience, is sign facing direction a factor in noticeable loss of fluorescent properties on your agency's fluorescent signs? If yes, please describe the facing direction(s) that causes or accelerates loss of fluorescent properties, and when the loss becomes noticeable (3-5, 6-10, 11-12, 13-15, 16-20 years).
13. In your experience, is sign facing direction a factor in noticeable loss of color on your agency's fluorescent signs? If yes, please describe the facing direction(s) that causes or accelerates loss of color, and when the loss becomes noticeable (3-5, 6-10, 11-12, 13-15, 16-20 years).
14. Do you notice cracked sheeting on fluorescent signs?
15. Is there a level of cracked sheeting that requires replacement or repair of the fluorescent sign? If yes, please describe the cracked sheeting level that requires replacement or repair.
16. In your experience, does cracked sheeting affect the sign's:
    - Retroreflectivity
    - Readability
    - Other sign functions
    - N/A
17. Does the color of your agency's fluorescent signs change when fluorescent properties are noticeably diminishing?
    - Fluorescent yellow
    - Fluorescent yellow-green
18. Does your agency replace fluorescent signs when the fluorescent properties are noticeably faded?
19. Is the retroreflectivity of your agency's fluorescent signs lost when fluorescent properties are lost?
20. In your experience, is fluorescent yellow more visible than standard yellow at night on your agency's signs?
21. In your experience, does fluorescent yellow offer more retroreflectivity than standard yellow at night on your agency's signs?
22. If you answered no to either of the previous two questions, do you believe fluorescent yellow provides more benefits to your agency than standard yellow? If Yes, describe the benefit that fluorescent yellow offers your agency.

23. Please indicate the sign sheeting manufacturer(s) that your agency uses:

- 3M
- Avery Dennison
- Orafol
- Other

Wrap-Up

Are you aware of any studies that have considered or evaluated sign life cycle based on color, retroreflectivity or fluorescence? If yes, provide a citation or link to any and all such studies, or attach a PDF for any and all such studies.

Please provide contact information for representatives from counties that contain major metropolitan areas in your state who make decisions about the topics covered in this survey

If you have collaborated with colleagues to complete this survey, please provide contact information for each person contributing to your survey responses.

Please use this space to provide any comments or additional information about your answers above.

Appendix B

Sign Life-Cycle Policies and Practices: Contact Information

Below is contact information for the individuals responding to the survey:

States

Alabama
Kerry NeSmith
Alabama Department of Transportation
nesmithk@dot.state.al.us, 334-242-6777

Andrew Harry
Alabama Department of Transportation
State Traffic Engineer
harrya@dot.state.al.us

Arkansas
John Mathis
Arkansas Department of Transportation
john.mathis@ardot.gov, 501-569-2658

Delaware
Rick Tracy
Delaware Department of Transportation
rick.tracy@state.de.us,

Florida
Paul Gentry
Florida Department of Transportation
Paul.Gentry@dot.state.fl.us, 850-414-4118

Idaho
Brett Purvis
Brett.Purvis@itd.idaho.gov, 208-334-8372

Illinois
Kyle Armstrong
Illinois Department of Transportation
kyle.armstrong@illinois.gov, 217-78/2-2076

Indiana
David Boruff
Indiana Department of Transportation
dboruff@indot.in.gov, 317-234-7975

Iowa
Kurtis Younkin
Iowa Department of Transportation
Kurtis.Younkin@iowadot.us, 515-239-1184

Kentucky
Jeff Wolfe
Kentucky Transportation Cabinet
jeff.wolfe@ky.gov, 502-782-5546

Maryland
Paul Stout
Maryland State Highway Administration
Pstout@sha.state.md.us, 410-787-7637

Massachusetts
Steve Timmins
Maryland State Highway Administration
stephen.timmins@state.ma.us, 857-368-9632

Michigan
Alonso Uzcategui
Michigan Department of Transportation
uzcateguia@michigan.gov, 517-410-9003

Mississippi
James Sullivan
Mississippi Department of Transportation
jssullivan@mdot.ms.gov, 601-359-1454

Nebraska
Kevin Wray
Nebraska Department of Transportation
kevin.wray@nebraska.gov, 402-479-4594

New Hampshire
Bill Lambert
New Hampshire Department of Transportation
William.Lambert@dot.nh.gov, 603-271-1679

New Mexico
Andrew Gallegos
New Mexico Department of Transportation
andrew.gallegos@state.nm.us, 506-827-5578

Ohio
Jason Yeray
Ohio Department of Transportation
jason.yeray@dot.ohio.gov, 614-466-2168

<u>**Oregon**</u>
Marie Kennedy
Oregon Department of Transportation
Marie.kennedy@odot.state.or.us, 503-986-4013

Joel Fry
Oregon Department of Transportation
Joel.D.FRY@odot.state.or.us, 503-986-4485

<u>**Pennsylvania**</u>
Justin Smith
Pennsylvania Department of Transportation
jussmith@pa.gov, 717-705-1443

Ken Reuther
Pennsylvania Department of Transportation
kreuther@pa.gov

Marchelle Davis
City of Philadelphia
marchelle.davis@phila.gov
215-685-1208

<u>**South Carolina**</u>
Walter Reed
South Carolina Department of Transportation
reedwa@scdot.org, 803-737-1290

<u>**South Dakota**</u>
Christina Bennett
South Dakota Department of Transportation
Christina.Bennet@state.sd.us, 605-773-4759

<u>**Texas**</u>
Doug Skowronek
Texas Department of Transportation
Doug.Skowronek@txdot.gov, 512-416-3120

Johnnie Miller
Texas Department of Transportation
Johnnie.miller@txdot.gov
512-506-5889

<u>**Vermont**</u>
Amy Gamble
Vermont Agency of Transportation
amy.gamble@vermont.gov, 802-477-3251

Wisconsin
Bill McNary
Wisconsin Department of Transportation
william.mcnary@dot.wi.gov, 608-266-1260

Wyoming
Ryan Shields
Wyoming Department of Transportation
ryan.shields@wyo.gov, 307-777-4290

Doug Hatch
307-777-4347

Canadian Province

Nova Scotia
Rob Hird
Nova Scotia Transportation and Infrastructure Renewal
rob.hird@novascotia.ca, 902-424-5389

Recommended Contacts

Respondents recommended the following contacts as potential sources of additional information.

Alabama
Richard Grace
Madison County
rgrace@madisoncountyal.gov

Bryan Kegley
Mobile County
bkegley@mobilecounty.net

Tracy Pate
Jefferson County
patet@jccal.org

George Speak
Montgomery County
georgespeake@mcala.org

Florida
Tim Allen
Florida Department of Transportation
im.Allen@dot.state.fl.us

Indiana

Michael Thornson
Fort Wayne, Ind./Allen County
mike.thornson@co.allen.in.us, 260-449-3638

Larry Jones
Indianapolis/Marion County
ljones@indy.gov, 317-327-8425

Iowa

Tim Crouch
Iowa Department of Transportation
Tim.Crouch@iowadot.us, 515-2139-1513

Maryland

Edwin Stellfox
University of Maryland
Stellfox@umd.edu

South Dakota

Doug Kinniburgh
South Dakota DOT—Local Governments
Doug.Kinniburgh@state.sd.us

Appendix C

FIELD INSPECTIONS

FOR

PANEL SIGN LIFE CYCLE

STUDY REPORT

(May 27, 2010)

By: Ting Nahrwold, P.E.
Evaluation Engineer

PURPOSE:

The purpose of this assignment is to aid in the determination of the panel sign life cycle. The study will help INDOT to provide guidance on sign sheeting replacement for panel signs

INTRODUCTION:

The major aim of this study was to obtain retroreflectivity and color measurements from ground mounted panel signs at various ages and locations.

A total of 93 ground mounted panel signs at various ages were selected in 5 districts (Greenfield, Crawfordsville, Fort Wayne, LaPorte, Vincennes).

METHOD OF EVALUATION:

Starting Sep 2008, INDOT Traffic Evaluation Section has been working with the districts on taking retroreflectivity and color measurements with Sign retroreflectometer(ART Technology, model 930) and Color spectrophotometer (HunterLab MiniScan XE- Plus 45/0) on the field.

- The panel signs at various ages were selected in five districts by the district traffic engineers. (See the attached table)

	Age (years)				
District	**10-12**	**12-14**	**14-16**	**>16**	**Total**
Greenfield	6	5	6	6	23
Crawfordsville	7	7	7	7	28
Fort Wayne	7	8	5	1	21
LaPorte	3	2	3	3	11
Vincennes	3	3	1	3	10
Total	26	25	22	20	93

- The retro-reflection readings for green background were taken at five different spots with an observation angle of 0.2° and entrance angle of -4° on each panel sign.
- The retro-reflection readings for white lettering were taken at five different spots with an observation angle of 0.2° and entrance angle of -4° on each panel sign.
- The color coordinates and luminance factors were taken at five different spots on the green background and five different spots on the white legends.

FINDINGS:

After two years of field inspection, the data was collected and analyzed in the attached tables and charts. (See the attachments)

All the average retroreflectivity readings are above the Federal Retroreflectivity Standards for both ground mounted and overhead signs. Even though only ground mounted signs were evaluated for this report, same materials used in overhead signs, so findings apply.

Federal Retroreflectivity Standards

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			Post-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 $cd/lx/m^2$ measured at an observation angle of 0.2° and an entrance angle of -4.0°.
[2] For text and fine symbol signs measuring at least 48 inches and for all sizes of bold symbol signs
[3] For text and fine symbol signs measuring less than 48 inches
[4] Minimum sign contrast ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity)
* This sheeting type shall not be used for this color for this application.

There is one retroreflectivity reading of the green background that is slightly below the FHWA minimum. This sign was installed in Crawfordsville district in 1988. The average of five readings on that sign was above minimum.

There is one retroreflectivity reading of the white legend that is slightly below the FHWA minimum. This sign was installed in Vincennes district in 1996. The average of five readings on that sign was above minimum. (See the attached summary).
The results were summarized in the following table:

District	Panel Sign Field Readings (Green)					
	MinimumRetroreflectivity (cd/m²/lux)					
	Age (years)				FHWA Min (Ground Mounted)	FHWA Min (Overhead)
	10-12	12-14	14-16	>16		
Greenfield	60.7	50	56.7	26	15	25
Crawfordsville	37.7	56.8	22.4	13.9	15	25
Fort Wayne	50.6	42.4	51.1	58	15	25
LaPorte	40.4	49.3	48.2	54.1	15	25
Vincennes	43.1	35.3	51.5	40.4	15	25

District	Panel Sign Field Readings (white)					
	MinimumRetroreflectivity (cd/m²/lux)					
	Age (years)				FHWA Min	FHWA Min (Overhead)
	10-12	12-14	14-16	>16		
Greenfield	165	288	242	279	120	250
Crawfordsville	267		263	248	120	250
Fort Wayne	263				120	250
LaPorte	212	223	238	313	120	250
Vincennes	244	101			120	250

- Note- These are minimum readings, not the average for sign.

CONCLUSION

The majority of the inspected panel signs were ASTM High Intensity Type III, some are Engineering and Super Engineering Grade ASTM Type I. Since January 2008, the signs supplied by INDOT Logistic Support Center have been the type IV sheeting, which is similar to Type III but are of higher retroreflectivity and longevity, with an estimated life cycle of 16 years.

Based on the field inspection findings, we propose to establish the life cycle for panel signs at 20 years. Since the Type IV prismatic sheeting has not been tested for the noted period of time, a follow up study will be performed in the next 4 and 10 years on panel signs.

Attachments:

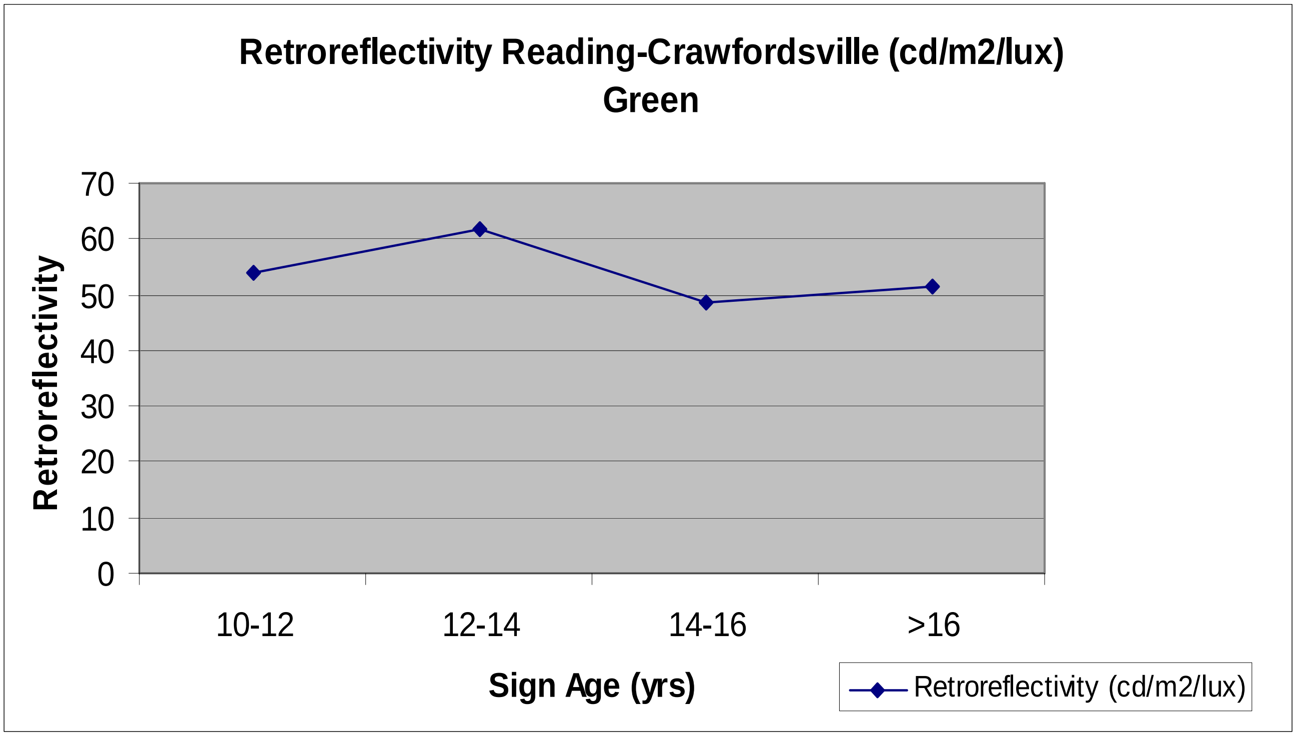
1. **Crawfordsville District Panel Sign Retroreflectance and Color Readings**
2. **Fort Wayne District Panel Sign Retroreflectance and Color Readings**
3. **Greenfield District Panel Sign Retroreflectance and Color Readings**
4. **LaPorte District Panel Sign Retroreflectance and Color Readings**
5. **Vincennes District Panel Sign Retroreflectance and Color Readings**

Panel Sign Retroreflectance and Color Readings
(Crawfordsville)

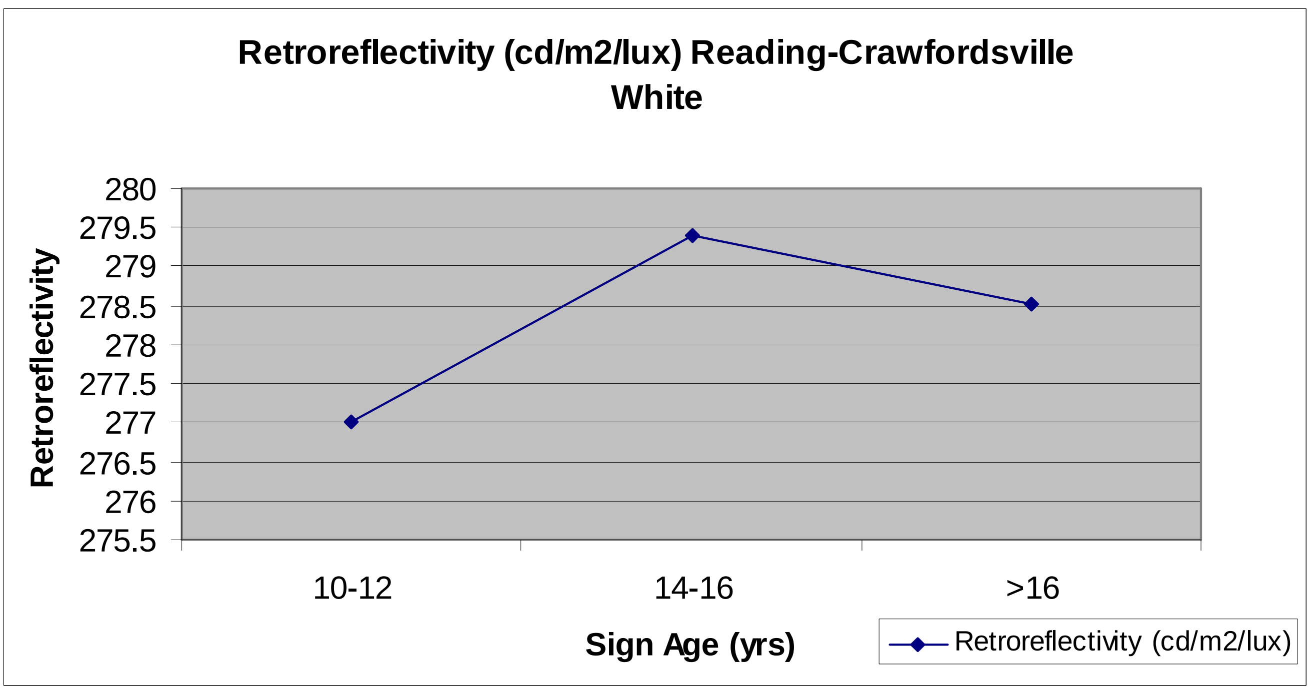
					Retroreflectivity (cd/m^2/lux)						Color Reading														
											1			2			3			4			5		
Sign Name	Road	Sign Age (yrs)	Sign Size(in)	Location	1	2	3	4	5	Average	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
Sheridan / Thorntown	I-65 off ramp	10-12	72 X168	Boone 1997	57	56	58	60	52	56.6	8.71	0.1694	0.4584	9.1	0.1699	0.4589	8.94	0.1687	0.4589	8.84	0.1691	0.4579	9.04	0.1699	0.4594
Dayton Lafayette Ivy Tech	I-65 ramp	10-12	108 X 144	Tpppecanoe 1997	60	57	57	68	56	59.6	8.58	0.1677	0.4524	8.71	0.1668	0.4609	8.8	0.1674	0.461	8.63	0.1652	0.4626	8.42	0.1651	0.4626
Dayton / Lafayette / Ivy Tech	I-65 NB ramp	10-12	108 X156	Tippecanoe 1997	60.6	57.4	55.5	58.7	58.9	58.22	8.71	0.1674	0.4581	8.31	0.1657	0.46	8.51	0.1673	0.4589	9.17	0.1697	0.4548	8.95	0.1685	0.4555
Rest Area / 45 degree Arrow	I-74 WB	10-12	180 X 132	Hendricks 1997	63.1	51.7	48.6	49.9	49.1	52.48	7.9	0.1605	0.2024	8.64	0.1632	0.2076	8.13	0.1613	0.2018	8.31	0.1624	0.205	8.15	0.1608	0.203
Exit 58 Lizton / Lebanon / 1 mile	I-74 WB	10-12	144 X132	Hendricks 1997	51.4	52.2	59.7	51.7	49.4	52.88	9.94	0.1731	0.4499	10.13	0.1724	0.4514	9.89	0.1724	0.4531	9.8	0.1874	0.4504	10.26	0.1788	0.4466
Exit 61 Pittsboro 45 degree arrow	I-74 WB	10-12	108 X 144	Hendricks 1997	46.6	44.9	48.4	37.7	47.8	45.08	9.56	0.1743	0.4489	11.37	0.1881	0.4439	10.39	0.1799	0.4503	9.99	0.1739	0.4543	9.71	0.1789	0.4499
										54.14333	8.9	0.168733	0.411683	9.376667	0.171017	0.413783	9.11	0.1695	0.414	9.123333	0.171283	0.414167	9.088333	0.170333	0.412833
St. Arrow Indianapolis St Louis Rt. Arrow	I-70 Ramp	12-14	72 X 192	Morgan 1995																					
Lt. Arrow Little Point	I-70 Ramp	12-14	48 X 180	Morgan 1995	60.7	56.8	65.8	64.9	62.4	62.12	8.78	0.1646	0.4643	8.87	0.166	0.4621	8.76	0.1659	0.463	8.95	0.1666	0.462	9.18	0.1665	0.4619
Exit 51 Co. Rd. 1100 W 1/2 mile	I-70 WB	12-14	72 X 228	Morgan 1995	61.8	63.7	60.9	60.3	60.6	61.46	9.37	0.167	0.4614	9.45	0.1679	0.4613	8.91	0.1647	0.4646	9.32	0.1665	0.463	9.05	0.1655	0.4652
										61.79	9.075	0.1658	0.46285	9.16	0.16695	0.4617	8.835	0.1653	0.4638	9.135	0.16655	0.4625	9.115	0.166	0.46355
Rest area 1 mile	I-74 EB	14-16	60 X 132	Hendricks 1994	34.5	26.2	25.2	22.4	23.8	26.42															
Rest area big arrow	I-74 EB	14-16	72 X 144	Hendricks 1994	33.4	34.5	26.7	26.9	37.1	31.72	7.82	0.1637	0.1981	6.64	0.163	0.1967	7.63	0.1623	0.1971	7.39	0.1629	0.1964	7.93	0.1641	0.2002
Exit 58 Lebanon / Lizton 1/2 mile	I-74 EB	14-16	168 X 144	Hendricks 1994	61.6	61.7	58.9	64.2	59.6	61.2	9.07	0.1691	0.4547	9.07	0.1696	0.4547	9.28	0.1695	0.4551	9.51	0.1698	0.4531	9.24	0.1688	0.4544
Linden / Crawfordsville 1 mile	I-74 WB	14-16	132 X 216	Montgomery 1994	60.5	63.4	64	62.4	62.3	62.52	9.23	0.1625	0.4603	9.38	0.1687	0.4592	9.07	0.1656	0.4635	9.24	0.1667	0.4629	9.1	0.1654	0.4622
Rossville / Lafayette 1 mile	I-65 SB	14-16	156x 156	Tippecanoe 1994	61.5	61.8	59.3	59.4	58.4	60.08	8.27	0.1655	0.464	8.21	0.1645	0.4661	8.47	0.1659	0.4647	8.34	0.1656	0.4639	8.09	0.1631	0.4658
										48.388	8.5975	0.1652	0.394275	8.325	0.16645	0.394175	8.6125	0.165825	0.3951	8.62	0.16625	0.394075	8.59	0.16535	0.39565
Lafayette next three Exits	I-65 NB	>16	60 X 144	Toppecanoe 1987	59.6	59	59.4	58.5	62.7	59.84	9.06	0.1691	0.4583	8.88	0.1678	0.4583	8.83	0.1678	0.4607	9	0.1702	0.4575	8.83	0.1669	0.46
Frankfort / Attica Rt arrow	I-65 NB	>16	144 X 156	Clinton 1987	45	50	50.9	46.7	48.6	48.24	8.85	0.1681	0.4584	8.89	0.1679	0.4589	8.6	0.1667	0.4601	8.84	0.1672	0.4597	8.89	0.1683	0.4593
Attica / Frankfort 1mi	I-65 NB	>16	24 X 108	Clinton 1987	52	50	49	51	51	50.6															
Exit 146	I-65 NB	>16	24 X 120	Boone 1988	15.5	17.1	13.9	17.8	17.1	16.28	5.98	0.1704	0.4293	6.12	0.1751	0.4281	5.99	0.1724	0.4224	6.03	0.1718	0.4248	6.02	0.1726	0.4246
Thorntown / Sheridan Rt arrow	I-65 NB	>16	156 X 168	Boone 1988	66.9	65.8	58.7	63.5	65.4	64.06	8.91	0.1689	0.4538	9.11	0.1702	0.4522	8.8	0.1683	0.4542	8.57	0.1671	0.456	8.73	0.1678	0.4563
Thorntown / Sheridan 1/2 mile	I-65 NB	>16	156 X 168	Boone 1988	64.53	62.5	62.7	58.2	59.3	61.446	8.82	0.1689	0.4553	8.91	0.1681	0.4536	8.79	0.1682	0.4548	9.12	0.1699	0.4516	8.88	0.1667	0.4546
Frankfort / Attica 1 1/4 miles	I-65 SB	>16	156 X 156	Clinton 1987	62.4	60.2	57.7	60.8	61.2	60.46	8.94	0.1697	0.4568	8.82	0.1678	0.4598	8.87	0.1685	0.4585	8.87	0.1678	0.4587	8.73	0.1689	0.312
										51.56086	8.426667	0.169183	0.451983	8.455	0.169483	0.451817	8.313333	0.16865	0.451783	8.405	0.169	0.451383	8.346667	0.168533	0.4278

Panel Sign Retroreflectance and Color Readings

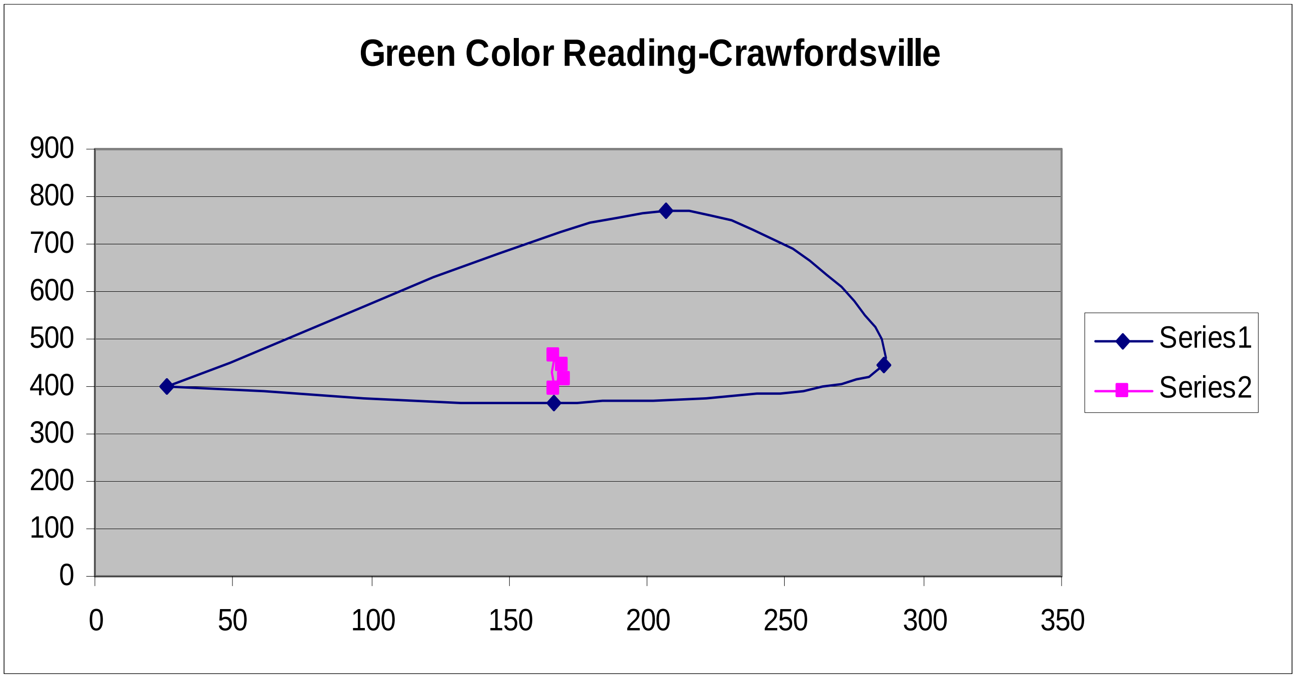
Sign Name	Road	Sign Age (yrs)	Sign Size(in)	Location	Retroreflectivity (cd/m^2/lux)						Color Reading														
											1			2			3			4			5		
					1	2	3	4	5	Average	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
Exit 58 Lizton / Lebanon / 1 mile	I-74 WB	10-12	144 X132	Hendricks 1997	285	288	274	271	267	277	36.05	0.3072	0.3296	35.93	0.3068	0.329	35.71	0.3071	0.3288	36.95	0.3061	0.3282	36.42	0.3066	0.3285
									267																
Rossville / Lafayette 1 mile	I-65 SB	14-16	156x 156	Tippecanoe 1994	274	285	314	299	263	287	32.27	0.3109	0.339	32.84	0.3109	0.3339	31.21	0.3109	0.3341	32.26	0.3109	0.3338	30.6	0.285	0.3338
Exit 58 Lebanon / Lizton 1/2 mile	I-74 EB	14-16	168 X 144	Hendricks 1994	275	278	270	280	265	273.6	37.15	0.3071	0.3299	37.7	0.308	0.3312	36.65	0.3075	0.3308	36.77	0.3073	0.3303	37.61	0.3077	0.331
Linden / Crawfordsville 1 mile	I-74 WB	14-16	132 X 216	Montgomery 1994	268	289	282	281	269	277.8	35.26	0.3092	0.3317	35.8	0.3093	0.3316	35.39	0.3096	0.332	35.36	0.3093	0.3318	35.2	0.3092	0.3317
										278.52		0.309067	0.333533	35.44667	0.3094	0.332233	34.41667	0.309333	0.3323	34.79667	0.309167	0.331967	34.47	0.300633	0.332167
Frankfort / Attica Rt arrow	I-65 NB	>16	144 X 156	Clinton 1987	253	265	248	256	252	254.8	34.79	0.3079	0.3301	34.09	0.3075	0.3294	33.68	0.3078	0.3301	34.21	0.3089	0.3321	33.71	0.3082	0.3304
Attica / Frankfort 1mi	I-65 NB	>16	24 X 108	Clinton 1987	283	277	287	272	258	275.4															
Frankfort / Attica 1 1/4 miles	I-65 SB	>16	156 X 156	Clinton 1987	297	305	281	290	285	291.6	34.27	0.309	0.3323	34.85	0.3092	0.3323	34.78	0.3094	0.3345	34.19	0.309	0.3323	34.11	0.3092	0.3323
Thorntown / Sheridan Rt arrow	I-65 NB	>16	156 X 168	Boone 1988	312	288	294	258	289	288.2	43.99	0.3095	0.3297	33.66	0.3084	0.3307	32.59	0.3085	0.3306	33.45	0.3092	0.3314	34.12	0.3084	0.3306
Thorntown / Sheridan 1/2 mile	I-65 NB	>16	156 X 168	Boone 1988	274	277	281	292	289	282.6															
										278.52		0.3088	0.3307	34.2	0.308367	0.3308	33.68333	0.308567	0.331733	33.95	0.309033	0.331933	33.98	0.3086	0.3311

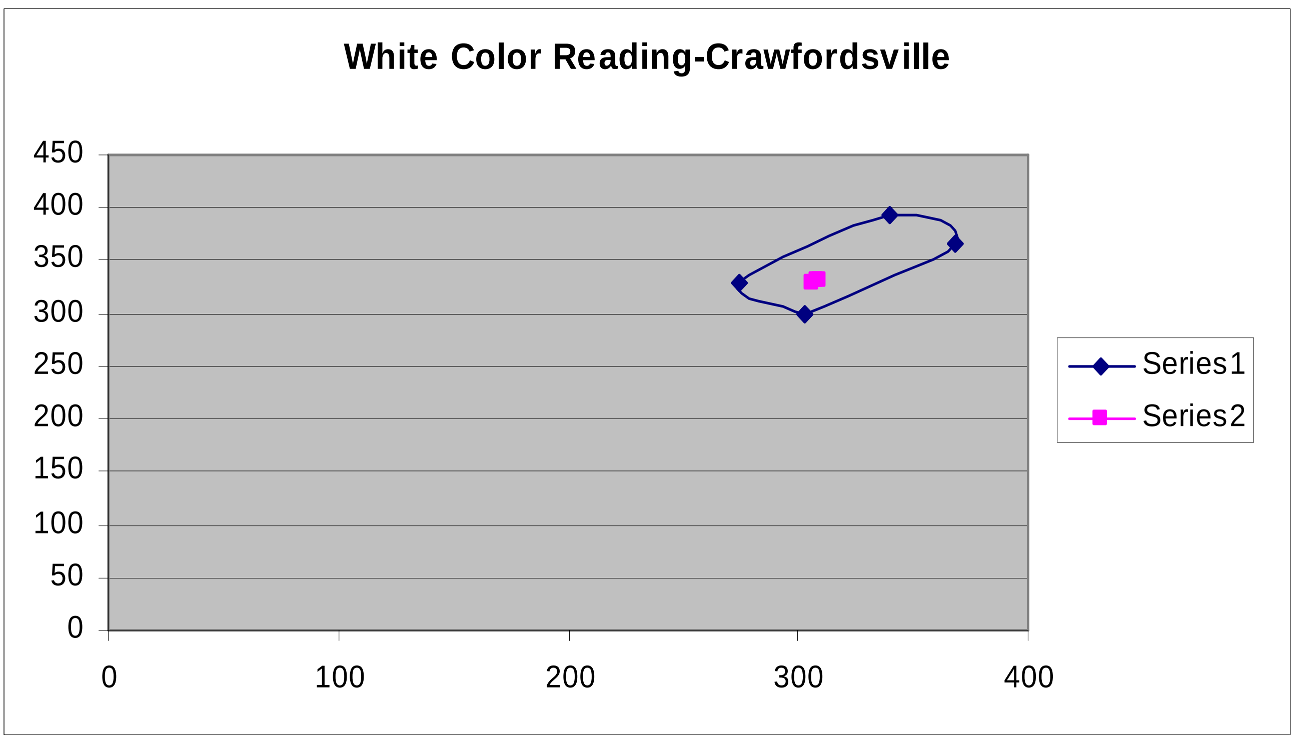


Retroreflectivity Reading-Crawfordsville (cd/m2/lux)
Green
Retroreflectivity
70
60
50
40
30
20
10
0
10-12
12-14
14-16
>16
Sign Age (yrs)
Retroreflectivity (cd/m2/lux)



Retroreflectivity (cd/m2/lux) Reading-Crawfordsville
White
Retroreflectivity
280
279.5
279
278.5
278
277.5
277
276.5
276
275.5
10-12
14-16
>16
Sign Age (yrs)
Retroreflectivity (cd/m2/lux)


Green Color Reading-Crawfordsville
900
800
700
600
500
400
300
200
100
0
0
50
100
150
200
250
300
350
Series1
Series2

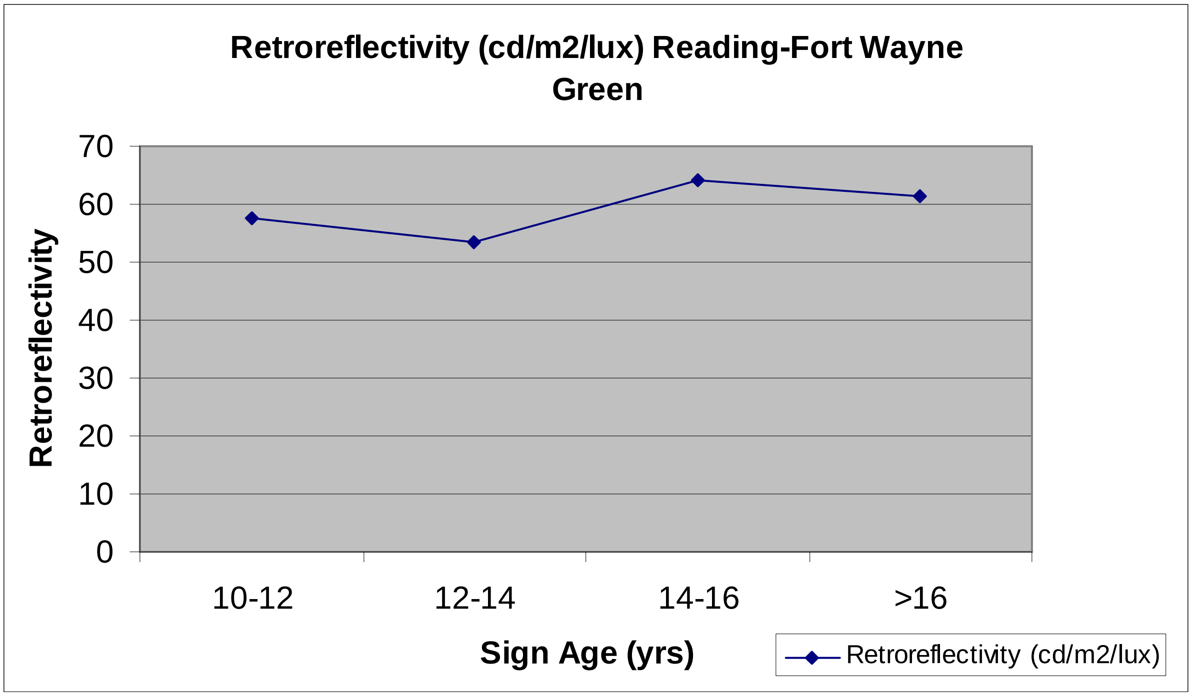

White Color Reading-Crawfordsville
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
Series1
Series2

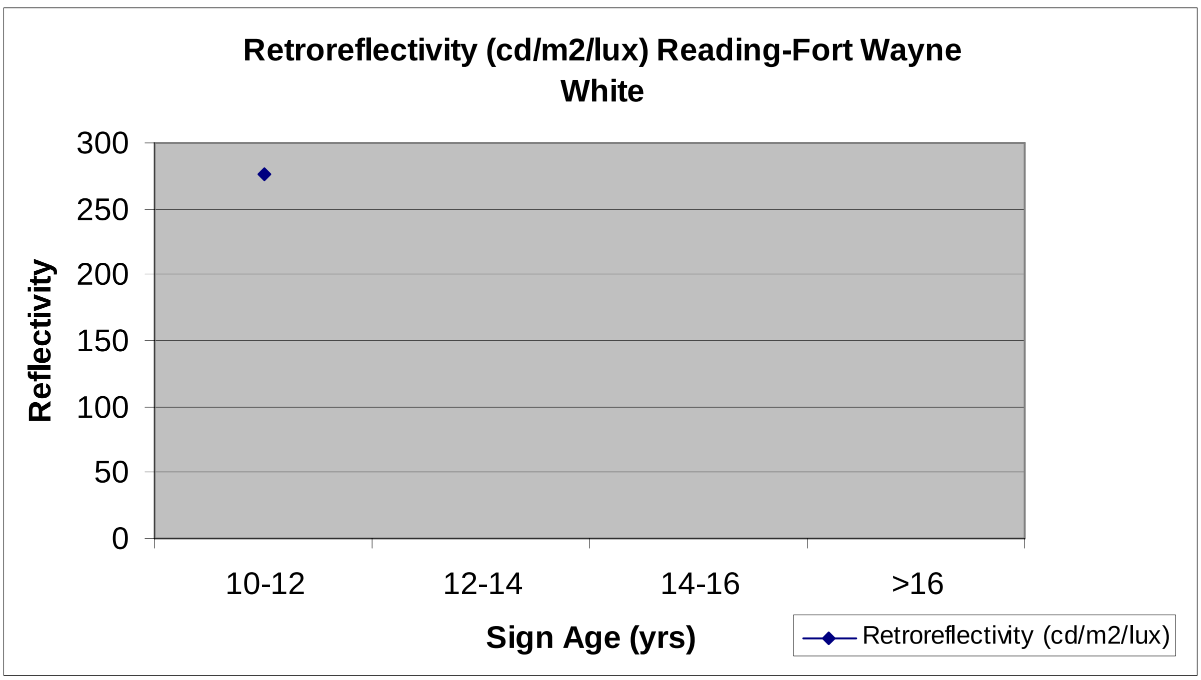
Panel Sign Retroreflectance and Color Readings
(Fort Wayne)

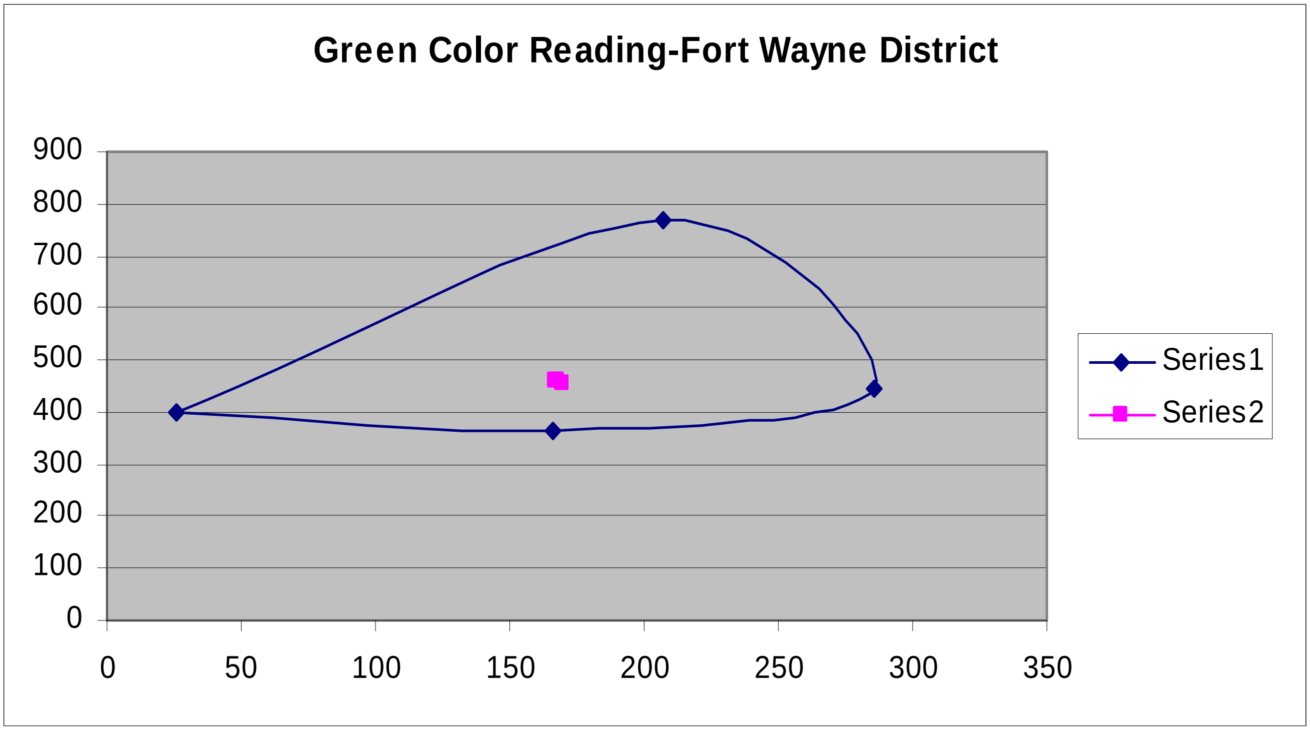
Sign No.	Sign Name	Sign Age (yrs)	Sign Size(in)	Location	Retroreflectivity (cd/m²/lux) 1	2	3	4	5	Average	Color Reading 1 Y	1 X*	1 Y*	2 Y	2 X*	2 Y*	3 Y	3 X*	3 Y*	4 Y	4 X*	4 Y*	5 Y	5 X*	5 Y*
1	69,469,24,33,3/4 mi	10-12	192x204	I-469E exit 0	60.9	59.7	66.4	60.8	62.2	62	8.83	0.1679	0.4519	9.04	0.17	0.4499	9.1	0.1687	0.4487	9.23	0.1709	0.4484	9.15	0.1707	0.4496
2	69,24,33 exit only	10-12	192x156	I-469E exit 0	53.9	55.3	57.4	52.4	55.9	54.98	9.15	0.1707	0.4496	9.43	0.1703	0.45	9.17	0.17	0.4515	9.36	0.1689	0.453	9.43	0.1703	0.4529
3	East Laffette center rd.	10-12	204x144	I-469E exit 1	59.7	57.9	57.7	59	61.5	59.16	9.36	0.1695	0.4527	9.08	0.1698	0.4536	9.16	0.1692	0.4547	9.11	0.1695	0.4517	9.44	0.1694	0.452
4	st.rd.1 us.27-9	10-12	156x84	I-469 2-4 mi.	54.2	54.9	53.9	57.7	54.5	55.04	9.37	0.1693	0.4577	9.32	0.1706	0.4566	9.41	0.1704	0.4587	9.17	0.1701	0.457	9.51	0.1705	0.4594
5	Ft.Wayne Intl. airport	10-12	168x132	I-469 MM6	54.7	53.1	52.5	53.8	57.2	54.26	9.19	0.1655	0.4645	9.18	0.1696	0.4517	9.32	0.1708	0.4506	9	0.1706	0.4518	9.3	0.1679	0.4611
6	MARION-1 TILLMAN 3	10-12	132X84	I-469 E of 27	58.4	58.7	56.5	56.5	50.6	56.14	9.36	0.1717	0.4499	9.31	0.1708	0.4514	9.29	0.1706	0.4517	9.39	0.1713	0.4522	9.22	0.1695	0.4533
7	exit 13 M arion 1/2 mi.	10-12	168x96	mm12	60.5	62.4	63.2	62.3	60.2	61.72	9.05	0.1699	0.4537	9.66	0.1722	0.4493	9.77	0.1733	0.4477	9.9	0.1737	0.4468	9.14	0.1706	0.4517
8	blue service sign	12-14	108x84	I-69 n exit 140						57.614	9.187	0.169	0.454	9.289	0.170	0.452	9.317	0.170	0.452	9.309	0.171	0.452	9.313	0.170	0.454
9	motorist service info.	12-14	228x84	I-69 n																					
10	REST AREA	12-14	144X72	GORE I-469 W																					
11	MAPLE CREST RD.	12-14	96X84	GORE I-469 W	44.7	44.5	44.8	42.4	45.1	44.3	8.55	0.1662	0.4558	8.78	0.1673	0.4558	8.76	0.1666	0.4567	8.53	0.1663	0.4569	8.84	0.169	0.4536
12	EXIT 31C	12-14	8X5	I-469 W	66.4	65.8	66.6	66.8	64.4	66	8.47	0.1673	0.4589	8.5	0.1663	0.4599	8.64	0.1674	0.4582	8.7	0.1671	0.4587	8.28	0.1665	0.4601
13	EXIT 31A	12-14	8X5	I-469 W	58.1	60.2	60.2	59.4	58.9	59.36	8.71	0.1679	0.4578	8.65	0.1664	0.4604	8.46	0.1659	0.46	8.44	0.1664	0.4597	8.55	0.168	0.4582
14	AUBRUN 3 ANGOLA 23	12-14	7X5	I-469 W	42.1	50.6	49.1	44.3	46.7	46.56	9.03	0.1697	0.4596	9.16	0.1719	0.4573	9.15	0.1712	0.4591	9.01	0.1695	0.4579	8.9	0.17	0.4596
15	AUBURN GARRETT 1 MILE		17X11	I-69N	54.9	52.1	55	43.9	45.7	50.32	9.25	0.1699	0.4607	8.75	0.1693	0.4595	9.33	0.1699	0.4588	9.03	0.1685	0.4608	8.86	0.1676	0.463
16										53.308	8.802	0.168	0.459	8.768	0.168	0.459	8.868	0.168	0.459	8.742	0.168	0.459	8.686	0.168	0.459
17	EXIT126 CO RD 11A	14-16	16X8	MM 126	57.7	58.1	53.7	51.1	58.7	55.86	9.29	0.1691	0.4598	9.45	0.1677	0.4525	8.99	0.167	0.4652	9.27	0.1702	0.4615	9.52	0.169	0.4527
18	AUBURN 1/2 MILE	12-14 14-16	11X15	MM 129	64.5	65.3	61.4	64.5	65.3	64.2	9.11	0.1702	0.4602	9.07	0.1685	0.4622	8.86	0.167	0.4629	9.36	0.1689	0.4602	8.98	0.1665	0.4643
									61.4	64.200	9.200	0.170	0.460	9.260	0.168	0.457	8.925	0.167	0.464	9.315	0.170	0.461	9.250	0.168	0.459
19	INDIANAOPOLIS	>16	240X72	I-469 E INDY. RD. 1 1/4 MILE	61.6	61.7	64.6	60.9	58	61.36	9.02	0.1675	0.4668	8.9	0.1675	0.4568	9.02	0.1676	0.4558	8.89	0.1681	0.4556	8.76	0.1655	0.4574
20		>16																							
		>16								61.360	9.020	0.168	0.467	8.900	0.168	0.457	9.020	0.168	0.456	8.890	0.168	0.456	8.760	0.166	0.457

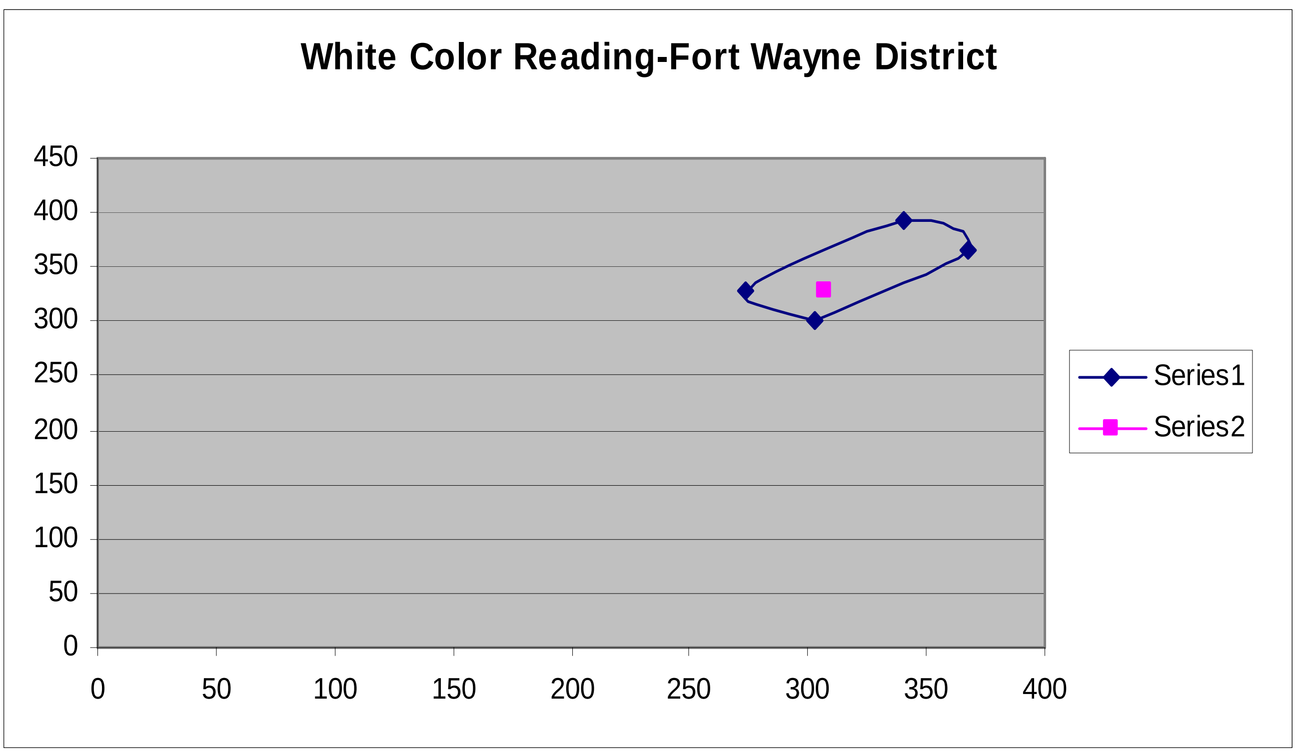
White

Sign No.	Sign Name	Sign Age (yrs)	Sign Size(in)	Location	Retroreflectivity (cd/m²/lux) 1	2	3	4	5	Average	Color Reading 1 Y	1 X*	1 Y*	2 Y	2 X*	2 Y*	3 Y	3 X*	3 Y*	4 Y	4 X*	4 Y*	5 Y	5 X*	5 Y*
1	69,469,24,33,3/4 mi	10-12	192x204	I-469E exit 0	295	272	263	276	275	276.2	37.03	0.3067	0.3293	36.82	0.3066	0.3293	37.59	0.3075	0.3302	37.33	0.3066	0.329	37.51	0.3064	0.3292


Retroreflectivity (cd/m2/lux) Reading-Fort Wayne
Green
Retroreflectivity
70
60
50
40
30
20
10
0
10-12
12-14
14-16
>16
Sign Age (yrs)
Retroreflectivity (cd/m2/lux)


Retroreflectivity (cd/m2/lux) Reading-Fort Wayne
White
Reflectivity
300
250
200
150
100
50
0
10-12
12-14
14-16
>16
Sign Age (yrs)
Retroreflectivity (cd/m2/lux)

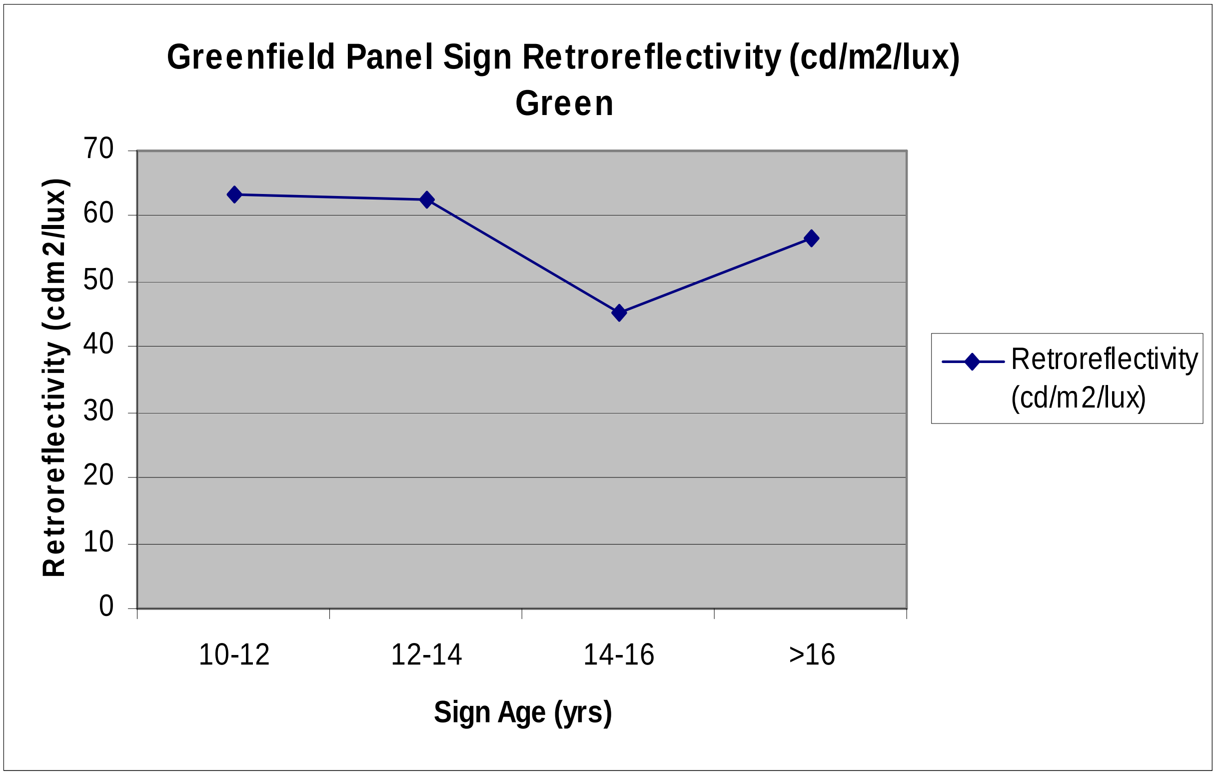

Green Color Reading-Fort Wayne District
900
800
700
600
500
400
300
200
100
0
0
50
100
150
200
250
300
350
Series1
Series2

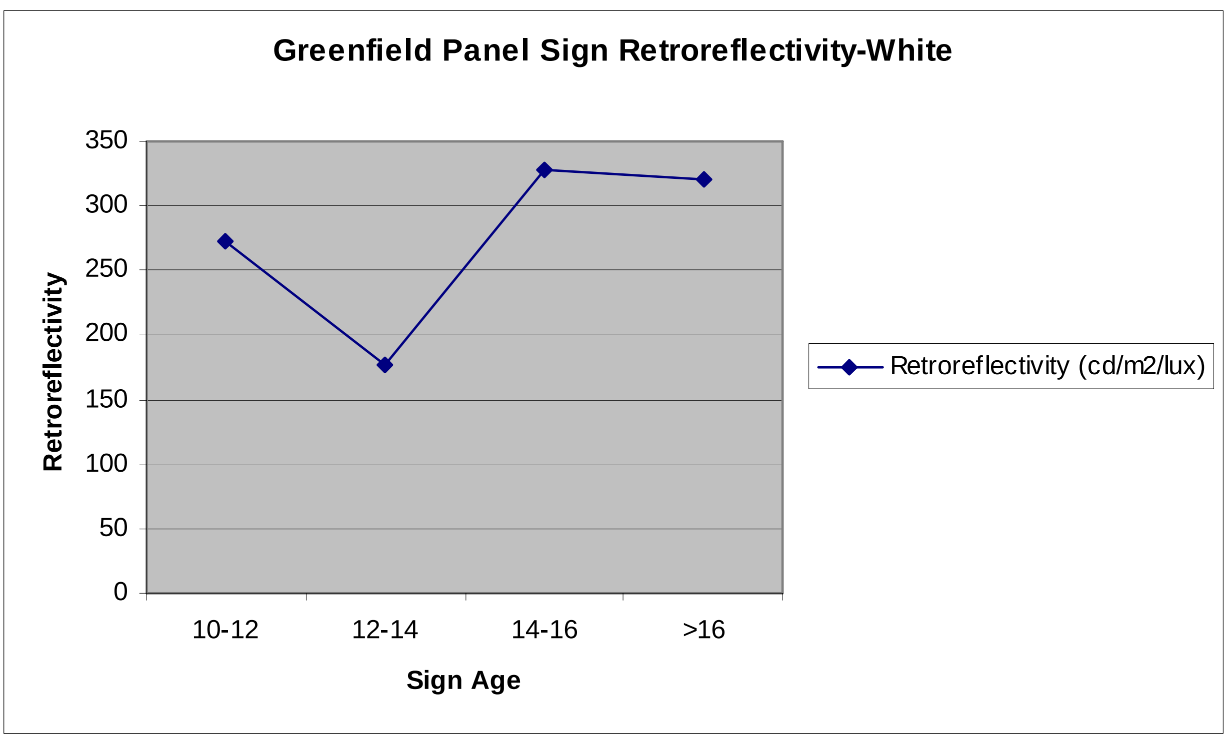

White Color Reading-Fort Wayne District
450
400
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
Series1
Series2

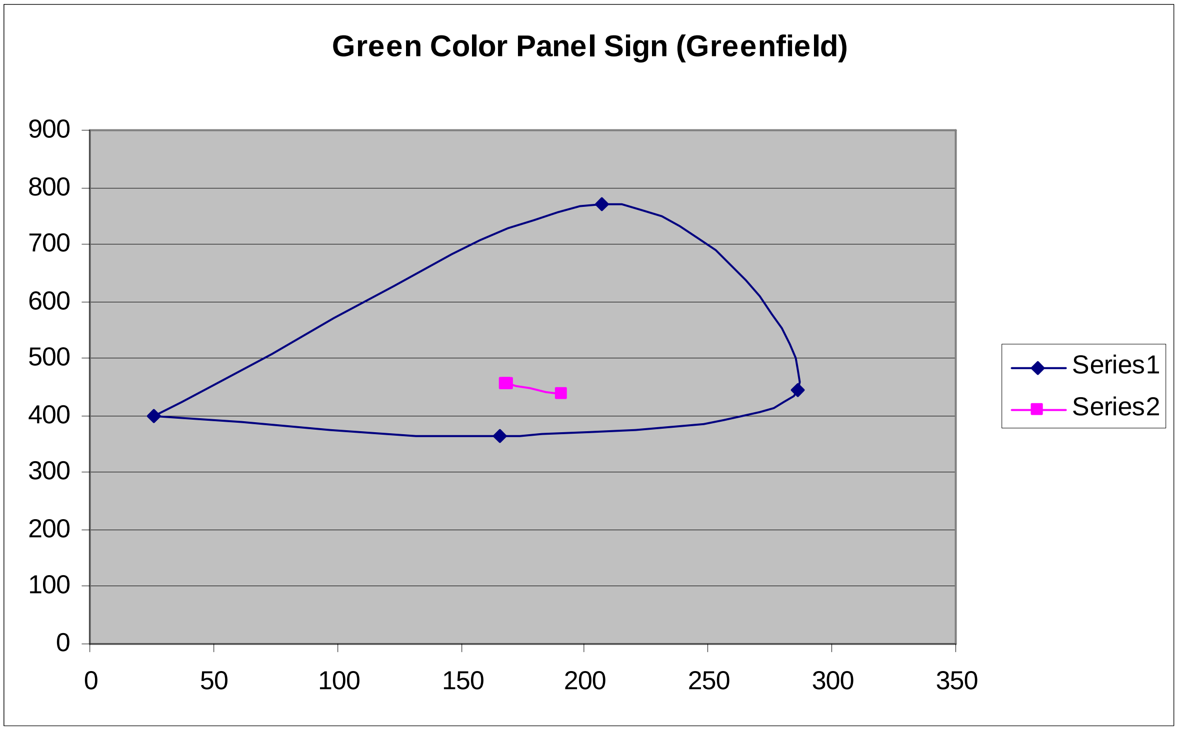
Panel Sign Retroreflectance and Color Readings
(Greenfield)

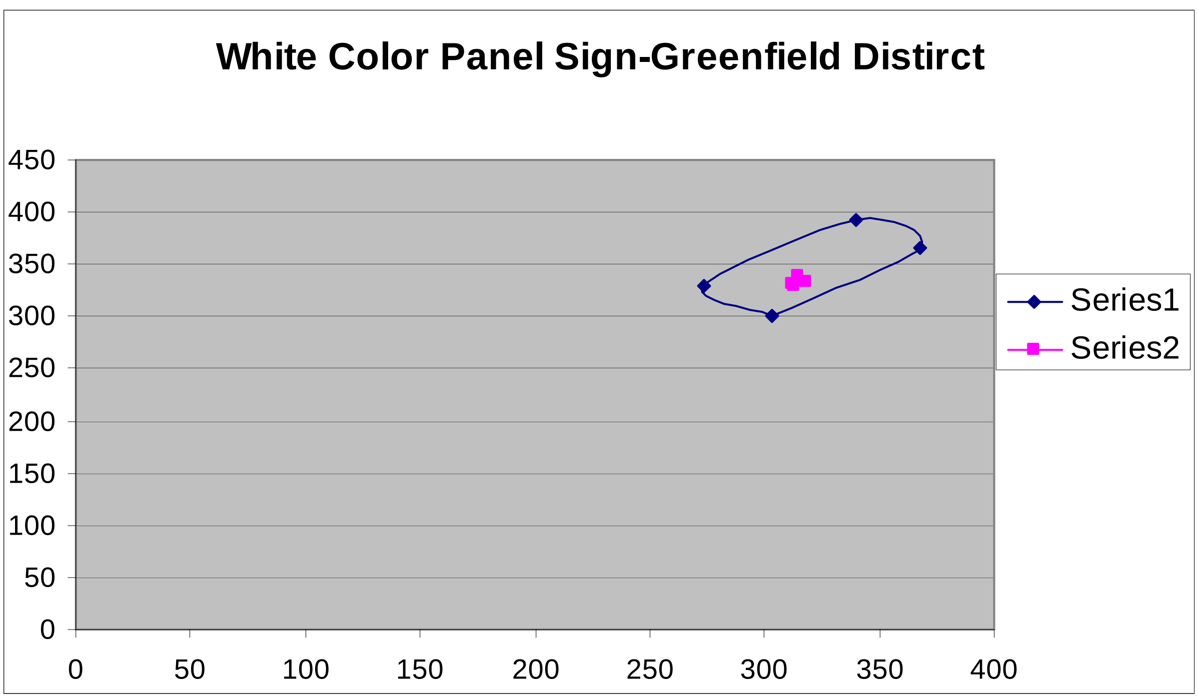
Sign Name	Sign Age (yrs)	Sign Size(in)	Location	Retroreflectivity (cd/m²/lux)					Average	Color Reading														
										1			2			3			4			5		
				1	2	3	4	5		Y	X*	Y*	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
Cincinnati 1/4 mi	10-12	144x120	I-65 s/b & 1/4 n/of I-465	483	504	504	584	584	53.18	8.84	0.1649	0.4578	8.87	0.1664	0.4618	9.29	0.1692	0.4585	8.79	0.1658	0.4592	8.89	0.167	0.4584
Exit 106 gore	10-12	60x84	I-65 s/b @ off ramp to I-465	599	584	609	694	601	61.74	8.22	0.1677	0.4572	8.36	0.1651	0.4608	8.41	0.1643	0.4616	8.37	0.1656	0.4611	8.23	0.1665	0.4595
Beechgrove exit 52	10-12	60 x156	I-465 e/b & w/of exit 52	589	602	570	579	554	57.88	9.12	0.1684	0.4533	9.44	.16.89	0.4546	9.22	0.17	0.453	9.32	0.1639	0.4552	9.23	0.1722	0.4511
1/2 mi. adv. Warn.	10-12	72x144	I-69 n/b & 1/2 mk s/of 82 st	65.3	60.7	62.9	62.6	68.2	63.94	8.85	0.1677	0.4543	14.81	0.1794	0.4686	8.88	0.1787	0.4531	8.86	0.1787	0.4531	8.69	0.1666	0.4544
adv warn, w/big arrow	10-12	144x144	SR 3 & n/of I-70	79.3	77.5	76.4	83.4	80.1	79.34	9.22	0.1686	0.4533	8.99	0.1686	0.4528	9.15	0.1626	0.4555	10.81	0.1874	0.4384	9.29	0.1684	0.4544
Exit 115 gore	10-12	60x84	I-70 w/b @ sr 109						**63.216**	**8.85**	**0.16746**	**0.45518**	**10.094**	**0.169875**	**0.45972**	**8.99**	**0.16896**	**0.45634**	**9.23**	**0.17228**	**0.4534**	**8.866**	**0.16814**	**0.45556**
univ. of indy exit 107	12-14	84x228	I-65 n/b 1/4 m n/of i-465	56.2	55.2	57.1	59.4	57.4	57.06	8.33	0.1651	0.4591	8.48	0.1671	0.4581	8.53	0.1652	0.4592	8.62	0.1669	0.4582	8.35	0.1649	0.4599
mileage dest.	12-14	60x108	I-74 e/b e/of fairland rd.	583	614	807	750	780	70.68	9.5	0.1686	0.451	8.64	0.1654	0.462	8.93	0.1663	0.4595	8.85	0.1672	0.4592	8.59	0.1669	0.4607
milage dest.	12-14	60x120	I-70 w/b & w/of SR 3	617	616	651	604	620	62.16	9.41	0.1411	0.4563	9.87	0.17	0.4571	9.27	0.1701	0.4573	9.43	0.1708	0.4558	9.45	0.1702	0.4563
								55.2																
directional with arrow	12-14	108x180	I-70 w/b onoff ramp to sr 109	53.1	58.8	58.2	55.3	55.8	56.24	8.86	0.1662	0.4558	9.01	0.1687	0.4527	8.85	0.1663	0.4556						
directional with arrow	12-14	132x180	I-69 n/b on off ramp to sr 238	58.1	50	59.3	74.6	85.7	65.54	9.99	0.1755	0.4447	9.55	0.1722	0.4479	9.81	0.1735	0.4464	9.49	0.1722	0.45	8.18	0.1734	0.4451
									62.336	**9.218**	**0.1633**	**0.45338**	**9.11**	**0.16868**	**0.45556**	**9.078**	**0.16828**	**0.4556**	**9.11**	**0.16918**	**0.45508**	**8.678**	**0.16854**	**0.45516**
adv warn, w/big arrow	14-16	144x156	I-74 w/b @ off ramp to sr 9	641	660	483	505	567	57.12	9.24	0.1523	0.4766	9.63	0.1721	0.4526	9.57	0.17	0.4529	9.65	0.1744	0.4491	9.46	0.1721	0.4528
advance warning	14-16	156x156	I-70 w/b I mi e/of sr 109	29.3	30.3	28.4	28.3	28.6	28.98	8.79	0.1652	0.4575	8.44	0.1662	0.4578	8.45	0.1629	0.4614	8.51	0.1655	0.4577	8.67	0.1646	0.4594
mileage dest.	14-16	60x120	I-69 n/b @ 6mm	56.7	58.4	57.9	58.1	59.1	58.04	8.85	0.1669	0.4578	8.08	0.166	0.4572	8.79	0.1657	0.4586	9.05	0.166	0.4587	9.98	0.1753	0.4523
directional with arrow	14-16	96x216	SR 3 & n/of I-70	6.69	6.53	6.48	6.87	6.58	6.63	9.07	0.1697	0.4514	9.38	0.171	0.4502	9.16	0.1701	0.4518	8.96	0.1689	0.4516	9.13	0.1711	0.4509
directional with arrow	14-16	96x216	SR 109 s/b & n/of I-70	75.1	76.2	77.7	74.3	74.7	75.6	8.74	0.167	0.456	8.9	0.1669	0.4565	8.98	0.1675	0.4556	9.13	0.1676	0.456	8.74	0.167	0.4554
									45.274	**9.128286**	**0.1657**	**0.456769**	**9.012857**	**0.169011**	**0.453966**	**9.119714**	**0.168283**	**0.454614**	**9.128571**	**0.169111**	**0.454026**	**8.976857**	**0.170291**	**0.453009**
mileage dest.	>16	60 x 120	I-65 s/b @ 105mm	59.9	55.8	63.2	67.8	67.5	62.84	6.54	0.1632	0.4639	8.8	0.1657	0.4603	8.88	0.1651	0.4597	8.84	0.1651	0.4608	9.13	0.1669	0.459
Truck and Trailer	>16	48 x 120	I-465 e/b e/of sr 67	30	29	38	39	37	34.6	46.27	0.3199	0.3427	46.78	0.3199	0.3427	46.2	0.3195	0.3423	47.03	0.3192	0.342	47.3	0.3191	0.3418
white river west fork	>16	36 x 96	I-465 @ white river	549	216	405	628	584	47.64	9.29	0.1749	0.4531	9.36	0.1775	0.4547	11.59	0.1934	0.4357	12.19	0.1917	0.4346	9.26	0.1756	0.4526
fairland rd 1 mile	>16	72x 192	I-74 e/b 1m w/of fairland rd.	702	643	664	687	619	66.3	9.53	0.1701	0.4541	9.71	0.1727	0.4505	9.5	0.1697	0.4531	9.56	0.1674	0.456	9.36	0.1675	0.4544
Big Blue River sign	>16	24x144	I-70 w/b & w/of SR 3	26.7	58.2	65.5	80.5	65.3	59.24	9.42	0.1855	0.4435	9.57	0.199	0.4311	9.97	0.1833	0.4453	9.86	0.1827	0.4454	10.4	0.1824	0.4466
1 mi adv. Warn.	>16	144x144	I-69 n/b & 1 mi s/of SR 37	67.3	71.4	69.4	74.2	68.3	70.12	9.8	0.167	0.4588	9.08	0.1645	0.4571	9.02	0.1658	0.4569	8.84	0.1657	0.4636	8.87	0.1631	..4698
									56.79	**13.58979**	**0.189163**	**0.441109**	**13.90161**	**0.191901**	**0.438358**	**14.15746**	**0.191573**	**0.437902**	**14.32232**	**0.191064**	**0.439053**	**14.00461**	**0.188986**	**0.437544**

Sign Name	Sign Age (yrs)	Sign Size(in)	Location	Retroreflectivity (cd/m²/lux)					Average	Color Reading														
										1			2			3			4			5		
				1	2	3	4	5		Y	X*	Y*	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
	10-12			312	309	285	308	322	307.2	31.57	0.31	0.3324	31.17	0.3404	0.3327	32.93	0.3106	0.3329	31.42	0.312	0.3326	32.27	0.3102	0.3325
Truck and Trailer	**10-12**	**42x120**	I-74 e/b e/of sr 9	271	282	308	165	169	239	35.19	0.308	0.3312	35.2	0.3084	0.3315	34.25	0.3091	0.3321	34.85	0.309	0.3018	34.94	0.3098	0.3328
									273.1	**33.38**	**0.309**	**0.3318**	**33.185**	**0.3244**	**0.3321**	**33.59**	**0.30985**	**0.3325**	**33.135**	**0.3105**	**0.3172**	**33.605**	**0.31**	**0.33265**
Truck and Trailer	**12-14**	**48x120**	I-70 w/b & w/of SR 3	48	44.7	50.4	58.9	53.9	51.18	44.4	0.3167	0.3391	45.71	0.3157	0.3381	44.52	0.3165	0.3389	44.79	0.3186	0.3393	44.45	0.3161	0.3386
Truck and Trailer	**12-14**	**48x120**	I-69 s/b 1/4 mi s/of sr 238	577	532	549	603	622	576.6	48.05	0.3206	0.3405	47.36	0.3209	0.3406	49.45	0.3182	0.3384	47.15	0.3211	0.3411	46.07	0.3214	0.3411
	12-14			288	304	315	295	312	302.8	34.85	0.3077	0.3605	34.99	0.3075	0.3288	33.97	0.3074	0.3285	32.81	0.3073	0.3285	32.34	0.3072	0.3283
									176.99	**42.43333**	**0.315**	**0.3467**	**42.68667**	**0.3147**	**0.335833**	**42.64667**	**0.314033**	**0.335267**	**41.58333**	**0.315667**	**0.3363**	**40.95333**	**0.3149**	**0.336**
Truck and Trailer	**14-16**	**42x120**	I-65 n/b @ the 108 mm	761	452	592	593	742	628	47.36	0.3207	0.3409	49.46	0.3198	0.34	48.52	0.3204	0.3406	48.37	0.3205	0.3409	49.85	0.3203	0.3408
	14-16			242	349	335	369	343	327.6	34.61	0.3084	0.3307	35.18	0.3285	0.3309	32.94	0.3494	0.3297	34.9	0.3283	0.3304	33.59	0.3082	0.3204
	14-16			26.4	30.9	30.8	30.7	31	29.96	34.09	0.3082	0.3304	33.79	0.3082	0.3303	33.74	0.3082	0.3303	34.545	0.3084	0.3307	34.45	0.3086	0.3308
									328.52	**38.68667**	**0.312433**	**0.334**	**39.47667**	**0.318833**	**0.333733**	**38.4**	**0.326**	**0.333533**	**39.27167**	**0.319067**	**0.334**	**39.29667**	**0.312367**	**0.330667**
	>16			323	314	330	308	325	320	33.2	0.3073	0.3292	32.78	0.3079	0.33	33.87	0.3077	0.3298	33.54	0.3078	0.3297	33.85	0.308	0.3219
Truck and Trailer	**>16**	**48 x 120**	I-65 s/b @ 105mm	No reflection- old sign						44.22	0.309	0.3023	43.21	0.3189	0.3423	44.94	0.319	0.3425	44.04	0.3186	0.3423	44.45	0.3181	0.3416
									320	**38.71**	**0.30815**	**0.31575**	**37.995**	**0.3134**	**0.33615**	**39.405**	**0.31335**	**0.33615**	**38.79**	**0.3132**	**0.336**	**39.15**	**0.31305**	**0.33175**


Greenfield Panel Sign Retroreflectivity (cd/m2/lux)
Green
Retroreflectivity (cdm2/lux)
70
60
50
40
30
20
10
0
10-12
12-14
14-16
>16
Sign Age (yrs)
Retroreflectivity (cd/m2/lux)


Greenfield Panel Sign Retroreflectivity-White
Retroreflectivity
350
300
250
200
150
100
50
0
10-12
12-14
14-16
>16
Sign Age
Retroreflectivity (cd/m2/lux)


Green Color Panel Sign (Greenfield)
900
800
700
600
500
400
300
200
100
0
0
50
100
150
200
250
300
350
Series1
Series2

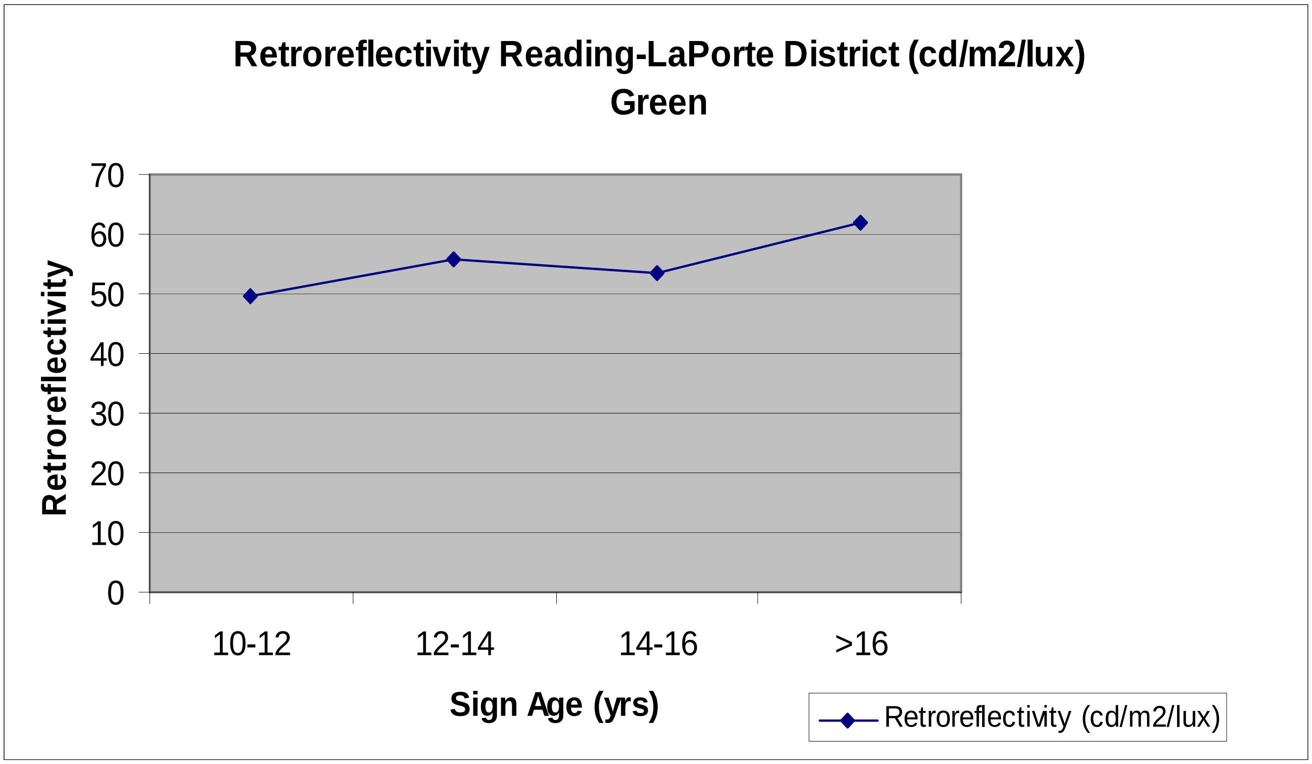

White Color Panel Sign-Greenfield Distirct
450
400
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
Series1
Series2

Panel Sign Retroreflectance and Color Readings
(LaPorte)

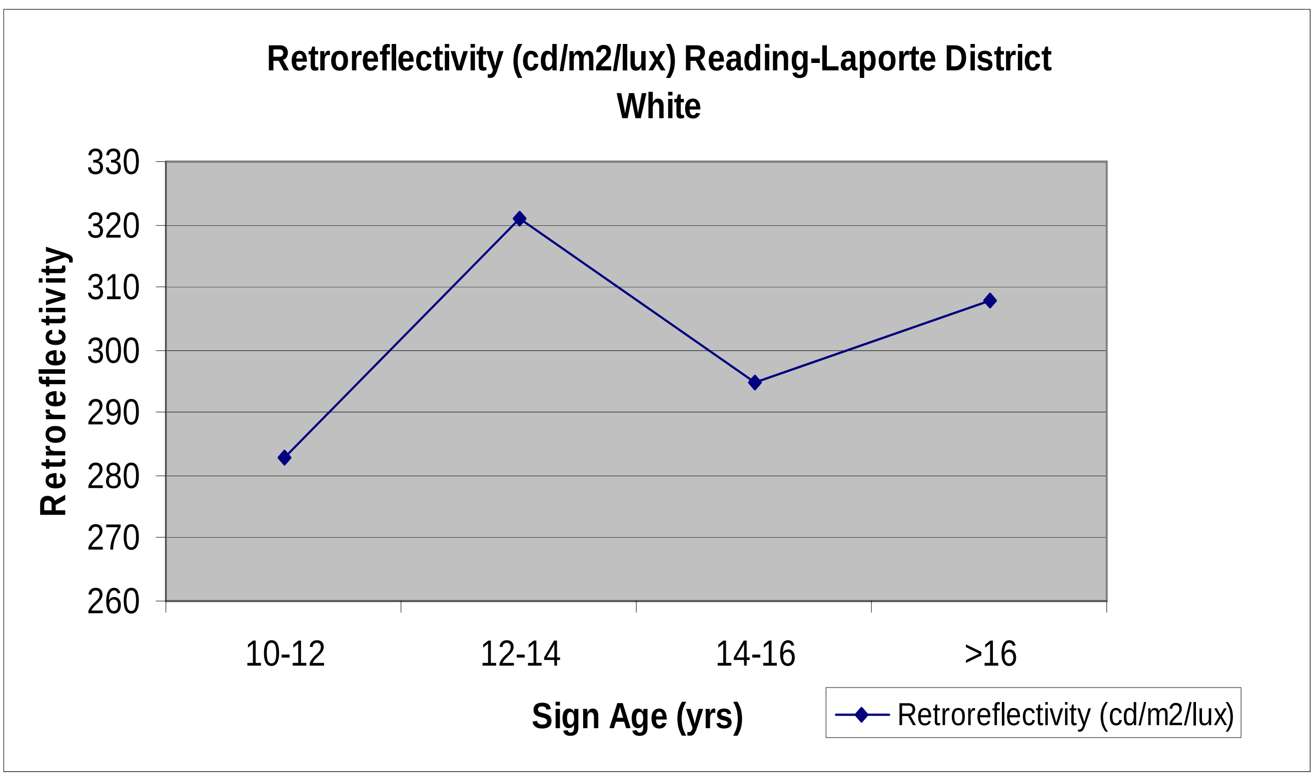
Sign No.	Sign Name	Sign Age (yrs)	Sign Size(in)	Location	Retroreflectivity (cd/m^2/lux)					Aver	Color Reading											
											1			2			3			4		
					1	2	3	4	5		Y	X*	Y*	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
5G	exit 14 a	10-12	72x108	WB @ SR 51	44.8	44	50.6	49.7	48.8	47.6	9.26	0.18	0.45	9	0.18	0.45	9.13	0.18	0.45	9.28	0.18	0.45
7G	exit 22A	10-12	96x216	EB @ Burns Harbor	44	44.8	45.9	45.2	40.4	44.1	9.21	0.16	0.46	9.63	0.17	0.45	9.45	0.17	0.45	9.45	0.17	0.45
31G	exit34A-B Mich.City/Westville 10-12 years				56.7	57.7	56.5	46.7	67.9	57.1	8.86	0.16	0.46	8.9	0.16	0.46	8.31	0.16	0.46	8.42	0.17	0.46
										49.6	9.11	0.17	0.46	9.18	0.17	0.46	8.96	0.17	0.45	9.05	0.17	0.46
11G	1mi chesterton valpo	12-14	120x228	WB 1 mi from SR 49	49.3	54.3	52.1	50.1	49.7	51.1	8.31	0.16	0.46	8.86	0.16	0.46	9.28	0.18	0.45	8.9	0.16	0.46
12G	valpo univ	12-14	96x216	WB @ SR 49	55.7	55.6	57.1	69.7	62.6	60.1	8.63	0.17	0.46	8.9	0.16	0.46	8.74	0.17	0.46	8.9	0.16	0.46
										55.6	8.47	0.16	0.46	8.88	0.16	0.46	9.01	0.17	0.45	8.9	0.16	0.46
15G	port of Ind	14-16	120x228	EB @ SR 249	54.5	54.8	56.5	70.6	70.9	61.5	9.18	0.18	0.45	9.05	0.17	0.45	9.18	0.17	0.45	9.1	0.17	0.45
17G	chesterton, valpo 1 mi	14-16	120x228	EB SR 49	48.5	48.2	49.3	50.8	49.4	49.2	8.97	0.17	0.46	8.95	0.17	0.46	8.93	0.17	0.46	8.87	0.17	0.46
19G	mich city laporte	14-16	72x108	EB east of SR 49	48.5	50.7	51.3	48.6	48.2	49.5	8.59	0.17	0.46	8.97	0.17	0.46	9.06	0.17	0.46	8.72	0.17	0.46
										53.4	8.91	0.17	0.46	8.99	0.17	0.46	9.06	0.17	0.46	8.9	0.17	0.46
24G	motorist info	>16	96x156	WB before 900N	56.6	55.2	60.4	54.1	55.5	56.4	8.61	0.16	0.46	8.79	0.16	0.46	8.81	0.16	0.47	8.87	0.16	0.46
29G	michigan/next 2 interchanges	>16			62.1	66.5	64.1	60.9	57	62.1	8.41	0.16	0.46	8.51	0.16	0.46	8.74	0.16	0.46	8.57	0.16	0.46
30G	exit40 A-B SBend/Mich.city	>16			68.2	69.3	71	62.9	67	67.7	9.61	0.18	0.45	8.82	0.17	0.46	8.63	0.17	0.46	8.74	0.17	0.46
										62.1	8.88	0.17	0.46	8.71	0.16	0.46	8.73	0.16	0.46	8.73	0.17	0.46

Panel Sign Retroreflectance and Color Readings (white)

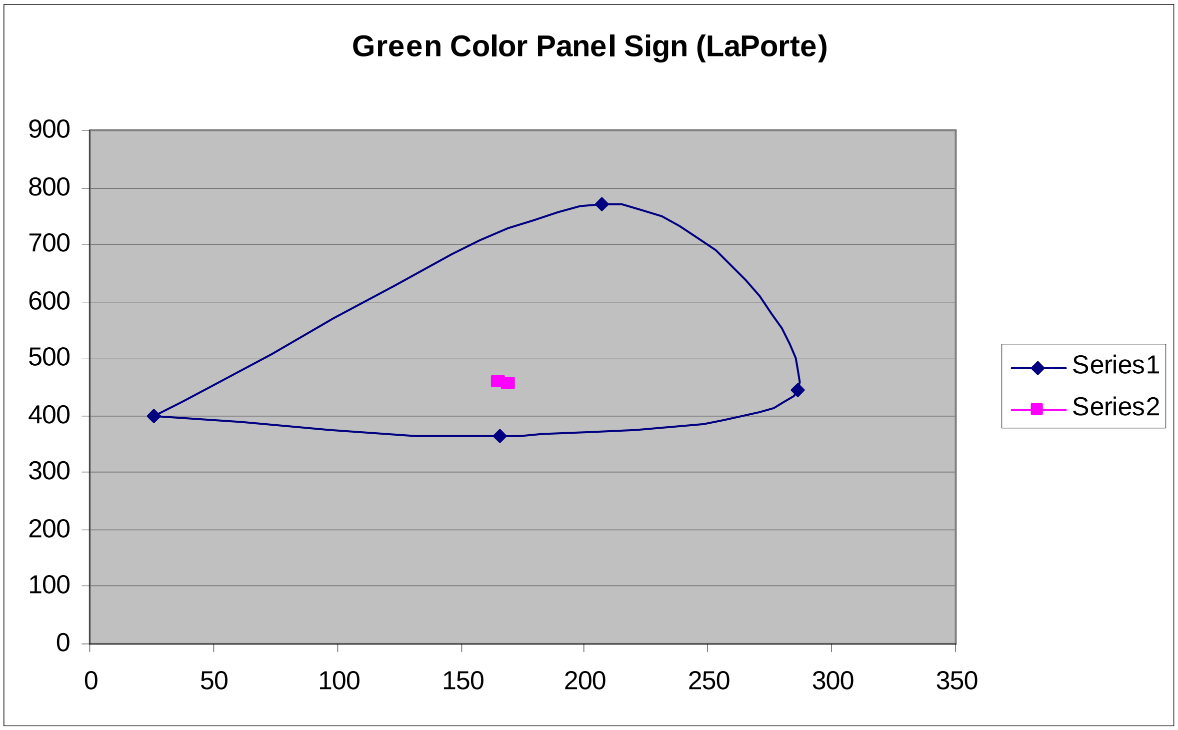
Sign No.	Sign Name	Sign Age (yrs)	Sign Size(in)	Location	Retroreflectivity (cd/m²/lux)					Aver	Color Reading											
											1			2			3			4		
					1	2	3	4	5		Y	X*	Y*	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
5G	**exit 14 a**	**10-12**	**72x108**	WB @ SR 51	309	297	252	303	307	**294**	33.8	0.31	0.33	33.2	0.31	0.33	33.2	0.31	0.33	33.5	0.31	0.34
7G	**exit 22A**	**10-12**	**96x216**	EB @ Burns Harbor	229	269	251	212	237	**240**	35.4	0.31	0.33	34.1	0.31	0.33	35.2	0.31	0.33	34.2	0.31	0.33
31G	**exit34A-B Mich.City/Westville 10-12 years**				336	231	340	331	336	**315**	32.9	0.31	0.33	35.4	0.31	0.33	35.4	0.31	0.33	33	0.31	0.33
										283	**34**	**0.31**	**0.33**	**34.3**	**0.31**	**0.33**	**34.6**	**0.31**	**0.33**	**33.6**	**0.31**	**0.33**
11G	**1mi chesterton valpo**	**12-14**	**120x228**	WB 1 mi from SR 49	291	327	289	223	307	**287**	35.4	0.31	0.33	32.9	0.31	0.33	33.5	0.31	0.34	35.4	0.31	0.33
12G	**valpo univ**	**12-14**	**96x216**	WB @ SR 49	328	332	366	374	372	**354**	34	0.31	0.33	35.4	0.31	0.33	33.7	0.31	0.33	35.4	0.31	0.33
										321	**34.7**	**0.31**	**0.33**	**34.2**	**0.31**	**0.33**	**33.6**	**0.31**	**0.33**	**35.4**	**0.31**	**0.33**
15G	**port of Ind**	**14-16**	**120x228**	EB @ SR 249	323	321	321	398	238	**320**	33.1	0.31	0.33	33	0.31	0.33	32.4	0.31	0.33	32.8	0.31	0.33
17G	**chesterton, valpo 1 mi**	**14-16**	**120x228**	EB SR 49	283	269	295	286	284	**283**	34.7	0.51	0.33	34	0.31	0.33	34.6	0.31	0.33	34.1	0.31	0.33
19G	**mich city laporte**	**14-16**	**72x108**	EB east of SR 49	303	263	273	298	277	**283**	34.3	0.31	0.33	34.9	0.31	0.33	34.7	0.31	0.33	34.3	0.31	0.33
										295	**34**	**0.38**	**0.33**	**34**	**0.31**	**0.33**	**33.9**	**0.31**	**0.33**	**33.7**	**0.31**	**0.33**
24G	**motorist info**	**>16**	**96x156**	WB before 900N	290	279	299	313	314	**299**	33.8	0.31	0.33	33.2	0.31	0.33	33.2	0.31	0.33	33.5	0.31	0.34
30G	**exit40 A-B SBend/Mich.city > 16**				323	324	318	320	297	**316**	33.5	0.31	0.33	33.7	0.31	0.33	34	0.31	0.33	33.7	0.31	0.33
										308	**33.7**	**0.31**	**0.33**	**33.5**	**0.31**	**0.33**	**33.6**	**0.31**	**0.33**	**33.6**	**0.31**	**0.33**

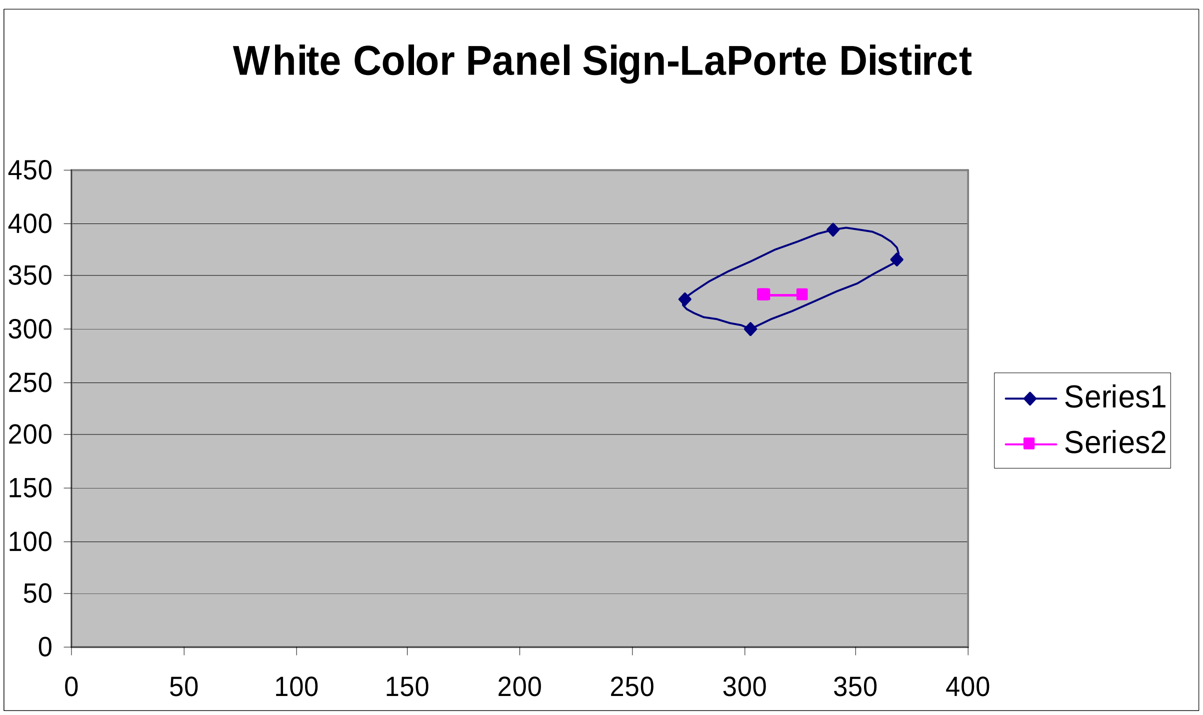


Retroreflectivity Reading-LaPorte District (cd/m2/lux)
Green
Retroreflectivity
70
60
50
40
30
20
10
0
10-12
12-14
14-16
>16
Sign Age (yrs)
Retroreflectivity (cd/m2/lux)



Retroreflectivity (cd/m2/lux) Reading-Laporte District
White
Retroreflectivity
330
320
310
300
290
280
270
260
10-12
12-14
14-16
>16
Sign Age (yrs)
Retroreflectivity (cd/m2/lux)


Green Color Panel Sign (LaPorte)
900
800
700
600
500
400
300
200
100
0
0
50
100
150
200
250
300
350
Series1
Series2


White Color Panel Sign-LaPorte Distirct
450
400
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
Series1
Series2

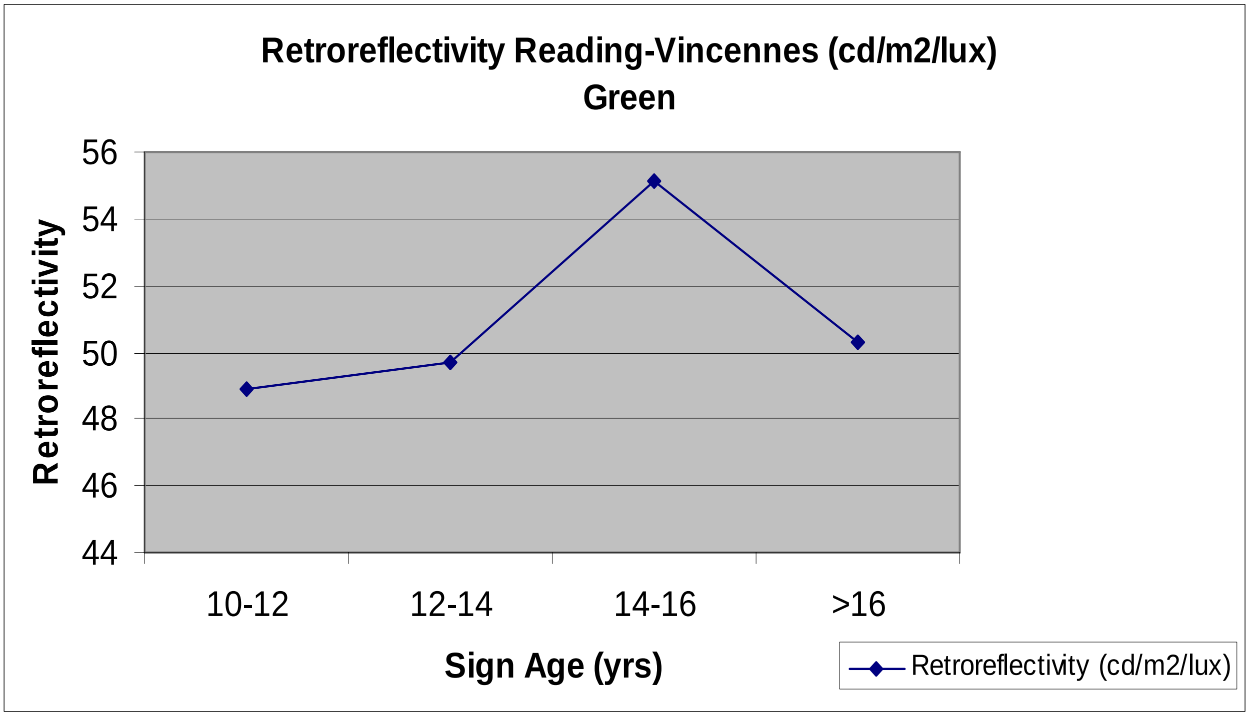
Panel Sign Retroreflectance and Color Readings-Green (Vincennes)

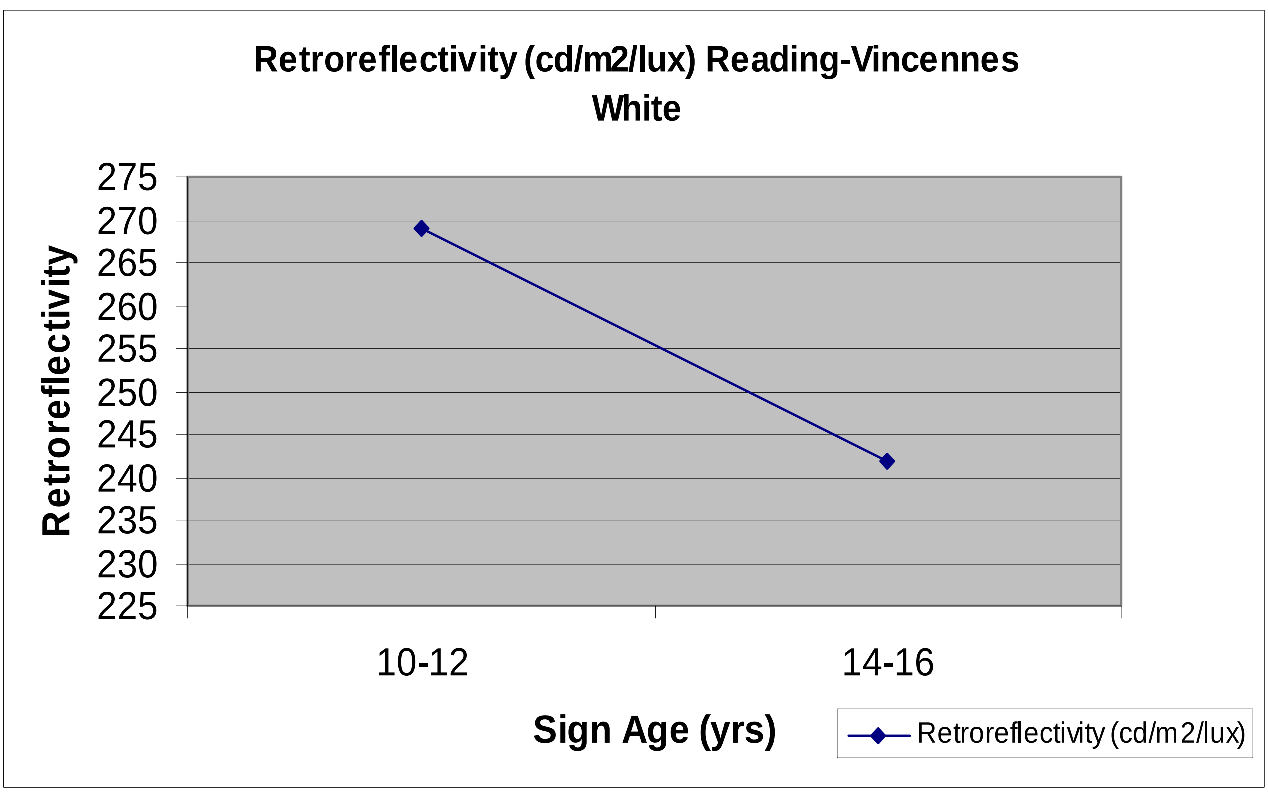
Sign No.	Sign Name	Sign Age (yrs)	Sign Size(in)	Location	Retroreflectivity (cd/m^2/lux)					Average
					1	2	3	4	5	
3 (green)	Washington 8 mi.	10-12	108 X 12	US 50 EB RP13.97 Knox	53.9	55.6	53.5	52.3	54.2	53.9
5 (green)	Maysville RD	10-12	132 X 36	US 50 EB RP 18.22 1988 Daviess	47.6	45.6	46.4	46.4	47.2	46.64
6 (green)	Maysville RD	10-12	132 X 36	US 50 WB RP 18.27 1988 Daviess	45.7	43.1	48.9	46.1	47	46.16
										48.9
9 (green)	Farmersburg	12-14	36 X 136	US 41 NB Sullivan CO 1996	54.6	57.9	50.9	51.7	48.3	52.68
10 (green)	Sullivan 12 / Vincennes 42	12-14	48 X 132	US 41 SB Vigo Co.1996	51	53.4	35.3	50.9	46.4	47.4
12 (green)	Hymera /Jasonville	12-14	48 X 156	US 41 S RP 93.7 Sullivan Co 1997	48.6	50.2	50.8	48.7	47.4	49.14
										49.74
15 (green)	Princeton 7 Vincennes 32	14-16	120 X 48	US 41N RP 23.47 Gibson Co 1994	51.5	53.6	56.4	59.1	55.1	55.14
										55.14
23 (green)	Exit 72 Bridseye /Bristow 1/2mi.	>16	168X144	I 64-EB Perry Co 1988 RP.71.46	57.5	59.8	53.7	50.3	52.4	54.74
27 (green)	Exit 72 Brideyes / Bristow 1.mi	>16	168X144	I-64 WB Perry Co 1988 RP.74.28	46.1	48.3	51.1	49.5	50.3	49.06
29 (green)	ST. Meinard Archabby Seminary		120 X144	I 64 WB Perry Co 1988 RP.73.41	51.3	46.9	44.1	40.4	52.2	46.98

>16

Panel Sign Retroreflectance and Color Readings-White

Sign No.	Sign Name	Sign Age (yrs)	Sign Size(in)	Location	Retroreflectivity (cd/m^2/lux)					Average
					1	2	3	4	5	
3 (white)	Washington 8 mi.	10-12	108 X 12	US 50 EB RP13.97 Knox	263	301	266	253	279	272.4
5 (white)	Maysville RD	10-12	132 X 36	US 50 EB RP 18.22 1988 Daviess	308	272	277	276	287	284
6 (white)	Maysville RD	10-12	132 X 36	US 50 WB RP 18.27 1988 Daviess	244	249	256	251	265	253
										269.8
9 (white)	Farmersburg	12-14	36 X 136	US 41 NB Sullivan CO 1996	268	264	269	259	274	266.8
10 (white)	Sullivan 12 / Vincennes 42	12-14	48 X 132	US 41 SB Vigo Co.1996	259	176	198	149	101	176.6
12 (white)	Hymera /Jasonville	12-14	48 X 156	US 41 S RP 93.7 Sullivan Co 1997	286	292	301	282	254	283
										242.13


Retroreflectivity Reading-Vincennes (cd/m2/lux)
Green
Retroreflectivity
56
54
52
50
48
46
44
10-12
12-14
14-16
>16
Sign Age (yrs)
Retroreflectivity (cd/m2/lux)


Retroreflectivity (cd/m2/lux) Reading-Vincennes
White
Retroreflectivity
275
270
265
260
255
250
245
240
235
230
225
10-12
14-16
Sign Age (yrs)
Retroreflectivity (cd/m2/lux)

Appendix D

FIELD INSPECTIONS

FOR

SHEET SIGN LIFE CYCLE

STUDY REPORT

(Oct 27, 2010)

By: Ting Nahrwold, P.E.
Evaluation Engineer

PURPOSE:

The purpose of this assignment is to aid in the determination of the sheet sign life cycle. The study will help INDOT to provide guidance on sign sheeting replacement for sheet signs

INTRODUCTION:

The major aim of this study is to obtain retroreflectivity and color measurements from ground mounted sheet signs at various colors, ages and locations to see if we can extend the current 14 year age replacement cycle.

A total of 211 sheet signs (white, red yellow, green) have been tested. 96 signs facing different directions from northern Indiana were selected by the districts, and 115 signs were selected from southern Indiana.

METHOD OF EVALUATION:

Starting August 2010, the INDOT Traffic Evaluation Section has been working on taking retroreflectivity and color measurements with a Sign retroreflectometer (ART Technology, model 930) and a Color spectrophotometer (HunterLab MiniScan XE- Plus 45/0) on the field.

Sign Selections:

- Sheet signs between 12-14 years or older were selected in north and south areas by the district maintenance staff.
- Districts helped identifying corridors where the signs at the older end of the spectrum (12 years or greater).
- Most of the signs in this study are Type III. However, there is a corridor (US 50 Vincennes District) with 10-11 year old Type IV sheeting signs. A sample of all 4 colors was tested.
- The sheet signs at various ages were inspected in Northern and Southern Indiana. (See the attached table)

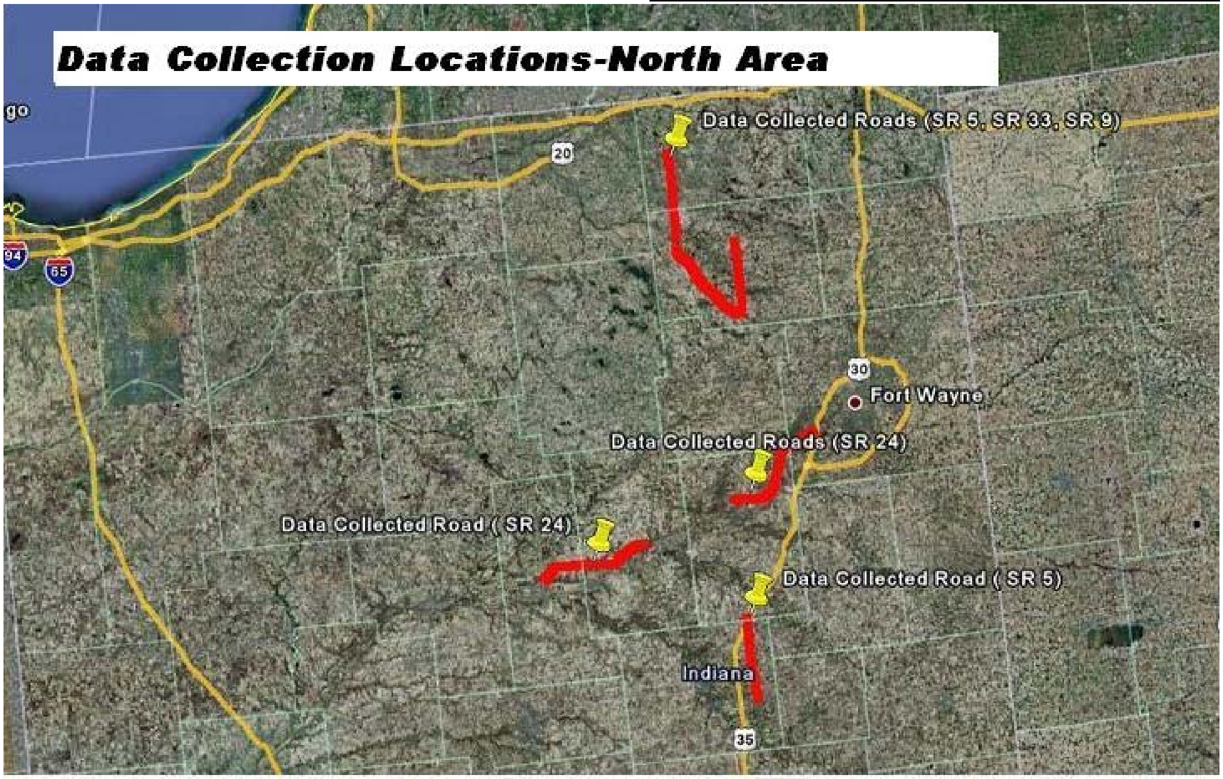
	Age (years)						
District	**10--12**	**13**	**14**	**15**	**16**	**>16**	**Total**
North Area	9	57	27			3	96
South Area	33	25	13	11	21	12	115
Total	42	82	40	11	21	15	211

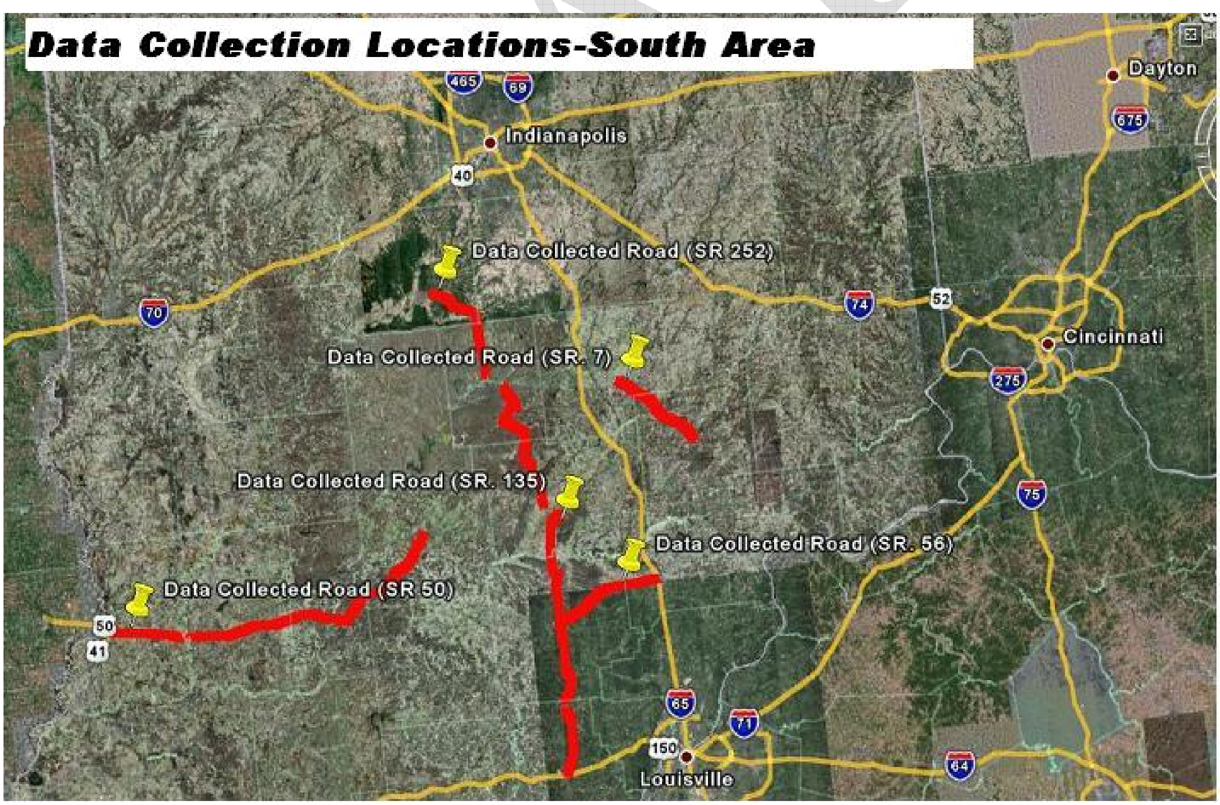
Background:

- Colors: white, green, yellow ,red (minimum 36 signs of each color, 18 from the north area, and 18 from the south area; minimum 6 signs facing north, 6 signs facing south and 6 signs facing either east or west)
- Readings- Northern Indiana and Southern Indiana. (Minimum 72 signs in each area).
- Directions- North facing and south facing. (Minimum 72 signs of each direction, so minimum 6 signs of each color facing same direction in each area.)

Data Collection:

- Wipe sign clean before taking the readings.
- Identify the sheeting type with the handheld microscope.
- The retro-reflection readings for sheet signs were taken at three different spots with an observation angle of 0.2° and entrance angle of -4° on each sign.
- The color coordinates and luminance factors were taken at three different spots on the sheet sign.
- Readings were compared with MUTCD minimums.
- The following State Roads were inspected in Northern and Southern Indiana:
    - US 24 East in the Fort Wayne District
    - US 24 West in the Fort Wayne District
    - SR 5 North in the Fort Wayne District
    - SR. 5 South in the Fort Wayne District
    - SR 9 in the Fort Wayne District
    - SR. 524 in the Fort Wayne District
    - US 33 in the Fort Wayne District
    - SR 135 in the Seymour District
    - SR. 56 in the Seymour District
    - US 50 in the Vincennes District
    - US 31 in the Seymour District
    - SR 252 in the Seymour District
    - SR 7 in the Seymour District
    - SR. 256 in the Seymour District


Data Collection Locations-North Area
Data Collected Roads (SR 5, SR 33, SR 9)
Fort Wayne
Data Collected Roads (SR 24)
Data Collected Road (SR 24)
Data Collected Road (SR 5)
Indiana


Data Collection Locations-South Area
Dayton
Indianapolis
Data Collected Road (SR 252)
Cincinnati
Data Collected Road (SR. 7)
Data Collected Road (SR. 135)
Data Collected Road (SR. 56)
Data Collected Road (SR 50)
Louisville


STOP
VIDED
HIGHWAY


STOP
DIVIDED
HIGHWAY


STOP
DIVIDED
HIGHWAY

FINDINGS:

After three weeks of field inspection, the data was collected and analyzed in the attached tables and charts.

Retroreflection:

All the average retroreflectivity readings in different colors are above the Federal Retroreflectivity Standards for the signs evaluated both in Northern and Southern Indiana.

All the inspected Type IV sheet signs installed in 2000 on US 50 were significantly higher than the FHWA minimums. (see the attached tables)

Federal Retroreflectivity Standards

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			Post-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 $cd/lx/m^2$ measured at an observation angle of 0.2° and an entrance angle of -4.0°.
[2] For text and fine symbol signs measuring at least 48 inches and for all sizes of bold symbol signs
[3] For text and fine symbol signs measuring less than 48 inches
[4] Minimum sign contrast ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity)
* This sheeting type shall not be used for this color for this application.

Two red signs and two yellow signs in the north area and nine white signs and five yellow signs were found to be below the federal minimums.

INDOT changed to all Hi-Intensity sheeting in the early 90's. However some of the districts had enormous stock of engineer grade sheeting at that time. So it is possible the low readings signs installed in mid 90's are still Type I engineer grade sheeting according to sign shop and district maintenance staff.

Color:

The color coordinates and luminance factors were taken at three different spots on each sheet sign. The chromaticity coordinates for all inspected green signs are still within the color specification limits. The majority of the inspected signs in white and yellow colors are within the color specification limits. Some of them are outside the limits. The inspected red signs, including the 10 year old type IV signs failed to meet the color requirements for the sheeting material according ASTM D4956-09. (See the attached charts).

Directions:

In general, the retroreflective readings for the signs facing east and west are slightly higher than the signs facing north and the retroreflective reading for the signs facing north are slightly higher than the signs facing south. No significant differences were found in the color readings for the signs that are facing different directions. (See the attached tables)

Signs Below Federal Retroreflectivity Standards					
	Green	Red	White	Yellow	Total
Total Inspected	45	49	58	59	211
Below Standards	0	2	2	7	11
%	0%	4%	3%	12%	5%

CONCLUSION

The majority of the inspected sheet signs were ASTM High Intensity Type III, some are Engineering and Super Engineering Grade ASTM Type I or Type IV prismatic sheeting. Since January 2008, the signs supplied by INDOT Logistic Support Center have been the type IV sheeting with an estimated life cycle of 16 years. There are 17 type IV sheet signs were inspected in the south area on US 50, they were installed in 2000 and the retroreflectivity readings for these signs were significantly higher than the Type III sheet signs and the FHWA minimums.

Based on the field inspection findings, we propose to establish the life cycle for sheet signs at 16 years. Since the Type IV prismatic sheeting has not been tested for the noted period of time, a follow up study will be performed in the next 4 and 6 years on sheet signs.

Attachments:

1. **Sheet Sign Retroreflectance and Color Readings (North Area)**
2. **Sheet Sign Retroreflectance and Color Readings (South Area)**
3. **Sheet Sign Retroreflectance Readings (Green Signs F-acing East&West)**
4. **Sheet Sign Retroreflectance Readings (Green Signs Facing North)**
5. **Sheet Sign Retroreflectance Readings (Green Signs Facing South)**
6. **Sheet Sign Retroreflectance Readings (Red Signs Facing East& West)**
7. **Sheet Sign Retroreflectance Readings (Red Signs Facing North)**
8. **Sheet Sign Retroreflectance Readings (Red Signs Facing South)**
9. **Sheet Sign Retroreflectance Readings (White Signs Facing East&West)**
10. **Sheet Sign Retroreflectance Readings (White Signs Facing North)**
11. **Sheet Sign Retroreflectance Readings (White Signs Facing South)**
12. **Sheet Sign Retroreflectance Readings (Yellow Signs Facing East&West)**
13. **Sheet Sign Retroreflectance Readings (Yellow Signs Facing North)**
14. **Sheet Sign Retroreflectance Readings (Yellow Signs Facing South)**
15. **Sign Retroreflectivity and Color Charts**

Sheet Sign Retroreflectance and Color Readings (North Area)

Sign No.	Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity ($cd/m^2/lux$)			Color Reading								
										1			2			3		
							1	2	3	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
1	Stop	13	III	R	S	U.S. 24E (from us 31 to SR 13)	24.8	28.4	27.7	4.72	0.5847	0.322	5.02	0.5729	0.3226	4.77	0.5734	0.3202
2	Divided Hwy	13	III	W	S	U.S. 24E (from us 31 to SR 13)	240	267	258	37.42	0.3067	0.3286	37.58	0.3665	0.3283	31.23	0.3065	0.3283
3	E	13	III	W	W	U.S. 24E (from us 31 to SR 13)	286	279	284	35.18	0.3089	0.3309	34.82	0.3088	0.3309	35.49	0.3081	0.3304
4	U.S. 24	13	III	W	W	U.S. 24E (from us 31 to SR 13)	267	277	272	35.24	0.308	0.3303	34.69	0.3092	0.3312	34.01	0.309	0.3309
5	S.L. 60MPH	13	III	W	W	U.S. 24E (from us 31 to SR 13)	280	283	277	35.51	0.3689	0.3311	35.88	0.3085	0.3307	36.05	0.3079	0.3382
6	JCT 19	13	III	W	W	U.S. 24E (from us 31 to SR 13)	358	346	335	35.02	0.3688	0.3304	36.34	0.3085	0.3303	35.56	0.308	0.3298
7	S 19	14	III	W	N	U.S. 24E (from us 31 to SR 13)	308	309	399	53.51	0.3081	0.3317	35.15	0.3021	0.332	34.06	0.3093	0.3321
8	E 24	14	III	W	S	U.S. 24E (from us 31 to SR 13)	399	309	311	34.56	0.3082	0.3301	34.85	0.3079	0.3303	30.5	0.3086	0.3309
9	STOP	13	III	R	S	U.S. 24E (from us 31 to SR 13)	30.8	29.3	28.7	5.04	0.5779	0.3225	5.14	0.5727	0.3219	5.12	0.5676	0.3216
10	Divided Hwy	13	III	W	S	U.S. 24E (from us 31 to SR 13)	293	288	289	36.53	0.3878	0.3298	37.19	0.3075	0.3296	57.07	0.3076	0.3297
11	Wabash 13	13	III	G	W	U.S. 24E (from us 31 to SR 13)	45.9	46.1	41.7	9.19	0.1689	0.4569	9.45	0.1683	0.9587	9.91	0.1689	0.4581
12	STOP	13	III	R	S	U.S. 24E (from us 31 to SR 13)	16.5	24.7	18.3	5.47	0.5703	0.3514	4.89	0.5694	0.3912	4.64	0.5572	0.317
13	Divided Hwy	13	III	W	S	U.S. 24E (from us 31 to SR 13)	286	290	284	37.05	0.307	32.89	37.45	0.3067	0.3285	36.6	0.3079	0.3296
14	STOP	13	III	R	N	U.S. 24W (from us 31 to SR 13)	28.2	19.2	34.1	4.6	0.5741	0.3188	4.55	0.5761	0.319	4.64	0.5734	0.3185
15	Divided Hwy	13	III	W	N	U.S. 24W (from us 31 to SR 13)	301	382	294	35.84	0.3079	0.3302	35.86	0.3074	0.3297	36.02	0.3079	0.3303
16	STOP	13	III	R	S	U.S. 24W (from us 31 to SR 13)	27.9	27.4	26.3	5.21	0.5671	0.3215	4.79	0.5699	0.32	5.08	0.5666	0.3206
17	Divided Hwy	13	III	W	S	U.S. 24W (from us 31 to SR 13)	276	286	288	37.18	0.3678	0.3298	36.77	0.3878	0.3295	36.66	0.3875	0.3296
18	Yield	13	III	R	S	U.S. 24W (from us 31 to SR 13)	45	37.2	35.1	6.9	0.5444	0.3331	6.68	0.5486	0.3317	6.59	0.5485	0.3323
19	Do Not Enter	13	III	R	W	U.S. 24W (from us 31 to SR 13)	34.5	31.9	34.9	6.59	0.5485	0.3323	5.59	0.5579	0.3262	5.45	0.5629	0.3263

Sign No.	Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m²/lux)			Color Reading								
										1			2			3		
							1	2	3	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
20	Yield	13	III	R	E	SR 524 (from us 24 to state park)	49.6	47.6	51.7	5.49	0.5665	0.3254	5.88	0.5619	0.3262	5.45	0.5671	0.3271
21	Do Not Enter	13	III	R	W	SR 524 (from us 24 to state park)	43.6	40.9	43.5	4.7	0.5754	0.3239	4.49	0.5748	0.3212	4.82	0.5746	0.3231
22	Stop	13	III	R	N	US 24E (SR9 to I 69)	25.1	23.6	25.9	4.37	0.5673	0.3185	4.46	0.5701	0.3188	4.54	0.5734	0.3187
23	Divided Hwy	13	III	W	N	US 24E (SR9 to I 69)	277	277	285	35.84	0.3084	0.3365	35.91	0.308	0.338	35.16	0.3883	0.3303
24	To Lognsport	13	III	G	E	US 24W (I69 TO SR9)	47.5	49.9	49	9.24	0.169	0.4529	9.11	0.1685	0.4598	8.88	0.1657	0.4637
25	SR 5 N	13	III	W	S	US 24W (I69 TO SR9)	349	350	342	34.78	0.3681	0.3302	34.59	0.3086	0.3307	34.38	0.309	0.331
26	US.24 E	13	III	W	S	US 24W (I69 TO SR9)	332	343	350	35.36	0.3085	0.3387	34.88	0.3884	0.3305	34.33	0.3084	0.3305
27	SR.9N	13	III	W	S	US 24W (I69 TO SR9)	342	333	352	34.19	0.3088	0.3388	34.19	0.3081	0.3305	34.77	0.3882	0.3301
28	Do Not Enter	17	III	R	W	US 24W (I69 TO SR9)	79.9	77.4	69.9	9.08	0.5747	0.3489	10.28	0.5123	0.5498	9.22	0.5189	0.3495
29	SR224 E	13	III	W	E	US 24W (I69 TO SR9)	329	322	336	35.13	0.3075	0.3301	34.02	0.3074	0.3298	34.54	0.3071	0.3298
30	SR 5 S	13	III	W	E	US 24W (I69 TO SR9)	362	362	374	34.71	0.3075	0.33	34.95	0.3654	0.3293	34.44	0.3071	0.3799
31	Bussiness Dist	13	III	G	E	US 24W (I69 TO SR9)	77	72.3	70.1	8.63	0.1648	0.4749	8.58	0.1648	0.4763	9.22	0.1677	0.4695
32	Yield	13	III	R	E	US 24W (I69 TO SR9)	25.2	26.1	24.7	4.3	0.5678	0.3179	4.41	0.5704	0.3186	4.46	0.5746	0.3209
33	Nat.Guard.Army	13	III	G	E	US 24W (I69 TO SR9)	55.9	53.6	58.7	8.86	0.1668	0.459	8.591	0.1654	0.4604	8.61	0.1649	0.4661
34	Huntington	13	III	G	E	US 24W (I69 TO SR9)	62	61.1	68.9	8.89	0.1669	0.4578	7.04	0.1667	0.4599	9.17	0.1671	0.4579
35	JCT 16	13	III	W	S	SR.5.N	319	320	323	32.62	0.3091	0.3316	33.51	0.3085	0.3317	32.31	0.3091	0.3315
36	Stop Ahead	14	III	Y	S	SR 5 S	201	203	198	19.98	0.5233	0.4471	20.1	0.5223	0.4462	20.99	0.522	0.4481
37	Stop Ahead	14	III	Y	S	SR 5 S	148	159	149	20.92	0.5138	0.4475	20.58	0.5162	0.4472	20.48	0.5156	0.4489
38	No Passing	14	III	Y	S	SR 5 S	156	125	152	20.71	0.5147	0.4456	21.18	0.5155	0.4466	21.09	0.5145	0.4461
39	No Passing	14	III	Y	N	SR 5 S	208	201	205	18.59	0.5325	0.4427	18.55	0.5321	0.4432	18.52	0.5307	0.4427
40	Curve 45 MPH	14	III	Y	N	SR 5 S	182	176	164	19.32	0.5283	0.4442	18.36	0.5214	0.4446	18.24	0.5197	0.4444
41	Curve	13	III	Y	N	SR 5 S	190	199	172	31.57	0.3628	0.3732	31.29	0.3767	0.3838	31.26	0.3675	0.3769
42	45 MPH	13	III	Y	N	SR 5 S	130	152	157	20.58	0.5131	0.4503	50.52	0.5164	0.4489	20.8	0.5149	0.4446
43	No Passing	13	III	Y	N	SR 5 S	194	189	197	19.92	0.5227	0.4465	19.72	0.5232	0.4476	19.5	0.5233	0.4475
44	STOP	14	III	R	N	SR 5 N	42.6	40.9	30.3	4.76	0.526	0.324	4.48	0.5395	0.3253	4.64	0.5246	0.3212
45	STOP	14	III	R	N	SR 5 N	24	25.6	27.8	4.44	0.566	0.3194	4.1	0.5829	0.3197	4.51	0.5717	0.3206
46	Taylor W	14	III	G	N	SR 5 N	53.1	55.8	56.7	9.99	0.1714	0.4549	9.33	0.1682	0.956	9.43	0.1703	0.4545

							Retroreflectivity (cd/m^2/lux)			Color Reading								
										1			2			3		
Sign No.	Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	1	2	3	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
47	Gas City	14	III	G	N	SR 5 N	55.8	58.6	58.6	9.22	0.1663	0.4587	9.21	0.1696	0.4555	9.07	0.1691	0.4614
48	No Passing	12	III	Y	E	SR 22 E	20.5	21.4	22.1	19.98	0.5147	0.4549	19.97	0.5956	0.4554	19.68	0.517	0.4523
49	Stop Ahead	13	III	Y	N	SR 5 N	197	199	195	18.84	0.5206	0.4447	19.21	0.523	0.4442	18.62	0.5237	0.4449
50	Stop Ahead	13	III	Y	N	SR 5 N	209	199	194	19.7	0.5222	0.4448	19.45	0.5237	0.4437	19.11	0.5264	0.4454
51	No Passing	14	III	Y	N	SR 5 N	181	195	203	19.65	0.5268	0.4419	19.14	0.5269	0.4425	18.97	0.5246	0.4442
52	No Passing	14	III	Y	S	SR 5 N	147	96	82	20.69	0.5184	0.4474	20.57	0.5185	0.4484	20.66	0.5185	0.4507
53	STOP	14	III	R	E	SR 5 N	31.7	26.4	24.3	5.68	0.5621	0.3243	5.87	0.8844	0.3247	5.38	0.574	0.3234
54	STOP	14	III	R	E	SR 5 N	27.9	25.1	25.1	4.83	0.5678	0.3221	4.88	0.5709	0.3219	4.74	0.5748	0.3234
55	SR.5	14	III	W	S	SR 5 N	291	293	285	33.94	0.3079	0.3306	33.3	0.3081	0.3307	34.12	0.3073	0.3299
56	No Passing	14	III	Y	S	SR 5 N	195	164	165	20.67	0.5109	0.4571	20.82	0.5102	0.4595	20.45	0.5107	0.4559
57	No Passing	14	III	Y	S	SR 5 N	216	201	263	19.92	0.5121	0.4567	20.25	0.5102	0.4567	20.16	0.5103	0.4578
58	SL 55MPH	12	III	W	N	SR 5 N	285	284	275	35.43	0.3074	0.3301	35.78	0.3071	0.33	35.28	0.302	0.3296
59	SR 5	14	III	W	N	SR 5 N	222	225	234	35.78	0.3072	0.33	35.82	0.3075	0.3502	35.05	0.3069	0.3297
60	VAN	14	III	G	S	SR 5 N	59.7	60.1	60.8	9.55	0.1752	0.4482	9.52	0.1734	0.4501	9.37	0.1745	0.4507
61	VAN	12	III	G	N	SR 5 N	37.6	64.1	48.6	8.79	0.1707	0.455	8.89	0.1714	0.4525	8.93	0.1737	0.4537
62	Light Ahead	13	III	Y	E	US 24W	231	240	231	18.97	0.5199	0.9536	19.26	0.5193	0.4552	19.34	0.5191	0.4552
63	Light Ahead	13	III	Y	E	US 24W	213	212	218	18.87	0.5217	0.4541	18.33	0.5233	0.4509	18.9	0.5213	0.4516
64	State Police Post	13	III	G	E	US 24W	57.9	57.3	56.2	9.38	0.1674	0.4549	9.07	0.1679	0.4507	9.23	0.1682	0.4534
65	Light Ahead	13	III	Y	W	US 24E	226	225	200	20.68	0.512	0.4565	19.82	0.5146	0.4555	20.35	0.5134	0.4573
66	RT LANE ENDS	18	III	Y	S	US 24W	28.9	28.7	13.8	21.22	0.513	0.4499	21.95	0.5106	0.4469	22.42	0.5073	0.4469
67	Roanke 10	13	III	G	E	US 24W	68.9	68.8	69.6	8.87	0.7684	0.4535	8.91	0.169	0.4529	9.08	0.1688	0.4514
68	ST.POLICE POST	13	III	G	W	US 24E	70.8	68.1	75.9	8.95	0.066	0.4534	8.84	0.1655	0.456	8.81	0.163	0.4562
69	STOP	13	III	R	N	US 24	42.7	41	40.9	4.4	0.5803	0.3186	4.42	0.5786	0.377	4.34	0.5838	0.3185
70	Divided Hwy	13	III	W	N	US 24	270	272	270	35.06	0.3088	0.3315	34.34	0.3088	0.3313	34.56	0.3085	0.3312
71	STOP	13	III	R	S	US 24	30.1	31.8	28.4	4.42	0.5679	0.316	5.09	0.545	0.3668	4.85	0.5542	0.3155
72	Divided Hwy	13	III	W	S	US 24	281	287	288	35.88	0.3075	0.3296	35.38	0.3074	0.3297	35.1	0.3077	0.33

Sign No.	Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m^2/lux)			Color Reading								
										1			2			3		
							1	2	3	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
73	Light Ahead	13	III	Y	W	US 24 E	209	211	210	19.34	0.5175	0.4504	19.35	0.5196	0.4514	19.14	0.52	0.4572
74	STOP	12	III	R	N	SR.9	11.4	12.5	11.6	3.78	0.5492	0.3176	3.63	0.5469	0.3175	3.61	0.546	0.3172
75	STOP	12	III	R	N	SR.9	3.2	3.8	3.2	5.26	0.4878	0.3271	4.73	0.5032	0.3265	4.87	0.5041	0.326
76	STOP	13	III	R	S	SR.9	2.1	2.2	2	5.36	0.4988	0.3218	5.16	0.5023	0.3218	5.26	0.5058	0.3228
77	Curve	13	III	Y	S	SR. 524	186	184	183	19.12	0.5308	0.4439	18.9	0.5197	0.4432	19.16	0.5304	0.449
78	Curve	17	III	Y	N	SR. 524	199	203	205	20.69	0.5268	0.4507	20.78	0.5232	0.4449	20.22	0.5263	0.4479
79	Wabash 6	13	III	G	S	SR. 524	50.4	52.6	50.7	8.68	0.1772	0.4574	8.8	0.1713	0.4464	8.71	0.172	0.4575
80	Lagro	13	III	G	N	SR. 524	57.6	57.8	59.7	9.29	0.1689	0.4567	9.35	0.17	0.4566	9.36	0.1701	0.4563
81	S.L. 45MPH	13	III	W	N	SR. 524	60.9	60.8	65.9	47.25	0.5178	0.3408	47.68	0.3173	0.3404	47.86	0.3177	0.3408
82	No Passing	14	III	Y	S	SR. 524	181	134	133	19.74	0.5259	0.4445	79.89	0.523	0.4441	19.88	0.5238	0.4445
83	45 MPH	14	III	Y	E	US 24 W	184	181	162	18.71	0.5229	0.4478	18.97	0.5233	0.449	19.37	0.5236	0.4478
84	45 MPH	14	III	Y	E	US 24 W	182	193	192	19.06	0.5215	0.4498	18.81	0.5222	0.4505	19.85	0.5224	0.4499
85	Heartland	13	III	G	E	US 24 W	56.9	57.4	55.2	9.12	0.166	0.4592	9.24	0.1671	0.4578	9.91	0.1712	0.4567
86	Huntington	13	III	G	W	US 24 E	551	54.7	55.2	9.07	0.1626	0.4651	9.13	0.1626	0.4643	9.1	0.1633	0.4639
87	Heartland	13	III	G	W	US 24 E	56.4	55.6	55.9	9.22	0.1668	0.459	9.25	0.1671	0.4568	9.33	0.1675	0.4584
88	Ligonier 16	12	III	G	S	US 33 N	40.2	39.9	39.4	8	0.194	0.4467	8.13	0.1924	0.4467	8.1	0.1937	0.4469
89	Albion	12	III	G	N	US 33 N	54.9	53.7	54	8.9	0.1699	0.4598	8.49	0.1688	0.4557	8.51	0.1686	0.4586
90	Burr Oak	12	III	G	N	US 33 N	54.2	52.2	50.7	9.13	0.1697	0.4574	9.47	0.17	0.4557	9.4	0.1699	0.4551
91	Knapp	14	III	G	S	US 33 N	41.9	39.9	39.4	8.45	0.1949	0.4458	8.33	0.1962	0.4429	8.64	0.1972	0.4415
92	Wolflake	14	III	G	N	US 33 N	66.5	64.5	56.4	9.03	0.1689	0.4436	9.08	0.1698	0.4533	9.34	0.1714	0.4515
93	Knapp Lake	14	III	G	N	US 33 N	52	52.3	50.6	8.97	0.1697	0.4556	9.1	0.1728	0.452	8.73	0.1686	0.4584
94	Ligonier	13	III	G	S	US 33 N	57.5	38.2	38	8.67	0.1994	0.4384	8.66	0.1966	0.4436	8.78	0.1996	0.4391
95	Ligonier	14	III	G	S	US 33 N	51.5	48.4	50.6	9.25	0.1776	0.4496	8.94	0.1764	0.4407	8.92	0.176	0.453
96	Lagrance Co	12	III	G	S	SR. 5	57.4	60.8	62.3	8.95	0.164	0.4631	9.59	0.1682	0.4561	9.36	0.168	0.4596

Sheet Sign Retroreflectance and Color Readings (South Area)

Sign No.	Sign Name	Sign Age (yrs)	Type (I, II, III)	Color	Direction (Facing)	Location	Retroreflectivity ($cd/m^2/lux$)			Color Reading								
										1			2			3		
							1	2	3	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
1	Curve	16	III	Y	S	SR 135 S.	171	179	180	18.84	0.5263	0.4453	18.13	0.5277	0.4447	18.69	0.5266	0.445
2	Curve	16	III	Y	N	SR 135 S.	197	182	202	13.14	0.5251	0.4481	17.9	0.52	0.4409	17.94	0.5219	0.4414
3	Camp	16	III	G	N	SR 135 S.	46.6	59.1	55.2	9.16	0.1804	0.4455	8.92	0.7691	0.4511	9.17	0.1711	0.4476
4	Curve	16	III	Y	S	SR 135 S.	201	198	166	17.92	0.5264	0.4479	18.2	0.5261	0.4471	18.62	0.5261	0.4457
5	Curve	16	III	Y	N	SR 135 S.	209	178	146	19.09	0.5163	0.4433	19.97	0.516	0.4471	18.62	0.5261	0.4457
6	Curve	16	III	Y	S	SR 135 S.	59	69	74	22.23	0.4882	0.4308	22.65	0.4901	0.4324	21.22	0.4858	0.4296
7	Curve	16	III	Y	N	SR 135 S.	117	124	141	20.06	0.9928	0.4283	79.74	0.4961	0.4288	20.33	0.4978	0.4299
8	Truck	16	III	Y	N	SR 135 S.	183	169	173	15.97	0.5268	0.4474	15.75	0.5304	0.4485	15.83	0.5223	0.4473
9	135	19	III	W	S	SR 135 S.	244	250	239	35.88	0.3662	32.86	36.45	0.3073	0.3201	35.97	0.3073	0.3302
10	Curve	16	III	Y	N	SR 135 S.	177	194	176	18.52	0.5737	0.4384	17.4	0.5228	0.4431	17.56	0.5279	0.4458
11	Curve	12	III	Y	S	SR 135 S.	210	221	199	18.78	0.5251	0.4448	18.47	0.5242	0.4438	18.58	0.5246	0.4433
12	35 MPH	12	III	Y	S	SR 135 S.	205	197	282	20.72	0.5183	0.4535	20.3	0.5172	0.4531	20.56	0.5182	0.4539
13	Curve	16	III	Y	S	SR 135 S.	113	76	66	20.02	0.5187	0.443	20.48	0.5227	0.4452	18.58	0.5233	0.4447
14	Arrow	14	III	Y	W	SR 135 S.	93	79	84	20.53	0.5773	0.4446	21.36	0.5774	0.444	20.44	0.5163	0.4437
15	Curve	16	III	Y	N	SR 135 S.	158	157	167	18.83	0.522	0.4473	18.24	0.5222	0.4477	18.07	0.5198	0.4472
16	Bike	16	III	Y	N	SR 135 S.	190	187	177	18.9	0.5258	0.4428	18.82	0.5253	0.4438	18.68	0.5235	0.4415
17	Stop Ahead	16	III	Y	S	SR 135 S.	231	222	217	18.47	0.5327	0.4437	18.21	0.5395	0.4447	18.04	0.5259	0.4407
18	135	16	III	W	S	SR 135 S.	243	248	231	36.97	0.3076	0.3305	36.45	0.3077	0.3306	36.96	0.3274	0.3303
19	Jct 58	12	III	W	N	SR 135 S.	292	281	273	36.07	0.308	0.3367	35.82	0.3091	0.3318	36.53	0.3086	0.3313
20	School Bus	16	III	Y	S	SR 135 S.	1.1	0.3	0.5	24.04	0.5021	0.444	24.18	0.5016	0.4415	23.13	0.5014	0.4447
21	Stop	13	III	R	E	SR 135 S.	29.8	28.8	31.3	4.45	0.5833	0.3219	4.62	0.5765	0.3127	4.5	0.5823	0.3231
22	No Passing	17	III	Y	N	SR 135 S.	94	122	69	20.09	0.5193	0.4489	20.73	0.5172	0.4482	20.55	0.5158	0.4488
23	Hickory Hills	13	III	G	S	SR 135 S.	56.7	56.8	55.7	9.06	0.1711	0.4542	9.23	0.1713	0.4536	9.69	0.1827	0.4467
24	School Bus	14	III	Y	N	SR 135 S.	128	121	147	20.68	0.5216	0.4466	20.77	0.5216	0.4463	20.9	0.5213	0.445
25	School Bus	14	III	Y	S	SR 135 S.	0.9	0.7	1.6	22.28	0.5028	0.4444	33.09	0.5003	0.4382	21.83	0.5034	0.4445
26	Stop	12	III	R	E	SR 135 S.	29.3	29.4	38.2	4.24	0.556	0.317	4.3	0.5614	0.3168	4.15	0.5699	0.3168
27	Stop	12	III	R	E	SR 135 S.	69.3	68.5	70.8	5.67	0.5634	0.3274	5.77	0.5642	0.3213	5.64	0.5628	0.3282

Sign No.	Sign Name	Sign Age (yrs)	Type (I, II, III)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m^2/lux)			Color Reading								
										1			2			3		
							1	2	3	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
28	30 MPH	18	I	W	W	SR 56 E	8	10	17	39.81	0.3194	0.3421	37.34	0.3192	0.342	40.1	0.3197	0.3426
29	Stop	14	III	R	S	SR 56 E	19.4	27.5	28.9	4.04	0.5709	0.3169	4.77	0.5728	0.3218	4.9	0.5732	0.3216
30	One Way	15	I	W	W	SR 56 E	2.9	3.2	4.4	38.22	0.3199	0.3424	38.34	0.3197	0.3425	36.48	0.3199	0.3426
31	One Way	15	I	W	E	SR 56 E	6.5	6	6.6	42.39	0.3184	0.3425	42.4	0.3187	0.3433	41.31	0.319	0.3431
32	One Way	15	I	W	W	SR 56 E	2	4	0.5	36.17	0.3222	0.3492	32.27	0.3256	0.347	34.41	0.323	0.3449
33	One Way	15	I	W	E	SR 56 E	2.3	1.2	2.2	40.4	0.3198	0.343	0.381	0.3207	0.3438	40.31	0.3197	0.3429
34	Stop	16	III	R	S	SR 56 E	31	30.3	284	4.57	0.5739	0.3206	4.54	0.255	0.2577	4.51	0.5734	0.3202
35	Stop	12	III	R	N	SR 56 E	45.46	52.17	57.1	5.39	0.5548	0.324	5.27	0.5555	0.3221	4.92	0.571	0.3235
36	35 MPH	13	III	W	E	SR 56 E	294	291	297	34.39	0.3098	0.3327	34.89	0.3096	0.3324	32.27	0.3077	0.3304
37	Center Lane	13	III	W	E	SR 56 E	286	278	272	33.92	0.3108	0.3341	35.18	0.3096	0.333	35.31	0.31	0.3335
38	45 MPH	13	III	W	E	SR 56 E	296	288	295	32.67	0.3115	0.3347	33.37	0.3116	0.3335	33.38	0.5104	0.333
39	Center Lane	13	III	W	W	SR 56 E	262	261	275	36.35	0.3083	0.3315	36.81	0.308	0.5512	36.52	0.3086	0.3381
40	35 MPH	13	III	W	W	SR 56 E	271	288	296	54.01	0.3096	0.3329	34.33	0.3102	0.3329	33.31	0.3111	0.3337
41	45 MPH	15	I	W	W	SR 56 E	24	34	27	42.76	0.3182	0.3412	43.22	0.3209	0.3437	42.36	0.3181	0.3408
42	45 MPH	13	III	W	E	SR 56 E	4.2	4.3	4.5	45.57	0.3183	0.3417	43.7	0.3186	0.341	44.45	0.3182	0.3409
43	No Passing	13	III	Y	W	SR 56 E	268	284	277	20.1	0.5068	0.4597	20.21	0.5091	0.4605	20.16	0.508	0.4617
44	Truck Ent.	16	III	Y	W	SR 56 E	1.1	7.5	2.7	21.58	0.507	0.4452	20.67	0.5098	0.4461	19.23	0.508	0.4415
45	Curve	13	III	Y	E	SR 56 E	197	224	170	19.14	0.5098	0.4552	19.24	0.5095	0.355	19.54	0.5087	0.4552
46	Stop	18	III	R	S	SR 56	28.1	25.9	26.1	4.99	0.5578	0.3212	0.5701	0.5561	0.3211	4.91	0.5591	0.3207
47	56	18	III	W	E	SR 56	280	266	298	32.9	0.3122	0.335	34.26	0.3116	0.3344	32.85	0.3111	0.3346
48	No Passing	15	III	Y	E	SR 56	9	72	76	22.17	0.5078	0.4449	21.08	0.5122	0.4467	20.59	0.5122	0.4443
50	Stop	10	III	R	S	US 50	522.2	54.2	57.5	6	0.5616	0.3269	5.81	0.5636	0.3271	6.06	0.5582	0.3269
51	Stop	10	III	R	N	US 50	48.2	51.2	57.7	5.45	0.5706	0.3738	5.69	0.5671	0.325	5.31	0.5799	0.3244
52	Light Ahead	10	III	Y	E	US 50	209	198	216	19.21	0.5228	0.4515	19.38	0.5217	0.4512	18.33	0.5132	0.4447
53	School Xing	10	III	Y	W	US 50	132	187	198	22.91	0.5095	0.4461	20.45	0.5158	0.4538	19.81	0.5174	0.3536
54	35 MPH	10	III	W	W	US 50	274	266	273	35.43	0.3116	0.3341	36.46	0.3105	0.333	35.57	0.3111	0.3337
55	35 MPH	10	III	W	E	US 50	290	281	292	35.12	0.3112	0.3339	35.67	0.3111	0.3339	35.45	0.3103	0.333
59	Jct 256	16	III	W	S	US 31	289	303	291	37.1	0.3085	0.3312	36.63	0.3032	0.3384	36.99	0.3086	0.3312
60	Clark Forest	13	III	G	N	US 31	66	64.8	67.1	9.83	0.1734	0.4506	10.07	0.1747	0.4491	9.65	0.172	0.454
61	Stop	14	III	R	W	US 31	32.7	32	29.9	4.03	0.5801	0.3161	4.18	0.578	0.3175	4.13	0.5834	0.3188

Sign No.	Sign Name	Sign Age (yrs)	Type (I, II, III)	Color	Direction (Facing)	Location	Retroreflectivity ($cd/m^2/lux$)			Color Reading								
										1			2			3		
							1	2	3	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
62	Curve	14	III	Y	N	US 31	204	165	206	18.86	0.5273	0.4452	18.77	0.527	0.4438	18.58	0.5265	0.4457
63	Jct 356	15	III	W	S	US 31	272	367	274	38.09	0.307	0.3294	38.99	0.3072	0.3296	37.91	0.3071	0.3295
64	E 356	15	III	W	S	US 31	281	272	274	37.91	0.3071	0.3295	38.69	0.3071	0.3295	37.02	0.3079	0.3303
65	Vienna	17	III	G	S	US 31	63.7	61.4	65.1	9.3	0.1682	0.4594	9.28	0.1684	0.4595	9.22	0.1693	0.46
66	55 MPH	14	III	W	N	US 31	49	45	49	47.99	0.3195	0.3436	47.23	0.3193	0.3433	46.72	0.3191	0.3431
67	Stop	13	III	R	W	US 31	18.9	17.9	19	3.78	0.555	0.3145	3.54	0.5661	0.3121	3.87	0.5974	0.3149
68	Stop	14	III	R	W	US 31	32.5	32.6	33.3	5.5	0.5684	0.3244	5.36	0.5717	0.3242	5.02	0.5695	0.3213
69	Stop	14	III	R	W	US 31	35.8	35.2	39.2	4.41	0.5673	0.3186	4.22	0.5763	0.3197	4.2	0.5777	0.3184
70	Stop	18	III	R	E	US 31	79.8	78.2	75.4	5.17	0.5697	0.3224	5.03	0.5767	0.3211	5.18	0.5708	0.3299
71	School Bus	13	III	Y	W	SR 252	141	100	134	20.42	0.5132	0.4465	19.74	0.5141	0.4469	19.65	0.518	0.4504
72	Stop	13	III	R	N	SR 252	242	268	275	3.53	0.557	0.3138	3.78	0.5673	0.3158	3.76	0.5639	0.3142
73	Light Ahead	13	III	Y	E	SR 252	89	119	101	20.76	0.9905	0.4278	19.51	0.5036	0.4315	20.12	0.4993	0.4292
74	Morgantown	15	III	G	W	SR 252	57.5	56.6	57.5	9.4	0.1693	0.4582	9.23	0.1687	0.4575	9.15	0.1674	0.4593
75	No Passing	13	III	Y	E	SR 252	164	185	193	22.25	0.5084	0.4609	21.68	0.5078	0.4104	22.17	0.5894	0.4591
76	No Passing	14	III	Y	W	SR 252	182	180	187	19.91	0.5227	0.4469	21.09	0.5204	0.4484	79.78	0.5235	0.7477
77	Stop	14	III	R	S	SR 252	20.1	19.3	21.7	4.54	0.5822	0.3268	4.71	0.5754	0.3207	4.6	0.5831	0.3211
78	Stop	13	III	R	S	SR 252	10.2	11.9	8.1	4.62	0.5561	0.3226	4.77	0.5552	0.3204	4.86	0.543	0.3204
79	Stop	13	III	R	N	SR 252	31.8	32.5	28.6	3.76	0.5784	0.3169	3.76	0.5803	0.317	3.46	0.5818	0.3159
80	Stop	16	III	R	N	SR 135	35.9	32.7	35.1	4.21	0.5845	0.3212	4.27	0.5835	0.3215	4.25	0.5773	0.3265
81	Stop	12	III	R	E	SR 135	29.8	23.5	26.8	4.54	0.5614	0.32	4.86	0.5632	0.3201	4.3	0.571	0.3184
82	Stop	14	III	R	E	SR 135	31.9	33.7	39.2	4.77	0.5726	0.3222	4.86	0.5607	0.3268	4.95	0.5603	0.3231
83	40 MPH	20	I	W	N	SR 135	33	33	30	43.28	0.3221	0.345	41.76	0.3233	0.3463	42.73	0.3229	0.3457
84	Morgantown	19	III	G	S	SR 135	66.6	70.5	70.3	9.78	0.1738	0.4499	10.12	0.7724	0.4004	10.06	0.7719	0.4507
85	Beanblossom	16	III	G	N	SR 135	47.8	52.1	45.3	8.91	0.1728	0.4584	9.05	0.1779	0.4588	8.99	0.1741	0.4577
86	S 135	16	III	W	N	SR 135	278	274	36.3	25.85	0.3105	0.3537	34.77	0.311	0.3341	34.44	0.3111	0.3344
87	30 MPH	14	III	W	N	SR 135	58	60	66.4	45.18	0.3174	0.3403	44.62	0.3196	0.3428	35.17	0.3172	0.3402
88	E 60	13	III	W	N	SR 135	301	388	300	31.78	0.3121	0.3349	33.19	0.3113	0.3342	32.69	0.311	0.3337
89	S 135	13	III	W	N	SR 135	397	385	385	34.07	0.309	0.3317	33.82	0.3095	0.3321	33.34	0.3116	0.333
90	Borden	13	III	G	N	SR 135	65.6	66.5	67.3	9.67	0.1726	0.4473	9.65	0.1729	0.4459	9.6	0.17	0.4495
91	Stop	13	III	R	W	SR 135	19	19.5	19	3.55	0.5604	0.3154	3.38	0.5724	0.3134	3.54	0.564	0.316

Sign No.	Sign Name	Sign Age (yrs)	Type (I, II, III)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m^2/lux)			Color Reading								
										1			2			3		
							1	2	3	Y	X*	Y*	Y	X*	Y*	Y	X*	Y*
92	New Salisb.	18	III	G	N	SR 135	56.8	54.9	53.3	8.53	0.1673	0.4508	8.49	0.1671	0.4517	8.74	0.1685	0.4501
93	Cent. Barren	18	III	G	N	SR 135	58.3	56.2	54.1	8.63	0.1654	0.4629	8.52	0.1664	0.4617	9.13	0.1725	0.4562
94	N 135	19	III	W	S	SR 135	280	235	258	31.72	0.3117	0.3337	31.69	0.3122	0.3345	3.94	0.3119	0.3341
95	N 7	15	III	W	S	SR 7	212	281	301	35.63	0.3099	0.3318	34.59	0.3103	0.3328	33.76	0.3106	0.3329
96	Queensville	13	III	G	S	SR 7	49.1	47	45.8	8.84	0.1691	0.4539	9.12	0.17	0.4529	8.6	0.1682	0.4542
97	JC Adult	16	III	G	S	SR 7	64.6	65.3	68.3	9.17	0.1673	0.4576	9.43	0.1697	0.454	9.1	0.1693	0.4573
98	Muscatat.Rv.	13	III	G	S	SR 7	63.7	64.2	64.3	9.34	0.1679	0.4567	8.84	0.166	0.463	9.26	0.1677	0.4586
99	Stop	11	III	R	N	US 50	45.7	49.2	48.8	9.93	0.5291	0.3562	9.67	0.5348	0.3555	9.5	0.5352	0.3543
100	Drop Center	12	III	G	W	US 50	35.9	38.3	33.2	9.98	0.1773	0.4399	9.99	0.1731	0.4426	10.07	0.1772	0.4395
101	Kent 15	13	III	G	W	SR 256	61.8	58.9	61.4	9.25	0.1682	0.4602	9.19	0.1678	0.4607	9.44	0.1696	0.4576
102	Austin 8	12	III	G	E	SR 256	60.4	63.1	61.9	8.86	0.1673	0.4591	9.09	0.1714	0.4544	9.54	0.1736	0.4526
56	Shoals 8	10	IV	G	W	US 50	44.7	71.8	59.1	8.57	0.1791	0.4412	8.71	0.1767	0.4435	8.75	0.1785	0.4414
57	4-H	10	IV	G	W	US 50	91.3	68.9	48.3	8.44	0.1712	0.448	8.64	0.1747	0.4535	8.65	0.1761	0.4417
58	4-H	10	IV	G	E	US 50	192	168	319	8.54	0.1771	0.446	8.39	0.177	0.444	8.37	0.1752	0.4441
103	JCT 231	10	IV	W	E	US 50	830	830	760	51.97	0.3159	0.3376	52.68	0.3156	0.3373	52.78	0.3151	0.3368
104	45 MPH	10	IV	W	E	US 50	818	843	663	51.34	0.3178	0.3399	51.43	0.3183	0.34	50.21	0.3204	0.3423
105	45 MPH	10	IV	W	W	US 50	811	705	824	51.48	0.3202	0.3424	49.99	0.3198	0.3419	49.13	0.3211	0.3433
106	50 MPH	10	IV	W	W	US 50	675	756	696	49.62	0.3237	0.3457	51.66	0.3211	0.3433	51.78	0.3215	0.3436
108	All Lane Ended	10	IV	W	W	US 50	566	687	688	51.71	0.3211	0.3431	51.53	0.3206	0.3427	54	0.3171	0.3393
109	Lane Ended	10	IV	Y	W	US 50	614	507	467	33.1	0.502	0.4703	33.05	0.5003	0.4686	33.16	0.4999	0.4695
111	Lane Ended	10	IV	Y	E	US 50	560	447	575	33.26	0.5042	0.4692	32.31	0.5044	0.4686	33.28	0.5046	0.4694
107	Intersection	10	IV	Y	W	US 50	635	558	984	32.63	0.4981	0.4661	31.81	0.4996	0.4645	32.81	0.9989	0.4654
115	Curve	10	IV	Y	E	US 50	361	387	499	30.39	0.518	0.4629	30.18	0.5186	0.4633	30.65	0.5172	0.4638
112	Stop	10	IV	R	S	US 50	93.5	93.1	99.4	9.41	0.5579	0.33	9.88	0.5595	0.3305	8.95	0.5649	0.3307
113	Stop	10	IV	R	S	US 50	102.5	99.5	108.1	8.4	0.5728	0.3277	8.74	0.5668	0.3284	8.59	0.5724	0.3297
114	Stop	10	IV	R	N	US 50	97.4	94.8	96.1	9.24	0.5615	0.3318	9.23	0.5621	0.3305	9.2	0.5636	0.3312
49	Stop	10	IV	R	S	US 50	141.5	126.7	97.5	9.81	0.5608	0.3351	9.68	0.5607	0.3337	9.68	0.5615	0.3352
110	Stop	10	IV	R	S	US 50	126.3	179.4	101.3	11.26	0.5435	0.3365	11.53	0.54	0.3376	11.74	0.5414	0.3368

Sheet Sign Retroreflectance Readings (Green Signs Facing East & West)

Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity ($cd/m^2/lux$) 1	2	3	Average	FHWA Min
Roanke 10	13	III	G	E	US 24W	68.9	68.8	69.6	69.1	25
Heartland	13	III	G	E	US 24 W	56.9	57.4	55.2	56.5	25
4-H	10	IV	G	E	US 50	192	168	319	226.3	25
Austin 8	12	III	G	E	SR 256	60.4	63.1	61.9	61.8	25
Wabash 13	13	III	G	W	U.S. 24E (from us 31 to SR 13)	45.9	46.1	41.7	44.6	25
ST.POLICE POST	13	III	G	W	US 24E	70.8	68.1	75.9	71.6	25
Huntington	13	III	G	W	US 24 E	55.1	54.7	55.2	55.0	25
Heartland	13	III	G	W	US 24 E	56.4	55.6	55.9	56.0	25
Shoals 8	10	IV	G	W	US 50	44.7	71.8	59.1	58.5	25
4-H	10	IV	G	W	US 50	91.3	68.9	48.3	69.5	25
Morgantown		III	G	W	SR 252	57.5	56.6	57.5	57.2	25
Drop Center	12	III	G	W	US 50	35.9	38.3	33.2	35.8	25
Kent 15	13	III	G	W	SR 256	61.8	58.9	61.4	60.7	25
Average						**69.0**	**67.4**	**76.5**	**71.0**	25

15

Sheet Sign Retroreflectance Readings (Green Signs Facing North)

Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m²/lux) 1	2	3	Average	FHWA Min
VAN	12	III	G	N	SR 5 N	37.6	64.1	48.6	50.1	25
Albion	12	III	G	N	US 33 N	54.9	53.7	54	54.2	25
Burr Oak	12	III	G	N	US 33 N	54.2	52.2	50.7	52.4	25
Lagro	13	III	G	N	SR. 524	57.6	57.8	59.7	58.4	25
Taylor W	14	III	G	N	SR 5 N	53.1	55.8	56.7	55.2	25
Gas City	14	III	G	N	SR 5 N	55.8	58.6	58.6	57.7	25
Wolflake	14	III	G	N	US 33 N	66.5	64.5	56.4	62.5	25
Knapp Lake	14	III	G	N	US 33 N	52	52.3	50.6	51.6	25
Camp	16	III	G	N	SR 135 S.	46.6	59.1	55.2	53.6	25
Clark Forest	13	III	G	N	US 31	66	64.8	67.1	66.0	25
Beanblossom	16	III	G	N	SR 135	47.8	52.1	45.3	48.4	25
Borden	13	III	G	N	SR 135	65.6	66.5	67.3	66.5	25
New Salisb.	18	III	G	N	SR 135	56.8	54.9	53.3	55.0	25
Cent. Barren	18	III	G	N	SR 135	58.3	56.2	54.1	56.2	25
Average						**55.2**	**58.0**	**55.5**	**56.3**	25

Sheet Sign Retroreflectance Readings (Green Signs Facing South)

Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity ($cd/m^2/lux$) 1	2	3	Average	FHWA Min
Ligonier 16	12	III	G	S	US 33 N	40.2	39.9	39.4	39.8	25
Lagrance Co	12	III	G	S	SR. 5	57.4	60.8	62.3	60.2	25
Wabash 6	13	III	G	S	SR. 524	50.4	52.6	50.7	51.2	25
Ligonier	13	III	G	S	US 33 N	57.5	38.2	38	44.6	25
VAN	14	III	G	S	SR 5 N	59.7	60.1	60.8	60.2	25
Knapp	14	III	G	S	US 33 N	41.9	39.9	39.4	40.4	25
Ligonier	14	III	G	S	US 33 N	51.5	48.4	50.6	50.2	25
Hickory Hills	13	III	G	S	SR 135 S.	56.7	56.8	55.7	56.4	25
Vienna	17	III	G	S	US 31	63.7	61.4	65.1	63.4	25
Morgantown	19	III	G	S	SR 135	66.6	70.5	70.3	69.1	25
Queensville	13	III	G	S	SR 7	49.1	47	45.8	47.3	25
JC Adult	16	III	G	S	SR 7	64.6	65.3	68.3	66.1	25
Muscatat.Rv.	13	III	G	S	SR 7	63.7	64.2	64.3	64.1	25
Average						**55.62**	**54.24**	**54.67**	**54.84**	25

Sheet Sign Retroreflectance Readings (Red Signs Facing East& West)

Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m²/lux) 1	2	3	Average	FHWA Min
Yield	13	III	R	E	SR 524 (from us 24 to state park)	49.6	47.6	51.7	49.6	7
Yield	13	III	R	E	US 24W (I69 TO SR9)	25.2	26.1	24.7	25.3	7
STOP	14	III	R	E	SR 5 N	31.7	26.4	24.3	27.5	7
STOP	14	III	R	E	SR 5 N	27.9	25.1	25.1	26.0	7
Stop	13	III	R	E	SR 135 S.	29.8	28.8	31.3	30.0	7
Stop	12	III	R	E	SR 135 S.	29.3	29.4	38.2	32.3	7
Stop	12	III	R	E	SR 135 S.	69.3	68.5	70.8	69.5	7
Stop	18	III	R	E	US 31	79.8	78.2	75.4	77.8	7
Stop	12	III	R	E	SR 135	29.8	23.5	26.8	26.7	7
Stop	14	III	R	E	SR 135	31.9	33.7	39.2	34.9	7
Do Not Enter	13	III	R	W	U.S. 24W (from us 31 to SR 13)	34.5	31.9	34.9	33.8	7
Do Not Enter	13	III	R	W	SR 524 (from us 24 to state park)	43.6	40.9	43.5	42.7	7
Do Not Enter	17	III	R	W	US 24W (I69 TO SR9)	79.9	77.4	69.9	75.7	7
Stop	14	III	R	W	US 31	32.7	32	29.9	31.5	7
Stop	13	III	R	W	US 31	18.9	17.9	19	18.6	7
Stop	14	III	R	W	US 31	32.5	32.6	33.3	32.8	7
Stop	14	III	R	W	US 31	35.8	35.2	39.2	36.7	7
Stop	13	III	R	W	SR 135	19	19.5	19	19.2	7
Average						**39.0**	**37.5**	**38.7**	**38.4**	**7**

Sheet Sign Retroreflectance Readings (Red Signs Facing North)

Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m²/lux) 1	2	3	Average	FHWA Min
STOP	**13**	**III**	**R**	**N**	**U.S. 24W (from us 31 to SR 13)**	28.2	19.2	34.1	27.2	7
Stop	**13**	**III**	**R**	**N**	**US 24E (SR9 to I 69)**	25.1	23.6	25.9	24.9	7
STOP	**14**	**III**	**R**	**N**	**SR 5 N**	42.6	40.9	30.3	37.9	7
STOP	**14**	**III**	**R**	**N**	**SR 5 N**	24	25.6	27.8	25.8	7
STOP	**13**	**III**	**R**	**N**	**US 24**	42.7	41	40.9	41.5	7
STOP	**12**	**III**	**R**	**N**	**SR.9**	11.4	12.5	11.6	11.8	7
STOP	**12**	**III**	**R**	**N**	**SR.9**	3.2	3.8	3.2	3.4	7
Stop	**12**	**III**	**R**	**N**	**SR 56 E**	45.46	52.17	57.1	51.6	7
Stop	**10**	**III**	**R**	**N**	**US 50**	48.2	51.2	57.7	52.4	7
Stop	**13**	**III**	**R**	**N**	**SR 252**	242	268	275	261.7	7
Stop	**13**	**III**	**R**	**N**	**SR 252**	31.8	32.5	28.6	31.0	7
Stop	**16**	**III**	**R**	**N**	**SR 135**	35.9	32.7	35.1	34.6	7
Stop	**11**	**III**	**R**	**N**	**US 50**	45.7	49.2	48.8	47.9	7
Stop	**10**	**IV**	**R**	**N**	**US 50**	97.4	94.8	96.1	96.1	7
Average						**51.7**	**53.4**	**55.2**	**53.4**	7

Sheet Sign Retroreflectance Readings (Red Signs Facing South)

Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m²/lux) 1	2	3	Average	FHWA Min
STOP	13	III	R	S	U.S. 24E (from us 31 to SR 13)	24.8	28.4	27.7	27.0	7
STOP	13	III	R	S	U.S. 24E (from us 31 to SR 13)	30.8	29.3	28.7	29.6	7
STOP	13	III	R	S	U.S. 24E (from us 31 to SR 13)	16.5	24.7	18.3	19.8	7
STOP	13	III	R	S	U.S. 24W (from us 31 to SR 13)	27.9	27.4	26.3	27.2	7
Yield	13	III	R	S	U.S. 24W (from us 31 to SR 13)	45	37.2	35.1	39.1	7
STOP	13	III	R	S	US 24	30.1	31.8	28.4	30.1	7
STOP	13	III	R	S	SR.9	2.1	2.2	2	2.1	7
Stop	14	III	R	S	SR 56 E	19.4	27.5	28.9	25.3	7
Stop	16	III	R	S	SR 56 E	31	30.3	284	115.1	7
Stop	18	III	R	S	SR 56	28.1	25.9	26.1	26.7	7
Stop	10	IV	R	S	US 50	141.5	126.7	97.5	121.9	7
Stop	10	III	R	S	US 50	52.2	54.2	57.5	54.6	7
Stop	14	III	R	S	SR 252	20.1	19.3	21.7	20.4	7
Stop	13	III	R	S	SR 252	10.2	11.9	8.1	10.1	7
Stop	10	IV	R	S	US 50	126.3	179.4	101.3	135.7	7
Stop	10	IV	R	S	US 50	93.5	93.1	99.4	95.3	7
Stop	10	IV	R	S	US 50	102.5	99.5	108.1	103.4	7
Average						**47.18**	**49.93**	**58.77**	**51.96**	**7**

Sheet Sign Retroreflectance Readings (White Signs Facing East&West)

Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m²/lux) 1	2	3	Average	FHWA Min
SR224 E	13	III	W	E	US 24W (I69 TO SR9)	329	322	336	329.0	50
SR 5 S	13	III	W	E	US 24W (I69 TO SR9)	362	362	374	366.0	50
One Way	15	I	W	E	SR 56 E	6.5	6	6.6	6.4	50
One Way	15	I	W	E	SR 56 E	2.3	1.2	2.2	1.9	50
35 MPH	13	III	W	E	SR 56 E	294	291	297	294.0	50
Center Lane	13	III	W	E	SR 56 E	286	278	272	278.7	50
45 MPH	13	III	W	E	SR 56 E	296	288	295	293.0	50
45 MPH	13	III	W	E	SR 56 E	4.2	4.3	4.5	4.3	50
56	18	III	W	E	SR 56	280	266	298	281.3	50
35 MPH	10	III	W	E	US 50	290	281	292	287.7	50
JCT 231	10	IV	W	E	US 50	830	830	760	806.7	50
45 MPH	10	IV	W	E	US 50	818	843	663	774.7	50
East	13	III	W	W	U.S. 24E (from us 31 to SR 13)	286	279	284	283.0	50
U.S. 24	13	III	W	W	U.S. 24E (from us 31 to SR 13)	267	277	272	272.0	50
S.L. 60MPH	13	III	W	W	U.S. 24E (from us 31 to SR 13)	280	283	277	280.0	50
JCT 19	13	III	W	W	U.S. 24E (from us 31 to SR 13)	358	346	335	346.3	50
30 MPH	18	I	W	W	SR 56 E	8	10	17	11.7	50
One Way	15	I	W	W	SR 56 E	2.9	3.2	4.4	3.5	50
One Way	15	I	W	W	SR 56 E	2	4	0.5	2.2	50
Center Lane	13	III	W	W	SR 56 E	262	261	275	266.0	50
35 MPH	13	III	W	W	SR 56 E	271	288	296	285.0	50
45 MPH	15	I	W	W	SR 56 E	24	34	27	28.3	50
35 MPH	10	III	W	W	US 50	274	266	273	271.0	50
45 MPH	10	IV	W	W	US 50	811	705	824	780.0	50
50 MPH	10	IV	W	W	US 50	675	756	696	709.0	50
All Lane Ended	10	IV	W	W	US 50	566	687	688	647.0	50
Average						303.3	306.6	302.7	304.2	50

Sheet Sign Retroreflectance Readings (White Signs Facing North)

Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m²/lux) 1	2	3	Average	FHWA Min
S 19	14	III	W	N	U.S. 24E (from us 31 to SR 13)	308	309	399	338.7	50
Divided Hwy	13	III	W	N	U.S. 24W (from us 31 to SR 13)	301	382	294	325.7	50
Divided Hwy	13	III	W	N	US 24E (SR9 to I 69)	277	277	285	279.7	50
SL 55MPH	12	III	W	N	SR 5 N	285	284	275	281.3	50
SR 5	14	III	W	N	SR 5 N	222	225	234	227.0	50
Divided Hwy	13	III	W	N	US 24	270	272	270	270.7	50
S.L. 45MPH	13	III	W	N	SR. 524	60.9	60.8	65.9	62.5	50
Jct 58	12	III	W	N	SR 135 S.	292	281	273	282.0	50
55 MPH	14	III	W	N	US 31	49	45	49	47.7	50
40 MPH	20	I	W	N	SR 135	33	33	30	32.0	50
S 135	16	III	W	N	SR 135	278	274	36.3	196.1	50
30 MPH	14	III	W	N	SR 135	58	60	66.4	61.5	50
E 60	13	III	W	N	SR 135	301	388	300	329.7	50
S 135	13	III	W	N	SR 135	397	385	385	389.0	50
Average						223.7	234.0	211.6	223.1	50

Sheet Sign Retroreflectance Readings (White Signs Facing South)										
	Sign Age					Retroreflectivity (cd/m²/lux)				
Sign Name	(yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	1	2	3	Average	FHWA Min
Divided Hwy	13	III	W	S	U.S. 24E (from us 31 to SR 13)	240	267	258	255.0	50
E 24	14	III	W	S	U.S. 24E (from us 31 to SR 13)	399	309	311	339.7	50
Divided Hwy	13	III	W	S	U.S. 24E (from us 31 to SR 13)	293	288	289	290.0	50
Divided Hwy	13	III	W	S	U.S. 24E (from us 31 to SR 13)	286	290	284	286.7	50
Divided Hwy	13	III	W	S	U.S. 24W (from us 31 to SR 13)	276	286	288	283.3	50
SR 5 N	13	III	W	S	US 24W (I69 TO SR9)	349	350	342	347.0	50
US.24 E	13	III	W	S	US 24W (I69 TO SR9)	332	343	350	341.7	50
SR.9N	13	III	W	S	US 24W (I69 TO SR9)	342	333	352	342.3	50
JCT 16	13	III	W	S	SR.5.N	319	320	323	320.7	50
SR.5	14	III	W	S	SR 5 N	291	293	285	289.7	50
Divided Hwy	13	III	W	S	US 24	281	287	288	285.3	50
135	19	III	W	S	SR 135 S.	244	250	239	244.3	50
135	16	III	W	S	SR 135 S.	243	248	231	240.7	50
Jct 256	16	III	W	S	US 31	289	303	291	294.3	50
Jct 356	15	III	W	S	US 31	272	367	274	304.3	50
E 356	15	III	W	S	US 31	281	272	274	275.7	50
N 135	19	III	W	S	SR 135	280	235	258	257.7	50
N 7	15	III	W	S	SR 7	212	281	301	264.7	50
Average						290.5	295.7	291.0	292.4	50

Sheet Sign Retroreflectance Readings (Yellow Signs Facing East&West)

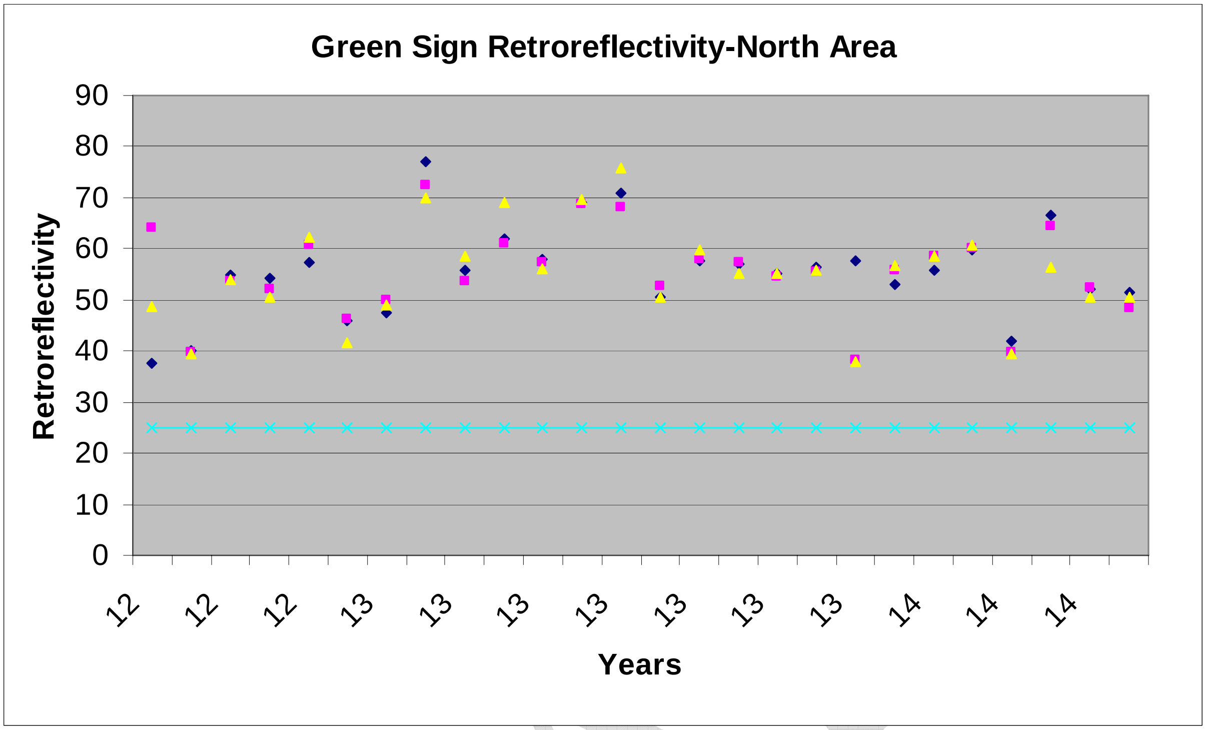
Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m²/lux) 1	2	3	Average	FHWA Min
No Passing	12	III	Y	E	SR 22 EAST	20.5	21.4	22.1	21.3	75
Light Ahead	13	III	Y	E	US 24W	231	240	231	234.0	75
Light Ahead	13	III	Y	E	US 24W	213	212	218	214.3	75
45 MPH	14	III	Y	E	US 24 W	184	181	162	175.7	75
45 MPH	14	III	Y	E	US 24 W	182	193	192	189.0	75
Curve	13	III	Y	E	SR 56 E	197	224	170	197.0	75
No Passing	15	III	Y	E	SR 56	9	72	76	52.3	75
Light Ahead	10	III	Y	E	US 50	209	198	216	207.7	75
Light Ahead	13	III	Y	E	SR 252	89	119	101	103.0	75
No Passing	13	III	Y	E	SR 252	164	185	193	180.7	75
Lane Ended	10	IV	Y	E	US 50	560	447	575	527.3	75
Curve	10	IV	Y	E	US 50	361	387	499	415.7	75
Light Ahead	13	III	Y	W	US 24E	226	225	200	217.0	75
Light Ahead	13	III	Y	W	US 24 E	209	211	210	210.0	75
Intersection	10	IV	Y	W	US 50	635	558	984	725.7	75
Arrow	14	III	Y	W	SR 135 S.	93	79	84	85.3	75
No Passing	13	III	Y	W	SR 56 E	268	284	277	276.3	75
Truck Ent.	15	III	Y	W	SR 56 E	1.1	7.5	2.7	3.8	75
School Xing	10	III	Y	W	US 50	132	187	198	172.3	75
School Bus	13	III	Y	W	SR 252	141	100	134	125.0	75
No Passing	14	III	Y	W	SR 252	182	180	187	183.0	75
Intersection	10	IV	Y	W	US 50	635	558	984	725.7	75
Lane Ended	10	IV	Y	W	US 50	614	507	467	529.3	75
Average						241.5	233.7	277.5	250.9	75

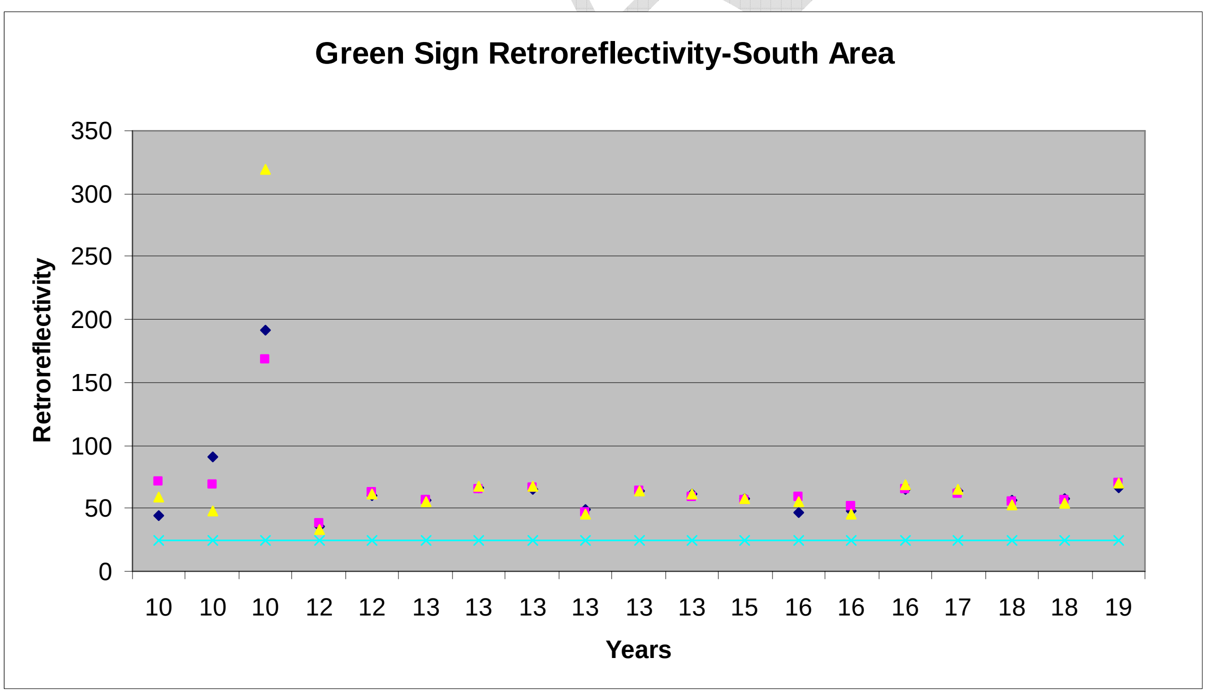
Sheet Sign Retroreflectance Readings (Yellow Signs Facing North)

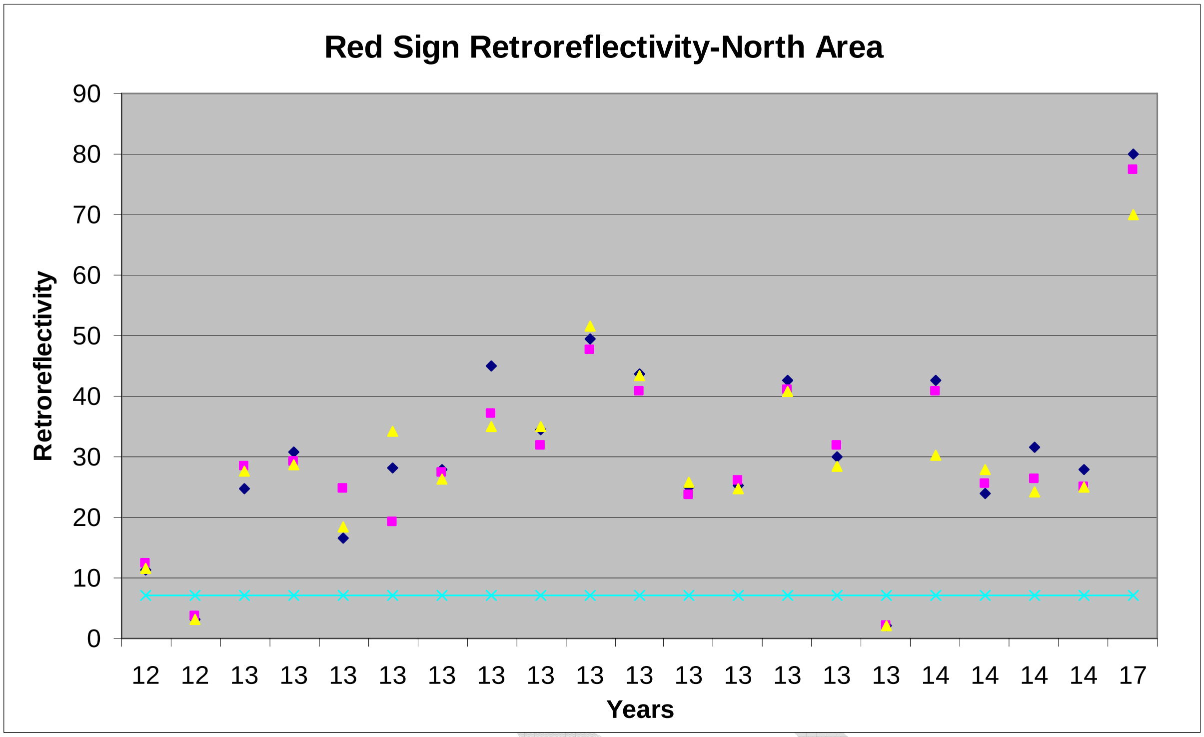
Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m²/lux) 1	2	3	Average	FHWA Min
No Passing	14	III	Y	N	SR 5 S	208	201	205	204.7	75
Curve 45 MPH	14	III	Y	N	SR 5 S	182	176	164	174.0	75
Curve	13	III	Y	N	SR 5 S	190	199	172	187.0	75
45 MPH	13	III	Y	N	SR 5 S	130	152	157	146.3	75
No Passing	13	III	Y	N	SR 5 S	194	189	197	193.3	75
Stop Ahead	13	III	Y	N	SR 5 N	197	199	195	197.0	75
Stop Ahead	13	III	Y	N	SR 5 N	209	199	194	200.7	75
No Passing	14	III	Y	N	SR 5 N	181	195	203	193.0	75
Curve	17	III	Y	N	SR. 524	199	203	205	202.3	75
Curve	16	III	Y	N	SR 135 S.	197	182	202	193.7	75
Curve	16	III	Y	N	SR 135 S.	209	178	146	177.7	75
Curve	16	III	Y	N	SR 135 S.	117	124	141	127.3	75
Truck	16	III	Y	N	SR 135 S.	183	169	173	175.0	75
Curve	16	III	Y	N	SR 135 S.	177	194	176	182.3	75
Curve	16	III	Y	N	SR 135 S.	158	157	167	160.7	75
Bike	16	III	Y	N	SR 135 S.	190	187	177	184.7	75
No Passing	17	III	Y	N	SR 135 S.	94	122	69	95.0	75
School Bus	14	III	Y	N	SR 135 S.	128	121	147	132.0	75
Curve	14	III	Y	N	US 31	204	165	206	191.7	75
Average						**176.2**	**174.3**	**173.5**	**174.6**	**75**

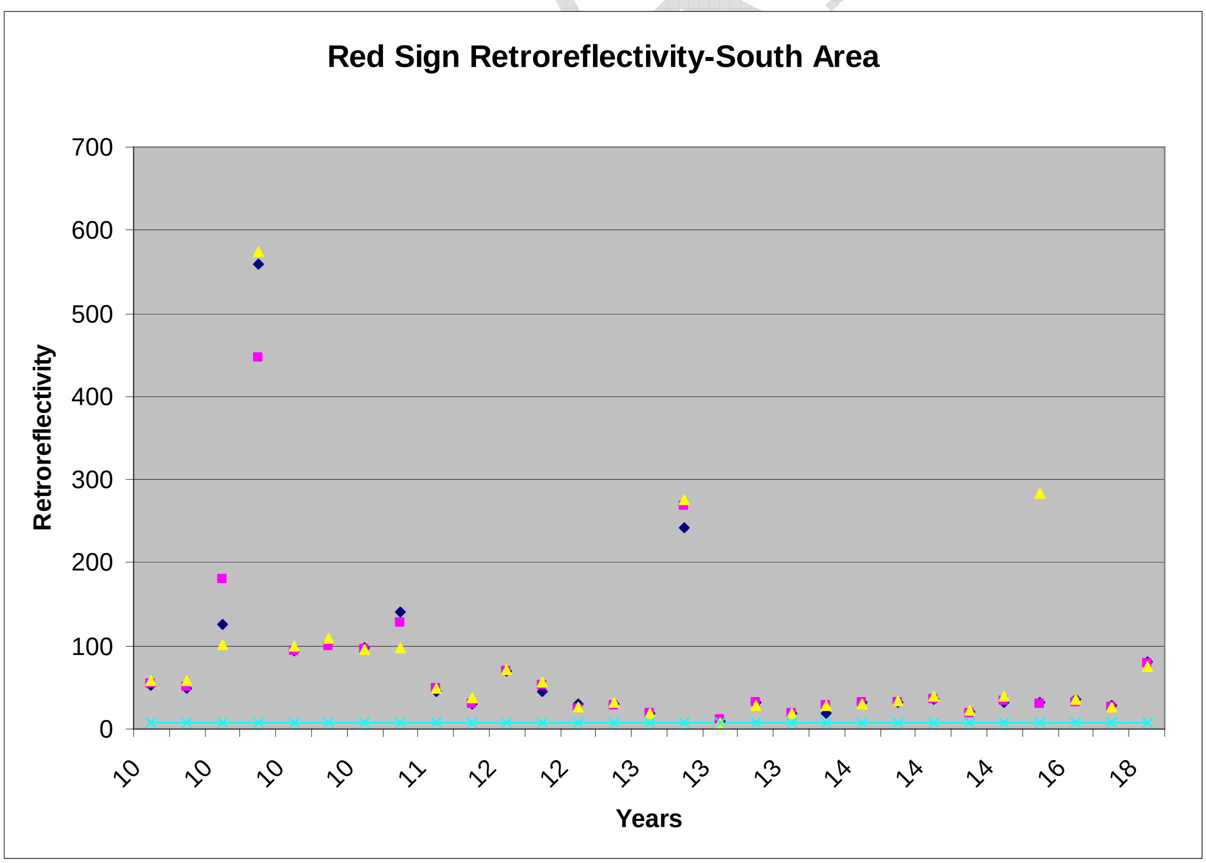
Sheet Sign Retroreflectance Readings (Yellow Signs Facing South)

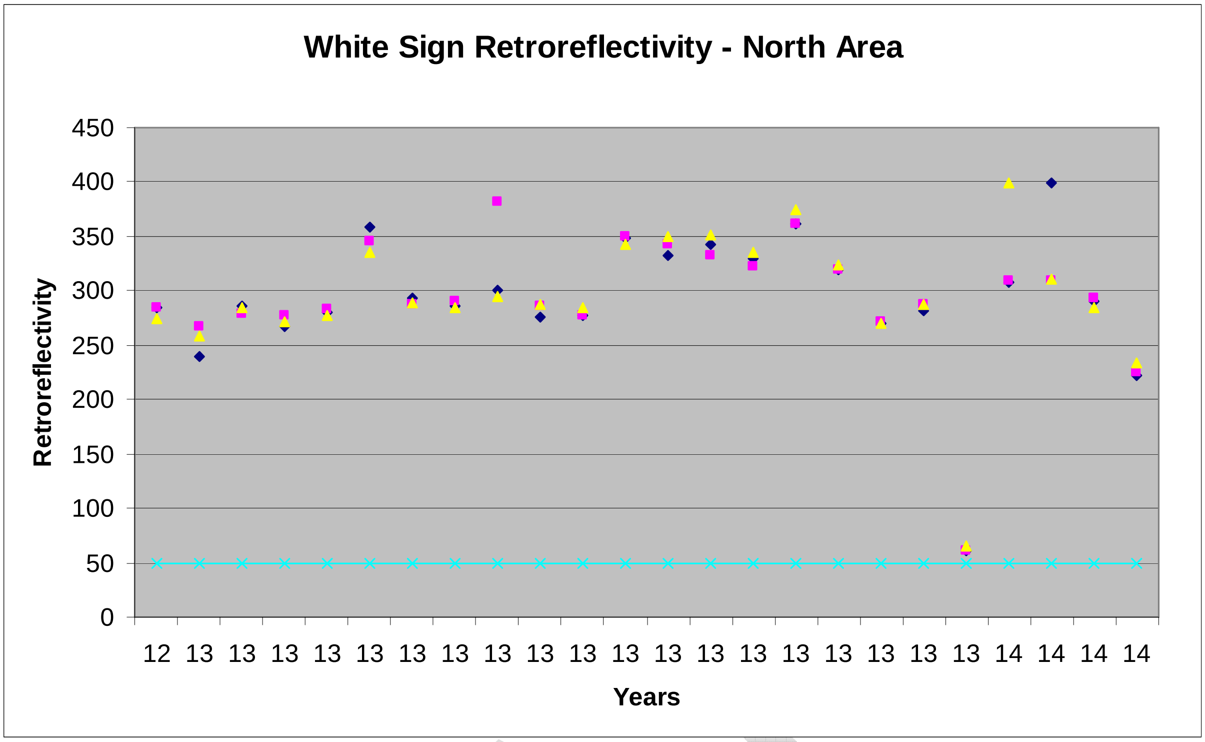
Sign Name	Sign Age (yrs)	Type (I,II, III,IV)	Color	Direction (Facing)	Location	Retroreflectivity (cd/m^2/lux) 1	2	3	Average	FHWA Min
Stop Ahead	14	III	Y	S	SR 5 S	201	203	198	200.7	75
Stop Ahead	14	III	Y	S	SR 5 S	148	159	149	152.0	75
No Passing	14	III	Y	S	SR 5 S	156	125	152	144.3	75
No Passing	14	III	Y	S	SR 5 N	147	96	82	108.3	75
No Passing	14	III	Y	S	SR 5 N	195	164	165	174.7	75
No Passing	14	III	Y	S	SR 5 N	216	201	263	226.7	75
RT LANE ENDS	18	III	Y	S	US 24W	28.9	28.7	13.8	23.8	75
Curve	13	III	Y	S	SR. 524	186	184	183	184.3	75
No Passing	14	III	Y	S	SR. 524	181	134	133	149.3	75
Curve	16	III	Y	S	SR 135 S.	171	179	180	176.7	75
Curve	16	III	Y	S	SR 135 S.	201	198	166	188.3	75
Curve	16	III	Y	S	SR 135 S.	59	69	74	67.3	75
Curve	12	III	Y	S	SR 135 S.	210	221	199	210.0	75
35 MPH	12	III	Y	S	SR 135 S.	205	197	282	228.0	75
Curve	16	III	Y	S	SR 135 S.	113	76	66	85.0	75
Stop Ahead	16	III	Y	S	SR 135 S.	231	222	217	223.3	75
School Bus	16	III	Y	S	SR 135 S.	1.1	0.3	0.5	0.6	75
School Bus	14	III	Y	S	SR 135 S.	0.9	0.7	1.6	1.1	75
Average					Average	147.27	136.54	140.27	141.36	75

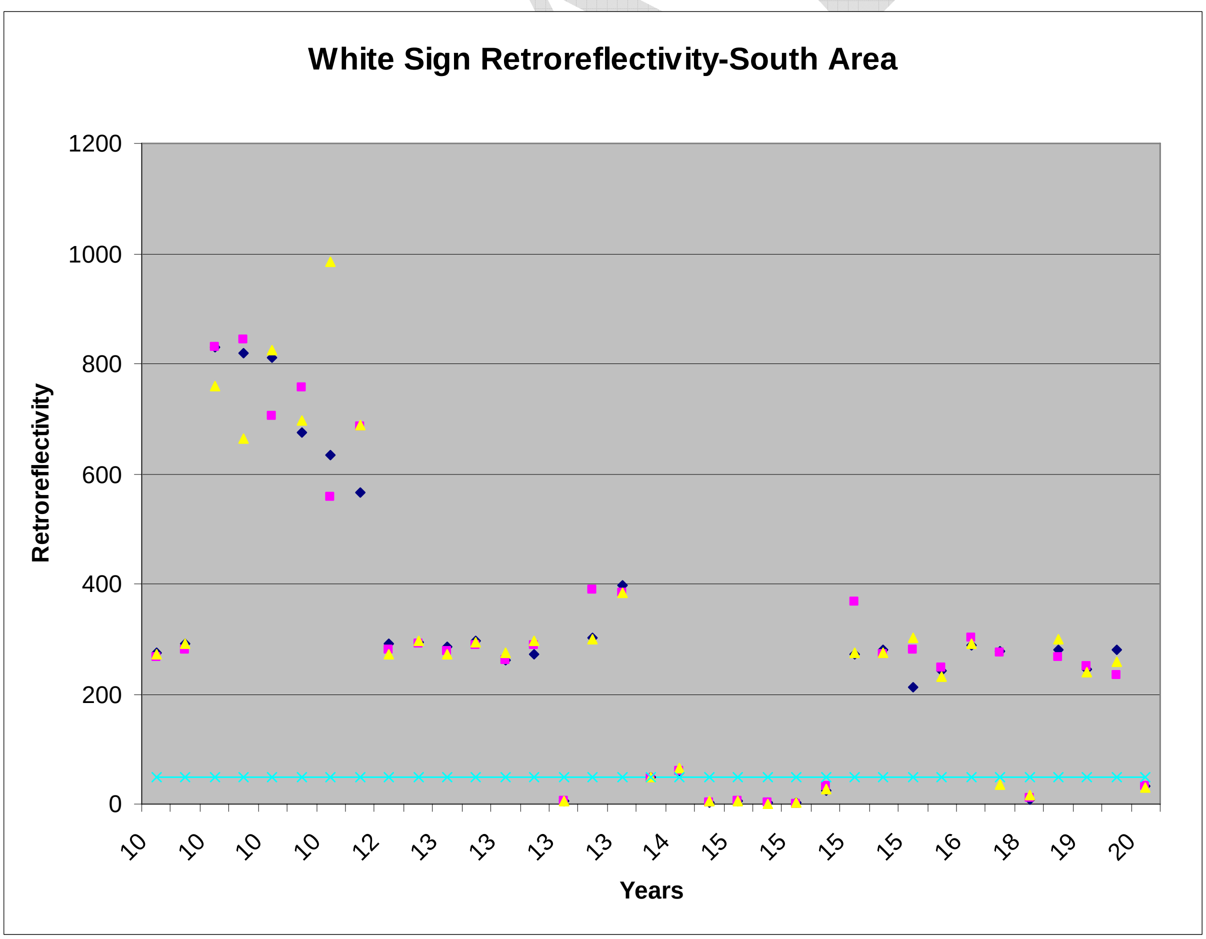

Green Sign Retroreflectivity-North Area
Retroreflectivity
90
80
70
60
50
40
30
20
10
0
12
12
12
13
13
13
13
13
13
13
14
14
14
Years

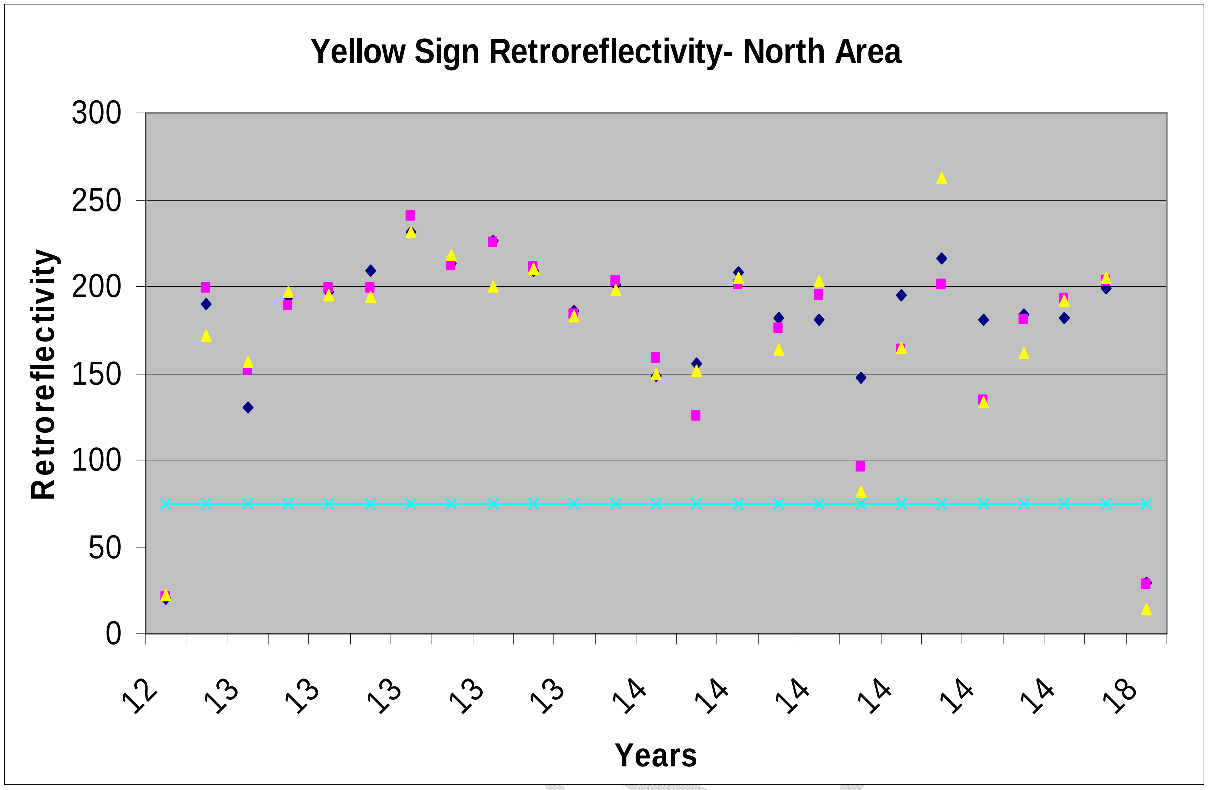

Green Sign Retroreflectivity-South Area
Retroreflectivity
350
300
250
200
150
100
50
0
10 10 10 12 12 13 13 13 13 13 13 15 16 16 16 17 18 18 19
Years


Red Sign Retroreflectivity-North Area
Retroreflectivity
90
80
70
60
50
40
30
20
10
0
12 12 13 13 13 13 13 13 13 13 13 13 13 13 13 13 14 14 14 14 17
Years

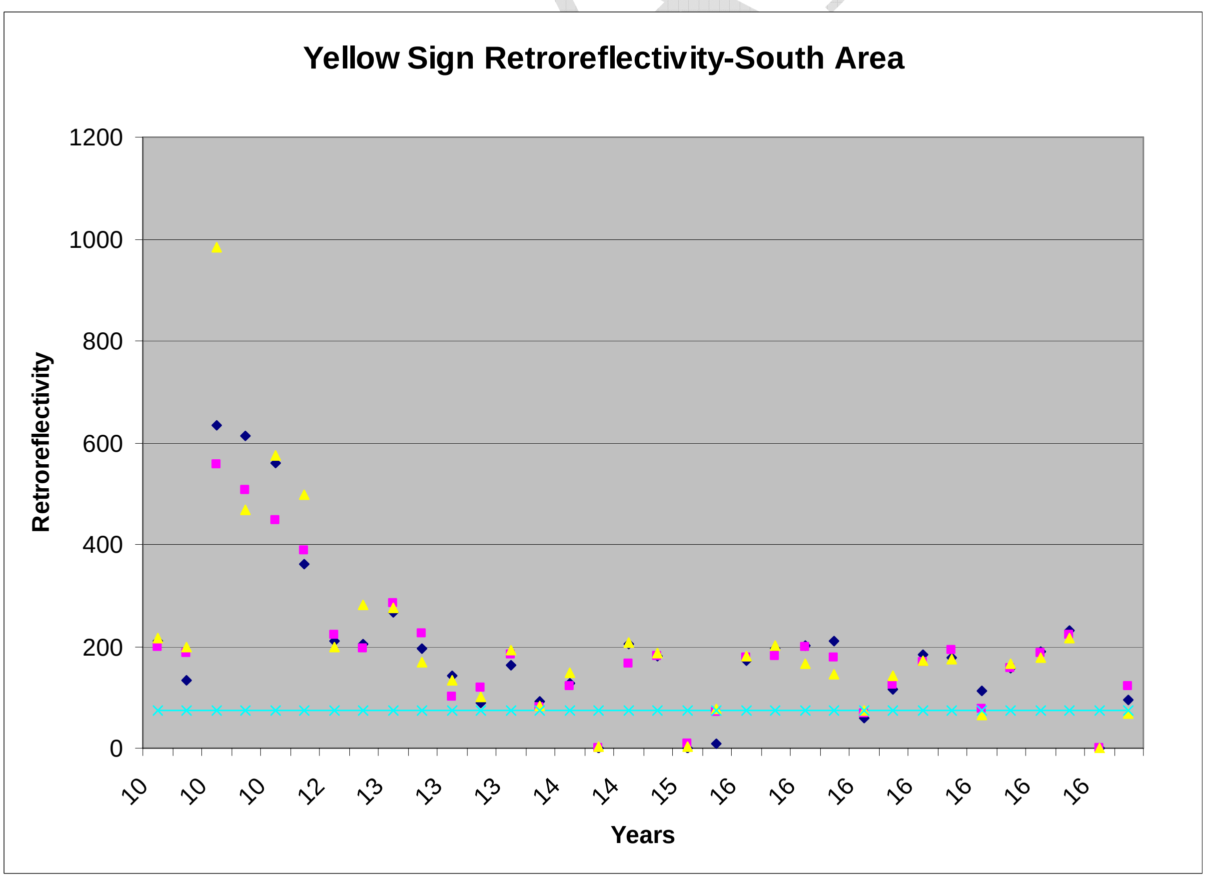

Red Sign Retroreflectivity-South Area
Retroreflectivity
700
600
500
400
300
200
100
0
10 10 10 10 11 12 12 13 13 13 14 14 14 16 18
Years


White Sign Retroreflectivity - North Area
Retroreflectivity
450
400
350
300
250
200
150
100
50
0
12 13 13 13 13 13 13 13 13 13 13 13 13 13 13 13 13 13 13 13 14 14 14 14
Years

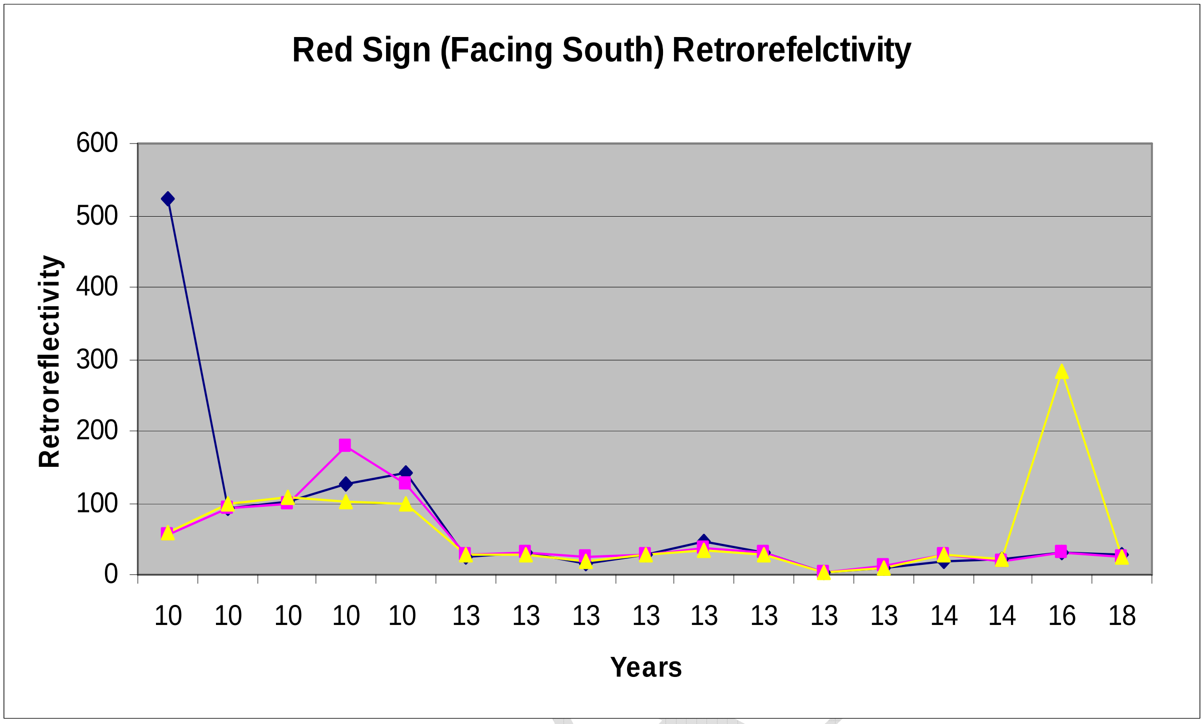

White Sign Retroreflectivity-South Area
Retroreflectivity
1200
1000
800
600
400
200
0
10 10 10 10 12 13 13 13 13 14 15 15 15 15 16 18 19 20
Years

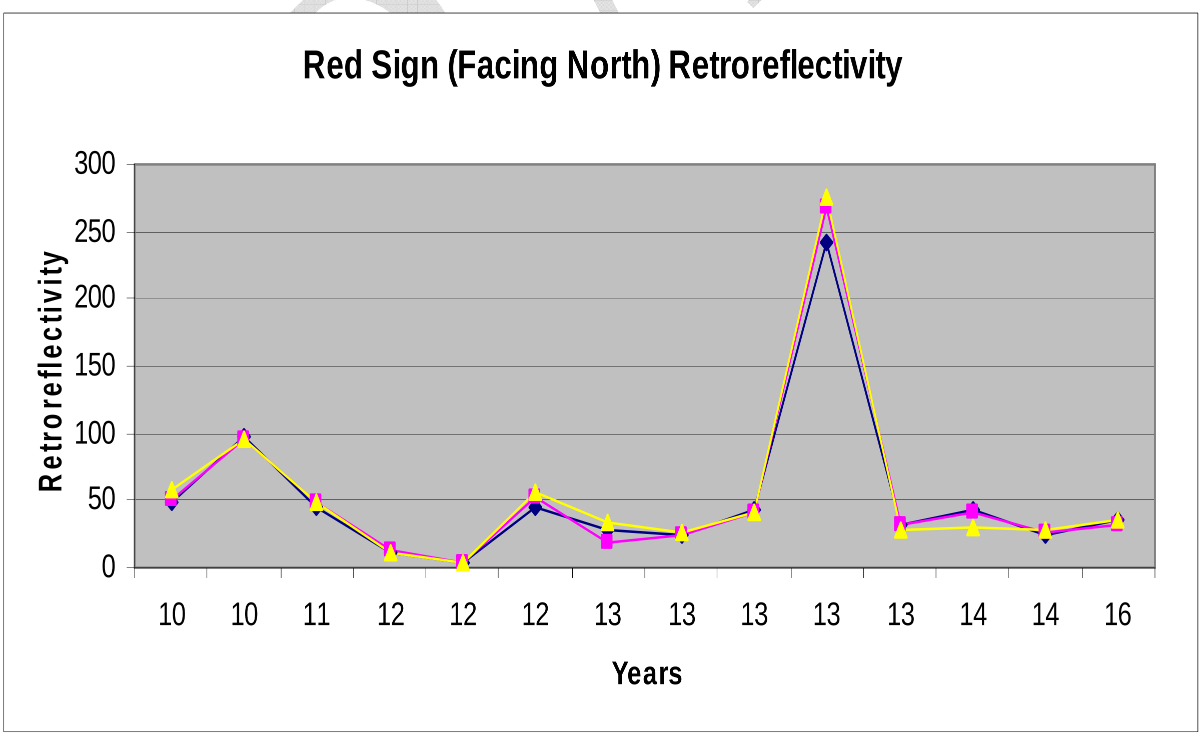


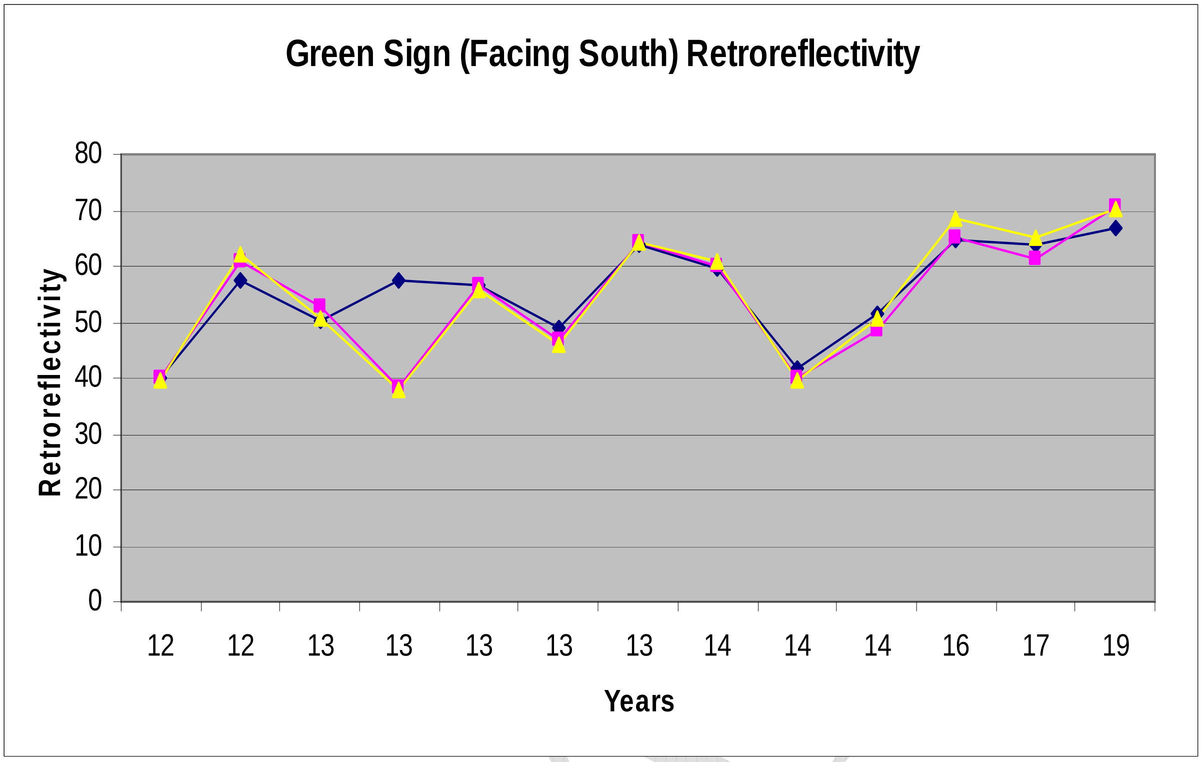
Yellow Sign Retroreflectivity- North Area
Retroreflectivity
300
250
200
150
100
50
0
12
13
13
13
13
13
14
14
14
14
14
14
18
Years

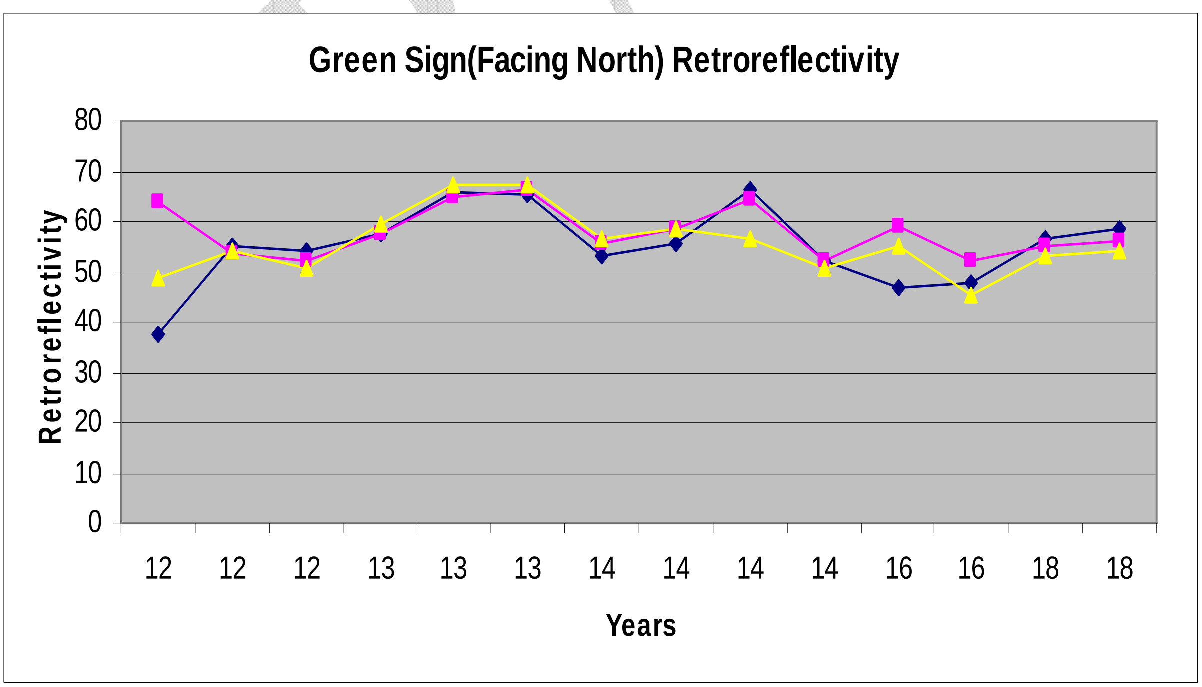


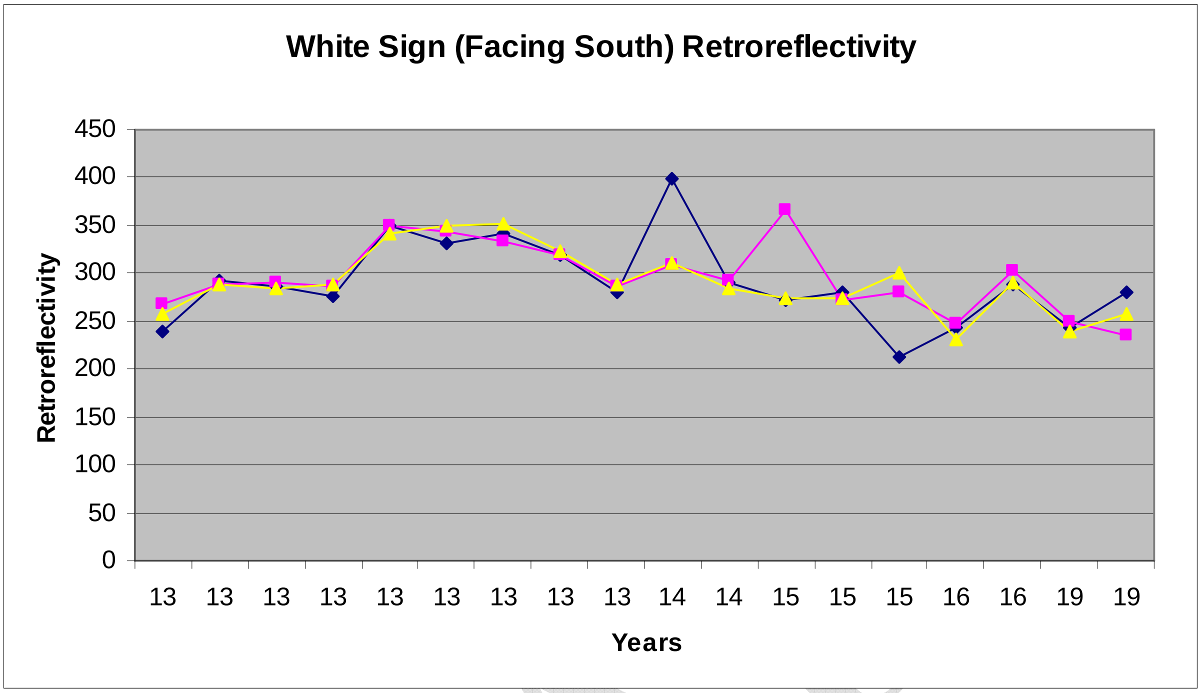
Yellow Sign Retroreflectivity-South Area
Retroreflectivity
1200
1000
800
600
400
200
0
10
10
10
12
13
13
13
14
14
15
16
16
16
16
16
16
16
Years

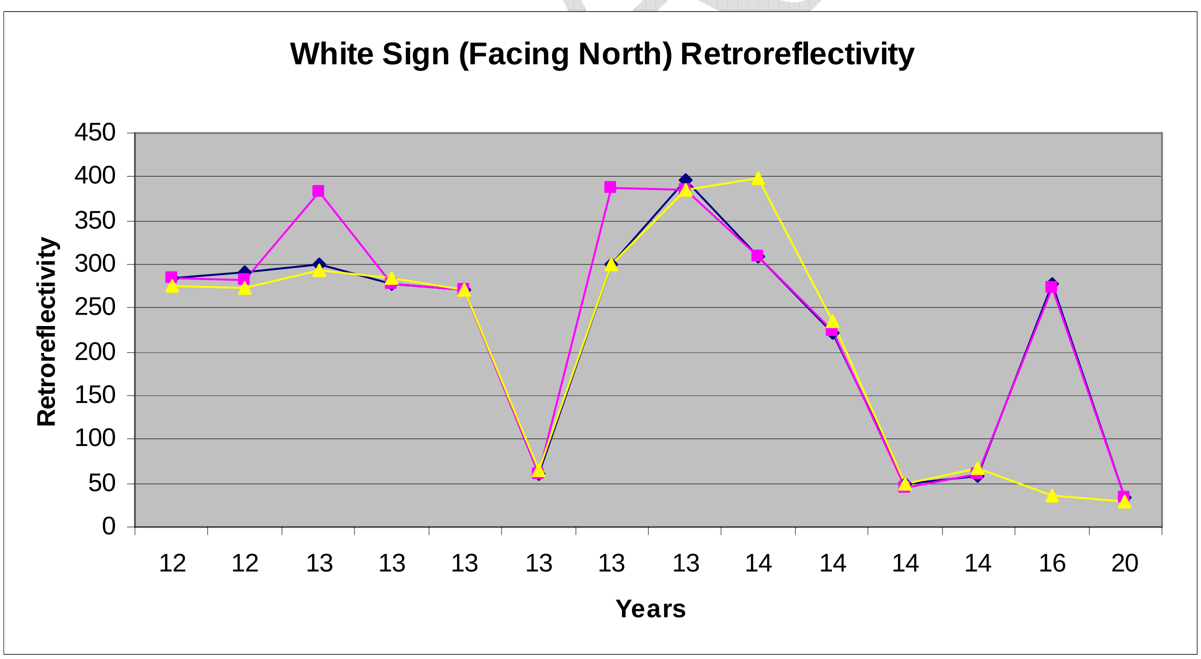

Red Sign (Facing South) Retrorefelctivity
Retroreflectivity
600
500
400
300
200
100
0
10 10 10 10 10 13 13 13 13 13 13 13 13 14 14 16 18
Years

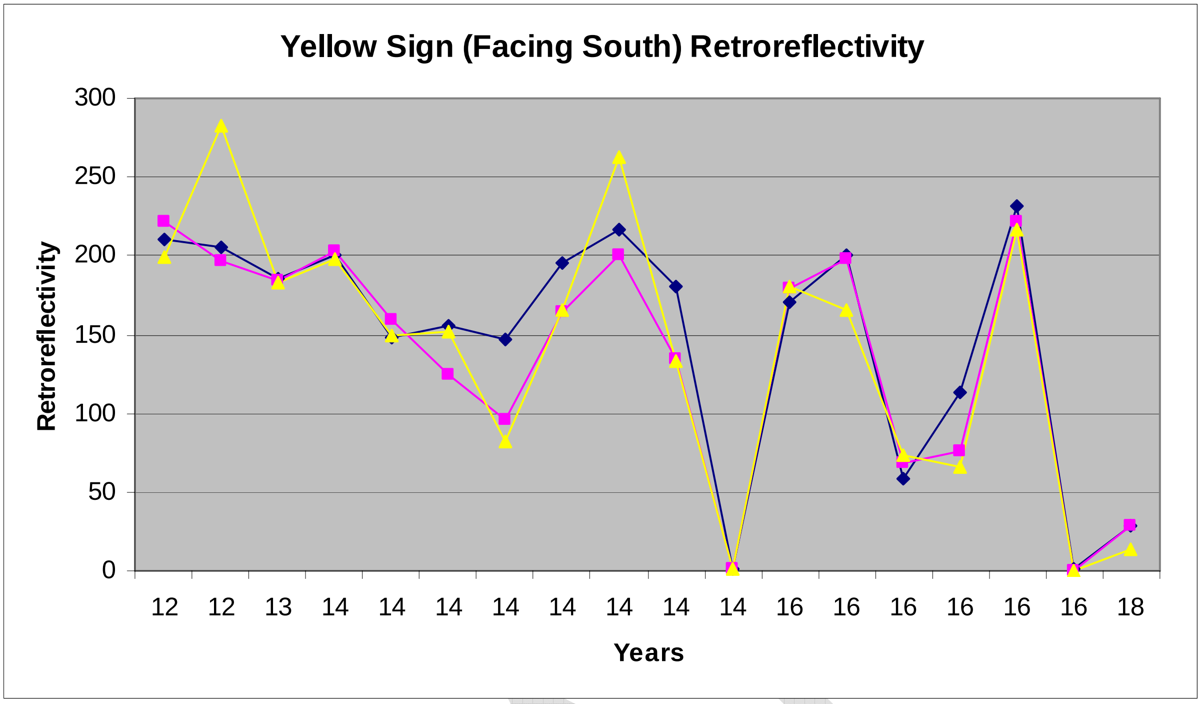

Red Sign (Facing North) Retroreflectivity
Retroreflectivity
300
250
200
150
100
50
0
10 10 11 12 12 12 13 13 13 13 13 14 14 16
Years

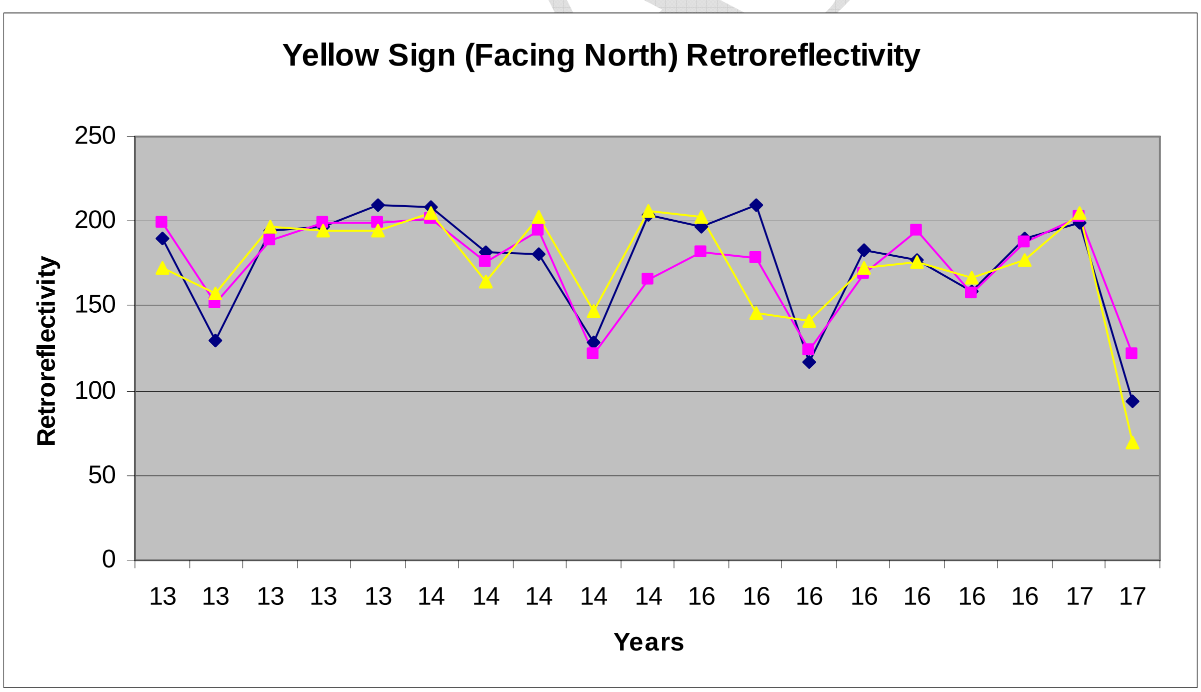

Green Sign (Facing South) Retroreflectivity
Retroreflectivity
0
10
20
30
40
50
60
70
80
12 12 13 13 13 13 13 14 14 14 16 17 19
Years

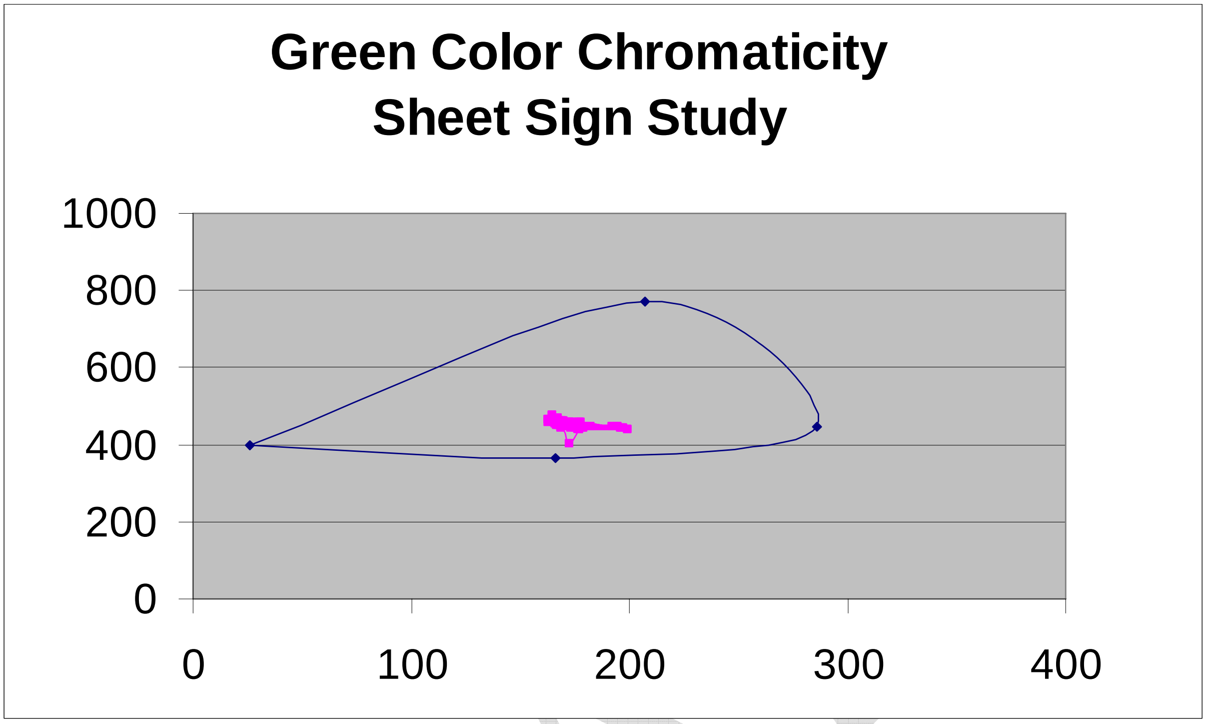

Green Sign(Facing North) Retroreflectivity
Retroreflectivity
0
10
20
30
40
50
60
70
80
12 12 12 13 13 13 14 14 14 14 16 16 18 18
Years

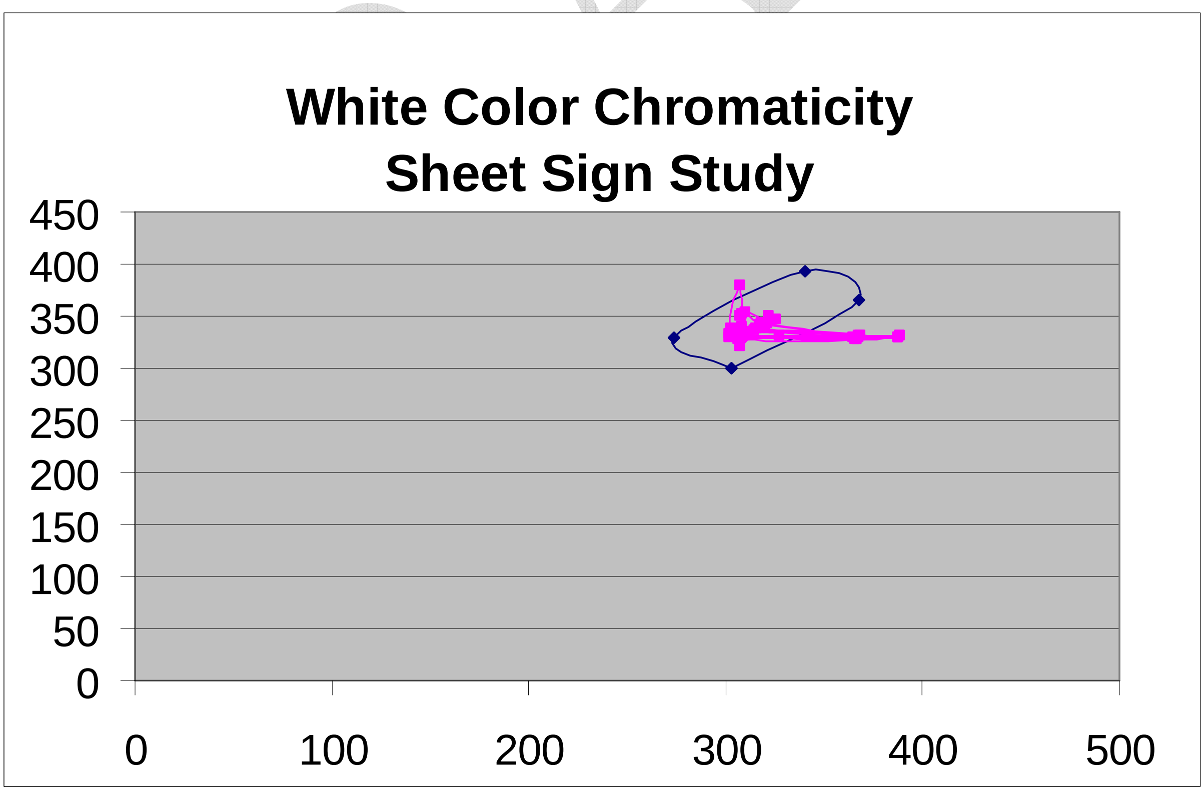

White Sign (Facing South) Retroreflectivity
Retroreflectivity
450
400
350
300
250
200
150
100
50
0
13 13 13 13 13 13 13 13 13 14 14 15 15 15 16 16 19 19
Years

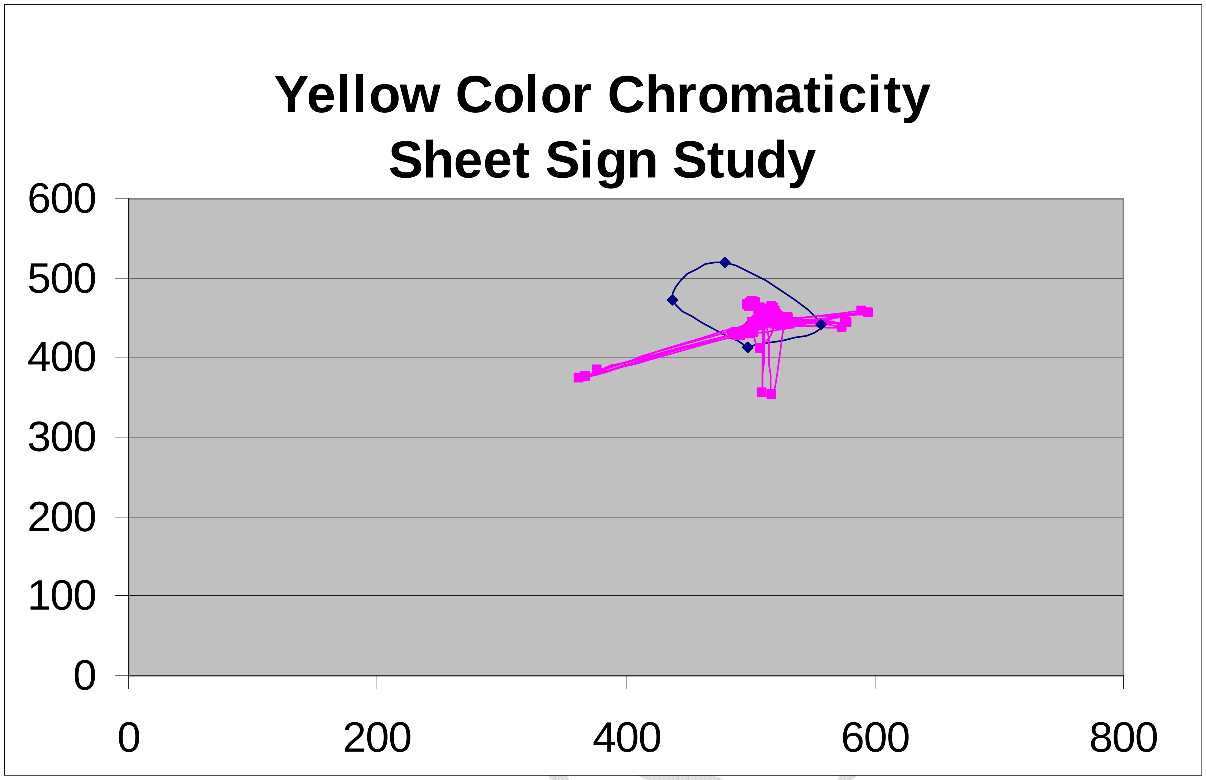

White Sign (Facing North) Retroreflectivity
Retroreflectivity
450
400
350
300
250
200
150
100
50
0
12 12 13 13 13 13 13 13 14 14 14 14 16 20
Years

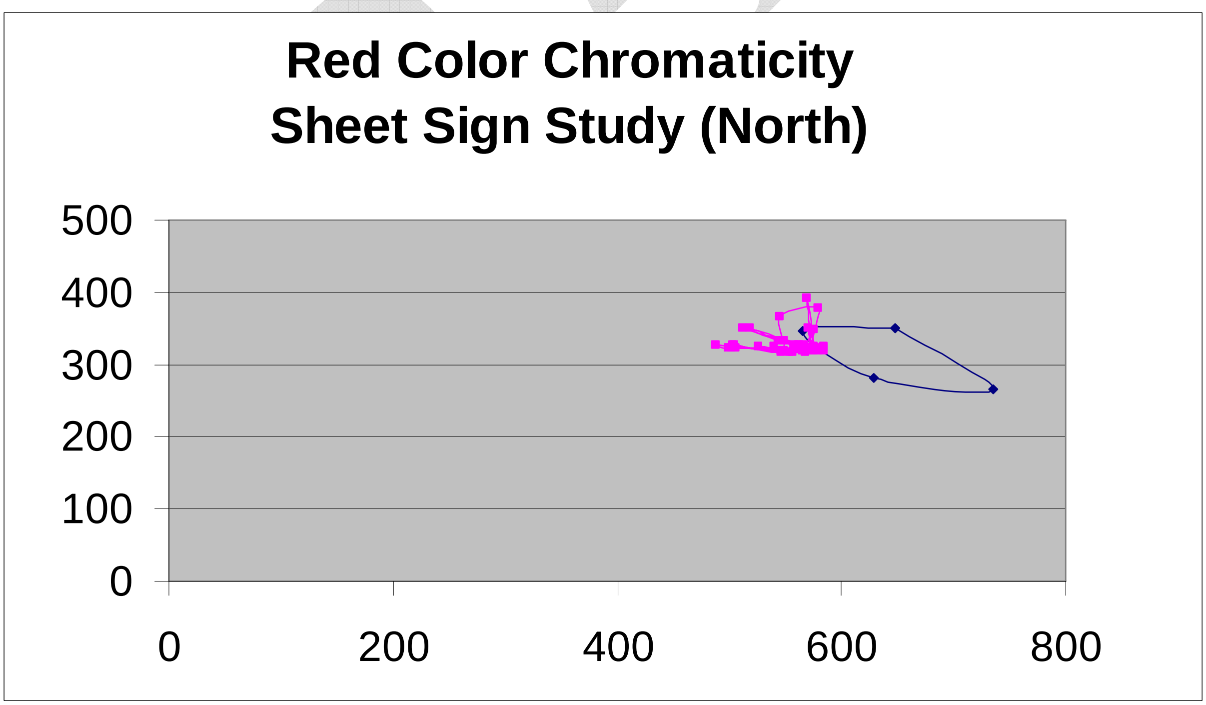

Yellow Sign (Facing South) Retroreflectivity
300
250
200
150
100
50
0
Retroreflectivity
12 12 13 14 14 14 14 14 14 14 14 16 16 16 16 16 16 18
Years

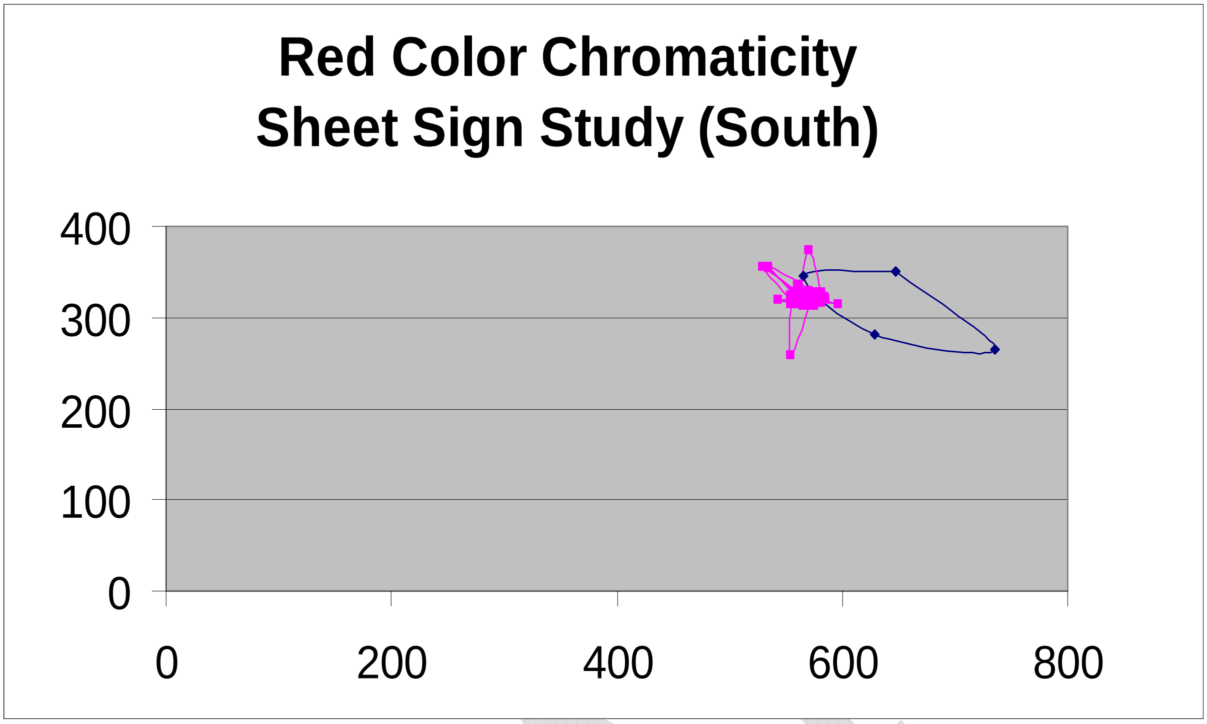

Yellow Sign (Facing North) Retroreflectivity
250
200
150
100
50
0
Retroreflectivity
13 13 13 13 13 14 14 14 14 14 16 16 16 16 16 16 16 17 17
Years

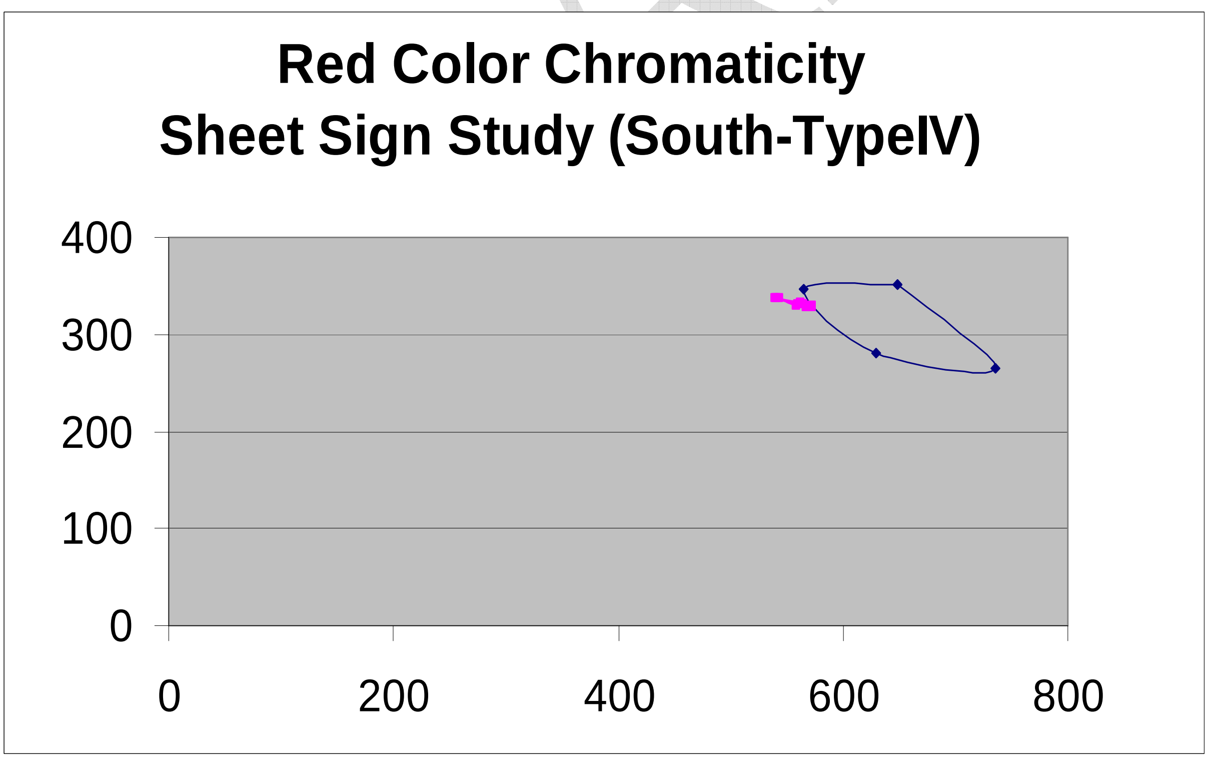

Green Color Chromaticity
Sheet Sign Study
1000
800
600
400
200
0
0
100
200
300
400


White Color Chromaticity
Sheet Sign Study
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500


Yellow Color Chromaticity
Sheet Sign Study
600
500
400
300
200
100
0
0
200
400
600
800


Red Color Chromaticity
Sheet Sign Study (North)
500
400
300
200
100
0
0
200
400
600
800


Red Color Chromaticity
Sheet Sign Study (South)
400
300
200
100
0
0
200
400
600
800


Red Color Chromaticity
Sheet Sign Study (South-TypeIV)
400
300
200
100
0
0
200
400
600
800

Appendix E

pennsylvania
DEPARTMENT OF TRANSPORTATION

Retroreflectivity of Existing Signs in Pennsylvania

FINAL REPORT

April 12, 2012

By McCormick Taylor, Inc.

McCormick Taylor
Engineers & Planners
Since 1946

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

FHWA-PA-2012-003-E01041-W09

DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-PA-2012-003-E01041-WO9		

4. Title and Subtitle	5. Report Date
Retroreflectivity of Existing Signs in Pennsylvania	April 2012
	6. Performing Organization Code N/A
7. Author(s) Kyle Clevenger, E.I.T Karen Colello, P.E., PTOE Jeannette Quirus, P.E., PTOE	**8. Performing Organization Report No.** 001
9. Performing Organization Name and Address McCormick Taylor, Inc. 2001 Market Street, 10th Floor Philadelphia, PA 19103	**10. Work Unit No. (TRAIS)**
	11. Contract or Grant No. E01041, Work Order 9
12. Sponsoring Agency Name and Address The Pennsylvania Department of Transportation Bureau of Planning and Research Commonwealth Keystone Building 400 North Street, 6th Floor Harrisburg, PA 17120-0064	**13. Type of Report and Period Covered** Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

N/A

16. Abstract

The Pennsylvania Department of Transportation (PennDOT) Bureau of Highway Safety and Traffic Engineering initiated this research effort in response to the release of the new 2009 Manual on Uniform Traffic Control Devices (MUTCD) which mandates that all states shall have a sign maintenance method designed to maintain traffic sign retroreflectivity at or above the established minimum levels in place by January 2012. The goal of this research effort was to collect and analyze sign retroreflectivity measurements on a subset of PennDOT owned and maintained signs throughout the Commonwealth of Pennsylvania in order to better understand the potential service life of signs with regard to nighttime visibility in Pennsylvania. As PennDOT implements its sign management system, with respect to compliance with the minimum retroreflectivity levels, the findings of this research will assist PennDOT in better determining when signs may need replaced. Retroreflectivity levels were measured on a sample of 1,000 traffic signs using a DELTA Light and Optics RetroSign 4500 retroreflectometer. In order to obtain regional variety, an equal portion of signs (one third in each county) were measured in Lackawanna, Lehigh and Lancaster counties to represent the northern, central and southern tiers of the state. The number of yellow warning signs, white regulatory signs, green directional signs and red Stop, Yield, Do Not Enter and Wrong Way signs to be measured was determined using the proportion of each sign color's overall population in the state. PennDOT's current standard specifications for reflective sheeting require the use of Type III or Type IV sheeting for post-mounted sign installations and the sign sheeting manufacturer warranties are typically 10 years; therefore the data collection efforts were limited to Type III signs aged 10 years or older. The study recommends an expected sign life of 15 years for yellow, white, red and green signs in Pennsylvania.

17. Key Words	18. Distribution Statement
Expected Sign Life Sign Retroreflectivity Sign Service Life Sign Management System	No restrictions. This document is available from the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	35	

Form DOT F 1700.7 **(8-72)** **Reproduction of completed page authorized**

Retroreflectivity of Existing Signs in Pennsylvania -
FINAL REPORT -

April 2012 -

Prepared for: -
Pennsylvania Department of Transportation -
Bureau of Highway Safety and Traffic Engineering -

Prepared By: -
Kyle Clevenger, E.I.T -
Karen Colello, P.E., PTOE -
Jeannette Quirus, P.E., PTOE -
McCormick Taylor, Inc. -

pennsylvania
DEPARTMENT OF TRANSPORTATION

McCormick Taylor
Engineers & Planners
Since 1946

ACKNOWLEDGMENTS -

The authors would like to express their appreciation to Mark Alexander, P.E., Manager, Sign Standards & Manufacturing and Kenneth Reuther, P.E., Senior Civil Engineer, of the Pennsylvania Department of Transportation Bureau of Highway Safety and Traffic Engineering for their help and cooperation in the conduct of this study and review of the report. The authors would also like to thank Michael Castellano, P.E. of Federal Highway Administration and Michael Bonini, Research Program Manager and Bonnie Fields, Program Analyst III, of the Pennsylvania Department of Transportation Bureau of Planning and Research for their support of this research project. And finally, the authors would like to thank the personnel of the other state Departments of Transportation who provided information on their sign management practices and the sign sheeting manufacturers who provided their product warranty information.

DISCLAIMER

This document is disseminated under the sponsorship of the Pennsylvania Department of Transportation Bureau of Highway Safety and Traffic Engineering in the interest of information exchange. The Commonwealth of Pennsylvania assumes no liability of its contents or the use thereof.

The contents of this report reflect the views of the authors, who are solely responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views of the Pennsylvania Department of Transportation.

The Commonwealth of Pennsylvania does not endorse products of manufacturers. Trademarks or manufacturer’s names appear herein only because they are considered essential to the object of this document.

This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS -

LIST OF TABLES

LIST OF FIGURES

Executive Summary

The 2009 release of the new Manual on Uniform Traffic Control Devices (MUTCD) mandates that all states shall have a sign maintenance method designed to maintain traffic sign retroreflectivity at or above the established minimum levels in place by January 2012. McCormick Taylor was retained by The Pennsylvania Department of Transportation (PennDOT) Bureau of Highway Safety and Traffic Engineering (BHSTE) to conduct a research study to better understand the potential service life of signs with regard to nighttime visibility. This report summarizes the study tasks which included a review of previous related studies, outreach to sign sheeting manufacturers for sign sheeting warranties and life expectancy information, outreach to the other 49 state Departments of Transportation to determine their sign management practices and policies and a field data collection effort and analysis on 1000 existing signs in Pennsylvania.

Retroreflectivity levels were measured on a sample of 1,000 traffic signs using a DELTA Light and Optics RetroSign 4500 retroreflectometer. In order to obtain regional variety, an equal portion of the signs (one third in each county) were measured in Lackawanna, Lehigh and Lancaster counties to represent the northern, central and southern tiers of the state. The number of yellow warning signs, white regulatory signs, green directional signs and red Stop, Yield, Do Not Enter and Wrong Way signs to be measured was determined using the proportion of each sign color's overall population in the state. PennDOT's current standard specifications for reflective sheeting require the use of Type III or Type IV sheeting for post-mounted sign installations and the sign sheeting manufacturer warranties are typically 10 years; therefore the data collection efforts were limited to Type III signs aged 10 years or older.

The data shows that the service life of traffic signs In Pennsylvania with regard to the FHWA minimum retroreflectivity levels is much greater than the manufacturer's warranty period. There were no distinguishable differences in the data from region to region. Similar to previous studies, the data analysis of this study did not show a strong correlation between retroreflectivity and age. However, given the large sample size of this study and the fact that of the 1,007 signs inspected, only 28 (2.8%) failed to meet minimum retroreflectivity requirements at an average age of 14.1 years old, we have a high degree of confidence that the service life of Type III sheeting in Pennsylvania is at least 15 years. Given the results of this study, an expected sign life of 15 years is recommended for yellow, white, green and red signs in Pennsylvania.

I. Introduction

The Pennsylvania Department of Transportation (PennDOT) Bureau of Highway Safety and Traffic Engineering initiated this research effort in response to the release of the new 2009 Manual on Uniform Traffic Control Devices (MUTCD) which mandates that all states shall have a sign maintenance method designed to maintain traffic sign retroreflectivity at or above the established minimum levels in place by January 2012. The 2009 MUTCD describes five different assessment or management methods that agencies should use to maintain their signs at the required levels. One method or a combination of methods can be used. The goal of this research effort was to collect and analyze sign retroreflectivity measurements on a subset of PennDOT owned and maintained signs throughout the Commonwealth of Pennsylvania in order to better understand the potential service life of signs with regard to nighttime visibility in Pennsylvania. As PennDOT implements its sign management system, with respect to compliance with the minimum retroreflectivity levels, the findings of this research will assist PennDOT in better determining when signs may need replaced.

The research efforts included a review of related literature and studies on sign service life, outreach to the other 49 states to determine the basis for their sign management systems, outreach to the two sign sheeting manufacturers that supply the majority of PennDOT's sign sheeting (Avery Dennison and 3M) and data collection and analysis of sign retroreflectivity measurements on a subset of PennDOT owned and maintained signs. PennDOT's current standard specifications for reflective sheeting require the use of Type III or Type IV sheeting for post-mounted sign installations and the sign sheeting manufacturer warranties are typically 10 years; therefore the data collection efforts were limited to Type III signs aged 10 years or older. These efforts are detailed in this report.

II. Background

A. Overview of Accepted Sign Assessment / Management Methods

The 2009 MUTCD and the supplemental 2007 FHWA Report *Maintaining Traffic Sign Retroreflectivity* describe five assessment / management methods that agencies should use to maintain sign retroreflectivity at the minimum required levels. One or more of the methods should be used (*1*). These methods are categorized as either assessment methods (Visual Nighttime Inspection and Measured Sign Retroreflectivity) or management methods (Expected Sign Life, Blanket Replacement and Control Signs). Assessment methods require evaluation of individual signs within an agency's jurisdiction and management methods provide an agency with the ability to maintain sign retroreflectivity without having to assess individual signs (*3*). The report *Sign Retroreflectivity: A Minnesota Toolkit* also provides detailed descriptions of the procedures, advantages and disadvantages of the five assessment / management methods.

1. Visual Nighttime Inspection

For this approach, trained inspectors visually assess the retroreflectivity of existing signs in the field from a moving vehicle at night. Signs that are identified to have retroreflectivity below the minimum levels should be replaced (*1, 3*).

There are three different procedures that can be used: calibration signs, comparison panels, or consistent parameters. In the calibration signs procedure, calibration signs at or above the minimum retroreflectivity level are viewed prior to inspection. During inspection, signs are evaluated in comparison with the calibration signs viewed earlier. For the comparison panel procedure, comparison panels are clipped to the sign under inspection and viewed by the inspector. For the consistent parameters procedure, inspectors follow 3 consistent parameters: inspections must be conducted during nighttime, using an SUV or pick-up truck model year 2000 or newer and the inspector must be at least 60 years old (*15*).

The advantages of this method are that factors other than sign reflectivity, such as damage or obstructions, can be assessed. Also, a sign inventory can be established as the inspector(s) drives around. This method reduces sign waste, thereby maximizing sign life. The disadvantages of this approach are that it is highly subjective and can be time consuming. Also, the inspectors need proper training and must work nighttime hours (*15*).

2. Measured Sign Retroreflectivity:

This approach involves manually measuring the retroreflectivity of sign using a retroreflectometer. Four measurements should be taken for each color on the sign and the measurement should then be averaged to obtain an overall measurement of the retroreflectivity of each color. Signs with retroreflectivity below the minimum levels should be replaced (*1, 3*).

The advantages of this approach are that it provides the most direct means of obtaining retroreflectiveness and removes all subjectivity inherent in visual inspection methods. The disadvantages of this approach are that retroreflectometers are expensive (approximately $10,000) and this approach can require a significant amount of time if every sign is to be measured. Few agencies implement this practice on all signs and use it more as a supplement to other methods (i.e.: measuring retroreflectivity of a sample set of signs as an assessment of their total inventory) (*15*).

3. Expected Sign Life:
For this approach, the installation date of every sign must be labeled or recorded when the sign is installed. The age of the sign is compared to the expected sign life which is based on the experience of sign retroreflectivity degradation in a geographical area compared to the minimum levels. Signs older than the expected sign life should be replaced (*1, 3*).

Some agencies put a sticker on the front or back of the sign indicating the installation date. Computerized sign management systems can be used to track the age of signs. For expected sign life, most agencies use the manufacturer's warranty period, although many agencies are beginning to extend their expected sign life based on new research. The advantages of this approach are that it is easy to identify aging signs. Also, the retroreflectivity of signs can be measured at the end of their expected life and findings can be used to adjust the expected sign life. The disadvantages of this approach are that little data is available on how different types of sheeting and colors deteriorate over time in a given climate and whether orientation affects the rate of deterioration. Basing sign life solely on age may result in removing signs before their service life is complete (*15*).

4. Blanket Replacement:
For this approach, all signs under either a spatial or strategic basis are removed and replaced at the same time, on the same schedule. For spatial basis, all signs in a given area or set of roads are replaced together; whereas for strategic basis, all signs of a specific type (regulatory, warning, guide, etc.) are replaced on the same schedule. The replacement interval is based on the expected sign life, compared to minimum levels, for the shortest-left material used on the affected signs (*1, 3*).

Of the agencies that use this method, most replace Type I signs every 7 to 10 years, Type III signs every 10 to 15 years, and Types VI, VII, and IX signs every 15 years. (Type III sheeting is most common). The advantages of this approach are that it is a very simple method that does not require knowledge or tracking of sign age or retroreflectivity. It is only necessary to record when the blanket actions were undertaken and when they need to be repeated. This method also ensures that signs will not be skipped or overlooked. The disadvantages are that signs may be wasted by removing them prior to the end of their service life, especially with the first replacement schedule and in locations where signs have been added or replaced after the last replacement cycle. Replacement times can vary depending on the type of sheeting, color, etc (*15*).

5. Control Signs:
For this approach, when new signs are installed, control signs are designated and monitored either in the field or in a maintenance yard and act as a sample of the whole population of signs. Retroreflectivity is measured on the control signs to determine the condition of the rest of the population. A minimum of 3 signs per type of sheeting and color should be monitored (*15*).

The advantage if this approach is that it is not as labor intensive as testing or inspecting each individual sign. Signs that may be past their warranty or expected service lives but still meet minimum retroreflectivity levels are not prematurely removed (as in the blanket replacement or service life methods). The disadvantage of this approach is that there is no specific guidance on the proper sample size for more reliable results. There is also no guidance on how often a new set of control signs should be established or how often the control signs should be checked for retroreflectivity (*15).*

B. Previous Studies

As part of the research efforts, several recent research papers on sign sheeting retroreflectivity and deterioration were reviewed. Table 1 on the next page provides a brief description of the papers reviewed. A more detailed summary of each paper is provided in the section that follows Table 1.

Table 1: Literature Review Summary

#	Title and Author	Date	Summary
1	*Sign Retroreflectivity - A Minnesota Toolkit (Report # 2010RIC02)* Marti and Kuehl	June 2010	Toolkit for local governments with guidance on FHWA's sign retroreflectivity requirements and resources including sample sign management programs and replacement schedules that can be used to meet the compliance deadlines.
2	*An Analysis of In-Service Traffic Sign Retroreflectivity and Deterioration Rates in Texas (Report # TRB 11-2542)* TTI - Re, Miles and Carlson	March 2011	TTI study to identify factors that significantly affect sign retroreflectivity, generate sign deterioration rates and service life projections and determine the usefulness of the models and estimates. Data collected on 859 signs in seven different regions of Texas, in a variety of locations and climates.
3	*Analysis of Retroreflectivity and Color Degradation in Sign Sheeting (Report # TRB 11-2148)* TTI - Brimley, Hawkins, and Carlson	November 2011	TTI study evaluated durability of retroreflective sign sheeting. Nine different materials tested on outdoor weathering racks for over 10 years real time with a 2:1 accelerated degradation rate to simulate over 20 years of service. Researchers evaluated failure of sign sheeting in terms of: retroreflectivity, chromaticity, luminosity and surface defects.
4	*Analysis of Traffic Sign Asset Management Scenarios* NCSU - Hummer, Rasdorf, Immanemi, Harris and Yoem	TRB 2007 Annual Meeting (June 2005)	Study evaluated traffic sign asset management practices in North Carolina and developed a simulation model that any DOT can use to evaluate up to 30 different sign asset management scenarios in terms of annual maintenance cost per sign and percent of signs not compliant with FHWA standards.
5	*Synthesis of Sign Deterioration Rates Across the US* Hummer, Rasdorf, Immanemi, Harris and Yoem	N/A	NCSU Study developed one component of the NCDOT simulation model: retroreflectivity deterioration rates for different colors and types of sheeting. Researchers combined data from five previous studies to produce new best-fit retroreflectivity versus age Curves.
6	*New Standards, New Signs: Determining Sign Performance Under Controlled Conditions* Hummer, Rasdorf, Immanemi and Harris	IMSA Journal Jan/Feb 2008	Article about the development of an experimental sign retroreflectivity measurement facility (ESRMF) for the North Carolina Department of Transportation to achieve a better understanding of Type III and IX long-term sign deterioration.
7	*Tapping into the Power of a Traffic Sign Inventory to Meet the New Retroreflectivity Requirements* Ellison	ITE 2008 Annual Mtg & Exhibit (April 2007)	Pierce County, WA study assessed retroreflectivity of their existing signs. The county's existing sign inventory was used to identify the oldest signs in service. Retroreflectometer readings were taken on a subset of these signs (3 readings per each color per sign and averaged) and results analyzed.
8	*Comparison of Observed Retroreflectivity Values with Proposed FHWA Minimums (Report # TRB 02-2502)* Purdue University - Nuber and Bullock	N/A	Indiana DOT study measured retroreflectivity of 10 or 11 year old signs in Indiana using a retroreflectometer. Data used to create histograms showing relative frequency of signs measured at given retroreflectivity compared to FHWA minimums. Charts of retroreflectivity vs. time for different colors and types of signs with linear trend lines and r-squared values were developed.
9	*Factors Affecting Sign Retroreflectivity - Final Report - SR 514 (Report # OR-RD-01-09)* OregonDOT - Kirk, Hunt and Brooks	January 2001	Oregon DOT study investigated factors that may affect sign retroreflectivity to assist in development of appropriate sign replacement schedules. Readings collected on red, yellow, green and white high intensity (Type III) signs. Ten readings taken per sign on background only (not legend). Signs washed and dried prior to measurements. Age and physical orientation recorded for each sign.
10	*Maintaining Traffic Sign Retroreflectivity: Impacts on State and Local Agencies (Report # FHWA HRDS-05)* Opiela and Andersen	April 2007	FHWA report focuses on negative impacts of new retroreflectivity requirements and concerns of participants at the 2002 FHWA Sign Workshops. Provides overview of how new requirements will affect agencies in terms of sign cost and upgrading sign sheeting to from Type I to Type III or higher.

1) Sign Retroreflectivity – A Minnesota Toolkit

The Minnesota Local Road Research Board (LRRB) developed a toolkit in March 2010 to provide local governments with guidance on FHWA's sign retroreflectivity requirements as well as resources that can be used to meet the compliance deadlines. The toolkit focuses on the January 2012 deadline requiring all agencies to establish a sign assessment or management method. The authors strongly recommend creating a sign inventory as part of the process of establishing a sign assessment / management method to increase maintenance efficiency in the future. The toolkit contains: sample letters to be sent to small local agencies that maintain their own signs, information on Minnesota's requirements, a summary of FHWA guides and resources, sign inventory examples, sign assessment / management examples and sample sign management agreement documents.

One sample management program for local governments uses nighttime visual inspection to rate signs as either fail, marginal, or adequate. Once signs are replaced, their installation dates are recorded and the Expected Sign Life method is used to maintain minimum retro levels. A basic replacement schedule is included:

- Engineer Grade (Type I) Sheeting – 8 year interval
- High Intensity Beaded (Type III) – 10 year interval
- Prismatic Sheeting – 12 year interval

The report includes an additional "Generic Rural County" Maintenance Procedure that also uses the nighttime visual inspection and sign life strategies with the following replacement schedule:

- Engineering Grade – 8 years
- HI or HIP
  - 10 Years (South facing)
  - 11 Years (East/West Facing)
  - 12 Years (North Facing)
- VIP or DG3
  - 13 Years (South facing)
  - 14 Years (East/West Facing)
  - 15 Years (North Facing)
- E-911 (HIP) - 12 Years
- E-911 (DG#) - 15 Years

2) An Analysis of In-Service Traffic Sign Retroreflectivity and Deterioration Rates in Texas

The Texas Transportation Institute (TTI) undertook a study in 2009 to assess the compliance of Type III signs throughout the state with the federal retroreflectivity requirements and to generate useful data that could benefit sign maintenance practices. The researchers sought to identify the factors that significantly affect sign retroreflectivity, generate sign deterioration rates and service life projections and determine the usefulness of the models and estimates.

The study began with a review of four previous studies: 1992 FHWA study, 2002 Louisiana Department of Transportation and Development (LDOTD) study, 2002 Purdue University Study and a 2006 North Carolina State Department of Transportation (NCDOT) Study. The findings of these studies were consistent: sign sheeting was often found to meet the minimum retroreflectivity requirements longer than the manufacturer's warranty of 10 years and the study data showed poor correlation of various variables with prediction models.

The data collection efforts for the TTI study encompassed collecting 859 samples in seven different regions in Texas. A variety of location and climates were chosen. Researchers reasoned that if sign performance was adequately addressed in regions with harsh or intense conditions, then signs in other regions should be performing at a similar or better level. The researchers classified signs into 5 different categories based on ASTM and material type. The researchers did not wash any signs and they recorded daytime visual condition as good, adequate, or poor. The study found that overall sign compliance rate was 99% for Type III signs and the observed likelihood of failure was 2% for signs 10-12 years old and 8% for signs 12-15 years old. Linear predictive models revealed differences in deterioration rates among regions; however, the models exhibited poor correlation between predicted and measured data. ANOVA (analysis of variance) models, which identify what factors may influence a given data set, showed that visual condition and sign orientation are not good indicators for reflectivity, but sign age and regional differences were relevant factors. The study concluded that deterioration rates and prediction models can be valuable components to a comprehensive sign maintenance program – but they do not by themselves ensure sign retroreflectivity compliance. Also, the 12-year service life may provide a basic and conservative estimation, but it is beneficial to implement robust maintenance practices and periodic nighttime visual inspection to replace non-compliant signs.

3) Analysis of Retroreflectivity and Color Degradation in Sign Sheeting

Another study was initiated at TTI in 1999 and concluded in 2010 to evaluate the durability of retroreflective sign sheeting materials. Nine different materials were tested on outdoor weathering racks for over 10 years in real time with a 2:1 accelerated degradation rate to simulate more than 20 years of service. The researchers evaluated the failure of the sign sheeting in terms of four criteria: retroreflectivity, chromaticity, luminosity and surface defects. With regard to retroreflectivity alone, each material was found to last as long as its warranty. The report concluded that there were many limitations in this “unfunded and limited attempt to assess the long-term performance of retroreflective sign sheeting” and that “a more thorough effort is needed.”

4) Analysis of Traffic Sign Asset Management Scenarios

This study, submitted to the 2007 TRB Annual Meeting, evaluated traffic sign asset management practices in North Carolina and developed a simulation model that any DOT can use to evaluate up to 30 different sign asset management scenarios in terms of annual maintenance cost per sign and percent of traffic signs not compliant with the FHWA standards. The parameters for the model are: Maintenance Strategy (all of them except for control sign method), Rejection Threshold (certain retroreflectivity level or age), Rate of Conversion of Type I to Type III signs as they are replaced, and Inspection Frequency. Maintenance costs were developed as a function of inspection frequency and average sheeting cost. For each inspection there is a labor and materials cost that varies based on inspection method. For example, an inspection cost of $0.55 per sign was determined for the visual nighttime inspection method, while the manually measured retroreflectivity method yielded a cost of $2.80 per sign due to high equipment costs and the additional time it takes to stop and manually inspect each sign.

The analysis found that the methods that are most expensive (blanket replacement, expected sign life, and manual measurement) result in less non-compliant signs, while the sign inspection methods can be much cheaper but result in a higher rate of non-compliant signs. Other DOT's can use this model by adjusting the parameters based on their own current practice or proposed plan.

5) Synthesis of Sign Deterioration Rates Across the US

North Carolina State University (NCSU) conducted this study in response to the addition of federal minimum retroreflectivity requirements in the 2003 MUTCD. The purpose of the study was to determine deterioration rates for sign retroreflectivity to assist the North Carolina Department of Transportation (NCDOT) with their sign management program. The study consisted of a review of five previous studies and a data collection effort of over 1000 signs in North Carolina. The researchers first analyzed the results of five previous retroreflectivity studies (1991 FHWA Study, 2001 State of Oregon Study, 2002 Louisiana State Study, 2002 Purdue University Study, 2006 North Carolina State University Study and an ongoing AASHTO Study). The researchers then took the raw data from the Purdue and Oregon studies as well as the raw data from the NCSU data collection effort and analyzed the data using the five different regression types (linear, polynomial, logarithmic, exponential and power) to determine the best-fit curve for retroreflectivity versus age, or in other words, the best predictive model for deterioration of sign retroreflectivity.

The study found that the linear regression model was the best-fit curve for retroreflectivity versus age based on R-squared for all of the seven sign color / sheeting combinations except for one. However, the R-squared values in the data analysis show a low correlation between retroreflectivity versus age for both the NCSU-collected data and the data from the previous studies and the study states that the standard errors in the data analysis are not as low as the researchers would like. The study states that the research was limited to sign age because it was considered by the researchers to be the most important factor. The researchers conclude that the study results likely mean that factors other than age influence the rate at which sign retroreflectivity deteriorates. The researchers state that these factors include measurement error, reflectometer error and uncontrolled field conditions and that while the effect of each of these factors on their own may be low, it is the combination of all of these factors which cause the scatter in the data.

6) *New Standards, New Signs: Determining Sign Performance Under Controlled Conditions*
This 2008 article is about the development of an experimental sign retroreflectivity measurement facility (ESRMF) for the North Carolina Department of Transportation to achieve a better understanding of Type III and IX long-term sign deterioration. The article mentions five uncontrolled sign deterioration studies (the same FHWA, Oregon, LSU, Purdue and NCSU studies mentioned above) and concludes that these studies focused on Type I signs and had trouble creating well-defined deterioration models. Further, the previous studies found very few Type III signs in the field older than 15 years and could only make limited conclusions about how these signs deteriorate, which is why ESRMF's should be established to obtain data on the new sheeting types for the future.

7) Tapping into the Power of a Traffic Sign Inventory to Meet the New Retroreflectivity Requirements
The Peirce County Traffic Division, Pierce County, Washington initiated this study in 2007 to assess their existing signs using the recommended federal minimum retroreflectivity levels. The study evaluated the five sign assessment / management methods described in the MUTCD. The county had an established sign inventory system which was used as a starting point for the study. A query was run using the sign inventory to identify the oldest signs still in service. A subset of the oldest sign group of each color (the control group) was identified for retroreflectivity measurements. Retroreflectometer readings were taken on the control group (3 readings per each color on a sign and averaged) and the results were analyzed.

The researchers found that all of the 10-12 year old Type III High Intensity signs were still well above the minimum MUTCD levels. The County selected a sign assessment / management method that uses elements of Measured Retroreflectivity, Expected Sign Life and primarily the Control Signs method. The researchers concluded that using a sign inventory as a foundation in combination with one or more of the five recommended maintenance methods works effectively with a minimal amount of additional workload or system administration. In addition, the study noted that placing date-stamped serial numbers on all new signs will assist in identifying signs and their age in the future.

8) Comparison of Observed Retroreflectivity Values with Proposed FHWA Minimums
This paper details the research efforts undertaken by the Indiana Department of Transportation in 2001 to compare measured retroreflectivity on existing signs in Indiana with the FHWA minimum retroreflectivity requirements. For the data collection efforts, the researchers took samples from 10 or 11 year old signs using a retroreflectometer set at +0.2 degree observation angle and a -4 degree entrance angle. The data was entered into a database to run queries and create histograms showing the relative frequency of signs measured at given retroreflectivity and how these values compare to the FHWA minimums. The data was also used to make charts of retroreflectivity vs. time for different colors and types of signs for which linear trend lines and their r-squared values were produced. The study found that only 4% of the 10 or 11 year old signs tested were below the absolute minimum for any sign. The researchers concluded that FHWA minimums on retroreflectivity should be simplified to one minimum for each color of sheeting.

9) Factors Affecting Sign Retroreflectivity – Final Report – SR 514

The purpose of this 2001 study was to investigate factors that may affect sign retroreflectivity, in order to develop criteria for appropriate sign replacement schedules for the Oregon Department of Transportation. The research methods included collecting readings on 80 high intensity (Type III) signs – 20 each of red, yellow, green and white signs. Ten readings were taken per sign, on the background only (not on the legend). The signs were washed and dried prior to taking measurements. The age and physical orientation (east, west, north, south) were recorded for each sign. An additional 57 signs were tested after the researchers determined the sample size was not large enough.

The study found that there is no clear relationship between sign retroreflectivity and age, nor is there any strong trend between the physical orientation of signs and their retroreflectivity. West and south facing signs were found to have more retroreflectivity variability, but gradation in the average levels was not as evident. The study recommended that sign locations, installation dates and orientations should be recorded on the back of sign and in the Oregon DOT sign database and that maintenance departments should invest in a retroreflectometer to collect readings from new signs and track them periodically for future analysis.

10) Maintaining Traffic Sign Retroreflectivity: Impacts on State and Local Agencies

This FHWA report focuses on the negative impacts of the new retroreflectivity requirements and the concerns brought up by participants at the FHWA Sign Workshops in 2002. It provides an overview of how the new requirements will affect agencies in terms of sign cost and upgrading sign sheeting to from Type I to Type III or higher. The report details the elements of sign costs and the factors affecting these costs, as well as the cost and factors for sign management processes. Previous studies done by TexasDOT, Indiana DOT, and North Carolina DOT are briefly reviewed. The negative impacts discussed include:

- Administrative Impacts – additional personnel, training, sign documentation
- Fiscal Impacts – increased replacement rates, training staff and paying overtime for nighttime inspections, cost of evaluation equipment/software, etc
- Implementation Impacts – The cost and effort of implementing these practices may be too much of a burden for some agencies
- Tort Impacts – How the new MUTCD requirements can affect agency's tort liability

C. Information Obtained from Other States

As part of the background research, researchers contacted the AASHTO Traffic Engineering Subcommittee members from the other 49 states to determine what type of sign management programs their states are using. The states were asked the following 4 questions:

1) Are you using the expected sign life approach, blanket approach, control signs approach or an assessment method?
2) If you are using the expected sign life approach, are you using the manufacturer's warranty (typically 10 years for Type III sheeting material) or other values?
3) If you are using other values, what research if any is that based on?
4) Are there any other criteria you consider critical in addition to sign age (i.e. orientation, type of sheeting, etc.)?

Overall, 27 of the 49 states responded (55%). Of those 27 states, 13 states plan on utilizing the expected sign life approach for their sign management / replacement policy. Five of the 12 states that are using the expected sign life method are coupling it with the blanket replacement approach in order to get specific corridors on the same replacement schedules. The states using the expected sign life method include:

- Delaware
- Indiana*
- Kentucky
- Louisiana
- Maine
- Michigan
- Mississippi*
- New York*
- Ohio*
- South Dakota
- Vermont
- Virginia
- Wisconsin*

*Coupling with blanket replacement method

Most states are using past experience and previously published research papers for the basis of the expected sign life they employ. However, a few of the states that responded have either conducted their own research or are planning to and this information is discussed below. A summary of the information received from all states that responded can be found in the Appendix.

Indiana

The Indiana Department of Transportation (INDOT) uses a combination of methods, typically expected sign life, but they are trying to get their sheet signs in a corridor on the same cycle. They have conducted field studies to establish an 18 year expected life for Type III and higher sign sheeting. Their field study looked at different colors in different orientations. The study found that Type III sheeting exceeded the MUTCD minimums at 18 years. Type I sheeting will not and is nearly phased out. INDOT switched to minimum Type IV sheeting two years ago. INDOT indicated that there is currently limited data available on Type IV sheeting and that they will likely extend their 18 year age in the future, as Type III signs are phased out.

INDOT provided the 2010 study they conducted to determine if they could extend their previous 14 year replacement schedule. The study collected retroreflectivity and color measurements from signs of various colors, ages and locations. A total of 211 ground-mounted signs were tested from northern and southern Indiana with a minimum of 36 of each color (yellow, white, green and red sheeting) and at least 72 signs facing north and 72 facing south. 42 signs (20%) were between 10-12 years old, 154 signs (73%) were between 13 and 16 years old, and 15 signs (7%) were over 16 years of age. The study's findings show that most signs exceeded the minimum retroreflectivity levels. All green signs passed inspection while 4% of red signs, 4% of white signs and 12% of yellow signs failed to meet minimum requirements. Based on these findings, INDOT proposed a life cycle for sheet signs at 18 years and plans to conduct a follow up study in the next four years.

Vermont

The Vermont Department of Transportation is using a combination of methods. For their smaller signs (<= 20 sq ft) they use an expected sign life cycle of 15 years based on a research study conducted by their Materials & Research section. For their larger signs, they are considering using a control group of signs to determine the replacement cycle. At this time, they have yet to finalize the method and specifics for accomplishing that task.

Vermont DOT provided a link to the research study they conducted on sign retroreflectivity. Similar to the PennDOT study, retroreflectivity was measured as a function of time in the Vermont study, but data correlation was completed with consideration to additional variables such as sheeting type, manufacturer, roadway type, orientation, condition and region. When performing the statistical analysis of the data, researchers found that none of those variables correlated to retroreflectivity levels, except for sheeting manufacturer. They found that Avery-Dennison sheeting outperformed 3M sheeting, although noted that a cluster of highly reflective Avery-Dennsion signs may not be representative due to their close proximity to one another. The sample size of Avery-Dennison signs was much smaller than that of 3M signs as well.

The study sample size consisted of 618 total signs, which included red, green, yellow and white Type III sheeting, ranging in age from 7 to 12.5 years, and yellow and yellow-green Type IX sheeting ranging in age between 5.4 to 6.4 years. Given the best fit trend lines and predicted retroreflectivity over time, the study recommended a life cycle of 15 years for red sheeting and noted that 15-20 years may be reasonable for green, white and yellow sheeting. Of the 618 signs tested, all exceeded minimum retroreflectivity levels. The study recommended additional data collection on the sample population in approximately five to seven years once the signs have experienced further deterioration, to paint a better picture of long term service life.

Virginia

The Virginia Department of Transportation (VDOT) is evaluating in-house sheeting samples after extended accelerated weathering. VDOT is moving forward with the expected sign life methodology in combination with spot audits of visual nighttime inspection. VDOT believes that following the manufacturer's warranty may result in premature replacement of signs and has established an initial assumption for expected life is a 15-year life cycle. They are considering doing their own testing and verification through sampling to establish the typical extended retroreflectivity life span of the sheeting material. They will be evaluating in-house sheeting samples after extended accelerated weathering (3 + years). Some of the criteria other than age that Virginia DOT may utilize in the management plan include: roadway classification and speed, sign type, sheeting type, life cycle, orientation, contrast ratio and road segment crash history.

Wisconsin

The Wisconsin department of Transportation (WisDOT) is utilizing both the expected sign life method and blanket replacement method. The blanket replacement method is utilized on roadway construction/improvement projects on which they normally include all sign replacements as part of the project. For the expected sign life method, WisDOT utilizes a 12 year replacement cycle which is currently based on their experience of utilizing the Type III sheeting. In order to make their policy more objective, WisDOT has established a control signs test deck at their central sign shop in Madison, which is also one of the approved MUTCD assessment/management method. The goal of the test deck is to provide support to their replacement criteria. As time progresses, the 12 year criteria may change. They are also evaluating the ASTM Types III, IV, IX and XI on the signing test deck with different colors. They are planning to begin evaluating the deterioration of colors and will factor that into their sign replacement criteria. All signs on their test evaluation deck face south to get the maximum sunlight and UV rays. At this time, their replacement criteria are based on south facing signs.

Ohio / Oklahoma

The Ohio Department of Transportation (ODOT) did not conduct their own study, but used a study conducted by the Oklahoma Department of Transportation as the basis for their replacement interval and shared that study information with us. ODOT currently uses the blanket replacement method, which is described in Section 260-5 of the ODOT Traffic Engineering Manual. They initiated their program in 2001 in anticipation of the upcoming federal requirements and recognition of the value of highly reflective signs to the motoring public. They use ASTM D 4956 Type III sheeting or higher (Type VII or higher for reflective legends on overhead signs), and a 15 year replacement interval. The 15 year replacement interval is based on a 1994 Oklahoma Department of Transportation study (Report number FHWA/OK 95(02)). ODOT provided page 60 of the report, which concludes an average service life of 15 years for Type IIIA sheeting based on data obtained from Oregon DOT divisions, sheeting manufacturers, and published literature. The study found that the application of regression equations resulted in very long service lives due to the shortcomings of the predictive equations.

D. Information Obtained from Sign Sheeting Manufacturers

As part of the background information review for this paper, the two sign sheeting manufacturers that supply PennDOT with the majority of their sign sheeting, Avery Dennison and 3M, were contacted to discuss their sign sheeting warranties. Both manufactures warranty their ASTM Type III and IV sign sheeting (white, yellow, red, green and blue colors) for 10 years. It should be noted that the product bulletins for both manufacturers indicate that the reflectivity measurements are to be taken after sign cleaning.

Avery Dennison

Avery Dennison provided the product bulletins for the T-6000 and W-6000 HIP Series High Intensity Microprismatic Retroreflective Film, which meets the specifications of ASTM D4956 Type III and IV sign sheeting. Both product types have warranties for 10 years (for white, yellow, red, green and blue colors) and 3 years (for orange), subject to the provisions in the warranty.

Avery Dennison provided additional information regarding the basis of their product warranties.

- Avery Dennison's testing is based on a comparison against known product durability and performance, and not against expected sign life.
- They commonly conduct forty five degree, south facing, outdoor weathering to anticipate the degradation patterns of their materials, but they have not invested in a broader project to categorize the failure modes for all sign installations.
- The durability testing models the worst case constructions, installations and weather, which are far harsher than what is expected expect in the majority of installations.
- Their product warranties are not designed to approximate the life of their products, but instead they are intended to guarantee that their products are manufactured appropriately for the safety installation for which they are intended.
- The warranties protect public agencies against manufacturing defect, but the goal is to create products that far outlast the warranty period.

3M

3M provided the product bulletins of their High Intensity Prismatic Reflective Sheeting Series 3930 (white, yellow, red, green, and blue colors) which meets the specifications of ASTM Type III and Type IV Sign Sheeting. 3M's High Intensity Prismatic Reflective Sheeting Series 3930 has a ten year warranty to remain effective for its intended use and meet the stated minimum values for coefficient of retroreflectivity subject to the provisions of the warranty.

III. Research

A. Field Research Methodology

The methodology employed for this study's data collection was measuring sign retroreflectivity. The procedure involved manually measuring the retroreflectivity of signs using a DELTA Light and Optics RetroSign 4500 Retroreflectometer, which the researchers borrowed from PennDOT BHSTE. The advantages of this methodology are that it provides the most direct means of obtaining retroreflectiveness and removes all subjectivity inherent in visual inspection methods. The field work was conducted from September 2011 to December 2011. Signs were not cleaned or wiped before the retroreflectivity measurements were taken. Three retroreflectivity measurements were taken for each color on the sign and were averaged to obtain an overall measurement of the retroreflectivity of each color on the sign.

The retroreflectivity of post-mounted yellow warning signs, white regulatory signs, green guide signs and red stop or yield signs was measured for this study. Because most sign sheeting manufacturers warranty their sign sheeting for 10 years, signs older than 10 years were selected for this study. A total sample size of 1000 signs 10 years of age or older was the goal. The sample size included a geographical representation of signs from the northern, central and southern tiers of Pennsylvania and included both silk screened and cutout legend signs. Signs in Lackawanna County (District 4-0) were used to represent the northern tier; signs in Lehigh County (District 5-0) were used to represent the central tier and signs in Lancaster County (District 8-0) were used to represent the southern tier.

B. Overview of Study Sign Selection Method

PennDOT has an existing SAP sign database which lists every state maintained sign installed on state-owned routes for every county in the Commonwealth. This database includes the nomenclature and sign description, installation date, sign dimensions, post type, as well as detailed sign location information including the route number, segment and offset, latitude and longitude coordinates, direction that the sign faces along the route (either ascending or descending along the route) and side of road the sign is located on. For this study, PennDOT personnel queried the signs in each of the three counties selected for the data collection efforts (Lackawanna, Lehigh and Lancaster counties) in their database and provided a spreadsheet for each county to the researchers. First, researchers removed all blue informational signs, township name signs, route markers and their plaques from the query results and then removed all signs with installation dates less than 10 years old resulting in a list of signs that meet our initial criteria.

Next, using GIS, the remaining data in the three spreadsheets were graphically placed on maps to illustrate the white, yellow, red and green sign locations by color throughout each county. From these figures, it quickly became clear that the quantity of red and green signs is much less than the quantity of yellow and white signs along PennDOT-owned routes; therefore, the red and green sign locations controlled the data collection route selection. The PennDOT Video Log was used to select corridors with ample shoulder room and favorable geometry and terrain for researchers to safely conduct the sign retroreflectivity measurements in the field.

In each of the spreadsheets, the researchers arranged the sign location data for each route in order of segment and offset in the direction of travel to simplify the field data collection process. Approximately 500 signs were included on each county list, anticipating that some signs would be skipped due to physical constraints of collecting the field data. The goal was to collect the retroreflectivity measurement on 333 signs in each district (334 in District 8-0) to total 1,000 signs for this study. **Table 2** below shows the sample size calculation for each sign color per county.

Table 2: Planned Sample Size Distribution Per County

Sign Type	PA State Total		Per County	
	# of Signs	% of Total	# of Signs	% of Total
Red Signs*	107,648	17.4%	58	17.4%
Green Directional Signs	21,269	3.4%	11	3.4%
White Regulatory Signs	222,224	36%	120	36%
Yellow Warning Signs	266,679	43.2%	144	43.2%
Total	617,820	100%	333	100%

*Red signs include Stop (R1-1), Yield (R1-2), Do Not Enter (R5-1), and Wrong Way (R5-1A) -

C. Data Analysis

Below are summary tables of the collected field data for each sign color measured. The tables show the sample size, average (mean) age of signs measured, average (mean) retroreflectivity measured and the percentage of signs measured that did not meet the MUTCD established minimum retroreflectivity levels. For each color, these results are reported first for each county and then for the three counties combined. Table 2A-3 from the MUTCD which contains the federal minimum retroreflectivity levels is included directly below for reference.

Table 3: MUTCD Table 2A-3 Minimum Maintained Retroreflectivity Levels

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			Post-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/m^2 measured at an observation angle of 0.2° and an entrance angle of -4.0°.
[2] For text and fine symbol signs measuring at least 48 inches and for all sizes of bold symbol signs
[3] For text and fine symbol signs measuring less than 48 inches
[4] Minimum sign contrast ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity)
* This sheeting type shall not be used for this color for this application.

Bold Symbol Signs

- W1-1,2 – Turn and Curve
- W1-3,4 – Reverse Turn and Curve
- W1-5 – Winding Road
- W1-6,7 – Large Arrow
- W1-8 – Chevron
- W1-10 – Intersection in Curve
- W1-11 – Hairpin Curve
- W1-15 – 270 Degree Loop
- W2-1 – Cross Road
- W2-2,3 – Side Road
- W2-4,5 – T and Y Intersection
- W2-6 – Circular Intersection
- W2-7,8 – Double Side Roads
- W3-1 – Stop Ahead
- W3-2 – Yield Ahead
- W3-3 – Signal Ahead
- W4-1 – Merge
- W4-2 – Lane Ends
- W4-3 – Added Lane
- W4-5 – Entering Roadway Merge
- W4-6 – Entering Roadway Added Lane
- W6-1,2 – Divided Highway Begins and Ends
- W6-3 – Two-Way Traffic
- W10-1,2,3,4,11,12 – Grade Crossing Advance Warning
- W11-2 – Pedestrian Crossing
- W11-3,4,16-22 – Large Animals
- W11-5 – Farm Equipment
- W11-6 – Snowmobile Crossing
- W11-7 – Equestrian Crossing
- W11-8 – Fire Station
- W11-10 – Truck Crossing
- W12-1 – Double Arrow
- W16-5P,6P,7P – Pointing Arrow Plaques
- W20-7 – Flagger
- W21-1 – Worker

Fine Symbol Signs (symbol signs not listed as bold symbol signs)

Special Cases

- W3-1 – Stop Ahead: Red retroreflectivity ≥ 7
- W3-2 – Yield Ahead: Red retroreflectivity ≥ 7; White retroreflectivity ≥ 35
- W3-3 – Signal Ahead: Red retroreflectivity ≥ 7; Green retroreflectivity ≥ 7
- W3-5 – Speed Reduction: White retroreflectivity ≥ 50
- For non-diamond shaped signs, such as W14-3 (No Passing Zone), W4-4P (Cross Traffic Does Not Stop), or W13-1P,2,3,6,7 (Speed Advisory Plaques), use the largest sign dimension to determine the proper minimum retroreflectivity level.

White Signs:

Minimum Maintained Traffic Sign Retroreflectivity Levels for Black on White signs = W ≥ 50 cd/lx/m² *(1)*

Table 4: White Sign Data

WHITE SIGN DATA					
	Planned Sample Size	Actual Sample Size	Mean Age	Mean White R*	% Non-Compliant
Lackawanna	120	125	13.1	337.1	0
Lehigh	120	122	13.5	353.8	0
Lancaster	120	121	15.1	245.6	0
Total	360	368	13.9	312.8	0

* R = Reflectivity (cd/lx/m²)

All of the white signs studied were found to be well over the minimum retroreflectivity level. Out of 368 signs tested, the lowest average retroreflectivity level was 109 cd/lx/m²)for a seventeen year old sign compared to the MUTCD required minimum of 50 cd/lx/m²).

Yellow Signs

Minimum Maintained Traffic Sign Retroreflectivity Levels for Black on Yellow signs for all sizes of bold symbol signs and text and fine symbol signs measuring at least 48" = W ≥ 50 cd/lx/m² *(1)*

Minimum Maintained Traffic Sign Retroreflectivity Levels for Black on Yellow signs for text and fine symbol signs measuring less than 48" = W ≥ 75 cd/lx/m² *(1)*

Table 5: Yellow Sign Data

YELLOW SIGN DATA					
	Planned Sample Size	Actual Sample Size	Mean Age	Mean Yellow R*	% Non-Compliant
Lackawanna	144	149	13.1	287.4	2
Lehigh	144	145	15.6	204.6	7.5
Lancaster	144	147	14.8	196.5	4.7
Total	432	441	14.5	229.7	4.8

* R = Reflectivity (cd/lx/m²)

95.2 % of the total yellow signs were well above the MUTCD minimum retroreflectivity level of 50 cd/lx/m² with a mean retroreflectivity level of 229.7 cd/lx/m². The remaining 4.8% of yellow signs that did not meet the minimum levels are detailed below.

- Lackawanna County: 3 out of 149 (2%) yellow signs tested did not meet minimum retroreflectivity levels. The 3 signs that failed were 18, 19 and 26 years old.

- <u>Lehigh County:</u> 11 out of 145 (7.5%) yellow signs tested did not meet minimum retroreflectivity levels. The 11 signs that failed were 16, 17(5 signs), 19(2 signs), 24(2 signs) and 28 years old.

- <u>Lancaster County:</u> 7 out of 147 (4.7%) yellow signs tested did not meet minimum retroreflectivity levels. The 7 signs that failed were 14, 15, 16, 17(3 signs) and 22 years old.

<u>Red Signs</u>

Minimum Maintained Traffic Sign Retroreflectivity Levels for White on Red signs = W ≥ 35 cd/lx/m² and R ≥ 7 cd/lx/m², with a Minimum Sign Contrast Ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity) *(1)*

Table 6: Red Sign Data

RED SIGN DATA							
	Planned Sample Size	Actual Sample Size	Mean Age	Mean Red R*	Mean White R*	Mean Contrast Ratio	% Non-Compliant
Lackawanna	58	61	12.8	37.3	343.6	29.3	8.2
Lehigh	58	66	14.6	34	302.7	9.9	0
Lancaster	58	58	13.1	46.4	340.6	8.9	3.4
Total	174	185	13.5	38.8	328.1		3.8

* R = Reflectivity (cd/lx/m²)

96.2 % of the total red signs were above but close to the MUTCD minimum retroreflectivity value of 35 cd/lx/m² with a mean retroreflectivity of 38.8 cd/lx/m². The remaining 3.8% of red signs that did not meet the minimum levels are detailed below.

- <u>Lackawanna County:</u> 5 of the 61 (8.2%) red signs tested did not meet minimum retroreflectivity levels for red (R ≥ 7). All 5 of these signs were 13 years old and were located at the same interchange, which suggests that these signs are not indicative of the rest of the population.

- <u>Lehigh County:</u> All 66 red signs collected exceed the minimum retroreflectivity levels.

- <u>Lancaster County:</u> 2 of the 58 (3.4%) red signs tested did not meet minimum standards. One 14 year old sign did not meet minimum retroreflectivity levels for red (R ≥ 7), while one 10 year old sign failed for white-to-red contrast ratio (W:R ≥ 3:1) after an abnormally high average red retroreflectivity reading of 183.

Green Signs

Minimum Maintained Traffic Sign Retroreflectivity Levels for White on Green signs for ground-mounted sign: G ≥ 15 cd/lx/m² and W ≥ 120 cd/lx/m² *(1)*

Table 7: Green Sign Data

GREEN SIGN DATA						
	Planned Sample Size	Actual Sample Size	Mean Age	Mean Green R*	Mean White R*	% Non-Compliant
Lackawanna	11	5	13.6	52.4	321.2	0
Lehigh	11	1	9.0	43.0	610	0
Lancaster	11	7	17.7	63.6	325.0	0
Total	33	13	15.9	57.6	315.8	0

* R = Reflectivity (cd/lx/m²)

Our goal was to collect retroreflectivity measurements on 33 green signs total; however, we were only able to collect usable data for 13 green signs. In the counties selected for our data collection efforts, the total population of ground-mounted directional green signs is very small in comparison to the amount of yellow warning, white regulatory and red stop, yield, do not enter and wrong way signs. When trying to locate the limited green signs that met our study criteria (10+ years old), we found that most green signs did not have manufacture or installation dates, so the age of the signs could not be confirmed. Many of the signs were fabricated and installed by contractors, so the typical PennDOT procedure of marking/dating signs was not followed. Of the green signs that did have dates, many were recently installed and did not meet the 10+ years old age criteria for this study. We also found that many green signs were mounted too high to reach with a ladder and therefore, would require equipment beyond the scope of this study to measure the signs.

All 13 of the green signs that we were able to collect with known ages exceeded the minimum retroreflectivity requirements for both green and white sheeting.

Retroreflectivity versus Age

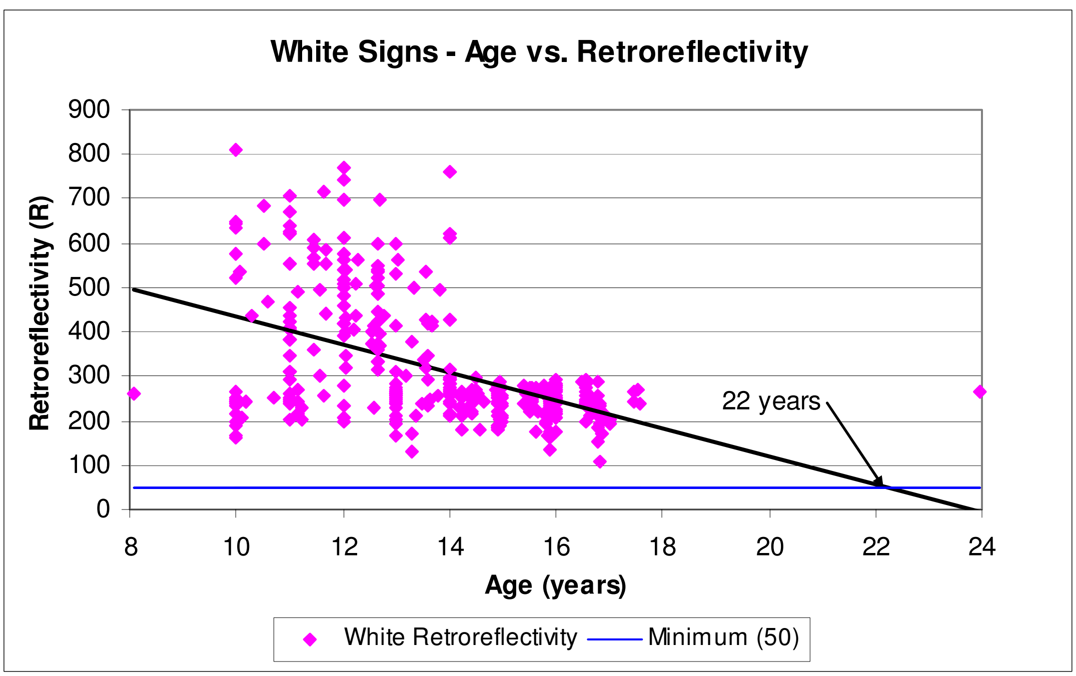
The data presented above shows that a majority of the signs measured have retroreflectivity values well above the minimum required retroreflectivity levels. When reviewing the average age and retroreflectivity levels for each county, there does not appear to be a noticeable geographic trend that suggests retroreflectivity varies greatly from region to region within Pennsylvania.

To gain a better understanding of the data, age versus retroreflectivity was plotted to determine if any correlation could be found between the two variables. For each plot, linear regression equations (lines of best fit) and R^2 (Coefficient of Determination) values were generated. The Coefficient of Determination (R^2) is a descriptive measure between 0 and 1 which represents the relative predictive power of a variable. An R^2 value of 1 implies that a model provides perfect predictions, while an R^2 value of 0 would indicate a poor model for prediction. For the linear regression lines we formed, a high R^2 value would indicate that age and retroreflectivity correlate very well and therefore, age can be used to determine retroreflectivity. Our models produced low R^2 values ranging from 0.10 to 0.30; therefore, our results indicate no direct correlation between age and retroreflectivity, which is similar to the previous studies and literature reviewed. Also, the linear regression equations for the various data sets produce very long service lives, which is unreasonable when compared to real life experience and warranty values.

These results of our study suggest that age alone cannot be used to predict retroreflectivity, as many other factors are involved. However, other studies have tested correlation between retroreflectivity and a number of other variables, with no direct relationships detected, and have shown that age is the single biggest factor affecting retroreflectivity over time. Given the high performance of signs in the 13 to 15 year old age range, we believe a minimum sign life of 15 years is acceptable, similar to other studies and states.

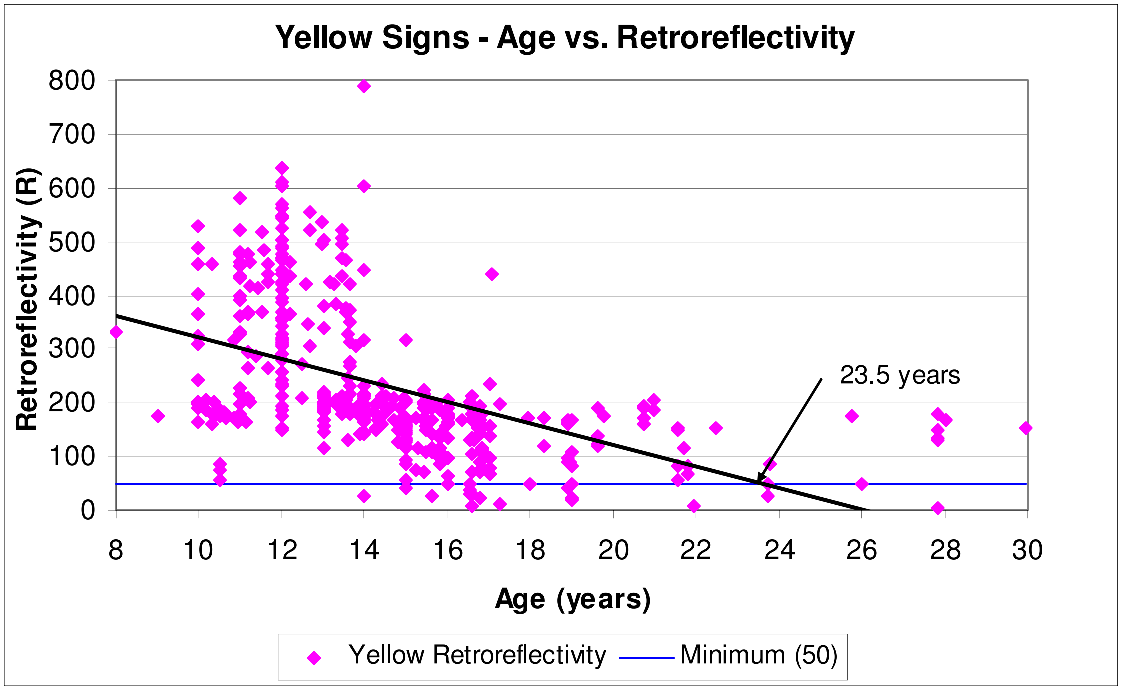
Figures 1 through 6 show age versus retroreflectivity for white, yellow, red and green signs (all counties combined), respectively. The Appendix includes individual plots for each color in each of the three counties, plus all three counties combined.

Figure 1: Age versus Retroreflectivity for White Signs (all counties combined)



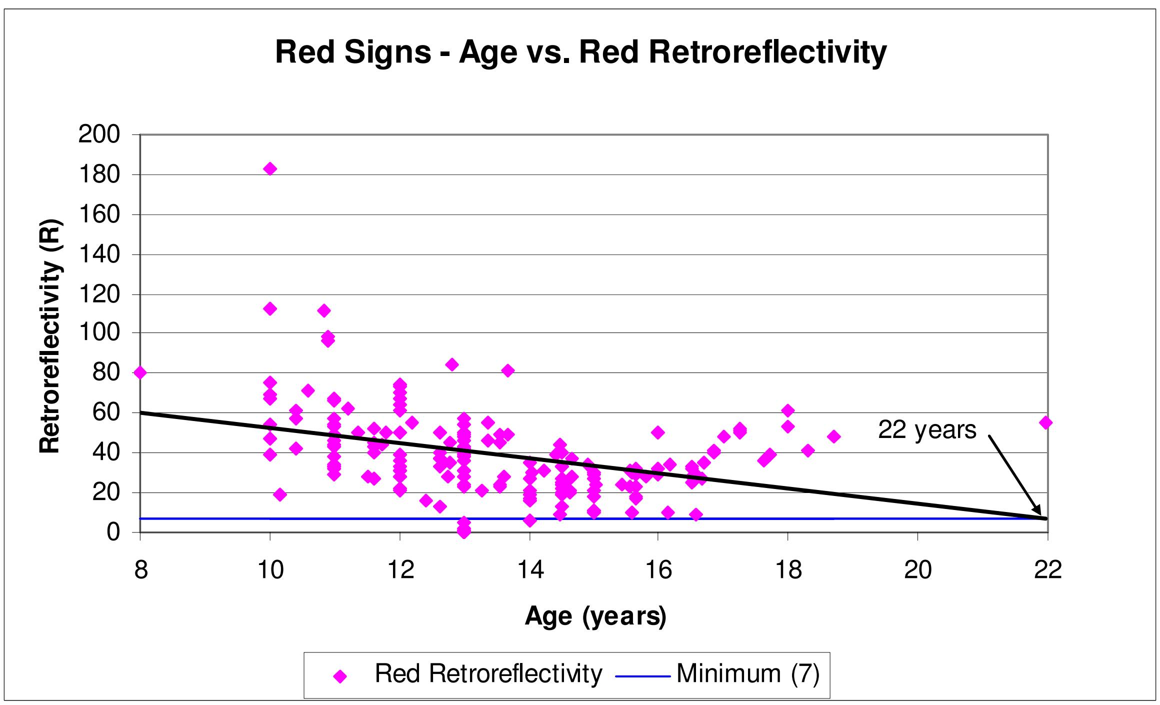
$y = -32.078x + 758.31$ $R^2 = 0.2527$

Figure 2: Age versus Retroreflectivity for Yellow Signs (all counties combined)



$y = -20.24x + 523.53$ $R^2 = 0.2533$

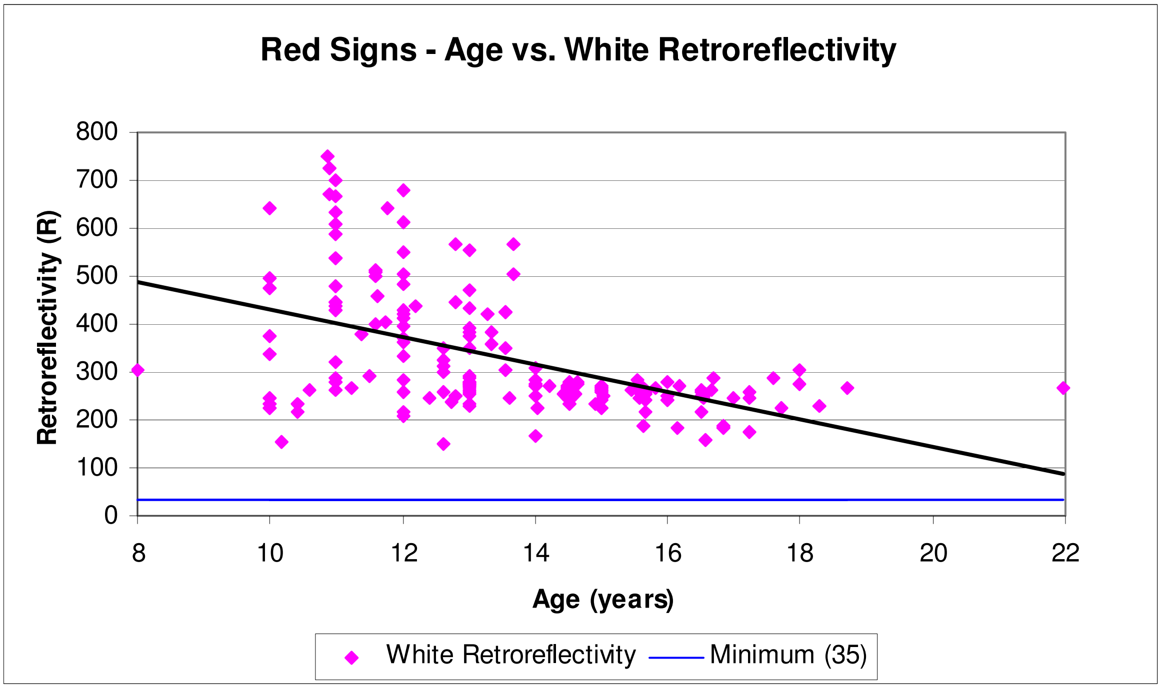
Figure 3: Age versus Retroreflectivity for Red Signs (Red) (all counties combined)



y = -

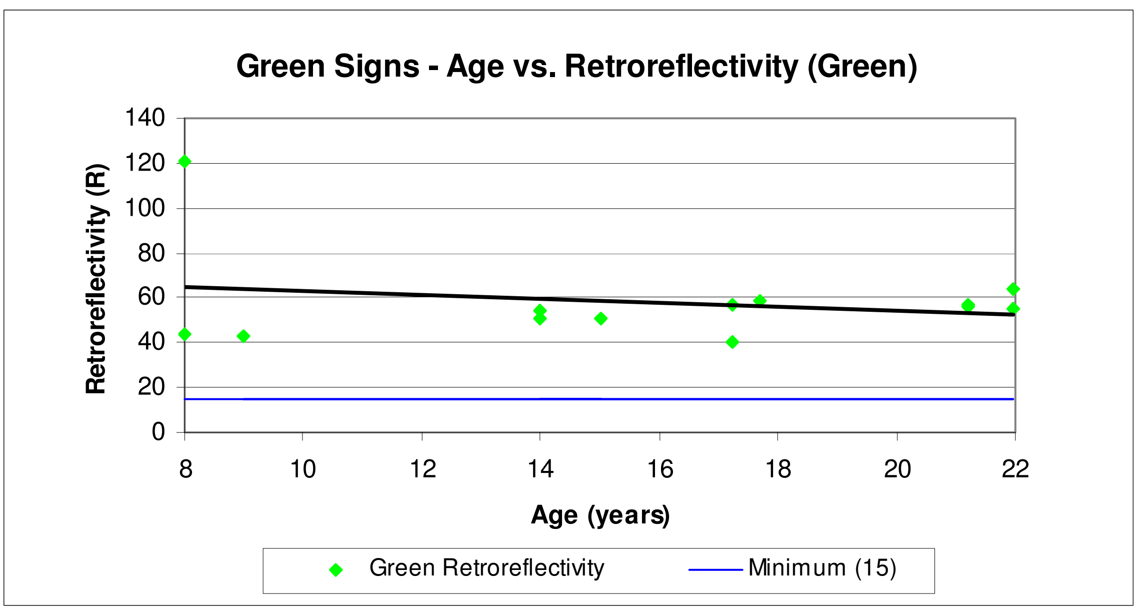
$y = 4.0818x + 94.055$ $R^2 = 0.1537$

Figure 4: Age versus Retroreflectivity for Red Signs (White) (all counties combined)



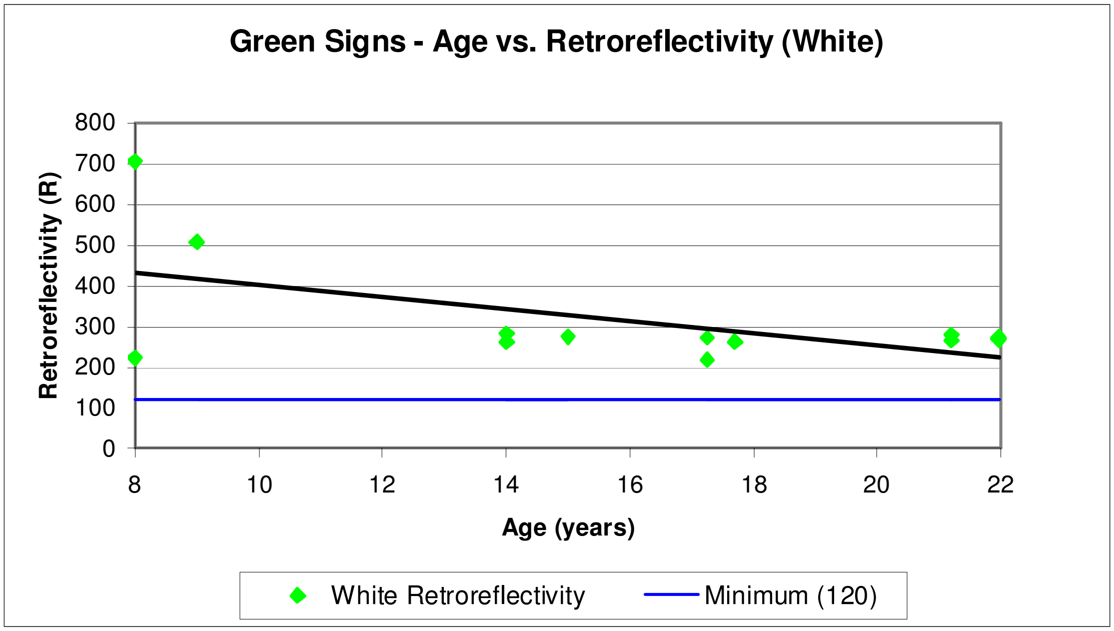
$y = -30.287x + 738.04$ $R^2 = 0.2643$ -

Figure 5: Age versus Retroreflectivity for Green Signs (Green) (all counties combined)



$y = -0.8512x + 71.165$ $R^2 = 0.0467$ -

Figure 6: Age versus Retroreflectivity for Green Signs (White) (all counties combined) -



y = -0.8512x + 71.165 R^2 = 0.0467 -

Standard Normal Distribution Analysis:

From our research on other states' sign management methods and the previous literature review, we found that most agencies are using a service life beyond the manufacturer warranty of 10 years and that typically a service life of 15 years is used for Type III sheeting. Given that most of the signs measured for this study are an average age of 13 to 15 years old with average retroreflectivity levels well above the minimum requirements, it seems reasonable to expect over 15 years of life from Type III sheeting in Pennsylvania. To determine if the expected sign life could be confidently extended beyond 15 years, a standard normal distribution analysis was performed on the data for signs 16 to 18 years old, for white, yellow and red signs only. This age range was chosen for the analysis because very few of the sample signs in our study are older than 19 years. We did not conduct a standard normal distribution analysis on green signs because of the very small sample size. Of the 13 green signs we were able to collect data for, only 3 signs fall in the 16-18 year age range. Because the sample population is so small, the standard normal distribution model cannot be used with a high degree of confidence to predict the probability of these signs exceeding the minimum retroreflectivity requirements.

Using the mean retroreflectivity level and standard deviation for each analysis group (white, yellow and red signs, aged 16-18 years) and assuming standard normal distribution, we are able to predict the probability that a sign aged 16 to 18 years old will meet the minimum retroreflectivity requirements. The Standard Deviation (σ) is a measure of the variation from the mean for a set of data. A small standard deviation indicates that the data points are located close to the mean, whereas higher standard deviation values indicate a wider dispersion of data from the mean. Standard Deviation (σ) is calculated as follows:

$\sigma = \sqrt{1/N\,[(x_1-\mu)^2 + (x_2-\mu)^2 + (x_N-\mu)^2]}$, where: - N = sample size

μ = mean

Using the sample size of each population we can also determine the tolerance of our calculated mean within a certain interval of confidence which is a way to determine the validity of the calculated mean. Tolerance (e) is a statistical interval, given a specific confidence level, in which a certain proportion of the population falls. The tolerance is calculated by first determining the Standard Error of the Mean (E) which is the standard deviation of the data divided by the square root of the sample population: $E = \sigma / \sqrt{N}$. The tolerance is equal to E multiplied by a coefficient specific to a given confidence level. For example, the true mean for various confidence levels can be calculated as follows:

$\mu = x \pm E$, with 68.3% confidence (tolerance, e = E)
$\mu = x \pm 1.96E$, with 95% confidence (tolerance, e = 1.96E)
$\mu = x \pm 3.00E$, with 99.7% confidence (tolerance, e = 3E)

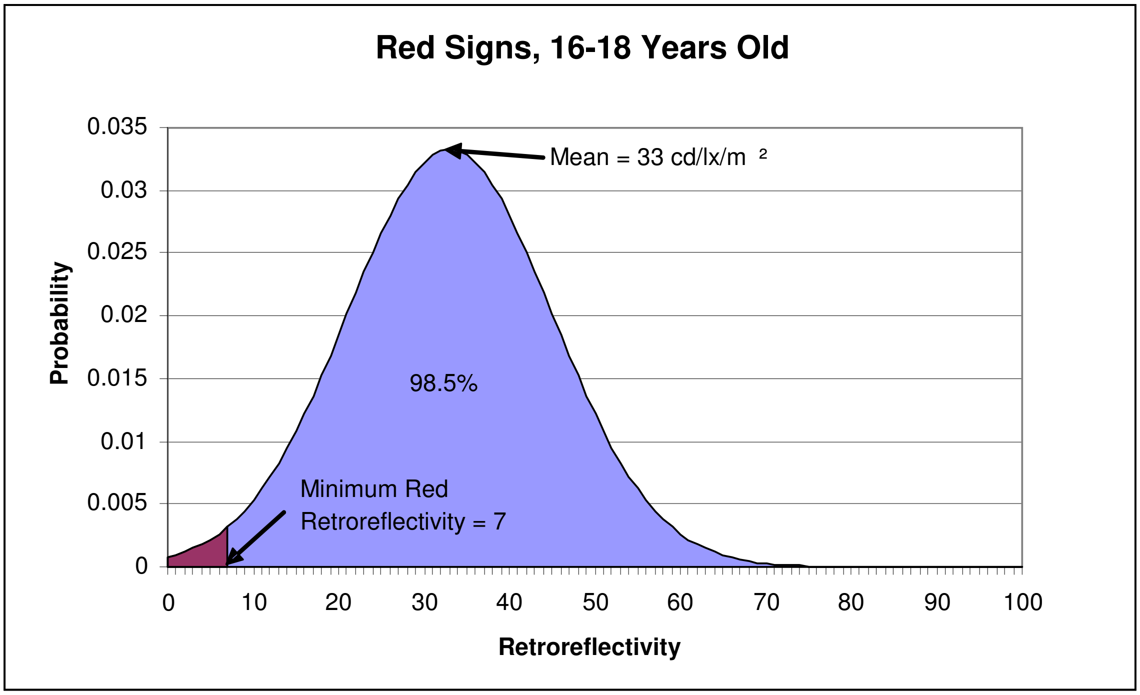
The results of the standard normal distribution analysis are shown beginning on the next page.

Red Signs, 16-18 years old

Sample Size = 40 signs
Calculated Mean Retroreflectivity = 33 cd/lx/m²
Standard Deviation = 12.0
True Mean Retroreflectivity = 33 ± 3.72 with 95% confidence

For this data set, the true mean was calculated to be 33 ± 3.72 with 95% confidence which means that there is 95% chance that the true mean retroreflectivity is between 29.28 and 36.72 cd/lx/m². **Figure 7** shows that for this data set, there is a 98.5 % probability that 16-18 year old red signs will have retroreflectivity greater than the required minimum level of 7 cd/lx/m².

Figure 7: Probability of Red Signs, 16-18 Years Old, Exceeding Minimum Retroreflectivity

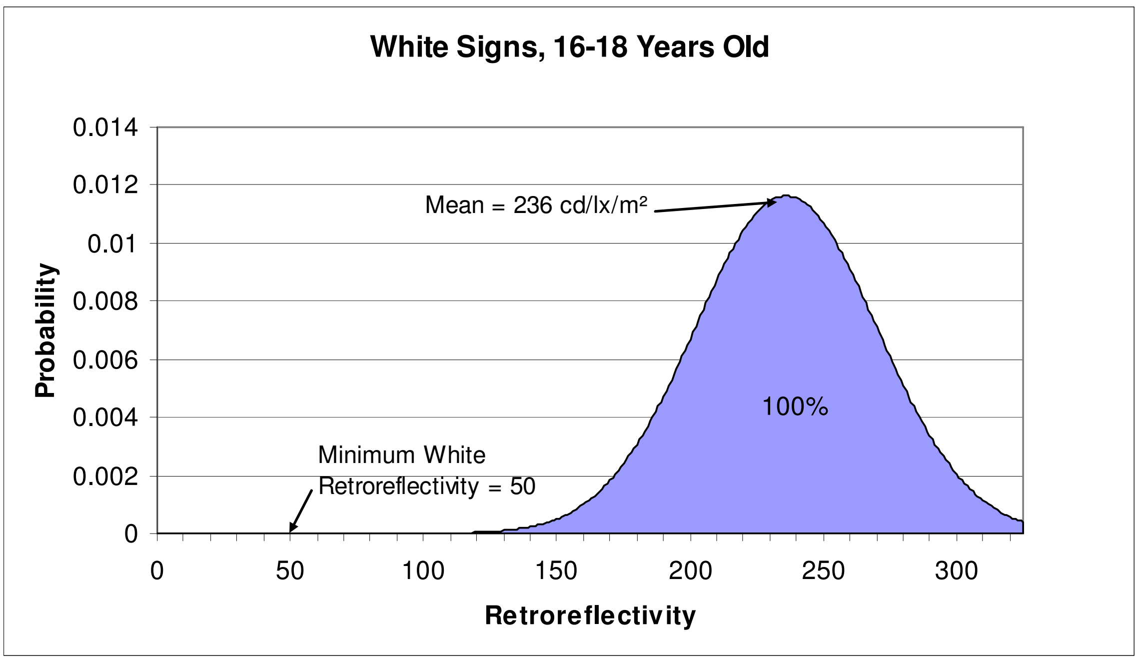


White Signs, 16-18 years old:

Sample Size = 116 signs
Calculated Mean Retroreflectivity = 236 cd/lx/m²
Standard Deviation = 34.3
True Mean Retroreflectivity = 236 ± 6.24 with 95% confidence

For this data set, the true mean was calculated to be 236 ± 6.24 with 95% confidence which means that there is 95% chance that the true mean retroreflectivity is between 229.76 and 242.24 cd/lx/m². **Figure 8** shows that from our data set, there is a 99.99% probability that 16-18 year old white signs will have retroreflectivity greater than the required minimum level of 50 cd/lx/m².

Figure 8: Probability of White Signs, 16-18 Years Old, Exceeding Minimum Retroreflectivity

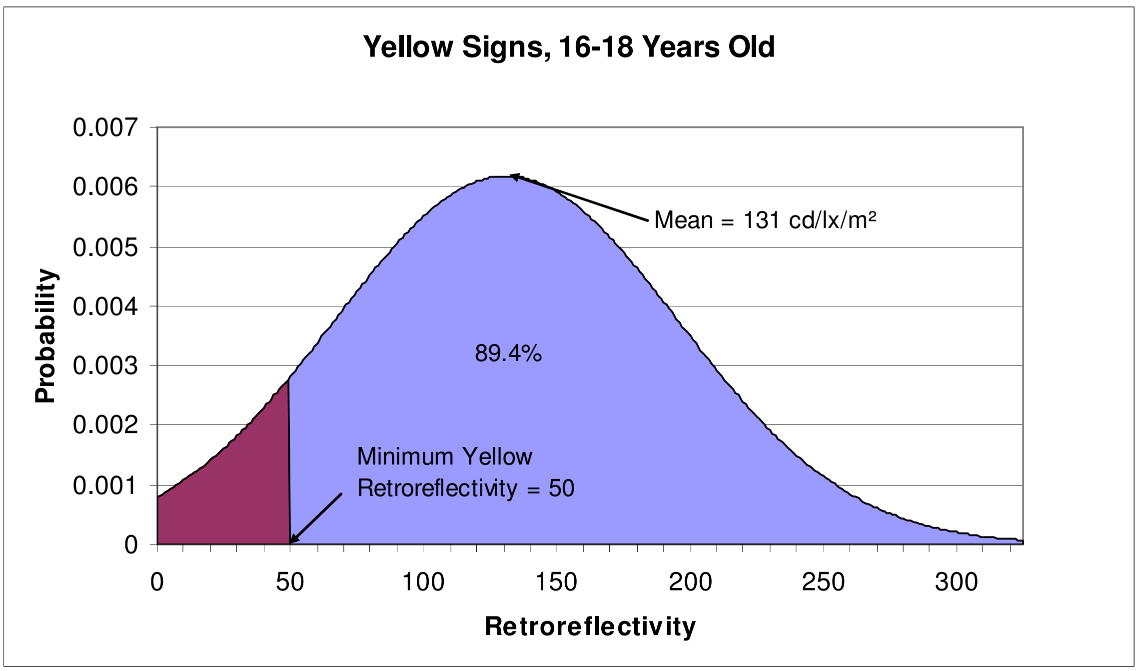


Yellow Signs, 16-18 years old:

Sample Size = 81 signs
Calculated Mean Retroreflectivity = 131 cd/lx/m²
Standard Deviation = 64.6
True Mean = 131 ± 14.1 with 95% confidence

For this data set, the true mean was calculated to be 131 ± 14.1 with 95% confidence which means that there is 95% chance that the true mean retroreflectivity is between 116.90 and 145.10 cd/lx/m². **Figure 9** shows that from our data set, there is a 89.4% probability that 16-18 year old yellow signs will have retroreflectivity greater than the required minimum level of 50 cd/lx/m².

Figure 9: Probability of Yellow Signs, 16-18 Years Old, Exceeding Minimum Retroreflectivity



D. Conclusion

The overall data collection results for each color of sheeting are shown below in **Table 8**.

Table 8: Data Collection Summary

Color	Sample Size	Mean Age (years)	Mean R (cd/lx/m²)	Min R (cd/lx/m²)	% Non-Compliant
Yellow	441	14.5	230	50	0
White	368	13.9	313	50	4.8
Red	185	13.5	39/328	7/35	3.8
Green	13	15.9	58/316	15/120	0
Total	1,007	14.1	N/A	2.8	2.8

Based on the raw data and statistical analysis, we can see that sign sheeting retroreflectivity performs well above minimum standards well beyond the manufacturer's warranty. While we could not find direct correlation between age and retroreflectivity, the raw data shows that the expected sign life can confidently be recommended as 15 years for yellow, white and red signs. Despite the limited green sign data, we have a high degree of confidence in recommending a service life of 15 years for green signs as well. Using simple statistical analysis, we also determined that there is a high probability that signs of all colors aged 16 to 18 years old will continue to exceed minimum retroreflectivity levels.

IV. References

1. - *Manual on Uniform Traffic Control Devices.* Federal Highway Administration, United States Department of Transportation, Washington, D.C. 2009
2. - Pennsylvania Department of Transportation Publication 408 *Specifications*, *Section 1103 – Traffic Signing and Marking*
3. - *Maintaining Traffic Sign Retroreflectivity.* Publication No. FHWA-SA-07-020. Federal Highway Administration, United States Department of Transportation, Washington, D.C. 2009
4. - *Methods for Maintaining Traffic Sign Retroreflectivity.* Publication No. FHWA-HRT-08-026. Federal Highway Administration, United States Department of Transportation, Washington, D.C. November 2007
5. - 3M High Intensity Prismatic Reflective Sheeting series 3930 with Pressure Sensitive Adhesive Product Bulletin 3930. 3M Traffic Safety Systems Division, St. Paul MN. August 2008
6. - Avery Dennison T-6000 & W-6000 Series Product Data Sheet. Graphics and Reflective Solutions, Painesville, OH. April 2011
7. - Ahmed, S.A. *Evaluation of Retroreflective Sheetings for Use on Roadway Traffic Signs.* Oklahoma State University. September 1994
8. - Brimley, B.K., Hawkins Jr., H.G. and Carlson, P.J. *Analysis of Retroreflectivity and Color Degradation in Sign Sheeting (Paper No. 11-2148).* Texas Transportation Institute, College Station, TX, Submitted November 2010 for presentation at the 90th Transportation Research Board Annual Meeting and publication in the Annual Meeting Compendium DVD.
9. - Ellison, J.W. *Tapping into the Power of a Traffic Sign Inventory to Meet the New Retroreflectivity Requirements.* Compendium of Technical Papers, 2008 Institute of Transportation Engineers Annual Meeting. 2008
10. Harris, E.A., Rasdorf, W., Hummer, J.E. *New Standards, New Signs: Determining Sign Performance Under Controlled Conditions* IMSA Journal January/February 2008
11. Harris, E.A., Rasdorf, W., Hummer, J.E., and Yeom, C. *Analysis of Traffic Sign Asset Management Scenarios.* North Carolina State University, Raleigh, NC, Transportation Research Board 2007 Annual Meeting CD-ROM
12. Immanemi, V.P.K., Hummer, J.E., Rasdorf, W.J., Harris, E.A. and Yeom, C. *Synthesis of Sign Deterioration Rates Across the US.* North Carolina State University, Raleigh, NC, Transportation Research Board 2007 Annual Meeting CD-ROM
13. Kipp, W.M. and Fitch, J.M. *Evaluation of Measuring Methods for Traffic Sign Retroreflectivity Final Report (Report 2009-8).* State of Vermont Agency of Transportation Materials and Research Section. December 2009
14. Kirk, A.R., Hunt, E.A. and Brooks, E.W. *Factors Affecting Sign Retroreflectivity – Final Report (SR 514).* Transportation Development Division – Research Group, Oregon Department of Transportation, Salem, OR, January 2001
15. Marti, M. *Sign Retroreflectivity A Minnesota Toolkit (Final Report #2010RIC02).* Minnesota Department of Transportation, Office of Policy Analysis, Research & Innovation. June 2010
16. Nahrwold, T. *Field Inspections for Sheet Sign Life Cycle – Study Report.* Indiana Department of Transportation. November 2010

17. Nuber, L. and Bullock, D. *Comparison of Observed Retroreflectivity Values with Proposed FHWA Minimums.* Transportation Research Record 1794, Paper No. 02-2502
18. Opiela, K.S. and Andersen C.K. *Maintaining Traffic Sign Retroreflectivity: Impacts on State and Local Agencies (FHWA Publication No. FHWA-HRT-07-042).* Federal Highway Administration, United States Department of Transportation, Washington, D.C. April 2007
19. Re, J. M., Miles, J.D. and Carlson, P.J. *An Analysis of In-Service Traffic Sign Retroreflectivity and Deterioration Rates in Texas (Paper No. 11-2542).* Texas Transportation Institute, College Station, TX, Submitted March 2011 for publication in Transportation Research Record: Journal of the Transportation Research Board
20. Roess, R.P., Prassas, E.A., and McShane, W.R. *Traffic Engineering (3rd Edition).* Prentice Hall. January 2004

Retroreflectivity of Existing Signs in Pennsylvania
FINAL REPORT

APPENDICIES

Appendix 1: Table of States Responses & Data Reduction

Appendix 2: Manufacturer Information

A . 3M High Intensity Prismatic Reflective Sheeting Series 3930 with Pressure Sensitive Adhesive Product Bulletin 3930

B. Avery Denison T-6000 & W-6000 Series Product Data Sheet

STATES RESPONSES

Questions posed to the AASHTO TE Subcommittee members from all 50 states:

1) Are you using the expected sign life approach, blanket approach control signs approach or an assessment method?
2) If you are using the expected sign life approach - are you using the manufacturer's warranty (typically 10 years for Type III sheeting material) or other values?
3) If you are using other values, what research if any is that based on?
4) Are there any other criteria you consider critical in addition to age (e.g., orientation, type of sheeting, etc.)?

[grey box] = No Response

State	Name	Question 1 Answer	Question 2 Answer	Question 3 Answer	Question 4 Answer
Alabama	Stacey N. Glass, P.E.	Alabama has implemented the Nighttime Inspection method using calibration panels.			
Alaska	Kurtis J. Smith, P.E.	We are using a two phase approach: 1) an initial sign inventory process, including collection of a large sampling of in-service sign retroreflectivity, using hand-held retroreflectometers, and 2) the visual nighttime inspection as an ongoing assessment method.			No. Inspectors are collecting orientation and sheeting type information during the inventory, but we're not sure whether that will play a role in determining when a sign is replaced. The nighttime inspectors will utilize calibration signs for their assessment method.
Arizona	Mike Manthey, P.E.	For freeway signing we are using the expected sign life approach, and for non-freeway signs we will use an assessment method. Both of these will be in conjunction with our Sign Management System database.	Since we are using high end prismatic sheeting, we have not yet determined the sign life. That is something we will be tracking for a sample of signs in our Sign Management System.	Will be based on future research.	Our approach will be to upgrade all of our signs to the high end prismatic sheeting, and then track a sample amount of signs to determine expected sign life. Orientation may become a part of the analysis, but to be safe we may replace all signs when the orientation becomes a factor.
Arkansas	Eric Phillips				
Arkansas	Tony Sullivan	We are using the blanket repacement approach at specified intervals of 10 years.	Yes, the 10 year intervals are based on the manufacturer's warranty for Type III sheeting.		
California	Robert Copp	No, we have traditionally utilized, and continue to employ the Visual Nighttime Inspection assesment method.			
Colorado	Gabriela Vidal				
Connecticut	John F. Carey, P.E.				
Delaware	Donald D. Weber, P.E.	DelDOT uses a combination of night time inspections and the expected sign life approach. The night time inspections also use a handheld retroreflectometer for any signs that are questionable. With the expected sign life approach every sign is labeled with a sticker noting the date of installation.	Yes	N/A	No, although the south facing signs do degrade at a faster rate.
Washington DC	Soumya S. Dey				
Florida	Mark C. Wilson, P.E.				
Georgia	Keith Golden, P.E.				
Hawaii	Alvin Takeshita	We have not decided on the type of sign management approach that we will be implementing.			We believe type of sheeting is an important factor since the higher type sheeting will have retro levels with greater margins over the minimum required level.

STATES RESPONSES
Questions posed to the AASHTO TE Subcommittee members from all 50 states:

1) Are you using the expected sign life approach, blanket approach control signs approach or an assessment method?
2) If you are using the expected sign life approach - are you using the manufacturer's warranty (typically 10 years for Type III sheeting material) or other values?
3) If you are using other values, what research if any is that based on?
4) Are there any other criteria you consider critical in addition to age (e.g., orientation, type of sheeting, etc.)?

[shaded box] = No Response

Idaho	Brent Jennings, P.E.	We have selected the visual assessment, nighttime inspection using calibration signs procedure.			We know that signs in the direct sunlight fade faster than others oriented a different direction, and that some colors fade faster than other colors. That has led to not using an expected sign life approach in our sign management system.
Illinois	Aaron Weatherholt				
Indiana	James Poturalski				
Indiana	Todd Shields	Combination of sign life and blanket replacement methods (typically sign life, but trying to get our sheet signs in a corridor on the same cycle)	18 years for Type III and above	We have done field studies looking at different colors in differing orientations. Type III sheeting exceeded the MUTCD minimum at 18 years. Type I will not, and is nearly phased out.	INDOT switched to minimum Type IV 2 years ago. The limited data we have with Type IV indicates we will likely extend our 18 year age in the future, as Type III are phased out.
Iowa	Timothy D. Crouch	We plan to use an assessment approach - visual inspection			Climate - snow belt vs. sun belt - sun angle is much less in the winter months in Iowa than it is in Arizona or Florida during the same time.
Kansas	Kenneth F. Hurst, P.E.				
Kentucky	Jeff Wolfe	In the short term we will be doing nighttime inspections. Routes will be reviewed every other year. At the same time, we are (1) developing a sign inventory, (2) developing a bar code system to track installation/fabrication/etc. for newly installed signs, and (3) created test decks for sign sheeting. As our inventory and sheeting data improves, we will ultimately get away from nighttime inspection and use replacement based on projected sign sheeting life.			
Louisiana	Peter Allain, P.E., PTOE	For years we have used the expected sign life method for sign management. We record the installation date on the back of the sign an then rpelace based on an expected life.	We asked several manufacturers for expected life values but were told they would not share that information. They suggested we use the warranty value, although we know from previous research that sheeting life extends well beyond these values.	We plan on reviewing a student paper exploring the use of AASHTO NTPEP data to estimate sign life (attached).	
Maine	Bruce A. Ibarguen, P.E.	We are using the expected sign life approach.	We are using the manufacturer's warranty - typically 10 years	N/A	Our program is only the regulatory and warning signs.
Massachusetts	Neil E. Boudreau	MassDOT currently replaces major directional signs on interstates and freeways under blanket sign replacements every 12 to 14 years. As guide signs are replaced, regulatory and warning signs are as well. MassDOT does not currently have a replacement program for secondary highways, but at this time they plan on basing future sign replacements on periodic nighttime inspections. They will begin this once the sign inventory system that is currently under development is in place.	The replacement cycle is based on historical experience in MA and adjoining states with high intensity (Type III) sheeting, which MassDOT has used since the late 1960's. However, as MasssDOT has been using high intensity prismatic sheeting (HIP Type VIII or better) the cycles has been extended to 16 to 18 years based on intial results observd with using HIP sheeting.		

STATES RESPONSES

Questions posed to the AASHTO TE Subcommittee members from all 50 states:

1) Are you using the expected sign life approach, blanket approach control signs approach or an assessment method?
2) If you are using the expected sign life approach - are you using the manufacturer's warranty (typically 10 years for Type III sheeting material) or other values?
3) If you are using other values, what research if any is that based on?
4) Are there any other criteria you consider critical in addition to age (e.g., orientation, type of sheeting, etc.)?

[shaded box] = No Response

Michigan	Mark W. Bott	Michigan has utilized the blanket replacement method based on expected sign life in its corridor approach to replacment of signs.	Based on our field experience, it's MDOT's goal to replace signs every 15 years, but with strains on the traffic signing budget, the expected replaement cycle is 17 years for freeway signs and 20 years for non freeway signs	To ensure appropriate replacement cycle length, a control group of signs is being measured by retroreflectometers to generate expected life curves.	N/A
Minnesota	Susan M. Groth				
Mississippi	Robert "Wes" Dean	We are using the expected sign life method, coupled with blanket replacement. We don't have a certain age that we use policy –wise, but we are assuming 10-12 years for Type III HIP and 15 years for Type XI. We are basically following the manufacturer's warranties as far as the life. Recieved PP on this that we are presenting at SASHTO this month.			
Missouri	Eileen Rackers	Missouri was orignally planning to use expected sign life as our approach but have since decided to use an assessment method - visual nighttime sign inspections. The reason that we changed direction is that we were changing out entire routes in order to get the route on the same cycle for the next replacement, and in the process we believe too many good signs were being replaced that still had useful life. We are interested in your research as it would be helpful to have better data as to how long the sign sheeting is reflective instead of having to use the manufacturer's warranty. We believe it is longer than 10 years, but did not have anything to base that on.			
Montana	Duane Williams, P.E.				
Nebraska	Daniel J. Waddle, P.E.				
Nevada					
New Hampshire	William Lambert				
New Jersey	David Martin				
New Mexico	Vacant				
New York		We're generally going to use a corridor approach with a 12-15 year cycle.			
North Carollina	J. Kevin Lacey, P.E., CPM	NCDOT conducts nighttime sign reviews to look for signs showing poor or low retroreflectivity. Interstate routes are reviewed each year; primary routes are reviewed every other year; and, secondary routes are reviewed every three years. Signs in bad condition are replaced during the day. Immediate action is taken to replace red series signs, whereas yellow signs are replaced as soon as possible. Directional sign replacements are scheduled as needed.			
North Dakota	Shawn Kuntz, P.E.	Assessment method - nighttime visual inspection	In the past we used manufacturer's warranty for regulatory and warning signs. Our new method (visual nighttime inspection) requires all signs must be inspected annually and identified as being in need of replacement if they appear to be at or near the minimum values of the TEST signs observed.		
Ohio	Jim Roth	Blanket replacement method.	15 year replacement interval	Oklahoma research (1994 Report named FHWA/OK 95(02)	No.
Oklahoma	Harold Smart				
Oregon	Edward L. Fischer, P.E., PTOE				

STATES RESPONSES

Questions posed to the AASHTO TE Subcommittee members from all 50 states:

1) Are you using the expected sign life approach, blanket approach control signs approach or an assessment method?
2) If you are using the expected sign life approach - are you using the manufacturer's warranty (typically 10 years for Type III sheeting material) or other values?
3) If you are using other values, what research if any is that based on?
4) Are there any other criteria you consider critical in addition to age (e.g., orientation, type of sheeting, etc.)?

[grey box] = No Response

Puerto Rico	Carlos M. Contreras				
Rhode Island	Robert Rocchio, P.E.				
South Carolina	Richard B. Werts, P.E.				
South Dakota	Laurie Schultz	We have a proposed draft policy utilizing the Expected Sign Life Method.	Engineer Sheeting (Type I) - 7 years, High Intensity (Type II or III) - 12 years, High Int. Prismatic (Type IV, VI, VIII or X) - 15 years, Diamond Grade Prismatic (Type IX or XI) - 18 years	The replacement schedules are based on data from MNDOT test decks, warranties of sheeting manufacturers, and experience with existing signs and weather conditions.	
Tennessee	Michael L. Tugwell				
Texas	Margaret (Meg) A. Moore, P.E.				
Utah	Robert E. Hull, P.E.				
Vermont	Bruce Nyquist, P.E.	For smaller signs (<= 20 sq ft) we are using the expected sign life method, utilizing a cycle of 15 years based on a research study conducted by our Materials & Research section (see attached link in email). For larger signs, we are considering using a control group of signs to determine our replacement cycle. We have yet to finalize the method and specifics for accomplishing this task.			
Virginia	Raymond J. Khoury, P.E.	VDOT is moving forward with the "expected life" methodology in combination with spot audits of visual nighttime inspection as the proposed management methodology.	Following manufacturer's warranty may result in premature replacement of sign, thus VDOT's own testing and verification through sampling are being considered to establish the typical extended retrorefelectivity life span of the sheeting material. VDOT's initial assumption for expected life is a 15-year life cycle.	VDOT will be evaluating in-house sheeting samples after extended accelerated weathering (3+ years). The use of available manufacturer's sheeting degradation information.	Some of the criteria that may be utilized in the management plan could include: roadway classification and speed, sign type, sheeting type, life cycle, orientation, contrast ratio and road segment crash history.
Washington	Theodore Trepanier, P.E.				
West Virginia	Cindy Cramer, P.E.				
Wisconsin	Thomas N. Notbohm, P.E., PTOE	WisDOT is utlizing both the expected sign life method and blanket replacement method. The blanket replacement method is utilized on roadway construction/improvement projects where we normally include all sign replacements as part of the project.	For the expected sign life method, WisDOT utilizes a 12 year replacement cycle.	Currently, our 12 year replacement cycle is based on experience of utilizing the Type III sheeting. In order to make our policy more objective, WisDOT has established a control signs test deck at our central sign shop in Madison, which is also one of approved MUTCD assessment / management method. The goal of the test deck is to provide Engineering support to our replacement criteria. As time profresses, the 12 year criteria may change.	We are evaluating the ASTM Types III, IV, IX and XI on our signing test deck with different colors. We will begin evaluating the deterioration of colors and factor that into our sign replacement criteria also. All signs on our test evaluation deck face south to get the maximum sunlight and UV rays. Our replacement criteria at this time is based on south facing signs.
Wyoming	Joel Meena, P.E.	Assessment method. We do keep track of age and have a rigid performance measurement system.	We have been getting more than 10 years.	We use a statistical method as you described above for our performance measures.	Silk screened sign. We have found that screened signs mostly for STOP signs have half the life as other signs. The red inks do not last very long.

Pennsylvania Green Sign Data

Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

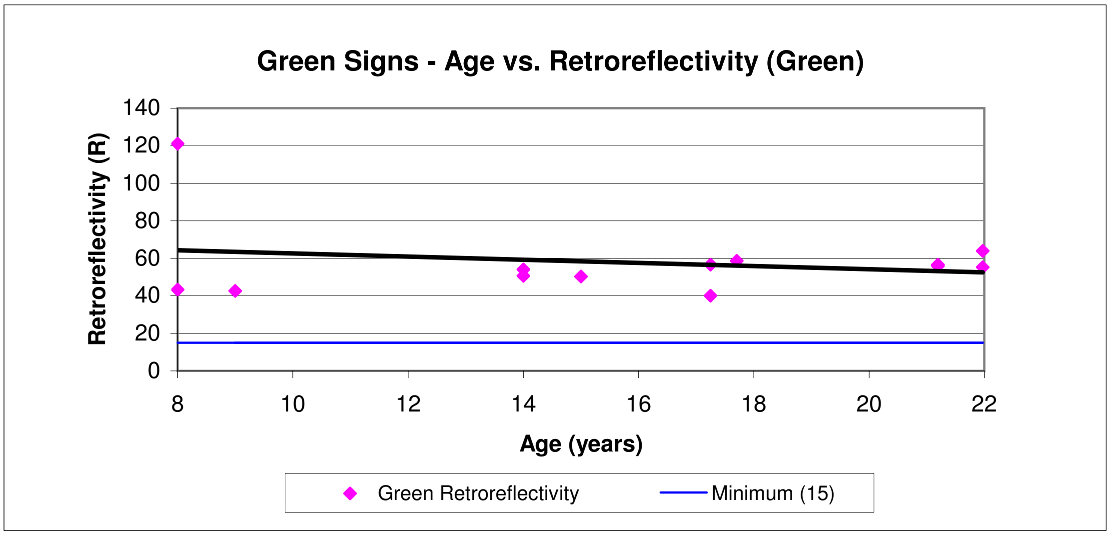
Green: $R \geq 15$ cd/lx/m² (Ground-mounted signs)
White: $R \geq 120$ cd/lx/m²

Sample Size: 13
PA Total Green: 21,269

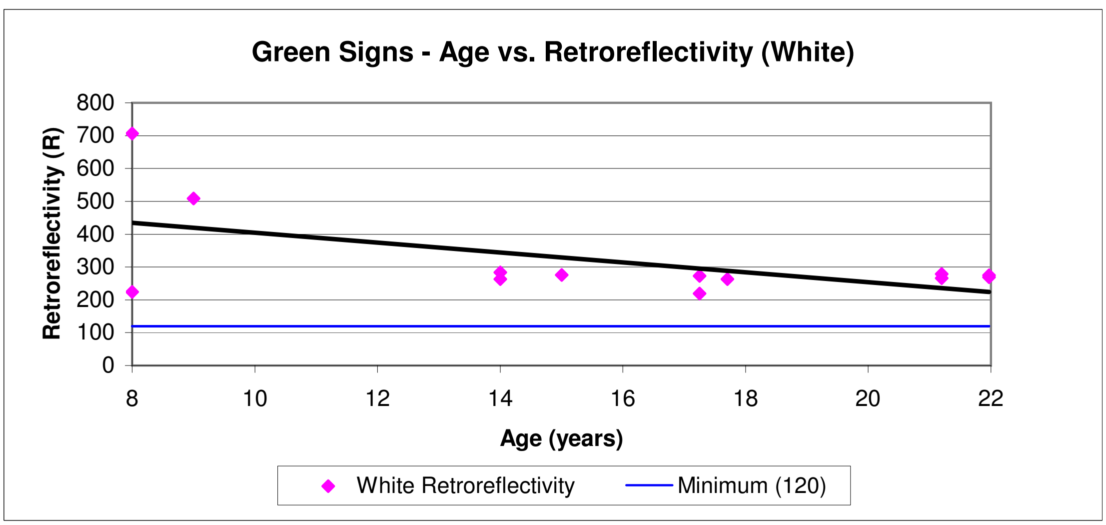
AGE INFO	
Mean Age:	15.9
Std Dev:	5.1
15th Percentile:	8.8
85th Percentile:	21.4

GREEN RETROREFLECTIVITY INFO	
Mean Green R:	57.6
Std Dev:	20.3
15th Percentile:	43.2
85th Percentile:	59.7

WHITE RETROREFLECTIVITY INFO	
Mean White R:	315.8
Std Dev:	136.9
15th Percentile:	255.3
85th Percentile:	328.4



$y = -0.8512x + 71.165$ $R^2 = 0.0467$



$y = -17.443x + 586.52$ $R^2 = 0.3247$

Pennsylvania Red Sign Data

Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

Red: R ≥ 7 cd/lx/m² for all red signs
White: R ≥ 35 cd/lx/m² for all red signs
Contrast Ratio: W:R ≥ 3:1 for all red signs

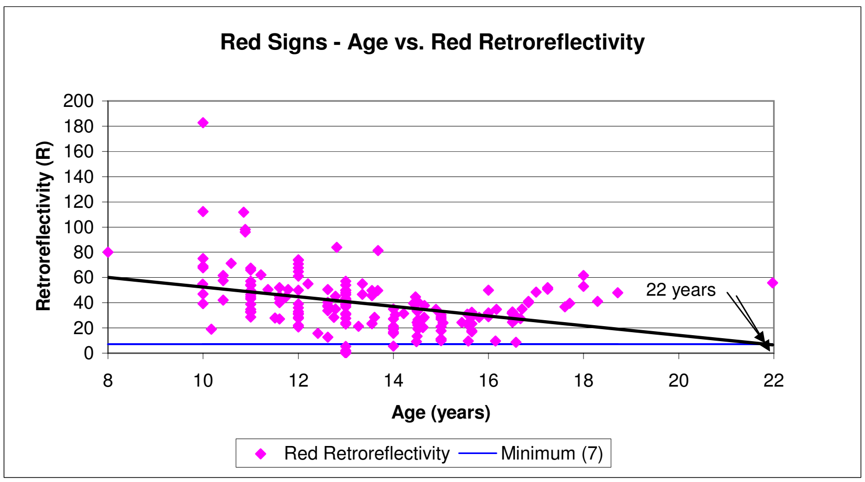
Sample Size: 185
PA Red Total: 107,648

AGE INFO	
Mean Age:	13.5
Std Dev:	2.2
15th Percentile:	11.0
85th Percentile:	15.7

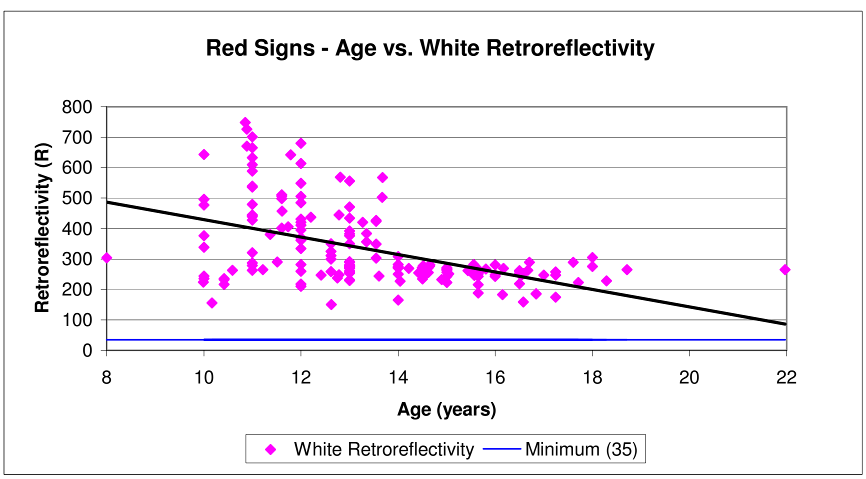
RED RETROREFLECTIVITY INFO	
Mean Red R:	38.8
Std Dev:	22.3
15th Percentile:	20.7
85th Percentile:	55.0

WHITE RETROREFLECTIVITY INFO	
Mean White R:	328.1
Std Dev:	126.0
15th Percentile:	242.5
85th Percentile:	462.8

CONTRAST RATIO INFO	
Mean:	16.1
Std Dev:	51.4
15th Percentile:	5.6
85th Percentile:	14.1



y = -4.0818x + 94.055 R^2 = 0.1537



y = -30.287x + 738.04 R^2 = 0.2643

RESULTS: 7 of 185 signs (3.8%) do not meet FHWA minimum requirements. 6 signs do not meet minimum requirments for red retroreflectivity (R ≥ 7) and one sign does not meet minimum requirements for contrast ratio (W:R ≥ 3:1)

Pennsylvania White Sign Data

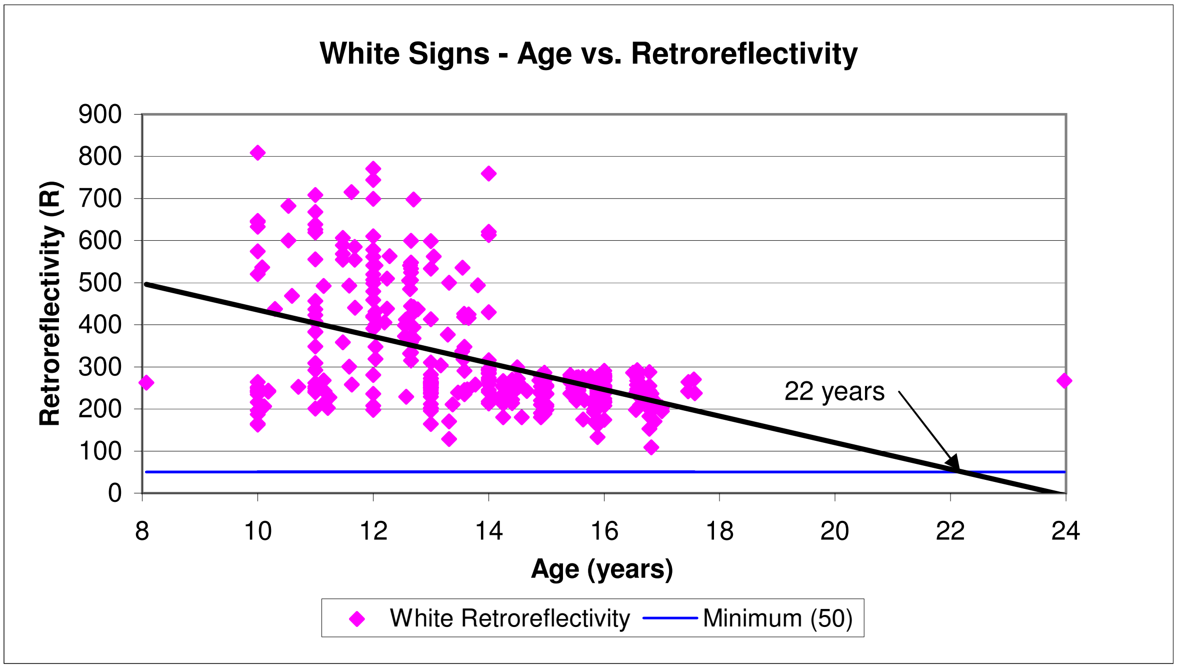
Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

White: R ≥ 50 cd/lx/m² for all white signs

Sample Size: 368
PA White Total: 222,224

AGE INFO	
Mean Age:	13.9
Std Dev:	2.1
15th Percentile:	11.2
85th Percentile:	16.0

RETROREFLECTIVITY INFO	
Mean White R:	312.8
Std Dev:	135.1
15th Percentile:	214.1
85th Percentile:	479.1



$y = -32.078x + 758.31$ $R^2 = 0.2527$

RESULTS: All white signs meet FHWA minimum requirements for white retroreflectivity (W ≥ 50)

Pennsylvania Yellow Sign Data

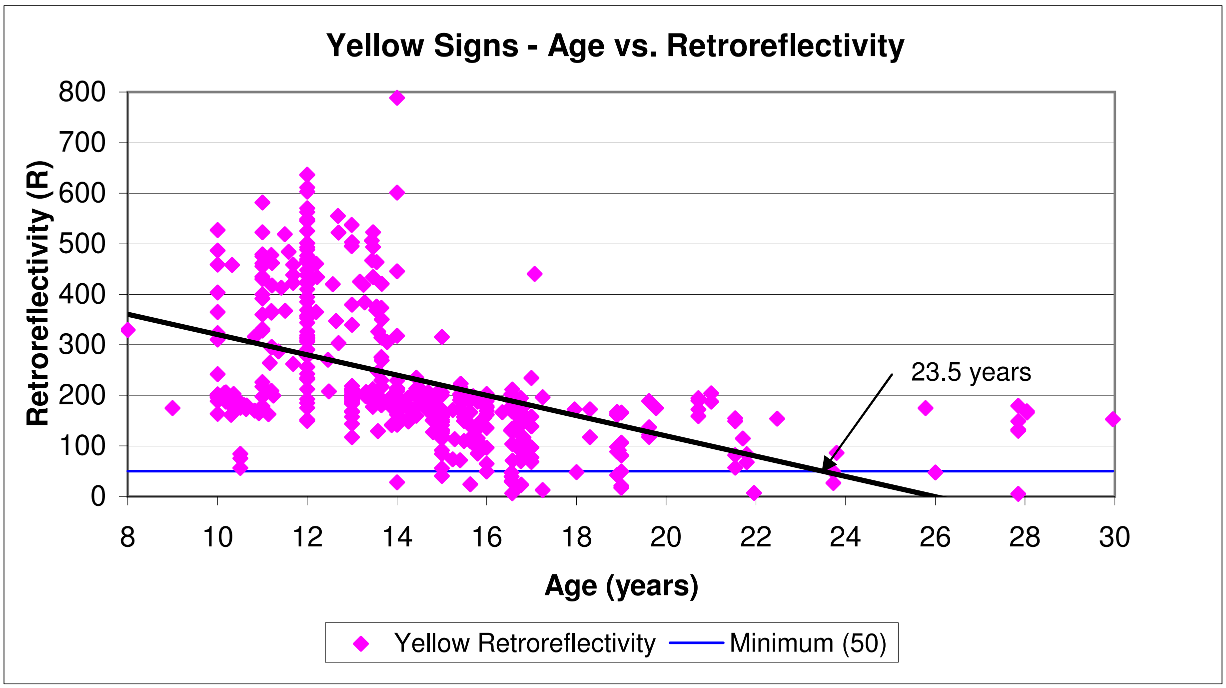
Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

Yellow : R ≥ 50 cd/lx/m² for all bold symbol signs and text/fine symbol signs ≥ 48"
R ≥ 75 cd/lx/m² for text/fine symbol signs ≤ 48"

Sample Size: 441
PA Yellow Total: 266,679

AGE INFO	
Mean Age:	14.5
Std Dev:	3.4
15th Percentile:	11.5
85th Percentile:	16.8

RETROREFLECTIVITY INFO	
Mean Yellow R:	229.7
Std Dev:	135.8
15th Percentile:	117.0
85th Percentile:	409.7



y = -20.24x + 523.53 $R^2 = 0.2533$

Lacakawanna County - Red Signs

Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

Red: R ≥ 7 cd/lx/m² for all red signs
White: R ≥ 35 cd/lx/m² for all red signs
Contrast Ratio: W:R ≥ 3:1 for all red signs

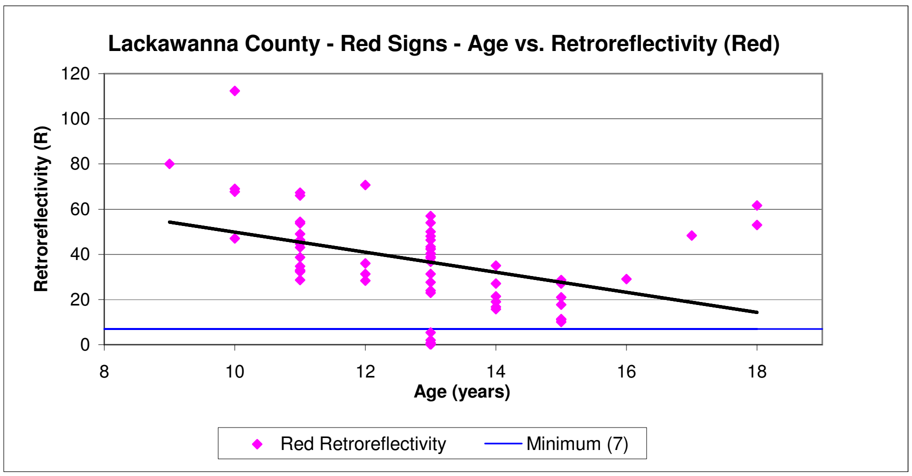
Sample Size: 61
PA Total Red: 107,648

AGE INFO	
Mean Age:	12.8
Std Dev:	1.9
15th Percentile:	11.0
85th Percentile:	15.0

RED RETROREFLECTIVITY INFO	
Mean Red R:	37.3
Std Dev:	21.2
15th Percentile:	16.7
85th Percentile:	54.3

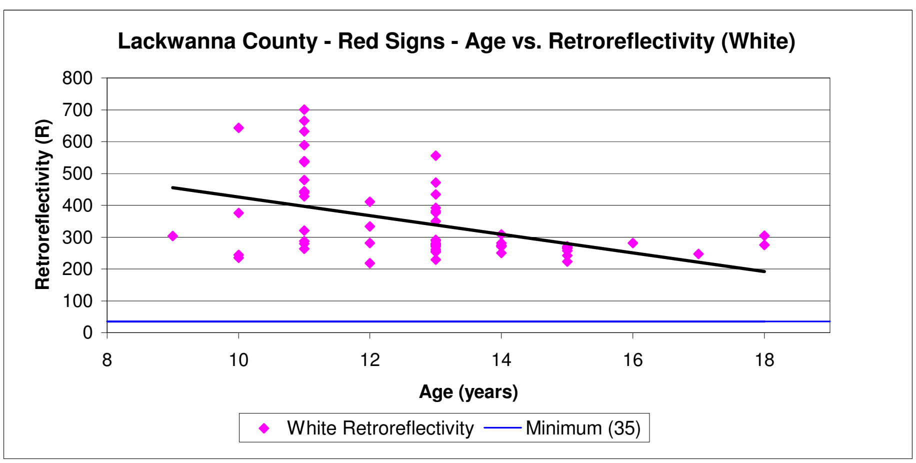
WHITE RETROREFLECTIVITY INFO	
Mean White R:	343.6
Std Dev:	122.7
15th Percentile:	256.3
85th Percentile:	471.0

CONTRAST RATIO INFO	
Mean:	29.3
Std Dev:	88.2
15th Percentile:	5.2
85th Percentile:	16.4



y = -4.4361x + 94.12
R^2 = 0.1597

5 of 61 (8.2%) signs failed to meet FHWA minimum requirements for red retroreflectivity (R ≥ 7)



y = -29.257x + 718.69
R^2 = 0.2075

All signs meet FHWA minimum requirements for white reflectivity (W ≥ 35)

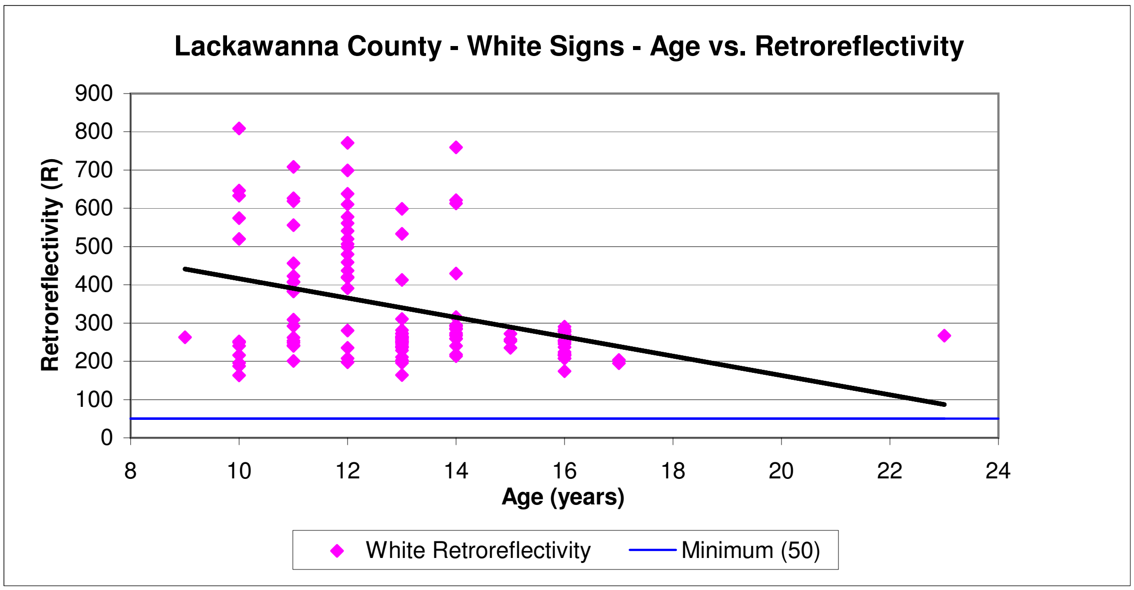
Lacakawanna County - White Signs

Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):
White: R ≥ 50 cd/lx/m^2 for all white signs

Sample Size: 125
PA Total White: 222,224

AGE INFO	
Mean Age:	13.1
Std Dev:	2.2
15th Percentile:	11.0
85th Percentile:	16.0

RETROREFLECTIVITY INFO	
Mean White R:	337.1
Std Dev:	153.5
15th Percentile:	216.0
85th Percentile:	536.2



y = -25.329x + 669.44
R^2 = 0.1271

All white signs meet minimum FHWA requirements.

Lackawanna County - Yellow Signs

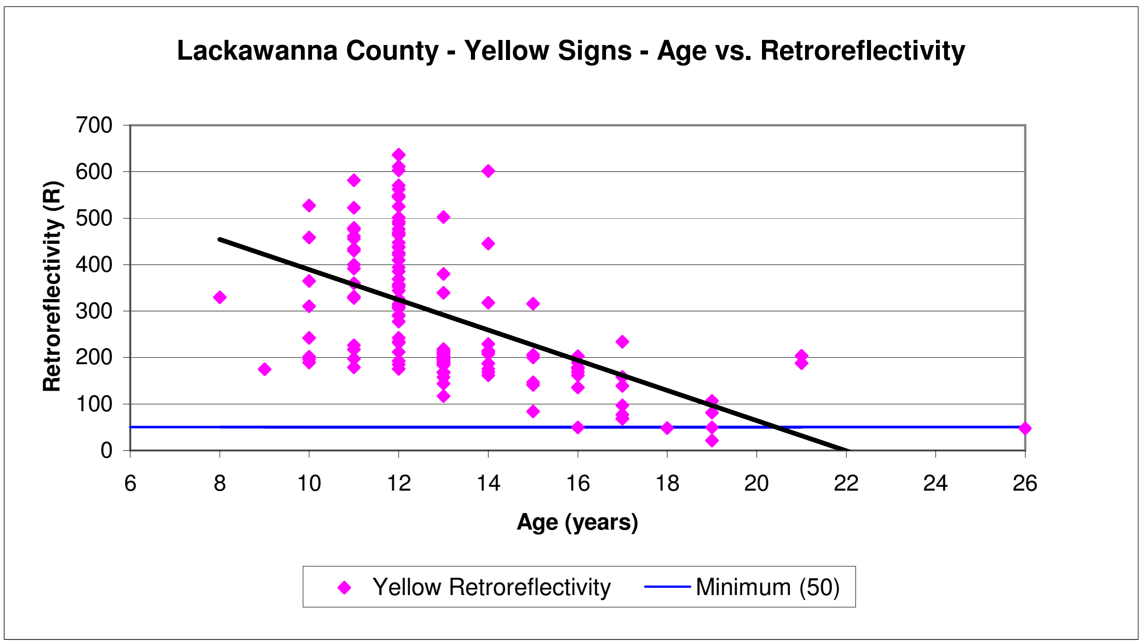
Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

Yellow : $R \geq 50$ cd/lx/m² for all bold symbol signs and text/fine symbol signs ≥ 48"
$R \geq 75$ cd/lx/m² for text/fine symbol signs ≤ 48"

Sample Size: 149
PA Total Yellow: 266,679

AGE INFO	
Mean Age:	13.1
Std Dev:	2.5
15th Percentile:	11.0
85th Percentile:	15.8

RETROREFLECTIVITY INFO	
Mean Yellow R:	287.4
Std Dev:	149.1
15th Percentile:	167.1
85th Percentile:	469.3



y = -32.518x + 714.51
R^2 = 0.2927

3 of 149 signs (2.0%) did not meet minimum FHWA requirements.

Lehigh County - Red Signs

Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

Red: R ≥ 7 cd/lx/m² for all red signs
White: R ≥ 35 cd/lx/m² for all red signs
Contrast Ratio: W:R ≥ 3:1 for all red signs

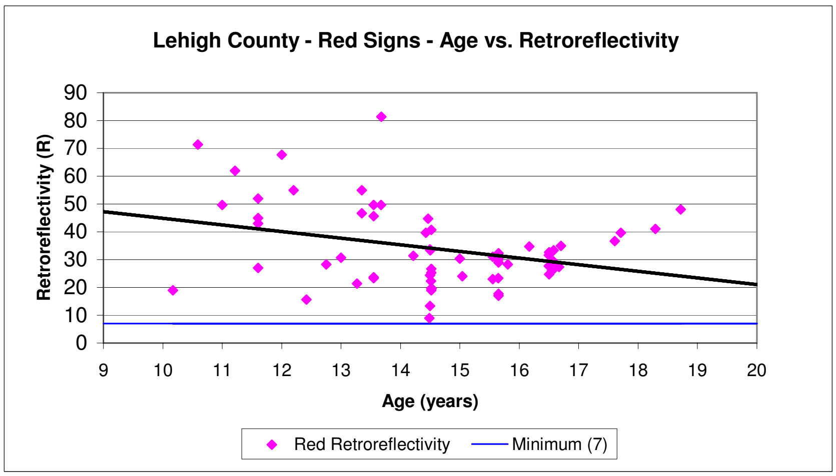
Sample Size: 66
PA Red Total: 107,648

AGE INFO	
Mean Age:	14.6
Std Dev:	1.9
15th Percentile:	12.4
85th Percentile:	16.5

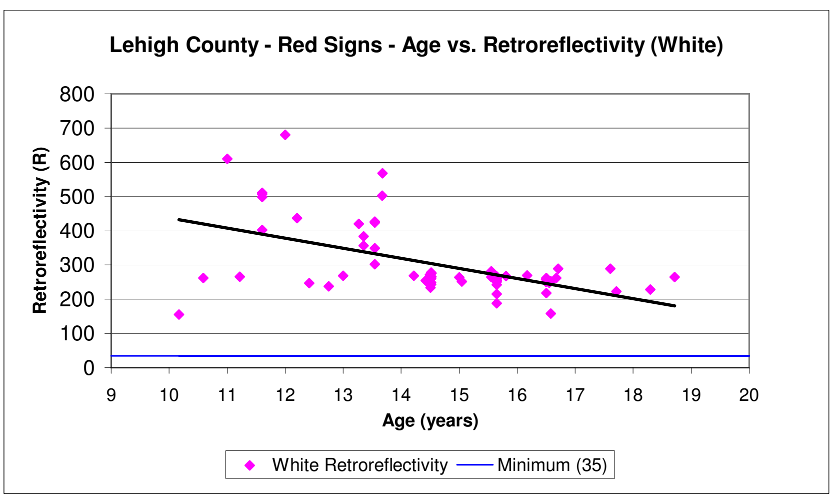
RED RETROREFLECTIVITY INFO	
Mean Red R:	34.0
Std Dev:	14.1
15th Percentile:	22.1
85th Percentile:	48.4

WHITE RETROREFLECTIVITY INFO	
Mean White R:	302.7
Std Dev:	105.1
15th Percentile:	243.1
85th Percentile:	421.2

CONTRAST RATIO INFO	
Mean:	9.9
Std Dev:	4.3
15th Percentile:	6.8
85th Percentile:	14.0



Y = -2.3829X + 68.67
R^2 = 0.1023



y = -29.413x + 731.21
R^2 = 0.2793

All signs meet FHWA minimum standards for red (R>7), white (W>35), and contrast ratio (>3:1)

Lehigh County - White Signs

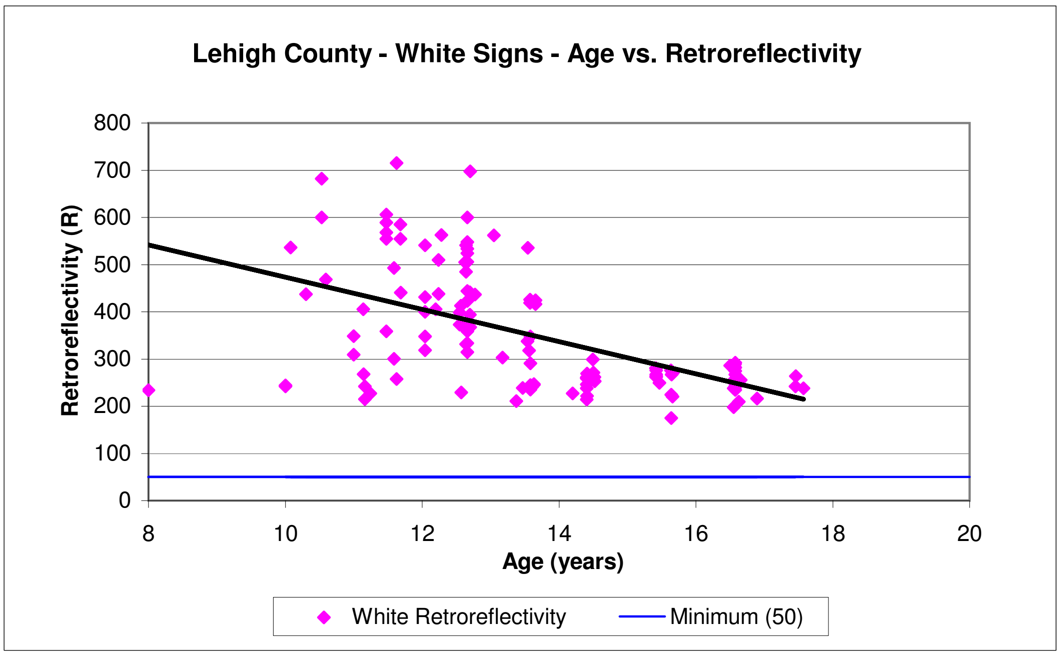
Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

White: R ≥ 50 cd/lx/m² for all white signs

Sample Size: 122
PA White Total: 222,224

AGE INFO	
Mean Age:	13.5
Std Dev:	2.0
15th Percentile:	11.5
85th Percentile:	16.5

RETROREFLECTIVITY INFO	
Mean White R:	353.8
Std Dev:	129.3
15th Percentile:	237.8
85th Percentile:	532.2



Y = -35.978x = 840.1
R^2 = 0.3041

All signs well above minimum FHWA standards.

Lehigh County - Yellow Signs

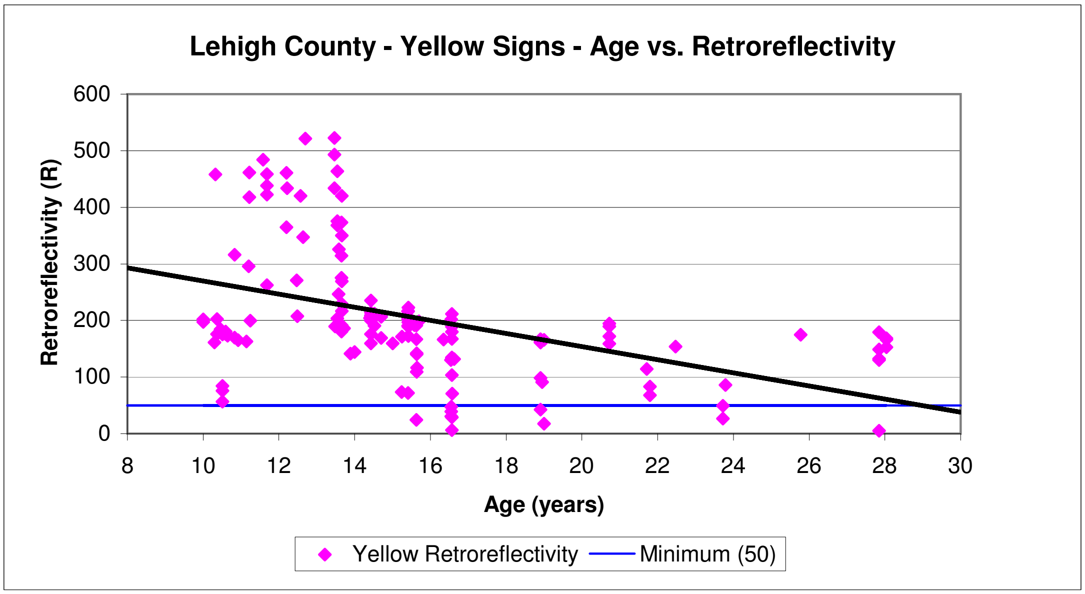
Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

Yellow : R ≥ 50 cd/lx/m² for all bold symbol signs and text/fine symbol signs ≥ 48"
R ≥ 75 cd/lx/m² for text/fine symbol signs ≤ 48"

Sample Size: 145
PA Yellow Total: 266,679

AGE INFO	
Mean Age:	15.6
Std Dev:	4.3
15th Percentile:	11.4
85th Percentile:	19.0

WHITE RETROREFLECTIVITY INFO	
Mean White R:	204.6
Std Dev:	115.2
15th Percentile:	101.5
85th Percentile:	334.5



y = -11.582x + 385.6
R^2 = 0.1903

11 of 146 (7.5%) did not meet FHWA minimum standards. These signs range in age from 16-28 years old.

Lancaster County - Red Signs

Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

Red: R ≥ 7 cd/lx/m² for all red signs
White: R ≥ 35 cd/lx/m² for all red signs
Contrast Ratio: W:R ≥ 3:1 for all red signs

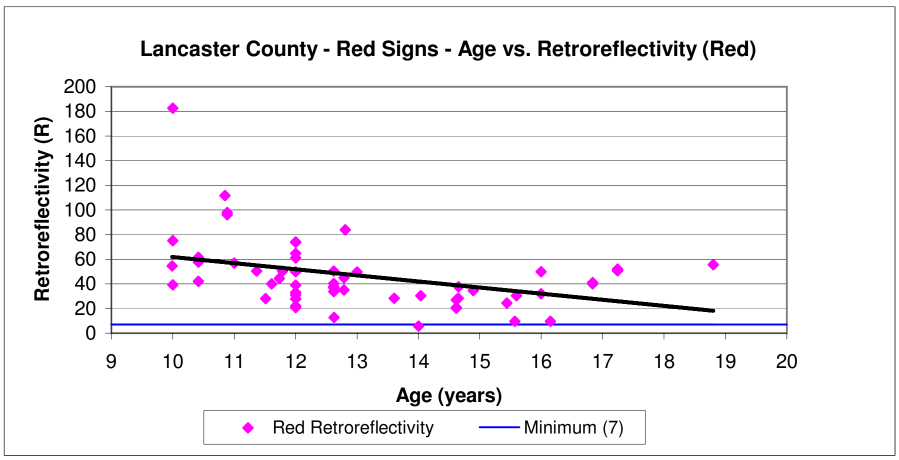
Sample Size: 58
PA Red Total: 107,648

AGE INFO	
Mean Age:	13.1
Std Dev:	2.2
15th Percentile:	10.9
85th Percentile:	15.8

RED RETROREFLECTIVITY INFO	
Mean Red R:	46.4
Std Dev:	28.2
15th Percentile:	25.8
85th Percentile:	63.0

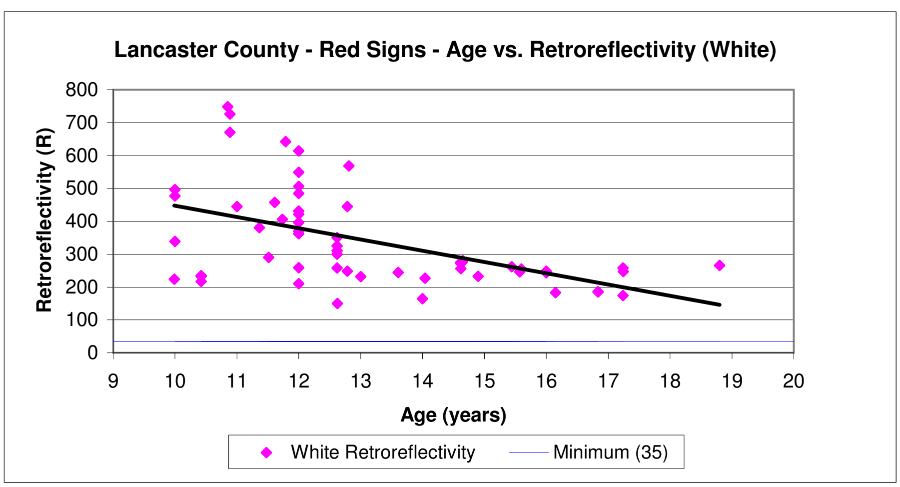
WHITE RETROREFLECTIVITY INFO	
Mean White R:	340.6
Std Dev:	147.0
15th Percentile:	225.5
85th Percentile:	490.0

CONTRAST RATIO INFO	
Mean W/R:	8.9
Std Dev:	15.7
15th Percentile:	23.5
85th Percentile:	55.0



y = -4.9806x + 111.7
R^2 = 0.1521

One sign is non-compliant for red (R>7) and one sign is non compliant for contrast ratio (>3:1)



y = -34.256x + 789.85
R^2 = 0.2651

All signs meet FHWA minimum standards for white retroreflectivity (W ≥ 35)

Lancaster County - White Signs

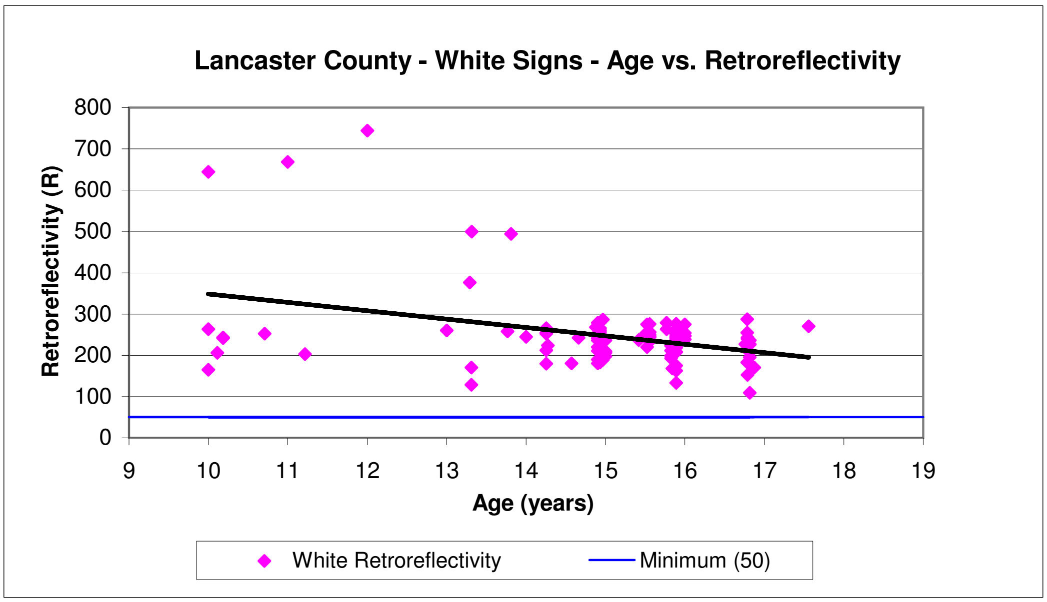
Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

White: R ≥ 50 cd/lx/m² for all white signs

Sample Size: 121
PA White Total: 222,224

AGE INFO	
Mean Age:	15.1
Std Dev:	1.6
15th Percentile:	14.3
85th Percentile:	16.0

RETROREFLECTIVITY INFO	
Mean White R:	245.6
Std Dev:	86.7
15th Percentile:	190.0
85th Percentile:	266.0



y = -20.228x + 550.52
R^2 = 0.1453

All signs meet FHWA minimum standards (W>50).

Lancaster County - Yellow Signs

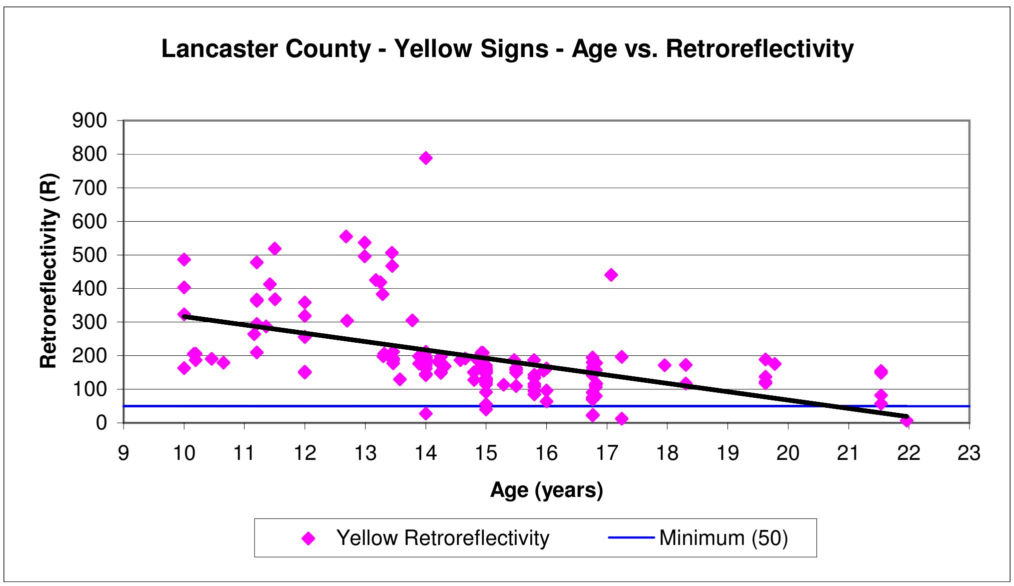
Minimum Maintained Traffic Sign Retroreflectivity Levels (Table A1, MUTCD):

Yellow : R ≥ 50 cd/lx/m² for all bold symbol signs and text/fine symbol signs ≥ 48"
R ≥ 75 cd/lx/m² for text/fine symbol signs ≤ 48"

Sample Size: 147
PA Yellow Total: 266,679

AGE INFO	
Mean Age:	14.8
Std Dev:	2.5
15th Percentile:	12.0
85th Percentile:	16.8

RETROREFLECTIVITY INFO	
Mean R:	196.5
Std Dev:	121.3
15th Percentile:	113.6
85th Percentile:	303.8



$y = -24.839x + 564.6$
$R^2 = 0.2634$

7 of the 147 (4.7%) signs were below FHWA minimum standards (Y>50 for all bold symbol signs and). The non compliant signs range in age from 14 to 22 years old.

3M

High Intensity Prismatic Reflective Sheeting

Series 3930 with Pressure Sensitive Adhesive

Product Bulletin 3930 **August 2008**

Replaces PB 3930 dated Sept. 2006

Description

3M™ High Intensity Prismatic Reflective Sheeting Series 3930 is a non-metalized micro-prismatic lens reflective sheeting designed for production of reflective durable traffic control signs, work zone devices and delineators that are exposed vertically in service. Applied to properly prepared sign substrates, 3M high intensity prismatic sheeting provides long-term reflectivity and durability. Series 3930 sheeting is available in the following colors.

Color	Product Code
White	3930
Yellow	3931
Red	3932
Orange	3934
Blue	3935
Green	3937
Brown	3939

Photometrics

Daytime Color (x,y,Y)

The chromaticity coordinates and total luminance factor of the retroreflective sheeting conform to Table A.

Color Test

Conformance to standard chromaticity (x,y) and luminance factor (Y, %) requirements shall be determined by instrumental method in accordance with ASTM E 1164 on sheeting applied to smooth aluminum test panels cut from Alloy 6061-T6 or 5052-H38. The values shall be determined on a HunterLab ColorFlex 45/0 spectrophotometer. Computations shall be done for CIE Illuminant D65 and the 2° standard observer.[1]

[1]The instrumentally determined color values of retroreflective sheeting can vary significantly depending on the make and model of colorimetric spectrophotometer as well as the color and retroreflective optics of the sheeting (David M. Burns and Timothy J. Donahue, Measurement Issues in the Color Specification of Fluorescent-Retroreflective Materials for High Visibility Traffic Signing and Personal Safety Applications, Proceedings of SPIE: Fourth Oxford Conference on Spectroscopy, 4826, pp. 39-49, 2003). For the purposes of this document, the HunterLab ColorFlex 45/0 spectrophotometer shall be the referee instrument.

Table A - CIE Chromaticity Coordinate Limits* for new sheeting

	1		2		3		4		Limit Y (%)	
Color	x	y	x	y	x	y	x	y	Min.	Max
White	.303	.300	.368	.366	.340	.393	.274	.329	40	-
Yellow	.498	.412	.557	.442	.479	.520	.438	.472	24	45
Red	.648	.351	.735	.265	.629	.281	.565	.346	3	12
Orange	.558	.352	.636	.364	.570	.429	.506	.404	14	30
Blue	.140	.035	.244	.210	.190	.255	.065	.216	1	10
Green	.026	.399	.166	.364	.286	.446	.207	.771	3	9
Brown	.430	.340	.610	.390	.550	.450	.430	.390	1	6

* The four pairs of chromaticity coordinates deteremine the acceptable color in terms of the CIE 1931 standard colormetric system measured with standard illuminant D65.

Coefficients of Retroreflection (R_A)

The values in Table B are minimum coefficients of retroreflection expressed in candelas per lux per square meter (cd/lux/m²).

Test for Coefficients of Retroreflection

Conformance to coefficient of retroreflection requirements shall be determined by instrumental method in accordance with ASTM E-810 "Test Method for Coefficient of Retroreflection of Retroreflective Sheeting" and per E-810 the values of 0° and 90° rotation are averaged to determine conformance to the R_A limits in Table B.

Table B - Minimum Coefficient of Retroreflection
R_A for new sheeting
(cd/lux/m²)

-4° Entrance Angle[2]

	Observation Angle[1]	
	0.2°	**0.5°**
White	560	200
Yellow	420	150
Red	84	30
Orange	210	75
Green	56	20
Blue	28	10
Brown	17	6

30° Entrance Angle[2]

	Observation Angle[1]	
	0.2°	**0.5°**
White	280	100
Yellow	210	75
Red	42	15
Orange	105	37
Green	28	10
Blue	14	5
Brown	8.4	3

[1]Observation (Divergence) Angle - The angle between the illumination axis and the observation axis.

[2]Entrance (Incidence) Angle - The angle from the illumination axis to the retroreflector axis. The retroreflector axis is an axis perpendicular to the retroreflective surface.

R_A for Screenprinted Colors and Overlay Films

For screenprinted transparent color areas on white sheeting, or white sheeting covered with 3M™ ElectroCut™ Film Series 1170 when processed according to 3M recommendations, the ratios of the R_A for the color to the R_A for the white shall be no less than 70% of the R_A listed for the integral color in Table B and the colors shall conform to Table A on page 1.

Adhesive

Series 3930 sheeting has a pressure-sensitive adhesive that is recommended for room temperature application. Room temperature application is defined as 65°F (18°C) or higher.

Test Methods of Adhesive and Film

Standard Test Panels

Unless otherwise specified, the reflective sheeting shall be applied according to the manufacturer's recommendations to smooth 0.063 inches (1.6mm) minimum thickness 6061-T6, 5052-H38 or equivalent aluminum panels that have been degreased and lightly acid etched. Lack of contamination of test panels must be confirmed by passing the water break test and tape snap test as described in 3M Information Folder 1.7.

Properties

Standard Conditioning: All mounted and unmounted test specimens shall be conditioned for 24 hours hours at 73°F +/- 2°F (23°C + 1°C) and 50% +/- 4% R.H. before testing.

1. Adhesion

Test Weight 1-3/4 lbs. (0.8 kg) Test Method - Apply 4 inches (10cm) of 1 inch x 6 inch (2.54x15cm) strip to panel and condition, face panel down and suspend test weight from free end. Requirement - Not more than 2 inches (5.0cm) of peel in five minutes.

2. Impact Resistance

Test Method - Apply sheeting to a standard panel 3 inch x 6 inch (7.6x15.2cm) and condition. Subject sheeting to a 50-inch pound (5.7Nm) impact in accordance with ASTM D-2794. Requirement - No separation from panel or cracking outside immediate impact area.

3. Shrinkage

Test Method - Following conditioning of 9 inch x 9 inch samples, remove liner, place specimen on flat surface with adhesive side up. Requirement - Shrinkage not greater than 1/32 inches (0.8mm) in 10 minutes or more than 1/8 inches (3.2mm) in 24 hours in any dimension.

4. Flexibility

Test Method - Following conditioning of 1 inch x 6 inch sample, remove liner and dust adhesive with talc. At standard conditions, holding the ends of the sample, bend in one second around 1/8 inch (3.2mm) mandrel with adhesive side facing mandrel. Requirement - No cracking, peeling or delamination.

5. Gloss

Test Method - Test in accordance with ASTM D523 using an 85° glossmeter. Requirement - Rating not less than 50.

Sign Fabrication Methods

Application

3M high intensity prismatic sheeting series 3930 incorporates a pressure sensitive adhesive and should be applied to the sign substrate at room temperature 65°F (18°C) or higher by any of the following methods:

Mechanical squeeze roll applicator - Reference 3M Information Folder 1.4 (Room temperature application)

Application to extrusions requires heat directed at the next-to-last edge roller. Cracking or edge lifting may occur if the top film is not sufficiently softened.

Hand squeeze roll applicator - Reference 3M Information Folder 1.6

Hand Application

Hand application is recommended for legend and copy only. Application of sheeting for complete signs or backgrounds must be done with a roll laminator, either mechanical or hand. See 3M Information Folder 1.5 for more details.

Hand applications will show some visual irregularities that are objectionable to aesthetically critical customers. These are more noticeable on darker colors. To obtain a close-up uniform appearance, a roll laminator must be used.

All direct applied copy and border MUST be cut at all metal joints and squeegeed at the joint.

Splices

Series 3930 sheeting should be butt spliced when more than one piece of sheeting is used on one piece of substrate. The sheeting pieces should not touch each other at the splice and a gap of up to 1/16 inch is acceptable. This is to prevent buckling as the sheeting expands in extreme temperature/humidity exposure. If the visual appearance of the splice is important or a slight gap is undesirable, the following procedures must be followed:

1. Overlap the sheeting at least one inch, with or without the liner attached.
2. Using a straight edge and a sharp utility knife, cut through both layers of reflective sheeting.
3. Peel back and remove cut remnants. If liner was left on, remove and roll down remaining sheeting.
4. Seal edge with thinned 3M™ Process Color 880I Clear using a fine artist paintbrush.

Double Faced Signs - Series 3930 sheeting on the first side must be protected by damage from the steel bottom roll of squeeze roll applicators with FR-2 sponge rubber and SCW 568.

Substrates

For traffic sign use, product application is limited to properly prepared aluminum (see 3M Information Folder 1.7). Extrusions can be wrapped or trimmed, and flat panel signs are to be carefully trimmed so that sheeting from adjacent panels do not touch on the assembled signs. Users are urged to carefully evaluate all other substrates for adhesion and sign durability. Series 3930 sheeting is designed primarily for application to flat substrates. Any use that requires a radius of curvature of less than five inches should also be supported by rivets or bolts. Plastic substrates are not recommended where cold shock performance is essential. Sign failures caused by the substrate or improper surface preparation are not the responsibility of 3M.

Screen Processing

Series 3930 sheeting may be screen processed into traffic signs before or after mounting on a sign substrate, using 3M Process Colors Series 880I (see Product Bulletin 880I) or Series 880N (see Product Bulletin 880N). Series 880I or 880N process colors can be screened at 60-100ºF (16-38ºC) at relative humidity of 20-50%. A PE 157 screen mesh with a fill pass is recommended. See Information Folder 1.8 for details. Use of other process colors series is not recommended. 3M assumes no responsibility for failure of sign face legends or backgrounds that have been processed with non-3M process colors or 3M process colors other than those listed above.

Care should be taken to avoid flexing Series 3930 sheeting before and especially after screening to eliminate the possibility of cracking from improper handling techniques.

Cutting and Matching

The sheeting may be hand cut or die cut one sheet at a time, and band sawed or guillotined in stacks.

Series 3930 sheeting can be hand cut from either side with a razor blade or other sharp hand tool. Like all reflective sheetings, when two or more pieces are used side by side on a sign, they must be matched to assure uniform day color and night appearance.

Cutting equipment such as guillotines and metal shears, that have pressure plates on the sheeting when cutting, may damage the optics. Padding the pressure plate and easing it down onto the sheets being cut will significantly reduce damage.

Maximum stack height for cutting Series 3930 sheeting is 1-1/2 inches or 50 sheets. Details on cutting can be found in 3M Information Folder 1.10.

Multi-piece signs should have all panels or pieces oriented identically for uniform appearance under all viewing conditions (arrow and the seal pattern in the same direction).

Edge sealing Series 3930 sheeting is generally not required. Following extended exposure, airborne dust particles may become trapped within the row of cut cells along the sheeting edge. This should have no adverse effect on sign performance. If the user chooses to edge seal, series 880I process color should be used.

Cleaning

Signs that require cleaning should be flushed with water, then washed with a detergent solution and bristle brush or sponge. Avoid pressure that may damage the sign face. Flush with water following washing. Do not use solvents to clean signs. See 3M Information Folder 1.10.

Storage and Packaging

Series 3930 sheeting should be stored in a cool, dry area, preferably at 65-75°F (18-24°C) and 30-50% relative humidity and should be applied within one year of purchase. Rolls should be stored horizontally in the shipping carton. Partially used rolls should be returned to the shipping carton or suspended horizontally from a rod or pipe through the core. Unprocessed sheets should be stored flat. Finished signs and applied blanks should be stored on edge. Screen processed signs must be protected with the adhesive liner or SCW 568 slipsheet paper. Place the glossy side of the slipsheeting against the sign face and pad the face with closed cell packaging foam. Double-faced signs must have the glossy side of the slipsheet against each face of the sign.

Unmounted screened faces must be stored flat and interleaved with SCW 568 slipsheet, glossy side against the sign face. Packages of finished sign faces must include sufficient nylon washers for mounting. Avoid banding, crating, or stacking signs. Package for shipment in accordance with commercially accepted standards to prevent movement and chafing. Store sign packages indoors on edge.

Panels or finished signs must remain dry during shipment and storage. If packaged signs become wet, unpack immediately and allow signs to dry.

See Information Folder 1.11 for instructions on packing for storage and shipment.

Installation

Nylon washers are recommended between the heads of all twist fasteners (such as screw heads, bolts, or nuts) and the sheeting to protect the sheeting from the twisting action of the bolt heads.

Health and Safety Information

Read all health hazard, precautionary and first aid statements found in the Material Safety Data Sheet, and/or product label of chemicals prior to handling or use.

General Performance Considerations

The durability of 3M high intensity prismatic reflective sheeting series 3930 will depend upon substrate selection and preparation, compliance with recommended application procedures, geographic area, exposure conditions, and maintenance.

Maximum durability of Series 3930 sheeting can be expected in applications subject to vertical exposure on stationary objects when processed and applied to properly prepared aluminum according to 3M recommendations provided in 3M Information Folder 1.7 on Sign Substrate Surface Preparation.

The user must determine the suitability of any nonmetallic sign backing for its intended use.

Applications to unprimed, excessively rough or non-weather-resistant surfaces, or exposure to severe or unusual conditions can shorten the performance of such applications. Signs in mountainous areas that are covered by snow for prolonged periods may also have reduced durability.

3M process colors, when used according to 3M recommendations, are generally expected to provide performance comparable to colored reflective sheeting, except for certain lighter colors, such as yellow, gold, or heavily toned colors or blends containing yellow or gold, whose durability depends on how much of each color is used.

Dilution of color and atmospheric conditions in certain geographic areas may result in reduced durability.

3M™ ElectroCut™ Film Series 1170 can be expected to perform satisfactorily for the life of the sign when direct applied to series 3930 sheeting.

Warranty

3M warrants that 3M™ High Intensity Prismatic Reflective Sheeting Series 3930 sold by 3M to be used as components for traffic control and guidance signs in the United States and Canada will remain effective for its intended use and meet the stated minimum values for coefficient of retroreflection for ten years, subject to the following provisions in:

Table C
Percentage of Table B Initial R_A Minimums Guaranteed Over 10 Year Warranty Period (Colors: white, yellow, red, green and blue)

Warranty Period	Minimum Percentage R_A Retained
1-7 Years	80%
8-10 Years	70%

R_A percentage retained above apply to all entrance and observation angles presented in Table B, and shall be measured per ASTM E 810.

All measurements shall be made after cleaning according to 3M recommendations. If a high intensity grade prismatic sign surface is processed and applied to sign blank materials in accordance with all 3M application and fabrication procedures provided in 3M's product bulletins, information folders, and technical memos (which will be furnished to the agency upon request), including the exclusive use of 3M matched component systems, process colors, clear coatings, electronic cuttable films, protective overlay films, and recommended applications equipment; and

If the sign deteriorates due to natural causes to the extent that: 1) the sign is ineffective for its intended purpose when viewed from a moving vehicle under normal day and night driving conditions by a driver with normal vision, or 2) the coefficient of retroreflection after cleaning is less than the minimums specified in Table C, 3M's sole responsibility and purchaser's and user's exclusive remedy shall be:

If the failure occurs within the first 7 years from the date of fabrication, 3M will, at its expense, restore the sign surface to its original effectiveness. If the failure occurs within the 8th through the 10th year from the date of fabrication, 3M will furnish the necessary amount of high intensity prismatic sheeting to restore the sign surface to its original effectiveness.

Warranty for 3934 Sheeting

3M warrants that 3M™ High Intensity Prismatic Reflective Sheeting 3934 Orange sold by 3M to be used as components for traffic control devices used in work zones in the United States and Canada will remain effective for its intended use and meet the stated minimum values for coefficient of retroreflection for three years, subject to the following provisions:

Minimum Coefficient of Retroreflection
Candelas per Foot Candle per Square Feet
Candelas per Lux per Square Meter
(0.2° observation and -4° entrance)*

Sheeting Color	Min. Coeff. of Retroreflection (Three Years)
Orange	80

*All measurements shall be made after sign cleaning according to 3M recommendations and in accordance with ASTM E 810 "Standard Test Method for Coefficient of Retroreflection of Retroreflective Sheeting."

If a high intensity prismatic sign surface is processed and applied to sign blank materials in accordance with all 3M application and fabrication procedures found in 3M's product bulletins, information folders and technical memos (which will be furnished to the agency upon request), including the exclusive use of 3M matched component systems, process colors, clear coatings, electronic cuttable films, protective overlay films, and recommeneded application equipment; and

If the sign deteriorates due to natural causes to the extent that: 1) the sign is ineffective for its intended purpose when viewed from a moving vehicle under normal day and night driving conditions by drivers with normal vision, or 2) the coefficient for retroreflection is less than the minimum herin specified, 3M's sole responsibility and purchaser's and user's exclusive remedy shall be that 3M will provide pro-rata replacement of the 3M materials:

If failure occurs within the first year from the date of fabrication, 3M will at its expense, restore the sheeting surface to its original effectiveness. If failure occurs in the second year, two-thirds of the sheeting will be replaced. If failure occurs in the third year, one-third of the sheeting will be replaced.

Conditions

Such failure must be solely the result of design or manufacturing defects in the 3M high intensity prismatic reflective sheeting and not of outside causes such as: improper fabrication, handling, maintenance or installation; use of process colors, thinners, coatings, or overlay films and sheetings not made by 3M; use of application equipment not recommended by 3M; failure of sign substrate; exposure to chemicals, abrasion and other mechanical damage from fasteners used to mount the sign; sign burial; collisions, vandalism or malicious mischief.

3M reserves the right to determine the method of replacement. Replacement sheeting will carry the unexpired warranty of the sheeting it replaces. Claims made under this warranty will be honored only if the signs have been dated at the time of sheeting application, which constitutes the start of the warranty period. Claims made under this warranty will be honored only if 3M is notified of a failure within a reasonable time, reasonable information requested by 3M is provided, and 3M is permitted to verify the cause of the failure.

Limitation of Liability and Remedies

3M's liability under this warranty is limited to replacement or allowance as stated herein, and 3M assumes no liability for incidental or consequential damages such as lost profits, business or revenue in any way related to the product regardless of the legal theory on which the claim is based.

THIS WARRANTY IS MADE IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY, OF FITNESS FOR A PARTICULAR PURPOSE, ANY IMPLIED WARRANTY ARISING OUT OF A COURSE OF DEALING OR OF PERFORMANCE, CUSTOM OR USAGE OF TRADE.

Literature Reference

IF 1.3 Instructions for Squeeze Roll Applicator

IF 1.5 Hand Application Instructions

IF 1.6 Instructions for Hand Squeeze Roll Applicator

IF 1.7 Sign Base Materials

IF 1.8 Color Application Instructions

IF 1.10 Cutting, Matching, Premasking, and Prespacing Instructions

IF 1.11 Storage Maintenance, and Removal Instructions

"Standard Highway Signs, As Specified in the Manual on Uniform Traffic Control Devices", U.S. Department of Transportation, Federal Highway Administration, 1979.

FOR INFORMATION OR ASSISTANCE
CALL:
1-800-553-1380

IN CANADA CALL:
1-800-265-1840

Internet:
www.3M.com/tss

3M assumes no responsibility for any injury, loss or damage arising out of the use of a product that is not of our manufacture. Where reference is made in literature to a commercially available product, made by another manufacturer, it shall be the user's responsibility to ascertain the precautionary measures for its use outlined by the manufacturer.

Important Notice

All statements, technical information and recommendations contained herein are based on tests we believe to be reliable, but the accuracy or completeness thereof is not guaranteed, and the following is made in lieu of all warranties, or conditions express or implied. Seller's and manufacturer's only obligation shall be to replace such quantity of the product proved to be defective. Neither seller nor manufacturer shall be liable for any injury, loss or damage, direct, special or consequential, arising out of the use of or the inability to use the product. Before using, user shall determine the suitability of the product for his/her intended use, and user assumes all risk and liability whatsoever in connection therewith. Statements or recommendations not contained herein shall have no force or effect unless in an agreement signed by officers of seller and manufacturer.

3M

Traffic Safety Systems Division
3M Center, Building 0225-05-S-08
St. Paul, MN 55144-1000
1-800-553-1380
www.3M.com/tss

3M Canada Company
P.O. Box 5757
London, Ontario N6A 4T1
1-800-3MHELPS

3M México, S.A. de C.V.
Av. Santa Fe No. 55
Col. Santa Fe, Del. Alvaro Obregón
México, D.F. 01210

Bolger 8080609
Electronic Only

Avery Dennison® T-6000 & W-6000 HIP Series

High Intensity Microprismatic Retroreflective Film

Issued: April 2011 Revision 1

Avery Dennison® T-6000 & W-6000 Series High Intensity Microprismatic (HIP) Retroreflective Film for permanent and temporary traffic signage, is a high-quality, durable, microprismatic retroreflective material with a pressure sensitive adhesive. Its unique microprismatic construction provides a high level of retroreflectivity for demanding traffic control situations.

T-6000 & W-6000 Series sheeting is an Omni-Directional microprismatic film that incorporates tiles of microprisms arranged in multiple orientations. This feature – “Smart at Every Angle” benefits agencies by providing confidence that all signs will perform with uniform visual reflectivity at all sign face orientations.

Performance:
ASTM D4956 Type III & IV,
CUAP Table 7
See Page 2 for complete list.

Orientation: Omni-Directional

Durability: 10 year
Vertical Exposure only

Face: High-Gloss Acrylic Retroreflective Film with Microprisms

Adhesive: Permanent Pressure Sensitive

Liner: Polypropylene Film

Features:

- Omni-Directional
- High Intensity Microprismatic Retroreflective Performance
- Field proven long term durability on safety devices worldwide
- Uniform daytime and nighttime visual appearance

Conversion:

☒ Screen Printing
☒ Thermal Transfer Printing
☒ Solvent Based Inkjet Printing
☒ Mild/Eco Solvent Inkjet Printing
☒ UV Inkjet Printing
☒ Thermal Die-Cut
☒ Flat Bed Sign-Cut
☒ Drum Roller Sign-Cut
☒ Steel Rule Sign-Cut

Product Availability*:

Traffic Products		
T-6500	White	
T-6501	Yellow	
T-6505	Blue	
T-6507	Green	
T-6508	Red	
T-6509	Brown	
Work Zone Products*		
W-6100	White	
W-6200	White	
W-6204	Orange	
W-6504	Orange	
W-6511	Fluorescent Yellow	
W-6513	Fluorescent Yellow-Green	
W-6142	Orange Pre-Striped Barricade	4” Left
W-6143		4” Right
W-6144		6” Left
W-6145		6” Right
W-6242		4” Left
W-6243		4” Right
W-6244		6” Left
W-6245		6” Right

*See Page 5 for Nomenclature.
**3 Year Durability

Applications:

☒ Rigid Permanent and Temporary Outdoor Signage
☒ Rigid Work Zone Devices
☒ Safety Devices that Require Robust Retroreflective Performance

Graphics and Reflective Solutions
250 Chester Street
Painesville, OH 44077

Avery Dennison® T-6000 & W-6000 HIP Series

High Intensity Microprismatic Retroreflective Film

Issued: April 2011 Revision 1

Retroreflectivity:

Table A:

Min. coefficients of retroreflection (R_A)[1] per ASTM D4956[2] Type III & IV

Observation Angle	Color	Entrance Angle - 4°	Entrance Angle + 30°
0.1°[3]	White	500	240
	Yellow	380	175
	Orange	200	94
	Blue	42	20
	Green	70	32
	Red	90	42
	Brown	25	12
	Fluorescent Yellow	300	140
	Fluorescent Yellow-Green	400	185
0.2°	White	360	170
	Yellow	270	135
	Orange	145	68
	Blue	30	14
	Green	50	25
	Red	65	30
	Brown	18	8.5
	Fluorescent Yellow	220	100
	Fluorescent Yellow-Green	290	135
0.5°	White	150	72
	Yellow	110	54
	Orange	60	28
	Blue	13	6.0
	Green	21	10
	Red	27	13
	Brown	7.5	3.5
	Fluorescent Yellow	90	40
	Fluorescent Yellow-Green	120	55

Table B:

Min. coefficients of retroreflection (R_A)[1] CUAP Table 7 (EN-12899 RA2)

α Observation Angle	Color	β1 (β2=0˚) Entrance Angle + 5°	+ 30°	+ 40°
12' (0.2°)	White	250	150	110
	Yellow	170	100	70
	Orange	100	60	29
	Blue	20	11	8
	Green	45	25	12
	Red	45	25	15
	Brown	12	8.5	5.0
20' (0.33°)	White	180	100	95
	Yellow	120	70	60
	Orange	65	40	20
	Blue	14	8.0	7.0
	Green	21	12	11
	Red	25	14	13
	Brown	8.0	5.0	3.0
2°	White	5.0	2.5	1.5
	Yellow	3.0	1.5	1
	Orange	1.5	1	--
	Blue	0.2	--	--
	Green	0.5	0.3	0.2
	Red	1	0.4	0.3
	Brown	0.2	--	--

HIP Series sheeting **exceeds** all values listed in **Table A** and **Table B.**

HIP Series sheeting also **exceeds** the current applicable requirements for the following specifications:

ASTM D4956	International
AASHTO M268	USA
CUAP	EU
GB/T 18833	China
N-CMT-5-03-001	Mexico
UNE 135340	Spain
NF XP98520	France
BSI 8408	UK
UNI 11122	Italy
JIS Z9117	Japan
SANS 1519-1	South Africa
AS/NZS 1906.1	Australia New Zealand
ABNT NBR 14644	Brazil
IRAM 3952	Argentina

Avery Dennison suggests you obtain the current requirements from your local agency and ensure product conformance with such requirements. Your Avery Dennison Representative can assist you in this regard.

R_A = candelas per foot-candle per square foot (cd/fc/ft^2) OR Candelas per lux per square meter (cd/lx/m^2)

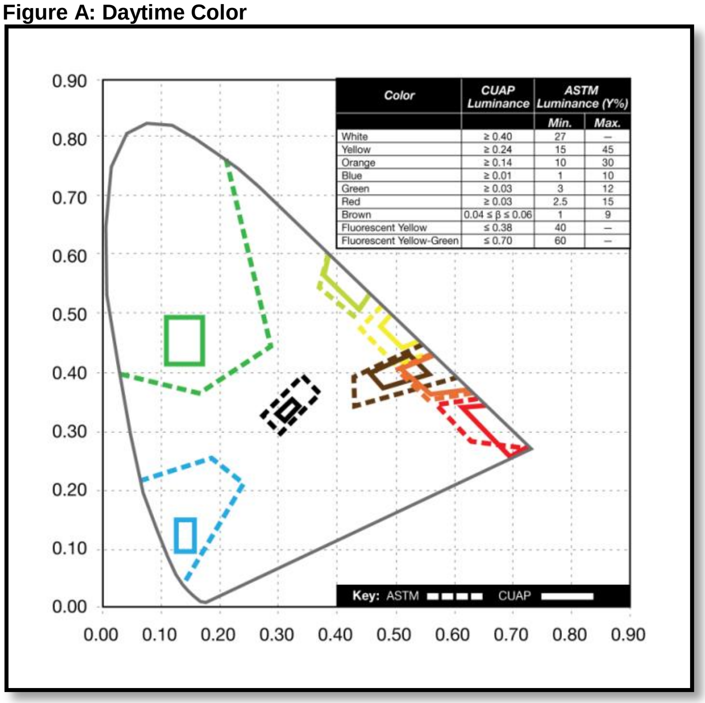
[2] Measured according to ASTM E810

[3] Note that 0.1° Observation angle is a "supplemental Requirement" in ASTM D4956. It represents long highway viewing distances of about 900 ft (275 Meters) and greater.

Graphics and Reflective Solutions
250 Chester Street
Painesville, OH 44077

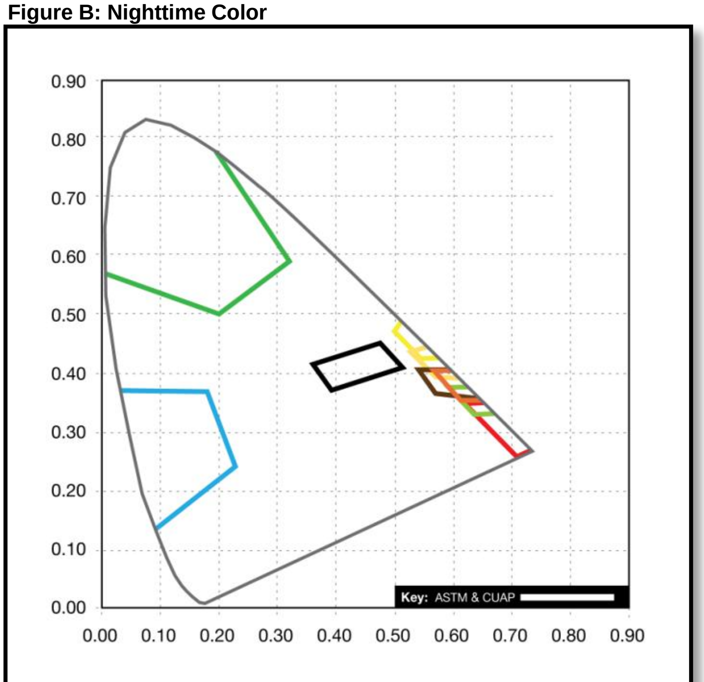
Colors and Specification Limits:

Figure A: Daytime Color



Color	CUAP Luminance	ASTM Luminance (Y%)	
		Min.	Max.
White	≥ 0.40	27	–
Yellow	≥ 0.24	15	45
Orange	≥ 0.14	10	30
Blue	≥ 0.01	1	10
Green	≥ 0.03	3	12
Red	≥ 0.03	2.5	15
Brown	0.04 ≤ β ≤ 0.06	1	9
Fluorescent Yellow	≤ 0.38	40	–
Fluorescent Yellow-Green	≤ 0.70	60	–

Figure B: Nighttime Color



HIP Series sheeting **meets** the current applicable daytime and nighttime color requirements for ASTM D4956 and CUAP as well as standards listed on Page 2.

Chromaticity Coordinate Limits

Figures A & B show the four pairs of chromaticity coordinates from ASTM D4956 and CUAP on the color grid.

Daytime Color

The four pairs of chromaticity coordinates in **Figure A** determine the acceptable color in terms of the CIE 1931 Standard Colorimetric System measured with Standard Illuminant D65 and CIE Publication no. 15 using CIE Standard Illuminant D65 and CIE 45/0 geometry. Luminance factor shall comply with table in **Figure A.**

Note: The saturation limit of green and blue may extend to the border of the CIE chromaticity locus for spectral colors

Nighttime Color

The four pairs of chromaticity coordinates in **Figure B** determine the acceptable color measured using CIE Illuminant A, observation angle of 0.33 degrees, entrance angle of +5 degrees, source and receiver apertures not to exceed 10 minutes of arc, and CIE 1930 (2 degree) standard observer per ASTM D4956.

Graphics and Reflective Solutions

250 Chester Street

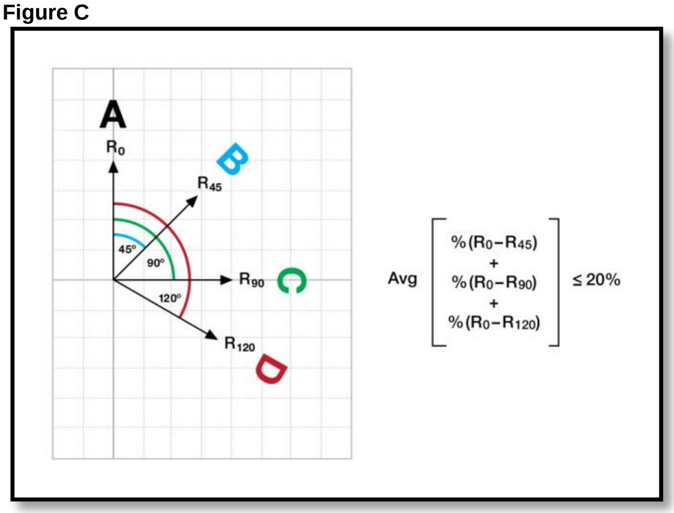
Painesville, OH 44077

www.reflectives.averydennison.com

Sheeting Orientation:

The American Association of State Highway Transportation Officials (AASHTO) has recognized that some retroreflective films are rotationally (orientation) sensitive. Because this impacts sign luminance, AASHTO has defined a specification to measure orientation performance. **Figure C** shows how the orientation sensitivity is measured. In order for a film to be considered rotationally insensitive the average percent difference (shown in **Figure C**) must be less than or equal to 20%.

Figure C



When measured for orientation sensitivity as described in AASHTO M 268-10, all Avery Dennison sheeting, both beaded and prismatic, **pass** the specification as **rotationally insensitive**. Therefore no special identification marks or other features (such as a datum mark, or distinctive seal pattern) are required to denote optimum orientation for sheeting. Because the user can expect visual uniformity regardless of orientation, no costly and cumbersome fabrication techniques are required to orient sheets, cut sign legend or border tape during sign fabrication.

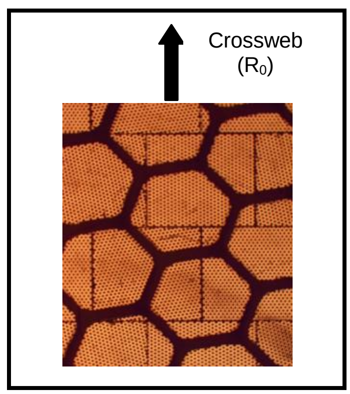
Specifying agencies and sign fabricators are cautioned that some retroreflective sheetings, even of the same ASTM "Type" may not provide consistent luminance for desired night visibility if the sheeting is not applied in the optimal, or in uniform orientation. Agencies and fabricators should be aware of this concern and discuss the potential effects of rotation on luminance of specific sheetings with their material supplier before beginning installation and/or fabrication.

HIP Series sheeting is Omni-Directional and **passes** the AASTHO specification as being **rotationally insensitive.**

Retroreflectivity R_A values taken per ASTM E810
0.5˚ Observation angle and
-4˚ or 5˚ Entrance angle

As a datum for laboratory measurements R_0 is identified in the crossweb direction. See **Figure D**

Figure D



Watermark: HIP Series contains the watermark seen in **Figure E.**

Figure E

HIP Lot #

Avery Dennison® T-6000 & W-6000 HIP Series

High Intensity Microprismatic Retroreflective Film

Issued: April 2011 Revision 1

Nomenclature:

T – 6 5 0 0

- Initial Letter(s): Application/Durability
- 1st Number†: Series
- 2nd Number: Adhesive
- 3rd & 4th Numbers: Color

Initial Letter	Application	Durability*
T	Traffic/Permanent Sheeting	10 year
W	Work Zone Sheeting	3 year
WR	Work Zone Reboundable	3 year

***** See your local representative for complete details.

Series	6000

2nd Number	Substrate
1	Pressure Sensitive for Plastic Substrates
2	Pressure Sensitive for Wood Substrates
5	Pressure Sensitive for Aluminum Substrates

3rd & 4th Numbers	Color
00	White
01	Yellow
04	Orange
05	Blue
07	Green
08	Red
09	Brown
11	Fluorescent Yellow
13	Fluorescent Yellow-Green
14	Fluorescent Orange
42	4” LEFT Orange Pre-Striped Barricade
43	4” RIGHT Orange Pre-Striped Barricade
44	6” LEFT Orange Pre-Striped Barricade
45	6” RIGHT Orange Pre-Striped Barricade

† OmniCube is the exception and leads with the number 11

The following Warranty is limited to North America.

WARRANTY

Avery Dennison T-6000 & W-6000 prismatic retroreflective sheeting (“Product(s)”) are warranted to be free from defects in material and workmanship for one (1) year from date of purchase (or the period stated on the specific product information literature in effect at time of delivery, if longer). It is expressly agreed and understood that Avery Dennison's sole obligation and Purchaser's exclusive remedy under this warranty, under any other warranty, express or implied, or otherwise, shall be limited to repair or replacement of defective Product without charge at Avery Dennison's plant or at the location of Product (at Avery Dennison's election), or in the event replacement or repairs is not commercially practical, to Avery Dennison's issuing Purchaser a credit reasonable in light of the defect in the Product.

Avery Dennison further warrants that Avery Dennison® T-6000 & W-6000 prismatic retroreflective sheeting will retain its effectiveness as a component of traffic control and guidance signs, and will meet the stated minimum values for coefficient of retroreflection (“Performance Warranty”) as set forth in accordance with the following standards:

Warranty Period*	Minimum Percentage R_A Retained
1-7 years	80%
8-10 years	80%

* Performance Warranty Period for Work Zone products is one to three (1-3) years

Note: For transparent color screen printed areas using Avery Dennison supplied or approved inks or OL-2000 Overlay films on Avery Dennison® T-6500 white sheeting, values shall be a minimum of 70% of values in Table A

R_A percentage retained above apply to all entrance and observation angles in Table A, and shall be measured per ASTM E 810.

All measurements shall be made after cleaning according to Avery Dennison procedures.

PERFORMANCE WARRANTY

If within ten (**10**) years from the initial date of installation, the Product deteriorates due to natural causes to the extent that: 1) the Product fails to retain the minimum reflectivity values warranted for the ten (**10**) year period under the standard in force at the time of installation, or 2) the Product is ineffective for its intended purpose when viewed from a moving vehicle under normal daytime or nighttime driving conditions, Avery Dennison will furnish a replacement amount of like Product at no cost to enable the installed surface to be restored to its original effectiveness. If within seven (**7**) years of installation such deterioration occurs or the Product fails to retain the minimum seven (**7**) year reflectivity values, Avery Dennison will restore the installation surface to its original effectiveness at no cost for materials or labor.

CONDITIONS.

This warranty shall be effective only if all of the following conditions are met:

Fabrication and/or installation must occur within one (1) year from the date of purchase.

The failure must have resulted solely from a manufacturing defect or deterioration of the Product due to natural causes under the Performance Warranty. Without limiting the generality of the foregoing, there is no warranty for the failure of the sheeting due to improper sign fabrication, storage, handling, installation, maintenance, failure of the sign substrate, vandalism or mischief. Slight color fading, cracking, chalking, edge lifting, or slight reduction in gloss or reflectivity will not materially detract from appearance and does not constitute a breach of warranty.

Avery Dennison has published instructional bulletins pertaining to the storage, handling, and cleaning of Product, approved substrates, and application procedures (collectively, the “Procedures”). The Product must have been processed and applied to blank, clean material in accordance with the Procedures, as such may be amended from time to time. Avery Dennison reserves the right to reject any warranty claim where the fabricator or installer cannot satisfactorily prove or demonstrate that the Avery Dennison procedures were utilized. The date of installation, warranty registration, and claim procedures established by Avery Dennison must be followed, and failure to follow such procedures shall void this warranty. Replacement Product carries only the unexpired warranty portion of the Product it replaces. The Product must be properly stored and applied within the shelf-life as stated in the applicable Avery Dennison Product Data Sheet including adhesive and other material product data sheets.

Graphics and Reflective Solutions
250 Chester Street
Painesville, OH 44077

Characteristics:

Property	*Value*	*Instructional Bulletins*
Shelf-Life	1 year from date of purchase when stored at the following conditions; 65°-75°F (18°-24°C) and 50% ± 5% R.H.	#8.00
Typical film Caliper	18 – 19 mils (457 – 483µ) Orange: 17 – 18 mils (432 – 457µ)	NA
Min. Application Temperature	65° F (18° C)	#8.10
Service Temperature	-10°F to +150°F (-23°C to + 65°C)	#8.00
Screen Printing	Long term durability of screen printing in combination with HIP series sheeting is warranted when used with approved inks and overlays. See Page 7.	#8.30 #8.55
Inkjet Printing	User assumes responsibility for fitness of use for this converting method. Long term durability of inkjet printing in combination with HIP series sheeting is not warranted.	#8.55
Thermal Transfer Printing	Long term durability of Thermal Transfer Printing in combination with any HIP series sheeting is warranted. Refer to Instructional Bulletin	#8.60

ADDITIONAL LIMITATIONS

Unintended Use: This warranty only applies to Product that is used by professional converters and installers for the defined end uses and in the combinations described in the applicable Avery Dennison Product Data Sheets and Instructional Bulletins. For any other use, the user is responsible for determining the suitability of the Product, and for any and all risk or liability associated with that use or application, and the user agrees to indemnify, defend and hold harmless Avery Dennison for any claims, losses, damages, judgments, expenses and/or expenses, including attorneys fees, resulting from such use or application. This warranty is expressly conditioned on the Product being processed by professional converters or installers in accordance with the Avery Dennison recommended written processing instructions, and being applied to properly prepared surfaces and cleaned and maintained in accordance with recommended Avery Dennison procedures. It is the converters, installers or other users responsibility to perform incoming raw material quality inspections, to assure proper surface preparation and that approved application procedures are followed, to retain converted samples, and to immediately cease using and notify Avery Dennison and/or its authorized agent or distributor of any Product, Materials and/or finished Product discovered to be (or reasonably capable of being discovered to be) defective.

Misuse and Force Majeure: Avery Dennison has no obligations or liability under this warranty with respect to Product that has been altered, modified, damaged, misused, abused, subject to accident, neglected or otherwise mishandled or improperly processed or installed. Product is not warranted against premature failure caused by chemical, environmental or mechanical means such as, but not limited to, vandalism, cleaning solutions, paints, solvents, moisture, temperature, mechanical washing equipment, engine fuel spills, engine exhaust, steam, organic solvents or other spilled chemicals pollutants, including industrial and volcanic ash. Damage from fire, structural failure, lightning, accidents, and other force majeure events are not covered by this warranty.

Third Party Product: Avery Dennison assumes no responsibility for any injury, loss or damage arising out of the use of a product that is not of our manufacture. Where installer or converter uses or reference is made to a commercially available product, made by another manufacturer, it shall be the responsibility of the user, installer or converter to ascertain the precautionary measures for its use outlined by the manufacturer.

The remedies provided under this warranty are exclusive. In no event shall Avery Dennison be responsible for any direct, indirect, incidental or consequential damages or specific relief whether foreseeable or not, caused by defects in such Product, whether such damage occurs or is discovered before or after replacement or credit, and whether or not such damage is caused by Avery Dennison's negligence. In no event shall Avery Dennison's liability hereunder exceed the remedies specifically set forth in this warranty. Avery Dennison's liability shall be limited, at Avery Dennison's option, to the purchase price, replacement of the defective Product and in some cases when authorized by Avery Dennison the repair and replacement of the defective Product.

THIS WARRANTY IS GIVEN IN LIEU OF ALL OTHERS. ANY AND ALL OTHER WARRANTIES, WHETHER EXPRESS OR IMPLIED, INCLUDING IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE HEREBY DISCLAIMED. NO WAIVER, ALTERATION, ADDITION OR MODIFICATION OF THE FOREGOING CONDITIONS SHALL BE VALID UNLESS MADE IN WRITING AND MANUALLY SIGNED BY AN OFFICER OF AVERY DENNISON.

Graphics and Reflective Solutions

250 Chester Street

Painesville, OH 44077

www.reflectives.averydennison.com

Converting Information:

The following Avery Dennison literature will provide information to the user for proper application, storage, and other requirements. Find the latest information on the Avery Dennison website, www.reflectives.averydennison.com. We encourage you to check our website periodically for updates.

Approved screen printing inks, overlays, thermal transfer ribbons:

Supplier	*Series*	*System*	*Instructional Bulletins*
Avery Dennison	4930 Inks	1 Part Solvent	#8.40
Avery Dennison	UVTS Nazdar	UV	#8.38
Avery Dennison	OL-2000	Acrylic Overlay	#8.01, #8.10, #8.25
Avery Dennison	OL-1000	Anti-Graffiti	#8.01, #8.10
Matan	DTS	Thermal Transfer	#8.60

Instructional Bulletins:

Film Care & Handling	#8.00
Substrate Requirements	#8.01
Application Techniques for PS Film	#8.10
Cutting Methods	#8.20
Computer Sign Cutting	#8.25
Screen Preparation	#8.30
Troubleshooting Printing & Processing	#8.34
UVTS Nazdar Inks	#8.38
4930 Series Inks	#8.40
Ink Recommendations Guide	#8.55
Matan Thermal Transfer Printing	#8.60

Substrates:

The application of Avery Dennison HIP Series sheeting is limited to properly prepared substrates which differ by product. For traffic products and W-6504, application is limited to properly prepared Aluminum. For products in the W-6100 line, application is limited to properly prepared plastic. For products in the W-6200 line, application is limited to properly prepared wood. Users are urged to carefully evaluate, under actual use conditions, any film application to other substrates. Failure of film caused by other substrates, materials, contamination, or improper surface preparation is not the responsibility of Avery Dennison. See Instruction Bulletin #8.01 for full details on substrate requirements.

DEFINITIONS

Durability: means that the Product in a finished graphic, panel or sign situated outdoors, subject to the limitations herein and Avery Dennison Product Data Sheets and Instructional Bulletins, and applied to recommended surfaces, will not deteriorate excessively such that the finished sign, panel or graphic is ineffective for its identification when viewed under normal conditions from the intended viewing distance.
Outdoor Durability: is based on normal middle European and central North American outdoor exposure conditions and application to recommended surfaces. Actual performance life will depend on a variety of factors, including but not limited to substrate preparation, exposure conditions and maintenance of the Product and finished graphic, panel or sign. In case the finished graphics, panel or sign is in areas of high temperatures or humidity, in industrially polluted areas or other areas with air laden particulate matter, and/or in high altitudes, Outdoor Durability may be reduced. Please see your local Avery Dennison representative for changes to warranties based on such localized conditions.
Vertical Exposure: means that the face of the finished graphic is ±10° from vertical.
Non-Vertical Exposure: means that the face of the finished graphic is greater than 10° from vertical and greater than 5° from horizontal. Retroreflective films are not warranted for this exposure.
Flat surfaces: means a two dimensional flat surface without protruding objects.
Weathering Effects: Some degradation of Product performance over time is considered normal wear. Slight color fading, chalking, edge lifting, or slight reduction in gloss or reflectivity due to normal wear exposure and other natural weathering, environmental or other conditions or damage caused by tornadoes, hurricanes, wind, excessive ice buildup or extraordinary frozen particulate conditions, large hail stones or other acts of God, do not constitute a breach of warranty or give rise to any liability by Avery Dennison.
Printing, Curing and Ink Defects: Ink contaminations, failures or other defects, or other failures due to improper printing conditions or settings including, but not limited to, unsuitable color calibration, incorrect ICC color profile or incompatible printing, do not constitute a breach of warranty. Product failure caused by ink over-saturation, excessive or under curing, failure of ink to render desired colors on Product, or other treatment or processing errors are not warranted.
Adhesion to Application Surfaces: This warranty does not cover the Product if the application surface is not properly prepared; nor does the warranty cover the Product or damage to the substrate because the layers of the substrate separate due to a lower bond between those layers than the bond between the Product and the top layer of the substrate, or surfaces which subsequently crack, peel, outgas, or become damaged beneath the Product

INDEPENDENT TESTING REQUIRED

All statements, technical information and recommendations about Avery Dennison products are based upon tests and information believed to be reliable but do not constitute a guarantee or warranty of any kind. All Avery Dennison products are sold with the understanding that Purchaser has independently determined the suitability of such products for its intended and other purposes.

Graphics and Reflective Solutions
250 Chester Street
Painesville, OH 44077
www.reflectives.averydennison.com
AnswerLine: 800-231-4654

Appendix F

Evaluation of Measuring Methods for
Traffic Sign Retroreflectivity
Final Report

December 2009

Report 2009 - 8

State of Vermont
Agency of Transportation
Materials and Research Section

Prepared by:

Wendy M. E. Kipp
Research Technician

Jennifer M. V. Fitch, P.E.
Research Engineer

Reviewed By:

William E Ahearn, P.E.
Materials and Research Engineer

Date: Dec 9, 2009

1. Report No. 2009-8	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Evaluation of Measuring Methods for Traffic Sign Retroreflectivity Final Report**		5. Report Date December 2009 6. Performing Organization Code
7. Author(s) Wendy M. E. Kipp, Jennifer M. V. Fitch		8. Performing Organization Report No. 2009-8
9. Performing Organization Name and Address Vermont Agency of Transportation Materials and Research Section National Life Building Drawer 33 Montpelier, VT 05633-5001		10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Highway Administration Division Office Federal Building Montpelier, VT 05602		13. Type of Report and Period Covered Final (2008-2009) 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report documents the evaluation of measuring methods for traffic sign retroreflectivity project. The primary objective of this research initiative was to establish a retroreflectivity assessment protocol for sign sheeting in order to meet new federal requirements. While two methods, sign assessment or management, are allowable under the new ruling, this study will focus on assessment strategies. The MUTCD provides various options for assessment including visual nighttime inspection, measured sign retroreflectivity and expected sign life. For this study, retroreflectivity was measured as a function of time. ASTM Type 3 and Type 9 sheeting was evaluated. Data correlation was completed in consideration to the following variables: age, sheeting type, color, manufacturer, condition, type of roadway, orientation, offsets, and region. Some of these variables were not found to have a significant importance in determining life-cycle projections. Based on the results, the blanket replacement method in combination with measured sign retroreflectivity appears to be the most cost-effective methods for the State of Vermont.

17. Key Words	18. Distribution Statement
Safety Retroreflectivity Traffic Signs	No restrictions

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. Pages	22. Price
Unclassified	Unclassified	56	

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1. EXECUTIVE SUMMARY

Traffic control devices (TCD), including signs, signals, and markings, provide an important means of communication for all roadway users. They are intended to promote driver safety by supplying advanced warning of upcoming regulatory, warning or guidance information. In addition to daylight hours, traffic control mechanisms must be capable of conveying information during inclement weather and evening hours when there may be little to no contribution from overhead lighting (*1*). Therefore, the appearance and proper recognition of traffic control devices are vital for the overall safety of the traveling public.

This study was conducted in order to establish a method for assessing sign sheeting retroreflectivity and generate recommendations for the cost-effective replacement of traffic signs in accordance with new MUTCD requirements. Field data collection efforts focused on evaluating the current condition of several sheeting types and color combinations including ASTM Type III and Type IX sheeting. These sheeting types were selected based upon the Agency's current practices. For ASTM Type III sheeting, four non-fluorescent sheeting colors were assessed as follows: green, red, yellow, and white. For ASTM Type IX sheeting, two fluorescent sheeting colors were examined: yellow, and yellow-green. The policy decision to consider only Type III or Type IX signs had a controlling effect on this study. Priority setting for replacement of other sign types is beyond the scope of this research.

All retroreflectivity measurements were taken in accordance with ASTM E 1709-08, "Standard Test Method for Measurement of Retroreflective Sign Using a Portable Retroreflectometer at a 0.2 Degree Observation Angle." Several parameters were recorded including: date of data collection, location (district, county, town, route, and lane direction), type of sheeting, color, age, compass orientation of the sign, GPS coordinates, sheeting manufacturer, retroreflectivity and general condition of the sign (poor/fair/good/excellent). Photographs and visual observations were also documented.

The data was graphed during summer of 2008 to examine long term performance. Curves were generated in an attempt to predict the amount of time, or months of service, until values would likely fall below future minimum requirements using the best fit trend line. Corollary statistics were also performed to identify variables affecting long term performance including orientation, offset, wind exposure, and roadway type. A correlation between sign condition and retroreflectivity could not be established.

The absence of a correlation between sign condition and time means daytime inspections are not sufficient indicators of retroreflectivity unless it is paired with measured retroreflectivity measurements using a portable retroreflectometer. The only correlation indentified was between the measured retroreflectivity and manufacturer. In all cases, the projected life expectancy for the Type III and Type IX sign sheeting exceeds 15 years. Blanket replacement on a 15 year cycle is supported by the results. This refers to the replacement of signs in an area/corridor or of a given type which eliminates the need to assess retroreflectivity or track the life of individual signs. With the use of the Agency's sign inventory, the age of all traffic signs within the inventory are known and can be easily queried.

With limited long term data it is difficult to recommend an accurate expected sign life in excess of 15 years. Of all 618 traffic signs incorporated into the study, none were found to be below the future retroreflectivity requirements. After 7 to 12.5 and 5.4 to 6.4 years of service for Type III and Type IX sheeting, retroreflectivity readings are still considered acceptable. Given the best fit trend lines and predicted retroreflectivity over time, a modeled life cycle of 15 years is recommended for red sheeting and 15-20 years may be reasonable for white, green and yellow sheeting. However, additional long term data collection is highly recommended for both types of sign sheeting. The data developed in this study should provide an initial data set for a future supplement in approximately five to seven years when signs have experienced further deterioration.

2. INTRODUCTION

Traffic control devices (TCD), including signs, signals, and markings, provide an important means of communication for all roadway users. They are intended to promote driver safety by supplying advanced warning of upcoming regulatory, warning or guidance information. In addition to daylight hours, traffic control mechanisms must be capable of conveying information during inclement weather and evening hours when there may be little to no contribution from overhead lighting (*1*). Therefore, the appearance and proper recognition of traffic control devices are vital for the overall safety of the traveling public.

Since 1993, the Federal Highway Administration (FHWA) has researched various methods to measure and maintain retroreflectivity of various types of sign sheeting. Retroreflectivity, otherwise known as luminance, allows for nighttime visibility. Contrast between the sign lettering, sign background and natural setting most significantly influence daytime visibility. Like most traffic control devices, sign sheeting deteriorates over time due to a number of factors including natural events (sun exposure, dirt, wind, ice, etc), manmade contaminants (roadway treatment chemicals and emissions) and vehicular impacts (*3*). While the MUTCD addresses uniformity, design, placement, operation and maintenance, deterioration rates likely vary as a function of the referenced factors. In theory retroreflectivity, in direct correlation with sign sheeting, also decays over time reducing nighttime visibility. To alleviate accidents that may be due inadequate nighttime visibility, the MUTCD recently established minimum retroreflectivity standards to promote safety (*4*).

In concert with new minimum retroreflectivity sign sheeting requirements set forth by the MUTCD and VTrans Traffic Safety and Design Section, the primary objective of this research initiative was to examine three suggested methods of assessing and maintaining traffic sign retro-reflectivity. According to the FHWA guide Know Your Retro 2007, "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 retroreflectivity of regulatory, warning, and ground-mounted guide signs is January 2015. For overhead guide signs and street name signs, the compliance date is January 2018" (*5*). In addition to assessing various methods, recommendations pertaining to cost-effective and advantageous sign replacement have been provided.

3. BACKGROUND

Traffic signs are a critical safety feature for local roads and interstates, as they provide regulations, warnings, and guidance information for road users. In order to ensure that motorists receive all pertinent roadway information, traffic signs must be visible to the driver under varying driving conditions. In addition, "regulatory, warning, and guide signs shall be retroreflective or illuminated to show the same shape and similar color by both day and night" (*6*). Three principle factors affecting recognition of traffic signs include contrast, color, and luminance. Perhaps the most critical factor that can affect visual performance, or how well a target can be seen by the eye, is the luminance of an object as compared to the luminance of the background. The greater the contrast between the two objects, the easier an object is to identify. This is especially important for nighttime visibility as there is typically little to no ambient lighting reducing the overall contrast between traffic signs and surroundings. In order to ensure adequate visibility at night, retroreflective sheeting is utilized during sign fabrication (*7,8*).

In order to produce reflective properties, a light source, such as a headlight from a vehicle, interacts with the sign sheeting to reflect a portion of the incoming light rays back towards the driver. This is a quantifiable property known as retroreflectivity (*9*). Due to the irregularities of the surface, most light beams tend to scatter in all directions, allowing only a small amount of incoming light to reflect back toward the light source. During daylight hours, there is generally enough surrounding light to make up for the lack of a light source (i.e. headlights). During evening hours, however, where overhead lighting is minimal to nonexistent the only source of lighting is headlights. It is important to note that greater retroreflectivity results in an increase in traffic sign visibility and preview distances (*10*). Many studies have shown that this is especially important for older drivers which require "more light to see delineation and are slower to react" (*10*). Additionally, beginning at age 20, the amount of light required to see doubles every 13 years.

According AASHTO M 268-08, "Standard Specification for Retroreflective Sheeting for Traffic Control," "Retroreflective sheeting shall consist of a white or colored sheeting having a smooth outer surface and that essentially has the property of a retroreflector over its entire surface. There are ten types and five classes of retroreflective sheeting. Types are determined by conformance to the retroreflectance, color and durability requirements. Type designation based on manufacturing technique provides a means for differentiating functional performance" (*11*). For example, Type III sheeting is considered a "high intensity" retroreflective sheeting that is "typically encapsulated glass-bead sheeting" (*11*). Type IX sheeting is regarded as, "A very-high intensity retroreflective sheeting having highest retroreflective characteristics at short road distances. This sheeting is typically an unmetallized microprismatic retroreflective element material" (*11*). Typical applications for both sheeting types include highway signing, construction-zone devices and delineators (*11*). Detailed descriptions of each type are located in Appendix A in Table A-1.

In accordance with the new federal requirement, minimum retroreflectivity requirements are based upon sheeting type and sign color. For ground-mounted signs with green sheeting and white lettering, the minimum requirement is 15 $cd/lx/m^2$. Minimum retroreflectivity requirements for red sheeting with white lettering, such as stop signs, are 7 $cd/lx/m^2$ (*5*). A summary of the retroreflectivity requirements for all sheeting types and color combinations incorporated into the study are summarized in Table 1 below. Additional requirements are for all sheeting types are provided in Table A-2 in Appendix A.

Table 1: Retroreflectivity Requirements.

Minimum FHWA Retroreflectivity Requirements for Sign Sheeting in cd/lx/m^2		
Sign Type	Sign Color	Min. Retro.
III	Red	7
III	Green	15[1]
III	Yellow	50
III	White	50
IX	Yellow	50
IX	Yellow-Green	50

(1) For ground mounted signs

FHWA has described five suggested methods in publication FHWA-SA-07-020 entitled, "Know Your Retro 2007" to aid public agencies and officials having jurisdiction to use a method that is designed to maintain sign retroreflectivity at or above the minimum levels. The five methods are broken into two categories: assessment and management. The assessment methods include visual assessment and measured sign retroreflectivity (*5*). The most common and accurate way to evaluate the retroreflectivity of sign sheeting is through the use of a portable retroreflectometer, an apparatus capable of quantifying nighttime luminance under daylight conditions, in concert with ASTM E 1709-08, "Standard Test Method for Measurement of Retroreflective Signs Using a Portable Retroreflectometer at a 0.2 Degree Observation Angle" (*12*). The three management methods are expected sign life, blanket replacement, and control signs. These methods suggest sign replacement based on predetermined factors such as retroreflectivity degradation classified by age and/or location. These methods replace signs as a group instead of on an individual basis. A more in-depth description of each method can be found in Table A-3 in Appendix A.

4. PROJECT SCOPE

The main objective of this research initiative was to establish and implement a sign assessment method and provide recommendations for the periodic replacement of traffic signs in a cost effective manner. The project scope was broken down into several components and included a cross-sectional sign sheeting evaluation and associated analysis. The four components of the project as originally stated within the project proposal are as follows:

1. Survey of States concerning sign sheeting and assessment methods.

2. Literature Review to determine what practices for evaluation of traffic signs exist in other states including research and operation activities. Advantages and disadvantages of the various methods were documented.

3. Cross-sectional retroreflectivity data collection of Type III and IX traffic signs. Retroreflectivity was evaluated with the use of a retroreflectometer capable of assessing varying types of sign sheeting and colors.

4. Corollary statistics were performed to determine key factors contributing to applicable decay rates. This information was used to assess sign sheeting replacement with consideration to possible contributing factors, such as sign orientation. Additionally, a decay analysis was performed to determine various life cycles.

A thorough literature search was performed in the summer of 2008 to examine traffic sign retroreflection and associated importance in the transportation field. The research focused on objectives, findings and/or conclusions regarding field studies and current sign sheeting management practices as well as existing standards and new regulation. In addition, publications relating sign sheeting and public safety were also examined. This information was used to guide data collection activities as described in the section below.

5. PROJECT DESCRIPTION

In an effort to establish a method for assessing sign sheeting retroreflectivity and generate recommendations for the cost-effective replacement of traffic signs in accordance with new MUTCD requirements, one assessment method and two management methods were examined, including the sign retro-reflectivity assessment method, blanket replacement and control signs. Field data collection efforts focused on evaluating the current condition of several sheeting types and color combinations including ASTM Type III and Type IX sheeting. These sheeting types were selected based upon the Agency's current practices. Per our project plans and special provisions, ASTM Type III sheeting is specified as the minimum sheeting type for the replacement of all traffic signs. In addition, it is general practice to specify the installation of ASTM Type IX fluorescent sheeting for pedestrian warning signs and documented dangerous locations such as sharp curves or hidden drives. For ASTM Type III sheeting, four non-fluorescent sheeting colors were assessed as follows: green, red, yellow, and white. For ASTM Type IX sheeting, two fluorescent sheeting colors were examined: yellow, and yellow-green. All sheeting types and colors examined are shown in Figure 1.

Type III Yellow

Type III Red

Type III White

Type III Green

Type IX Fluorescent Yellow-Green

Type IX Fluorescent Yellow

Figure 1: ASTM sheeting types and colors examined in the study.

Originally, the intent was to collect a minimum of 30 retroreflectivity readings per sheeting type and color at 5, 10 and 15 years of service. Locations for readings were expected to be selected from the Agency's Asset Management Program's "Signs Inventory." This inventory contains a large amount of information including inventory record number, sheeting type, sign type, background color, text legend color, location (district, county, town, route, lane position, and mile marker), MUTCD code, and age. Initially, a query was used to extract sheeting types of interest at the years of service referenced above. Each record within this query was numbered in ascending order from one through the total number of records. The sample population was selected through the use of a random number generator in Microsoft Excel. Unfortunately, this method did not yield anticipated results. For example, Type IX sheeting was introduced to the Agency roughly six years ago so the sampling pool could not satisfy the original method of choosing signs at 5, 10, and 15 years old. It was also difficult to find any Type III sheeting with a service life greater than 12.5 years. Finally, as stated above, Type III sign sheeting is a minimum requirement for most sign replacements. During the investigation, it was noted that there has been a wide use of Type IV sheeting as opposed to Type III sheeting between 2003 and 2009, however, only the minimum required Type III sheeting type was logged into the "Signs Inventory" database. Therefore, the original method of sampling using a minimum of 30 readings per sheeting type at 5, 10, and 15 years was abandoned.

A revised sampling method was derived to account for discrepancies within the "Signs Inventory" database. First, the State was divided into the Operation Division's 9 districts. Spreadsheets containing the location of all Type III and IX sheeting were generated for each district including the county, town and route. Signs were evaluated in conjunction with other ongoing research initiatives for economy and field inspection efficiency. For example, if concurrent research initiative was located in a particular town, the applicable spreadsheet would be examined to cross reference signs of interest along the route to access the site. Prior to leaving the office, signs would be selected at random and assessed along the way regardless of the age of the sign. A "FHWA Retroreflective Sheeting Identification Guide" published in 2005 was utilized to distinguish the type of sign sheeting and associated manufacturer (*13*). Signs with applicable sheeting types would be highlighted on the list to keep track of how many of each type and color were evaluated. When a Type IV or greater sheeting was encountered as opposed to a Type III, the sign's data was removed from the Type III dataset. In keeping with the original scope, a minimum of 90 signs per sheeting type and color were assessed.

5.1 Data Collection Techniques

All retroreflectivity readings were collected in accordance with ASTM E 1709-08, "Standard Test Method for Measurement of Retroreflective Sign Using a Portable Retroreflectometer at a 0.2 Degree Observation Angle." Measurements gathered by this method "are related to the night time brightness of retroreflective traffic signs approximately facing the driver of a mid-sized automobile equipped with tungsten filament headlights at about 200 m distance" (*12*). All measurements were collected using a portable handheld sign retroreflectometer, "Model 922", manufactured by

RoadVista. This handheld sign retroreflectometer measures all types of retroreflective materials, requires only one reference standard, contains a built in GPS, and can store up to approximately 4,500 readings (*14*).

In accordance with the test method, the entrance and observation angles were set to -4^{o} and 0.2^{o}, respectively. Then the retroreflectometer was placed in contact with the sign within the area to be sampled. The trigger on the instrument was depressed to collect and record the associated reading. The retroreflectometer was then moved to another position on the sign and a second reading was recorded. As required by the test method, a minimum of four readings were collected and all results were averaged per each sign (*12*). In addition to assessing current retroreflective properties of each sign, several other parameters were recorded including: date of data collection, location (district, county, town, route, lane direction), type of sheeting, color, age, compass orientation of the sign, GPS coordinates, sheeting manufacturer, and general condition of the sign (poor/fair/good/excellent). Photographs and visual observations were also documented. All data was compiled into a dedicated spreadsheet. Following the data collection methods, corollary statistics were utilized to determine factors contributing to the rate of decay. In many cases, the signs were difficult to access due to the height of the sign. In this instance, an extension pole and ladder was used to ensure safe and accurate data collection. A photograph of standard data collection techniques is provided in Figure 1 below:

Figure 2: Retroreflectivity data collection.

A total of 618 traffic signs were evaluated over the summer of 2008. Table 2 provided below contains a summary of the final population analyzed within this study. A map with the locations of all project locations retained within the study shown as Figure B-1 is provided in Appendix B.

Table 2: Summary of Sample Population.

Sign Sheeting Sample Population Summary						
Sign Type	Sign Color	Number of Signs	Sign Age (Months)		Retroreflectivity Reading (average cd/lx/m^2)	
			Minimum	Maximum	Minimum	Maximum
III	Red	94	10	148	7.9	267.5
III	Green	105	8	150	24.6	656.5
III	Yellow	91	11	104	45.2	579.5
III	White	108	13	150	61.1	804.5
IX	Yellow	89	11	65	210.5	1025.3
IX	Yellow-Green	131	7	77	297.5	1008.8

In examining the characteristics of the sample population, it is interesting to note variation in the service ages with respect to the type of sheeting. The service ages of the Type III and Type IX sheeting ranges between 8.7 to 12.5 years and 5.4 to 6.4 years, respectively. In addition, the minimum retroreflectivity readings reflected in the table have yet to fall below future mandatory requirements. Therefore, the sample population may be insufficient for accurate prediction of the full service life of the various types of sign sheeting will need to be replaced. On the other hand, given the number of readings, the Agency can be fairly confident that these types of sign sheeting will not need to be replaced within the limits determined by this study. Finally, in comparison to Type III sheeting, Type XI signs display a greater initial retroreflectivity.

5.2 Explanatory Variables

Several variables potentially affecting retroreflectivity performance over time were examined within this study as described below:

Color – The six contrasts chosen for the study were based on the new federal requirements that were established and by VTrans personnel. There were four non-fluorescent Type III sheeting types chosen: white on green, white on red, black on white, and black on yellow. Two fluorescent Type IX sheeting types were chosen: black on yellow and black on yellow-green. These contrasts were not only the basis of the new FHWA final rule, 23 CFR Part 655 stating that agencies must maintain traffic signs to a minimum level of retroreflectivity, but are also the most common contrasts used for traffic signs nationwide according to the MUTCD, section 2A.08 (*15*).

Manufacturer – There are two primary sign sheeting manufacturers used within the state of Vermont. Every 2-4 years, a new sign contract for maintenance operations is awarded based on the low bidder. Generally either 3M or Avery Denison is awarded the contract.

For our research purposes we included both manufacturers. Federal aid construction projects may use any approved manufacturer's product.

Orientation – There has been some research that has concluded that extended sunlight exposure affects the retroreflectivity of sign sheeting. Ultraviolet light is known to degrade most polymeric compounds. For this reason, the orientation of each sign tested was recorded using a hand-held compass.

Offset – There are state standards requiring signs depending on the type to be placed at previously determined offsets (horizontal and vertical) to the roads' surface. Some signs are lower to the ground than others. There was some speculation that the lower the sign is to the ground, the more damaging effects to the sign face there would be. Therefore to determine this, the VTrans' design standards were utilized to determine the offsets of each sign tested.

Wind Exposure – Along with sun damage, there were concerns raised as to whether or not particles carried by wind would damage the sign face. For each sign tested, the same cardinal directions were used to determine wind directions.

Sign Type – There are ten types of ASTM retroreflective sheeting. Types are determined by conformance to the retroreflectance, color, and durability requirements listed within ASTM M 268. In Vermont, there is a requirement that states a minimum of Type III sheeting must be used statewide. Type IX signs are used in Vermont in cases where extra caution is necessary (i.e. sharp curves, hidden drives, and pedestrian crossings). Because Type III and Type IX signs are the majority of what is used in the state, these two types were used for evaluation in this study.

Type of Roadway – The signs evaluated for this study were located on several types of routes including, interstates, US and VT routes. The purpose of choosing various routes was to determine whether AADT affected the sign condition.

Physiographic Location – Vermont is divided into six physiographic regions based on the age and type of rock in the area, landscape (lowlands, hills, mountains), and climate. The six regions include Taconic Mountains, Champlain Valley, Vermont Valley, Green Mountains, Vermont Piedmont, and Northeastern Highlands. Each has specific characteristics that define the area as a region. For example, the Green Mountains region is considered the backbone of Vermont because of its' location in the state. A map defining the regions is shown in Figure B-2 and detailed summary containing a description of each region can be found in Appendix B. Due to the varying regions of Vermont, it was important to determine if the climates in these regions would have any affect on sheeting (*16*).

6. DATA ANALYSIS

As stated previously, the intent of this project was to perform a cross-sectional analysis of the retroreflectivity of sign sheeting types and colors of interest. This was to be accomplished by plotting performance curves of retroreflectivity values over time for each sheeting type and color contrast and determining when values fell below the future minimum requirements. In addition, retroreflectivity values were binned by various potential explanatory variables for each sheeting type and color contrast to identify those affecting performance. For example, type III sheeting retroreflectivity results were binned by the manufacturer, either 3M or Avery-Dennison. Once binned, time-series plots were generated for each of the variables. Best fit trend lines of sign sheeting performance with respect to retroreflectivity were generated for each time-series plot. It is important to note that all data was included, therefore any potential outliers were not removed in the subsequent analyses.

Prior to examining all subsequent analysis, it is important to examine the range of the sample population as the intent of the study was to examine long term sign sheeting performance. However, as stated previously, Type IX sheeting has been utilized by the Agency for approximately 6 years. This was not a sufficient amount of time to examine long term performance conclusively. In addition, the installation of Type III sheeting is a minimum requirement and subsequently Type IV was widely used between 2003 through 2009 creating a gap in the data set. A summary of the number of signs expressed by service lives is provided in Table 3 below:

Table 3: Range of the Sample Population.

Sample Population Summary by Months of Service						
Age in Months	Type III				Type IX	
	Red	Green	Yellow	White	Yellow	Yellow-Green
0-12	1	4	1	0	1	7
13-24	0	20	6	28	41	27
25-36	20	33	6	22	31	26
37-48	16	17	30	26	2	15
49-60	28	14	12	27	6	45
61-72	25	3	27	3	8	10
73-84	1	5	3	1	0	1
85-96	2	6	0	0	0	0
97-108	0	1	6	0	0	0
109-120	0	0	0	0	0	0
121-132	0	1	0	0	0	0
133-144	1	0	0	0	0	0
145-156	0	1	0	1	0	0

As shown within Table 3, the majority of the sample population is comprised of sign sheeting with services ages between 13 to 72 months, or 1 to 6 years. Given the large number of sample population for each type of sheeting and color contrast, predicted performance derived from this subset is considered statistically significant within the reference timeframe. However, the number of records beyond 6 years of service appears to be insufficient with respect to assessing long term performance. Although Type III was introduced into the state of Vermont as early as the late 1980’s the use was minimal and typically used at high impact areas such as curves. During this time span from the late 1980’s to May 2004, Type I and Type II signs were still allowed to be used for all sign types statewide. In May 2004, the use of Type III signs became mandatory. Therefore the population of signs of this type became much larger than that of Type I and Type II after this date.

6.1 Sign Sheeting Performance

As stated above, time series plots were generated from the cross-sectional data collected during summer of 2008 to examine long term performance. Given the large sample population, any potential outliers were not removed as these were anticipated to have little influence on any subsequent results. Once graphed, performance curves were generated utilizing Microsoft Excel in an attempt to predict the amount of time, or months of service, until values would likely fall below future minimum requirements using the best fit trend line

6.1.1 Type III Sheeting

Figure 3 below displays a graphical time-series plots of Type III sign sheeting retroreflectivity over time with respect to color regardless of manufacturer or other variables. Performance curves along with the R^2 values, or goodness of fit, are displayed on the graphs.

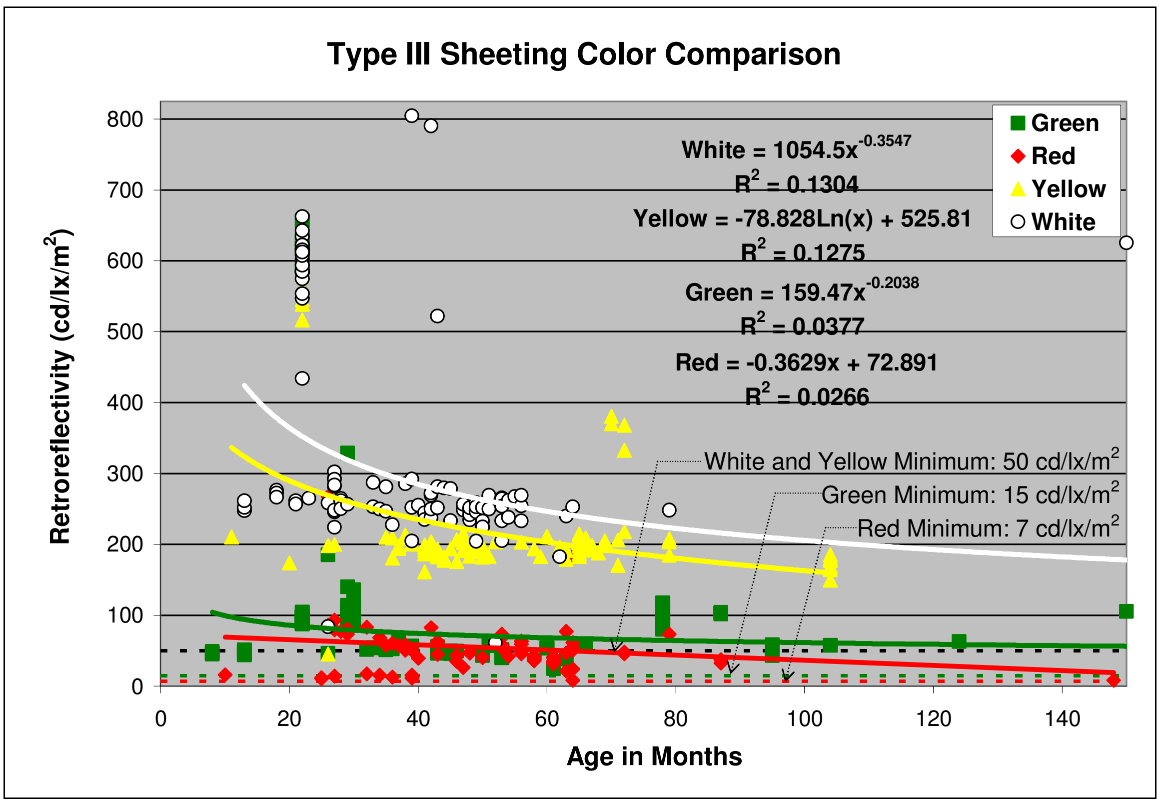


Figure 3: Type III sheeting performance comparison.

As shown in the Figure above, white sign sheeting was shown to display the highest retroreflectivity over time in comparison to all other Type III colors incorporated into the study. Conversely red sheeting was found to exhibit the lowest retroreflectivity. While the majority of the readings are fairly consistent for a particular color of sheeting, some readings appear to be significantly higher than the majority of the sample population. This may be due to the manufacturer as discussed below. While there are fewer within the sample population, signs produced by Avery-Dennison were found to display much higher readings as compared to signs manufactured by 3M. However, these were not removed from this data set in an effort to accurately depict true retroreflectivity values. Non-linear best fit trend lines were established for all Type III sheeting colors with the exception of red sheeting. All were found to decay over time. R^2 values are low indicating a large spread between the best fit trend line and actual data. However, this was anticipated as potential outliers were not removed.

6.1.2 Type IX Sheeting

Figure 4 below displays a graphical time-series plots of Type III sign sheeting retroreflectivity over time with respect to color regardless of manufacturer or other variables. Performance curves along with the R^2 values are displayed on the graphs.

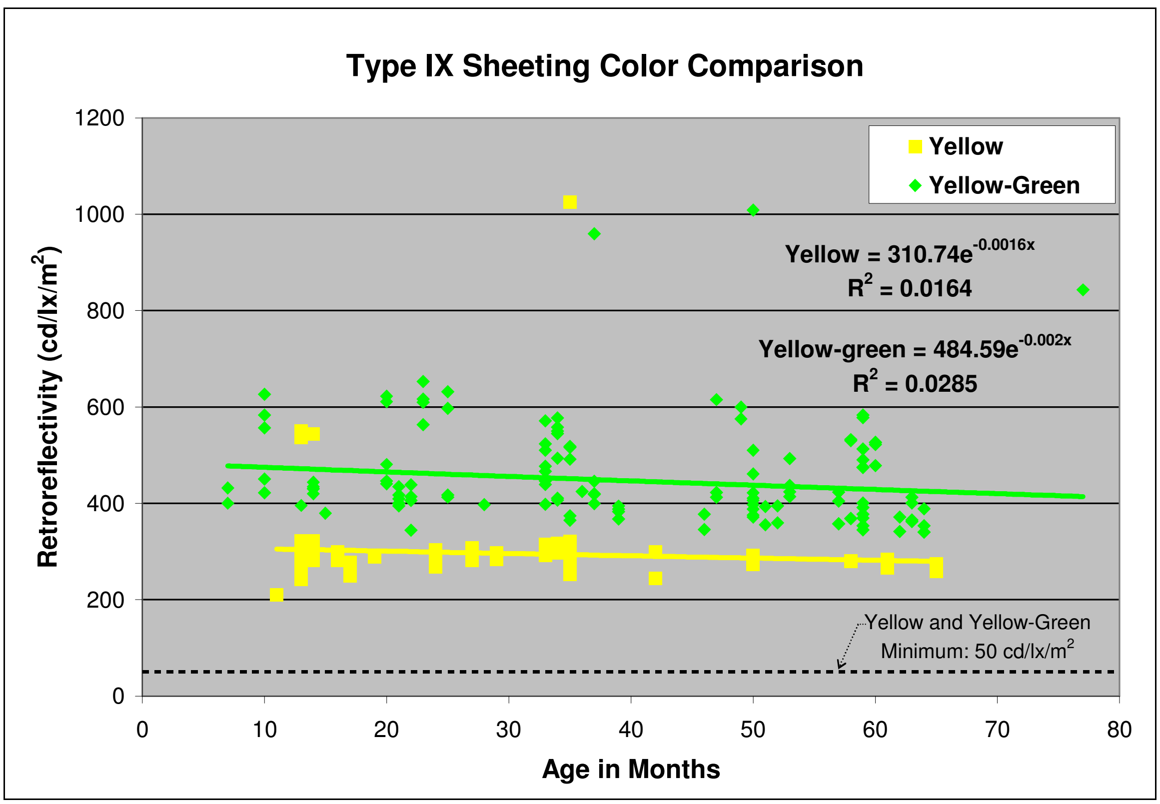


Figure 4: Type IX sheeting performance comparison.

Yellow-green Type IX sheeting was found to display higher retroreflectivity as compared to yellow sheeting with an average retroreflectivity of 457 and 303 cd/lx/m^2, respectively. It is important to note that all of the yellow Type IX sheeting incorporated into the study was manufactured by Manufacturer B whereas 27% of the yellow-green population was manufactured by Manufacturer A. In examining the consistency of the two colors, yellow sheeting appears to be more consistent over time as compared to yellow-green sheeting. This however is likely due to differences between the two manufacturers. Non-linear decay curves were generated for both colors of sheeting and although the R2 values are low, the trend lines are still believed to be fairly accurate with respect to performance over time. Most importantly, both colors are well above the minimum future retroreflectivity requirements of 50 cd/lx/m^2 following 5.4 to 6.4 years of service.

6.1.3 Predicted Replacement Cycles

In an effort to predict replacement cycles, the best fit trend lines as described and shown above were utilized to calculate the number of years sign retroreflectivity would be at or above future retroreflectivity requirements. Limited correlation was found to exist. Results are summarized in Table 4.

Table 4: Predicted Replacement Cycle Summary.

Type:	Color:	Decay Eq.:	R^2:	Minimum Intensity Requirement:	Years to reach min requirement:
III	Red	Y = -0.3629X + 72.891	0.0266	7	15
III	Green	$Y = 159.47X^{-0.2038}$	0.0377	15	9083
III	Yellow	Y = -78.828LN(X) + 525.81	0.1275	50	35
III	White	$Y = 1054.5X^{-0.3547}$	0.1304	50	450
IX	Yellow	$Y = 310.74EXP^{-0.0016X}$	0.0164	50	95
IX	Yellow-Green	$Y = 484.59EXP^{-0.002X}$	0.0285	50	95

With the exception of Type III red and possibly yellow sheeting, all other predicted life cycles appear to over predict a reasonable duration of service life. This is likely due to limited long term data as the result of recently introduced sheeting types and associated specification changes. Therefore, a second round of data collection for all signs is recommended in five years. However, after 8.7 to 12.5 years of service for Type III sheeting and 5.4 and 6.4 years of service for Type IX sheeting, readings have yet to fall below future minimum requirements as described within Table 4. Finally, Type IX yellow sheeting appears to outperform Type III yellow sheeting with respect to the predicted number of years prior to falling below future minimum retroreflectivity requirements.

6.2 Variables Affecting Sheeting Performance

As stated previously, sign sheeting was theorized to deteriorate over time due to exposure to natural constituents, including sun exposure, dirt and wind, manmade contaminates such as emissions and pollutants and vehicular impacts. Therefore additional sign characteristics including orientation, offset and wind direction were recorded and analyzed. This was accomplished by sorting the sample population for each sheeting type and color by the variable of interest and then plotting the age of the individual sign by the associated retroreflectivity reading. Once again, no potential outliers were removed. Prior to initiating this process, correlation matrixes were generated in Minitab to aid in the identification of explanatory variables. Unfortunately, this method did not identify any strong correlations. This is likely due to the size of the sample population. As variables are binned for each characteristic, the size of the sample population continues to decrease resulting in increased variability.

6.2.1 Sheeting Type Comparison

Figure 5 below displays a graphical time-series plots of sign sheeting retroreflectivity over time with respect to sheeting type. Only yellow sheeting produced by 3M was considered for comparative purposes. As stated previously, Type III sheeting is considered to be "high intensity" while Type IX sheeting is regarded at a "very-high intensity retroreflective sheeting having highest retroreflective characteristics at short road distances."

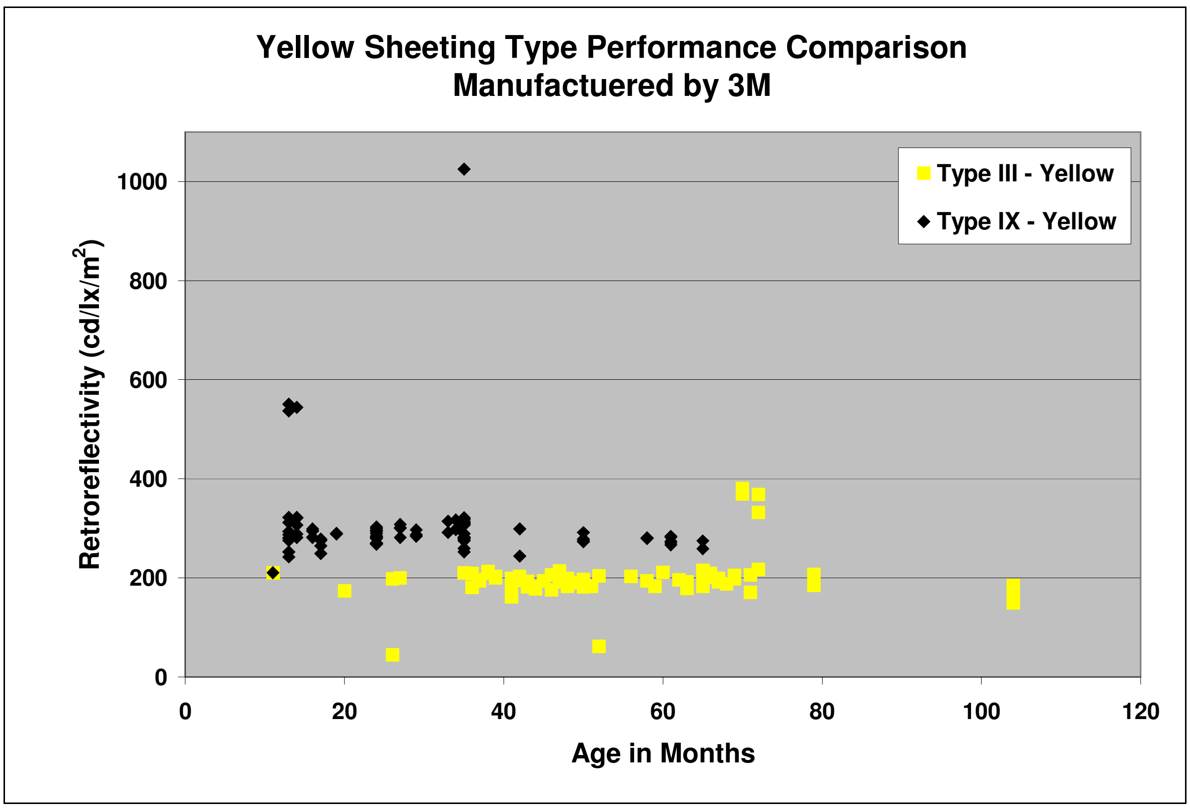


Figure 5: Type IX vs. Type III yellow age comparison.

On average Type IX sheeting was found to produce higher retroreflectivity readings as compared to Type III. Initial retroreflectivity values gathered from the yellow Type III and Type IV control signs manufactured by 3M resulted in readings of 361 cd/lx/m^2 and 200 cd/lx/m^2, respectively. Overall, Type IX sheeting displayed an average of 303.19 cd/lx/m^2 over time whereas Type III had an average of 198.29 cd/lx/m^2. It is interesting to note that some readings appear to be significantly higher or lower than the majority of the sample population. This is somewhat counterintuitive given continued improvements in the manufacturing process with respect to consistency. However, this may be attributed to additional factors as discussed below. Clearly the Type IX sheeting displays a nonlinear rate of decay. However, long term performance of the Type III sheeting appears to be relatively consistent.

6.2.2 Manufacturer Comparison

Figures 6 through 8 below display graphical time-series plots of sign sheeting retroreflectivity over time with respect to the two manufacturers. Given the smaller sample population size of Manufacturer A, only a comparison between Type III green and white sheeting and Type IX yellow-green sheeting is provided below.

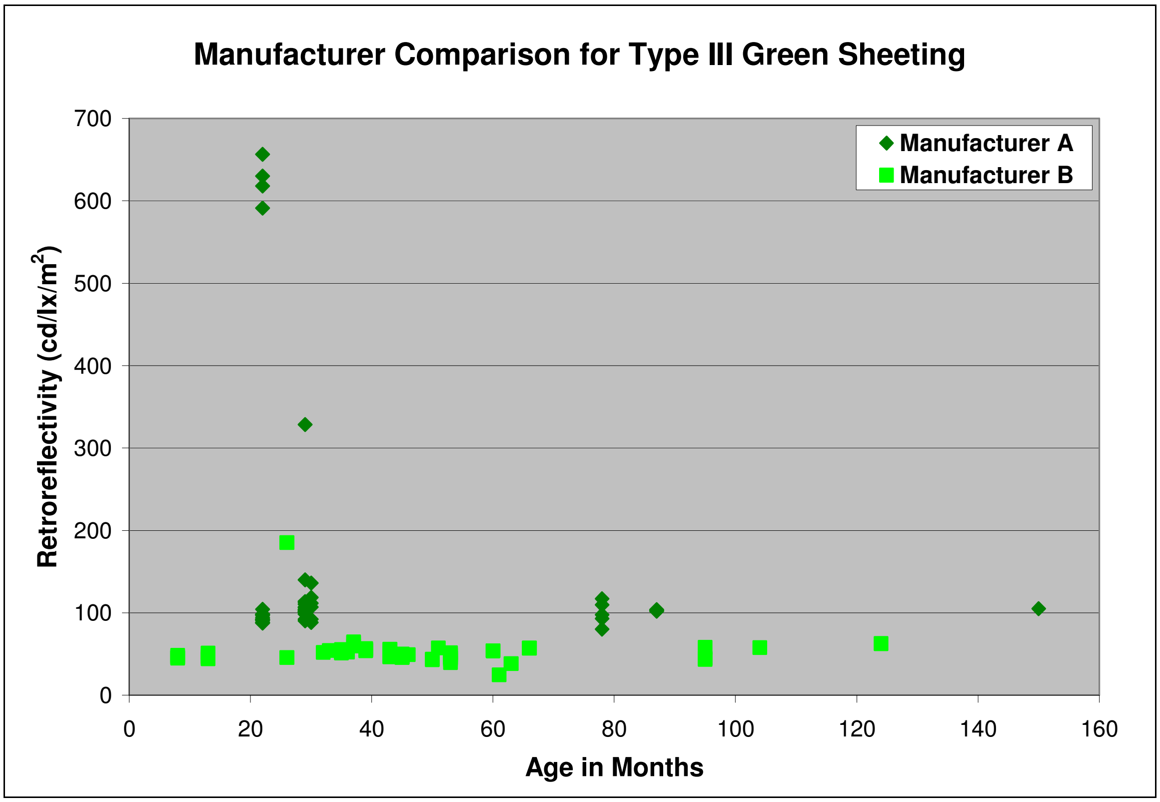


Figure 6: Type III green sign sheeting comparison by manufacturer.

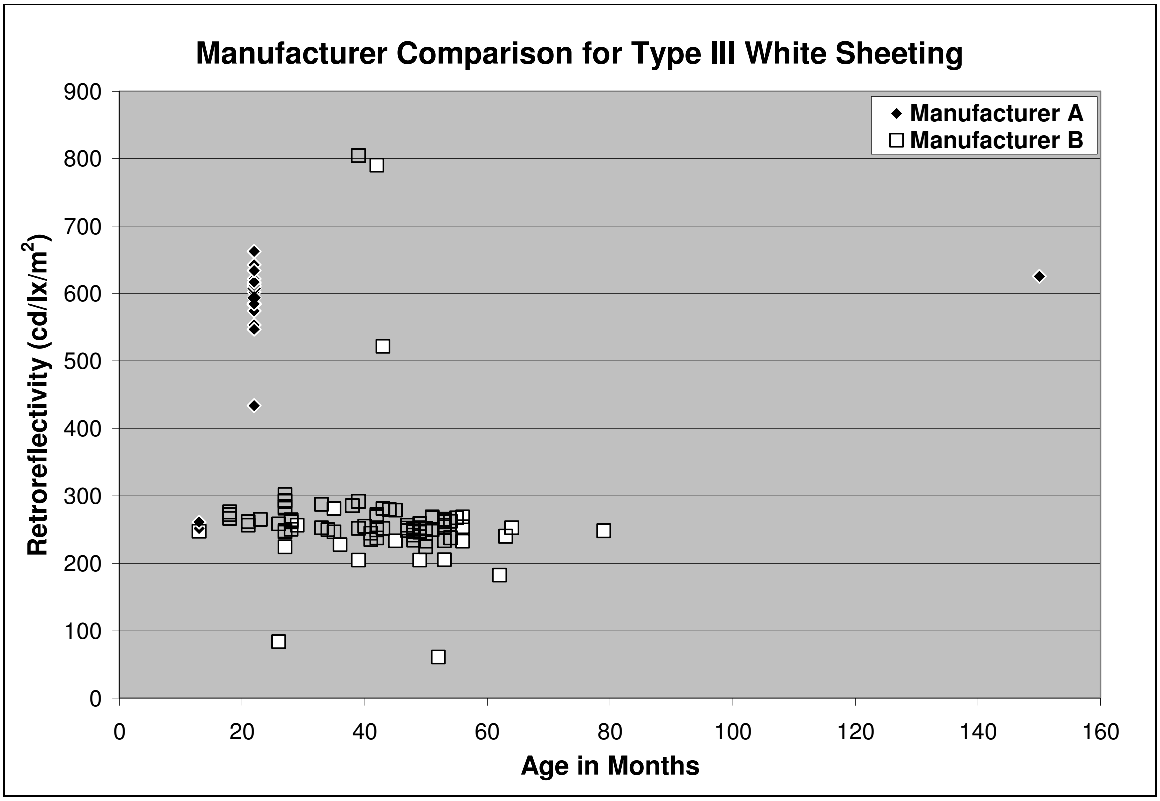


Figure 7: Type III white sign sheeting comparison by manufacturer.

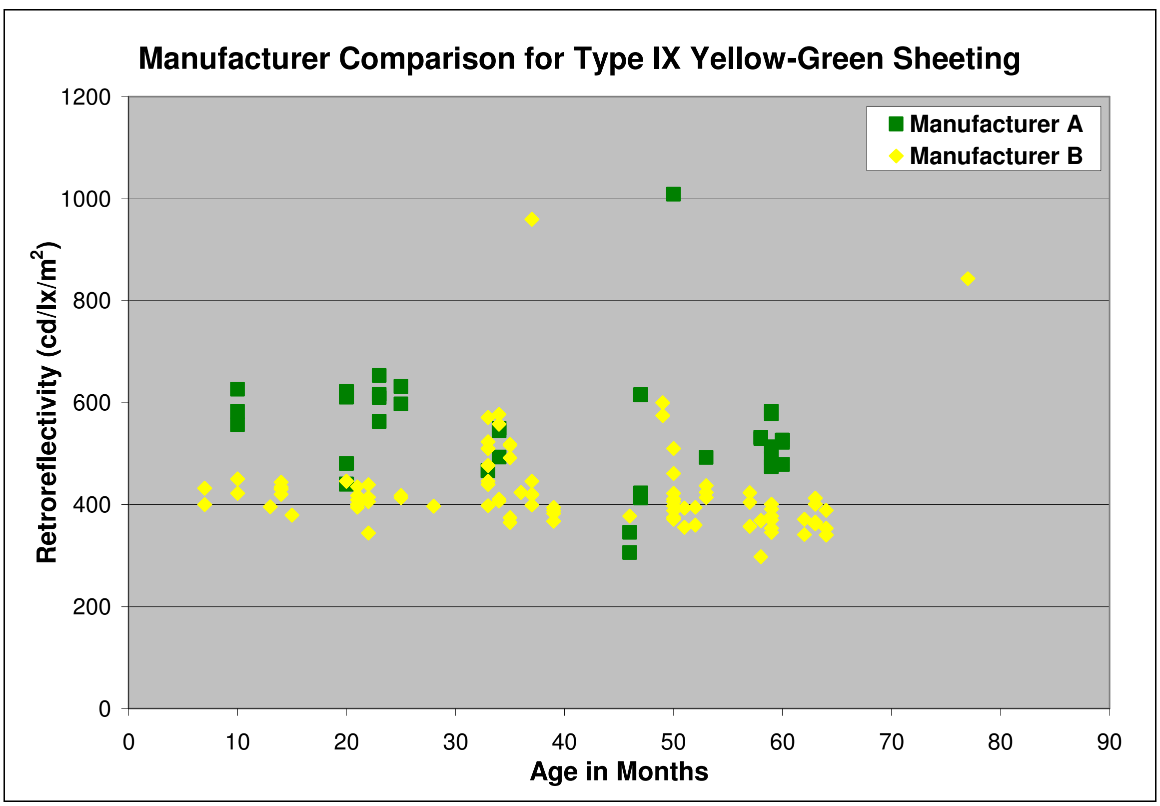


Figure 8: Type IX yellow-green sign sheeting comparison by manufacturer.

In general Manufacturer A sign sheeting was found to display higher retroreflectivity readings as compared to Manufacturer B. This is more evident in the Type III sheeting sample population. Type III green sheeting produced by Manufacturer A accounts for roughly 46% of the respective population, the greatest percentage of all other sheeting types and colors. In almost all cases, Manufacturer A signs outperform Manufacturer B sheeting. However, the cluster of Manufacturer A signs with retroreflectivity values greater than 590 cd/lx/m^2 may not be representative. In examining the data set, these four signs are located within 0.08 miles of one another and replaced during the same timeframe. Therefore they may have been from the same lot. Only 20% of the Type III white sheeting is comprised of signs manufactured by Manufacturer A. However, of the limited sample size, Manufacturer A signs were found to display greater retroreflectivity. Of the 22 Manufacturer A signs, 19 of them at 22 months of service are all located within 0.48 miles along Route 7. Once again these signs may all be from the same lot or manufactured at the same time. 27% of the Type IX yellow-green sheeting is composed of signs produced by Manufacturer A. In this case, both data sets display fairly consistent downward trend over time. Once again, Manufacturer A signs were found to display slightly higher retroreflectivity values.

6.2.3 Overall Orientation Comparison

Figure 9 provided below displays a graphical time-series plot of sign sheeting retroreflectivity over time with respect to either northerly or southerly orientation. Simply stated, all signs that faced a northerly direction, including northwest, north, and northeast indicated that the sign face was oriented in the direction of the northern pole while southerly facing signs including southwest, south, and southeast indicated that the sign faced in the direction of the southern pole. It was hypothesized that southern facing signs would be subjected to a greater amount and intensity of sunlight throughout the day resulting in accelerated decay from ultraviolet radiation. For comparative purposes, only Type III green sheeting produced by Manufacturer B was examined.

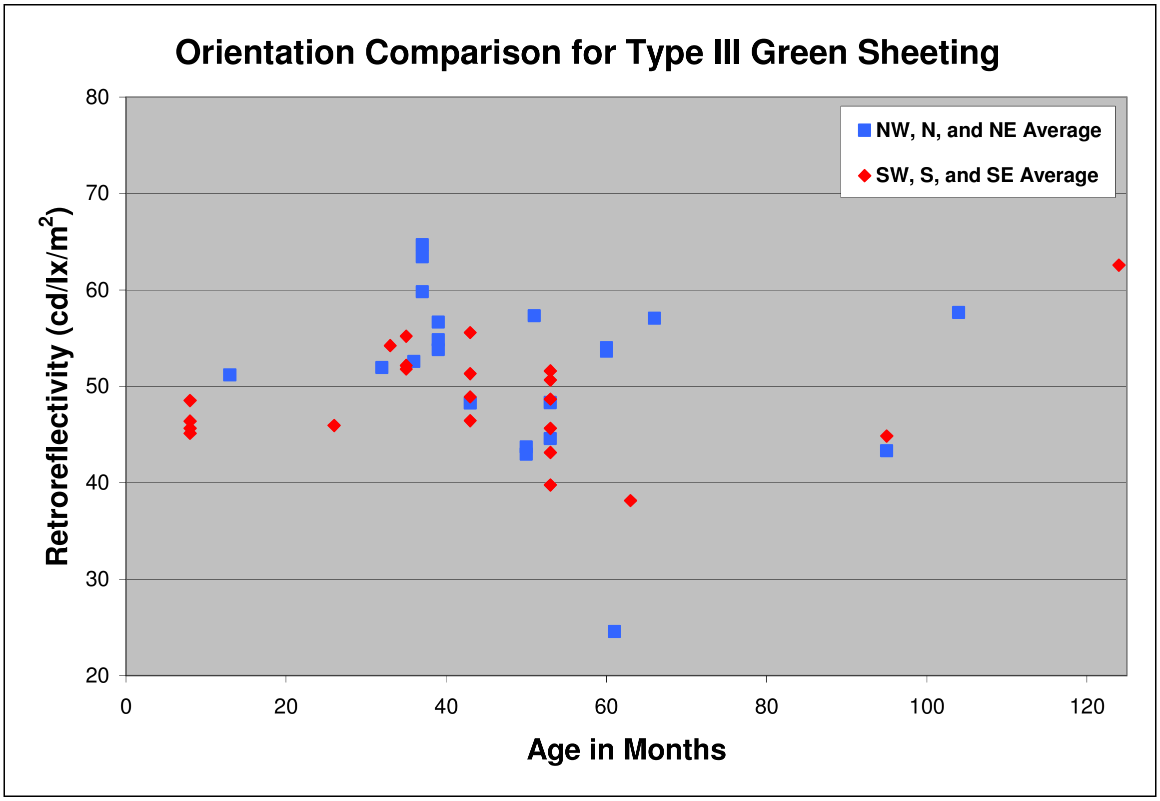


Figure 9: Northerly vs. southerly sign orientation for Type III green sheeting.

One can see in Figure 9 that the northerly facing signs retained a slightly higher retroreflectivity over time as compared to southern signs. However, given the small sample population of 8 and 14 southerly and northerly oriented signs, respectively, the difference in performance does not appear to be significant. Additional data collection is warranted to assess the affect of prolonged sunlight on sign sheeting. At this time there is not enough evidence to establish that orientation should be considered for sign replacement strategies. However, ultraviolet radiation is known factor affecting the degradation of signs. At a annual National Transportation Product Evaluation Program (NTPEP) conference, general feedback from state departments of transportation indicated that fading pigments and subsequent decrease in contrast between the sign sheeting and lettering may decrease more rapidly as compared to retroreflectivity.

6.2.4 Overall Sheeting Condition

It has been said that looks can be deceiving. This study illustrated this point quite clearly through daytime data collection. Figures 10 through 13 shows 4 signs included in the study. Each photograph lists the condition rating, age, and retroreflectivity reading. Figures 10 depicts a sign that is 56 months old and was rated in poor condition having many scrapes, dents, and delaminated sheeting. This sign however has an average retroreflectivity rating of 53 cd/lx/m^2. Comparatively, the sign in Figure 11, is 64 months old, considered by be in poor condition, and has a significantly lower retroreflectivity of 8 cd/lx/m^2.

Signs that are considered to be in excellent condition can be deceiving as well. Figure 12 is of a sign that is 25 months old, in excellent condition (free of defects), and had an average retroreflectivity value of 10 cd/lx/m^2, a considerably low reading especially for a "young" sign. Comparatively the sign shown in Figure 13 is a sign that is 64 months old, in excellent condition with an average retroreflectivity value is 77 cd/lx/m^2. It is apparent from Figures 10 through 13 that daytime inspections are not sufficient indicators of retroreflectivity unless it is paired with measured retroreflectivity measurements using a portable retroreflectometer. Due to the cost and subjectivity of nighttime inspections this may not be the safest or most cost efficient option for many states. To illustrate this point further, a plot comparing retroreflectivity and age by conditional rating is supplied in Figure 14. For consistency and ease comparison, only Type III red sheeting is shown.

Figure 10

Figure 11

Figure 12

Figure 13

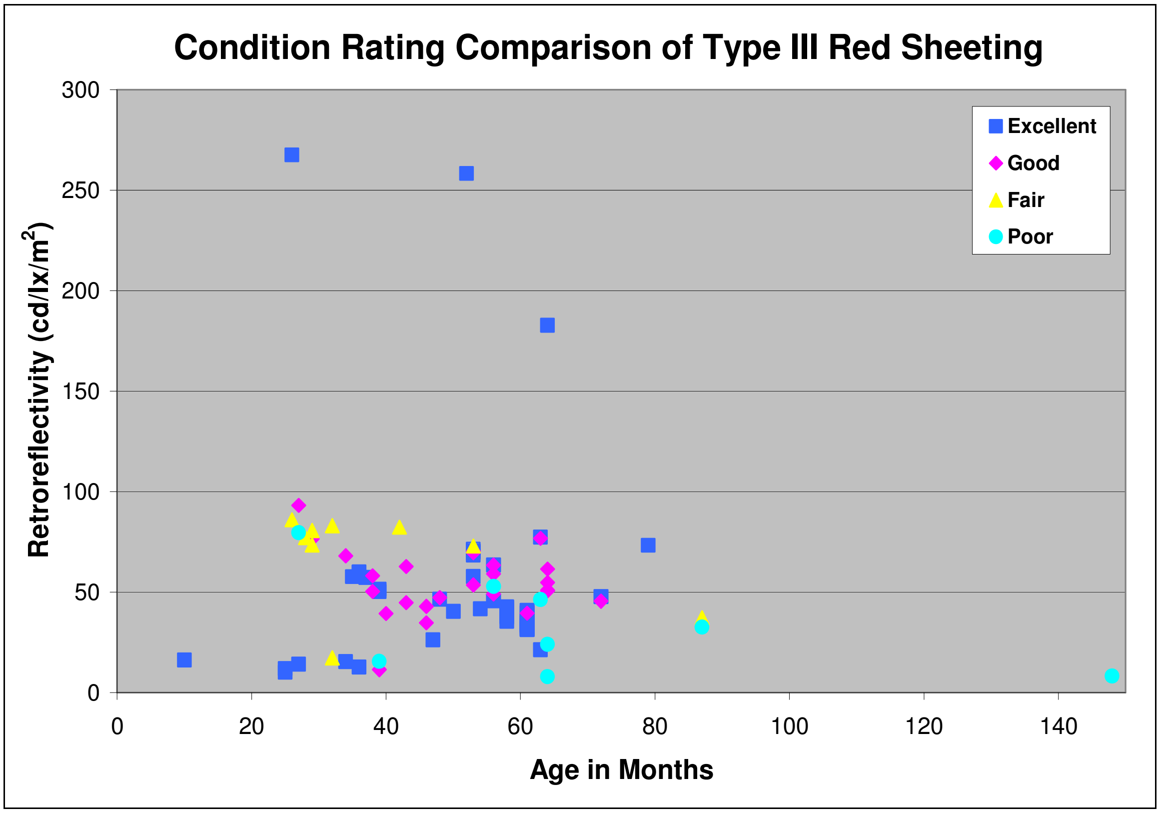


Figure 14: Overall condition rating by month for Type III red sheeting.

As seen in the graph all of the condition averages are very similar, which indicates again that visual inspections is not an accurate inspection method to determine proper sign replacement intervals. Many signs considered to be in "excellent condition" were found to low retroreflectivity values. Even a few signs assessed as "poor" displayed moderately high retroreflectivity reading. It should be noted that the ratings are highly subjective. For this examination, criteria for conditional rating were established prior to implementing field data collection. However even with pre-established criteria, visual assessments will vary from person to person.

6.2.5 Wind Comparison

Figure 15 provided below displays a graphical time-series plot of sign sheeting retroreflectivity over time with respect wind exposure. Typically wind blows from southwest to northeast. Therefore signs facing to the northeast to easterly direction are exposed to a greater amount of wind and associated debris. Therefore, these signs were expected to decay more quickly overtime. For comparative purposes, only Type III green sheeting produced by 3M was examined.

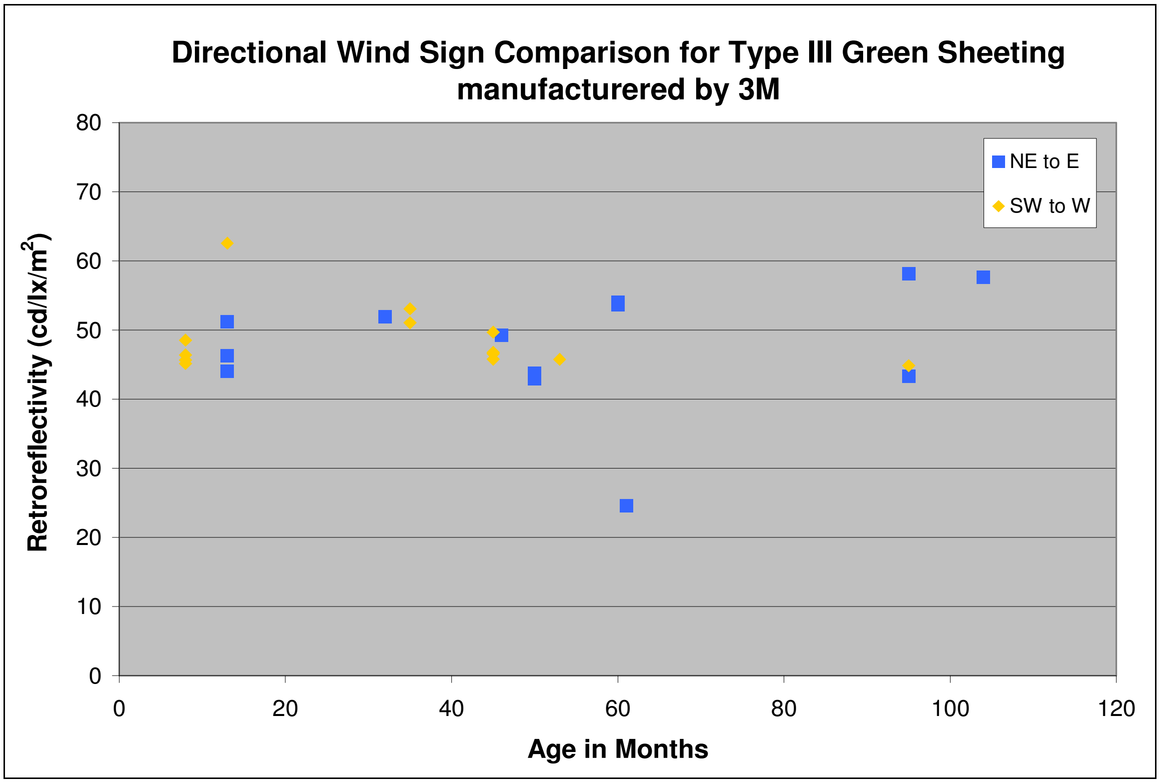


Figure 15: Wind exposure comparison for Type III green sheeting.

As shown within the graph above, there does not appear to be a large difference in performance between signs facing northeast to east and southwest to west. However, given the small sample population of 13 to 12 signs for each referenced orientation respectively, the pool is considered too small to be statistically significant. In addition, increased decay due to excessive wind exposure is largely time based and unfortunately, there is little long term data. Therefore, a more extensive long term study is recommended to drawn any definitive conclusions. For short term performance, wind exposure does not have a large influence on sign sheeting performance.

7. CONTROL SIGNS

One of the management methods, known as control signs, was assessed as part of this study. The use of control signs is to provide an agency with the ability to maintain sign retroreflectivity without having to assess individual signs. This method includes using a control sample of signs that represent all signs in an agency's inventory. All samples are monitored and associated signs are replaced based on their performance.

For this effort, manufacturers provided several types of sheeting including Type III, Type IV, Type IX and Type XI. Colors in association with measured sign sheeting were assessed including, sign sheeting white, yellow, green, red, fluorescent yellow-green and fluorescent yellow. Two samples per sheeting type and color were used. All samples were cut into small rectangular sections and placed onto the back of recycled aluminum signs (“boards”). A total of four boards were created and stationed within the Materials and Research Lab Facility as shown below in Figure 16.

Figure 16: North facing control sign boards.

Figure 17: South facing control sign boards.

The sheeting “boards” were then hung under the eaves of an adjacent building.. The two North A and North B boards faced the northerly direction. The two South A and South B boards faced the southerly direction. The retroreflectivity of the signs were tested and recorded using the Agency’s handheld retroreflectometer in accordance with ASTM E 1709-08, “Standard Test Method for Measurement of Retroreflective Sign Using a Portable Retroreflectometer at a 0.2 Degree Observation Angle.” As required by the test method, a minimum of four readings were collected and all results were averaged per each sign. In general, all readings were fairly consistent.

The signs have been evaluated annually. Subsequent results are summarized in Table 5 below:

Table 5: Control Sign Retroreflectivity Summary.

Control Signs - Retroreflectivity (mcd/m²/lx)					
NORTH A - Facing North			**SOUTH A - Facing South**		
Type 3	**8/14/2008**	**8/13/2009**	**Type 3**	**8/14/2008**	**8/13/2009**
White	262	259	White	259	271
Green	50	64	Green	46	47
Red	59	71	Red	56	70
Yellow	203	203	Yellow	197	214
Type 4	**8/14/2008**	**8/13/2009**	**Type 4**	**8/14/2008**	**8/13/2009**
White	550	482	White	529	505
Green	73	93	Green	69	94
Red	116	116	Red	107	130
Yellow	381	370	Yellow	377	418
Type 9	**8/14/2008**	**8/13/2009**	**Type 9**	**8/14/2008**	**8/13/2009**
YG	397	359	YG	378	403
NORTH B - Facing North			**SOUTH B - Facing South**		
Type 9	**8/14/2008**	**8/13/2009**	**Type 9**	**8/14/2008**	**8/13/2009**
White	402	428	White	410	432
Green	50	76	Green	53	71
Red	126	141	Red	124	145
Yellow	370	364	Yellow	353	389
Type 11	**8/14/2008**	**8/13/2009**	**Type 11**	**8/14/2008**	**8/13/2009**
White	720	670	White	687	781
Green	103	107	Green	104	118
Red	178	183	Red	181	192
Yellow	585	503	Yellow	581	561
Type 9	**8/14/2008**	**8/13/2009**	**Type 9**	**8/14/2008**	**8/13/2009**
Yellow	277	289	Yellow	270	305

As shown in the Table 5, one year of data is clearly not enough to determine at what rate each sheeting type decays. Some samples show that the sheeting's retroreflectivity values are increasing and some are decreasing. At this time, these results are inconclusive and the samples will be continued to be tested on an annual basis.

8. SURVEY

As part of the project scope, a nationwide survey was conducted to obtain a consensus of how other state transportation departments are tackling the new requirements as shown below. In short, 18 of 50 states responded, a fairly high response rate. Three of the eighteen states are conducting or proposing studies to establish the most cost-effective method of sign replacement. These studies include developing a sign maintenance program in Texas beginning September 2009, setting up a mini test deck to evaluate control signs to predict life expectancy in Wisconsin, and researching various methods in Oregon to choose an appropriate method. The majority of the states currently replace signs based on age using blanket replacement in cycles (eight states) or condition using visual inspections (eight states). Tennessee did replace interstate signs on a twelve year cycle but ended several years ago due to budget constraints. Maine was the only state that did not have a statewide policy, sign replacement is the responsibility of each region. Twelve of the states have chosen their method of replacement. Many states are exploring using a combination of methods including blanket replacement, nighttime inspections, and life expectancy. The primary factors for choosing a method(s) were feasibility and simplicity. Sixteen states have some type of inventory or are trying to establish one and fourteen states expect the inventory to aid in the future replacement process. The survey questions and results are displayed in Appendix D.

9. SHEETING COSTS

Periodically, the State distributes a "Request for Proposal" or RFP for specified types of sign sheeting. Interested manufacturers and suppliers respond with bid prices of sheeting per square foot. Typically, a sign sheeting supplier is awarded based on the lowest bid. Once awarded under a contract, respective sign sheeting may be purchased for any Agency project including knock-down requests, specific sign replacement projects or any other roadway rehabilitation projects that includes sign replacement. Table 6 supplies a summary of contract prices that have been in effect from 1999 through 2009. Low bid was the basis of award in all cases.

Table 6: Sign Sheeting Bid Price Summary.

Sheeting Cost Comparison				
Sheeting Type:	Years		Manufacturer:	Cost (sq ft):
	To:	From:		
Type III	1999	2003	3M	$1.75
Type IV	2003	2007	3M	$1.23
Type IV	2007	2009	3M	$1.23
Type IX	1999	2003	3M	$4.90
Type IX	2003	2007	3M	$4.39
Type IX	2007	2009	Avery-Dennison	$4.50

As stated previously, the cost for Type IV sign sheeting produced by 3M is lower than the cost for Type III as shown in the table. It is also interesting to note that Type IX sheeting costs approximately 3.6 times that of Type III sheeting. While this may seem like a large difference in cost, it minimally increases the overall cost for the traffic sign. According to FHWA, "the estimated of an 18-in by 23-in Chevron sign with Type III sheeting is about $335. This estimate was based on a unit price of 1.20/ft^2 for sheeting. Applying an estimated cost of $4.00/ft^2 of fluorescent color microprismatic sheeting brings the total sign cost to $343, a cost increase of only 2.4%" (*17*). Given additional safety benefits of Type IX sheeting including a longer viewing distance and increased visibility along with a longer projected sign life, continued placement of Type IX sheeting along sharp horizontal curves and other areas of concern is highly recommended.

10. RECOMMENDATIONS

Data analysis did not confirm any variables affecting long term performance when considering orientation, offset, wind exposure or roadway type with the exception of the manufacturer. In light of this finding expected sign life or blanket replacement is recommended. With respect to expected sign life, signs older than the expected sign life should be replaced. Given that the Agency maintains a sign inventory, the age of all traffic signs within the inventory are known and can be easily queried to identify those older than the expected sign life. Blanket replacement refers to the replacement of signs in an area/corridor or of a given type at specified intervals which eliminates the need to assess retroreflectivity or track the life of individual signs. This replacement interval should be based upon expected sign life for the shortest-life materials used on the affected signs unless a more complex system is devised to address category and type.

With limited long term data it is difficult to recommend an accurate expected sign life. Of all 618 traffic signs incorporated into the study, none were found to be below the future retroreflectivity requirements. After 7 to 12.5 and 5.4 to 6.4 years of service for Type III and Type IX sheeting, retroreflectivity readings are still considered acceptable. Given the best fit trend lines and predicted retroreflectivity over time, a replacement cycle of 15 years is recommended for red sheeting and 15-20 years for white, green and yellow sheeting. A recommended replacement cycle for Type IX sheeting is not feasible at this time given the current data pool. It is easy to suspect that replacement cycles for Type IX sheeting would be greater than those of Type III sheeting given short term performance. However, additional long term data collection is highly recommended for both types of sign sheeting.

11. SUMMARY

The main objective of this research initiative was to establish and implement a sign assessment method and provide recommendations for the periodic replacement of traffic signs in a cost effective manner in concert with future minimum sign sheeting retroreflectivity requirements set forth by the MUTCD. This was accomplished by examining one assessment method and two management methods including the sign retro-reflectivity assessment method, blanket replacement and control signs. Field data collection efforts focused evaluating the current condition of several sheeting types and color combinations including ASTM Type III and Type IX sheeting. These sheeting types were selected based upon the Agency’s current practices. ASTM Type III sheeting is specified as the minimum sheeting type for the replacement of all traffic signs. In addition, it is general practice to specify the installation of ASTM Type IX fluorescent sheeting for a pedestrian warning signs and documented dangerous locations such as sharp curves or hidden drives. For ASTM Type III sheeting, four non-fluorescent sheeting colors were assessed as follows: green, red, yellow, and white. For ASTM Type IX sheeting, two fluorescent sheeting colors were examined: yellow, and yellow-green.

All retroreflectivity readings were collected randomly in accordance with ASTM E 1709-08, "Standard Test Method for Measurement of Retroreflective Sign Using a Portable Retroreflectometer at a 0.2 Degree Observation Angle." A total of 618 traffic signs were evaluated over the summer of 2008. Several potential explanatory variables were examined including condition, manufacturer, wind direction, orientation, color, type, physiographic location, type of roadway, AADT, and offsets (vertical and horizontal). Although the intent was to perform a cross-sectional study documenting sheeting retroreflectivity over a 15 year service life, given policy changes and introduction of new sheeting types, this was not feasible. For example, due to a specification change implemented on March 1st 2003, a minimum sheeting grade of Type III was required for most signs. Prior to this date, Type I and II was widely used. Type IX fluorescent sheeting utilized for a pedestrian warning signs and documented high crash locations such as sharp curves or hidden drives was not introduced until 2002. Therefore we were unable to collect any long term data.

As data analysis did not identify variables affecting long term performance including orientation, offset, wind exposure or roadway type with the exception of the manufacturer, expected sign life or blanket replacement is recommended. With limited long term data it is difficult to recommend an accurate expected sign life. Of all 618 traffic signs incorporated into the study, none were found to be below the future retroreflectivity requirements. Given the best fit trend lines and predicted retroreflectivity over time, a replacement cycle of 15 years is recommended for red sheeting and 15-20 years for white, green and yellow sheeting. A recommended replacement cycle for Type IX sheeting is not feasible at this time given the current data pool. It is easy to suspect that replacement cycles for Type IX sheeting would be greater than those of Type III sheeting given short term performance. However, additional long term data collection is highly recommended for both types of sign sheeting. Control sign sheeting data collection will be performed annually and be used to supplement the findings in this report.

12. REFERENCES

1. U.S. Department of Transportation – Federal Highway Administration (FHWA). "MUTCD Overview." FHWA – Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD). 12/05/2007. http://mutcd.fhwa.dot.gov/kno-overview.htm.

2. U.S. Department of Transportation – Federal Highway Administration (FHWA). "History of Sign Retroreflectivity." FHWA. 12/20/2007. http://safety.fhwa.dot.gov/roadway_dept/retro/sign/back_history.htm.

3. Wolshon, Brian, Ph.D., P.E., Degeyter, Robert, P.E., and Swargam, Jyothi. "Analysis and Predictive Modeling of Road Sign Retroreflectivity Performance." 16th Biennial Symposium on Visibility and Simulation, June 2-4, 2002. Iowa City, IA.

4. Facet Technology Corporation. "Retroreflectivity." Facet. 2008. www.facet-tech.com/transportation/retroreflectivity.htm.

5. U.S. Department of Transportation – Federal Highway Administration (FHWA). "Know Your RETRO – 2007." FHWA-SA-07-020. 2007. http://safety.fhwa.dot.gov/roadway_dept/retro/sa07020/.

6. U.S. Department of Transportation – Federal Highway Administration (FHWA). "Manual on Uniform Traffic Control Devices for Streets and Highways – Revision 2."

7. Adrian, W. "Visibility of Targets: Model for Calculation." *Lighting Research Technology*, Volume 21, No. 4, Great Britain, 1989.

8. Olson, P.L. "Minimum Requirements for Adequate Nighttime Conspicuity of Highway Signs. Technical Report UMTRI-88-8." University of Michigan Transportation Research Institute, Ann Arbor, Michigan, 1988.

9. Facet Technology Corporation. "Retroreflectivity." Facet. 2008. www.facet-tech.com/transportation/retroreflectivity.htm.

10. Migletz, James, and Jerry Graham. "Long-Term Pavement Marking Practices." *National Cooperative Highway Research Program* Synthesis 306 (2002): 1-4.

11. American Association of State highway and Transportation Officials (AASHTO). "AASHTO M268-08: Standard Specification for Retroreflective Sheeting for Traffic Control." Standard Specifications for Transportation Materials and Methods of Sampling and Testing. Part 1B Specifications. 27th Edition. 2007.

12. American Society for Testing and Materials (ASTM). "ASTM E 1709-08: Standard Test Method for measurement of Retroreflective Signs Using a Portable

Retroreflectometer at a 0.2 Degree Observation Angle." 2009 Annual Book of ASTM Standards, Section Six: Paints, Related Coatings, and Aromatics, Volume 06.01: Paint-Tests for Chemical, Physical, and Optical Properties; Appearance. 2009.

13. U.S. Department of Transportation – Federal Highway Administration (FHWA). "FHWA Retroreflective Sheeting Identification Guide – September 2005." 2005.

14. RoadVista. "User's Manual – 922 Field Retroreflectometer." Gamma Scientific, Inc. 2005.

15. Federal Highway Administration. "Sign Colors." Manual on Uniform Traffic Control Devices. Section 2A.11, Page 2A-5. 2003.

16. Saint Michael's College. "The Physiographic Regions of Vermont." http://academics.smcvt.edu/vtgeographic/textbook/physiographic/physiographic_regions_of_vermont.htm#sparsely%20populated.

17. U.S. Department of Transportation – Federal Highway Administration (FHWA). "Chapter 3: Enhanced Basic Treatments." Low Cost Treatments for Horizontal Curve Safety. http://safety.fhwa.dot.gov/roadway-dept/horicurves/fhwasa07002/ch3.cfm.

Appendix A

Table A-1: AASHTO M268-08 & ASTM D 4956-07 - Description of Sheeting Types.

AASHTO M268 Sign Sheeting Type Descriptions	
Type	**Description**
I	A medium-intensity retroreflective sheeting referred to as "engineering grade" and typically enclosed lens glass-bead sheeting. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.
II	A medium-high-intensity retroreflective sheeting sometimes referred to as "super engineer grade" and typically enclosed lens glass-bead sheeting. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.
III	A high-intensity retroreflective sheeting that is typically encapsulated glass-bead retroreflective material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.
IV	A high-intensity retroreflective sheeting. This sheeting is typically an unmetallized microprismatic retroreflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.
V	A super-high-intensity retroreflective sheeting. This sheeting is metalized microprismatic retroreflective element material. This material is typically used for delineators.
VI	An elastomeric high-intensity retroreflective sheeting without adhesive. This sheeting is typically a vinyl microprismatic retroreflective material. This sheeting is typically used for orange temporary roll-up warning signs, traffic cone collars, and post bands.
VII	A super-high-intensity retroreflective sheeting having highest retroreflectivity characteristics at long and medium road distances. This sheeting is typically an unmetallized microprismatic retroreflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.
VIII	A super-high-intensity retroreflective sheeting having highest retroreflectivity characteristics at long and medium road distances. This sheeting is typically an unmetallized microprismatic retroreflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.
IX	A very-high-intensity retroreflective sheeting having highest retroreflectivity characteristics at short road distances. This sheeting is typically unmetallized microprismatic retroreflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.
X	A super-high-intensity retroreflective sheeting having highest retroreflectivity characteristics at medium road distances. This sheeting is typically unmetallized microprismatic retroreflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

Table A-2: Minimum Retroreflectivity Value Table.

Minimum Maintained Retroreflectivity Levels					
Sign Color	Sheeting Type (ASTM D4956-04) (1)				Additional Criteria
	Beaded Sheeting			Prismatic Sheeting	
	I	II	III	III, IV, VI, VII, VIII, IX, X	
White on Green	W* G ≥ 7	W* G ≥ 15	W* G ≥ 25	W ≥ 250; G ≥ 25	Overhead
	W* G ≥ 7	W ≥ 120; G ≥ 15			Ground-mounted
Black on Yellow or Black on Orange	Y*; O*	Y ≥ 50; O ≥ 50			(2)
	Y*; O*	Y ≥ 75; O ≥ 75			(3)
White on Red	W ≥ 35; R ≥ 7				(4)
Black on White	W ≥ 50				—

(1) The minimum maintained retroreflectivity levels shown in this table are in units of $cd/lx/m^2$ 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 Color Ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity)
* This sheeting type should not be used for this color for this application.

Table A-3: FHWA Proposed Assessment and Management Methods Table.

FHWA Methods	
Assessment Methods	**Description**
Visual Assessment	Fours suggestions to utilize this method are: nighttime inspection, calibrated sign comparison, comparison panels procedure, and consistent parameters procedure.
Measured Sign Retroreflectivity	The retroreflectivity of a sign is measured and directly compared to the minimum level using the Standard Test Method for Measurement of Retroreflective Signs Using a Portable Retroreflectometer (ASTM E1709).
Management Methods	**Description**
Expected Sign Life	All signs are replaced based on expected sign life which is determined by sign retroreflectivity degradation.
Blanket Replacement	All signs in an area or of a given type are to be replaced at specified intervals, eliminating the need to assess retroreflectivity or track the life of individual signs.
Control Signs	Replacement of signs in the field is based on the performance of a sample of control signs.

<u>FHWA Suggested Methods for Maintaining Sign Retroreflectivity Summary</u>

<u>Assessment Methods:</u>

1. **Visual Assessment**
   1. **Please note that one or more procedures (b, c, and/or d) are recommended to be used to support the Nighttime Inspection.**

   a.) **Nighttime Inspection:** On-the-fly nighttime assessments are made by an inspector. The following recommendations provide guidance for proper inspection techniques:
      - o Develop guidelines and procedures for inspectors to use in conducting the nighttime inspections and train inspectors in the use of these procedures.
      - o Conduct inspections at normal speeds from the travel lane.
      - o Conduct inspections using low-beam headlights and minimize interior vehicle lighting.
      - o Evaluate signs at typical viewing distances, giving the driver adequate timing to provide an appropriate response.

   b.) **Calibration Signs Procedure:** An inspector views a "calibration sign" prior to conducting the nighttime inspection. The signs should have known retroreflectivity levels at or above the minimum levels and be set up where the inspector can view them in a manner similar to nighttime field inspections. The visual appearance of the sign should allow the inspector to establish the evaluation threshold for that night's inspection activities. The following factors provide additional information for using this procedure:
      - o Signs are needed for each color.
      - o Signs are viewed at typical viewing distances using the inspection vehicle.
      - o Signs need to be properly stored between inspections to insure their retroreflectivity does not deteriorate over time.
      - o Retroreflectivity of these signs should be verified periodically.

   c.) **Comparison Panels Procedure:** Panels will be utilized to assess signs that have marginal retroreflectivity. The panels shall be fabricated at retroreflectivity levels at or above the minimum levels. When the inspector identifies a sign that has marginal retroreflectivity, a comparison panel is attached to the sign so that the inspector can view the variances between the two.

   d.) **Consistent Parameters Procedure:** Nighttime inspections can be conducted under the following similar factors that were used to develop the minimum retroreflectivity levels:
      - o Use a sport utility vehicle or pick-up truck to perform the inspection.
      - o Use a model year 2000 or newer for the inspection.
      - o Use an inspector who is at least 60 years old.

2. **Measured Sign Retroreflectivity**
   2. This method will utilize ASTM E1709, the Standard Test Method for Measurement of Retroreflective Signs Using a Portable Retroreflectometer to measure the retroreflectivity of a sign and directly compare it to the minimum level appropriate for any given sign.

Management Methods:

1. Expected Sign Life

3. Individual signs are replaced before reaching the end of their projected service life, which is the time anticipated for the retroreflective material to degrade to the appropriate minimum level.

4. Based on sign sheeting warranties, weathering deck results, measurements of field signs, or other criteria.

5. A system must be developed and used to track sign age. Various approaches can be used including: sign labels marking the year of fabrication or installation or sign management systems.

2. Blanket Replacement

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

3. Control Signs

- A control sample of signs is used to represent all of an Agency's signs. The signs will be monitored and replacement of field signs will be based on performance of the control group.
- Recommendations:
  - **a.** Agencies should develop a sampling plan to determine the appropriate number and type of control signs needed to represent the overall total.
  - **b.** Control signs may be actual signs in the field or signs in a maintenance year (for convenience).
  - **c.** The retroreflectivity of the control signs should be monitored using an assessment method.

Appendix B

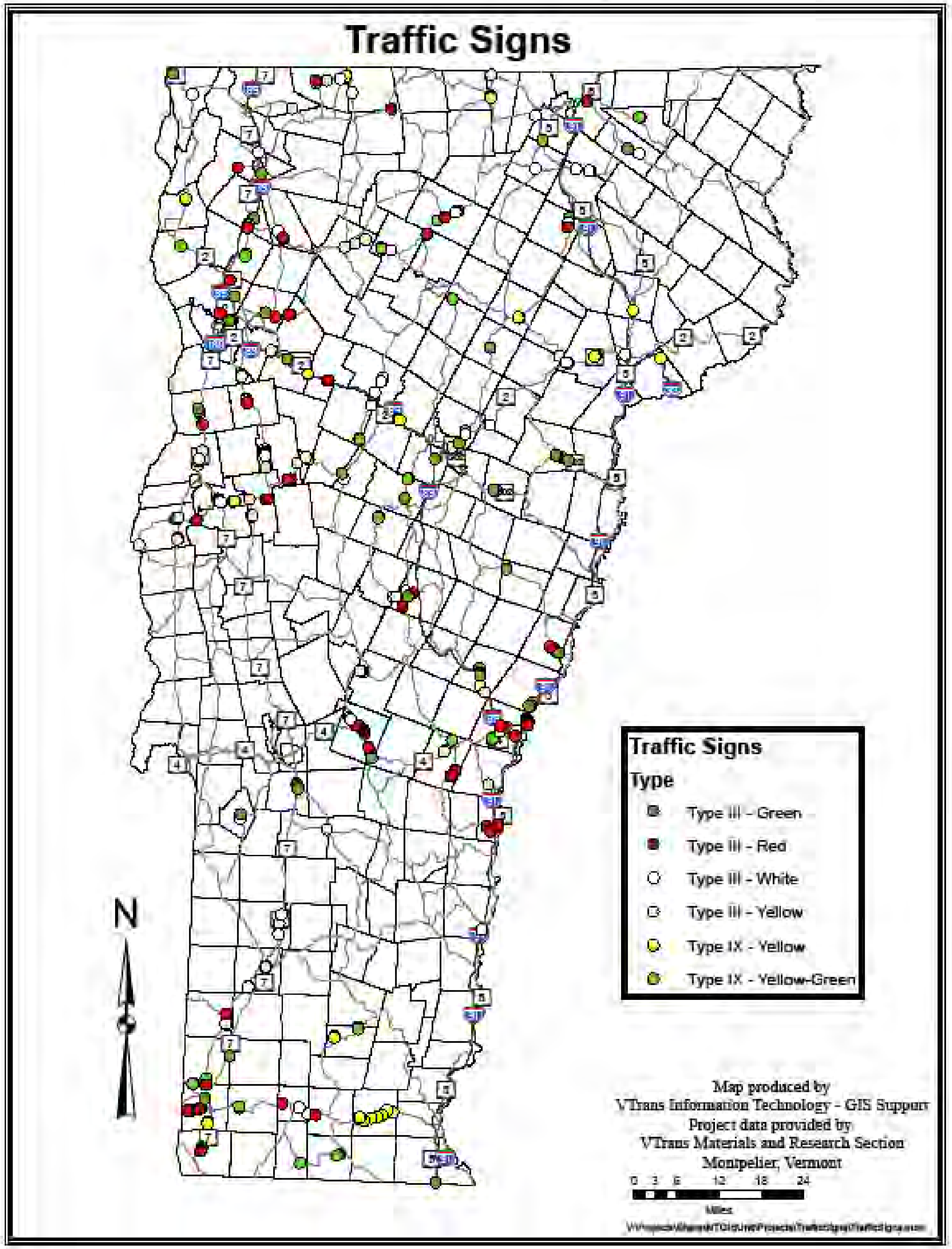


Figure B-1: All signs tested.

Six Physiographic Regions of Vermont

Vermont Lowlands

Located on the western side of the state, the lowlands extend from the Brandon area to the Poultney River near the Canadian border. Lying between the Adirondack Mountains to the west in New York and the Green Mountains on the east, the region has a low elevation. This paired with the moderate temperatures around Lake Champlain, this region is the mildest region in the state, receiving the least precipitation. The milder climate and fertile soil permits the region to strive in agricultural endeavors.

The Green Mountains

Part of the Appalachian Mountain chain, the Green Mountains are known as the backbone of Vermont. Scientists have found evidence that the mountains in this region which extend the length of the state, varying in width from 20 to 35 miles are some of the oldest on the planet, having formed over 400 million years ago. The climate in this region is harsher than the other regions in the state. The temperatures in the region are often much lower and there is a large amount of precipitation.

The Taconic Mountains

Located in the Southwestern corner of Vermont, this region is full of peaks rising above 3,000 feet. The climate in the region is similar to that of the Green Mountain region.

The Valley of Vermont

Sandwiched between the two mountain regions within the state, the smallest region in the state is very similar to the Vermont Lowlands region. It is considered by many as an extension of the Lowlands region because it exhibits the same climate and agricultural characteristics.

The Vermont Piedmont

To the east of the Green Mountain region, the Piedmont region made up of several rolling hills and valleys, is the largest region in the state. The region contains some of the Monadnock Mountain chain and also is abundant with lakes and ponds.

The Northeast Highlands

Located in the Northeast corner of the state in Essex County, this region is very similar in nature to that of the White Mountains in New Hampshire. This area has an abundance of swamps and bogs due to the poor water drainage qualities throughout the region caused by sand and loose rock deposits left by the glaciers that once covered Vermont thousands of years ago.

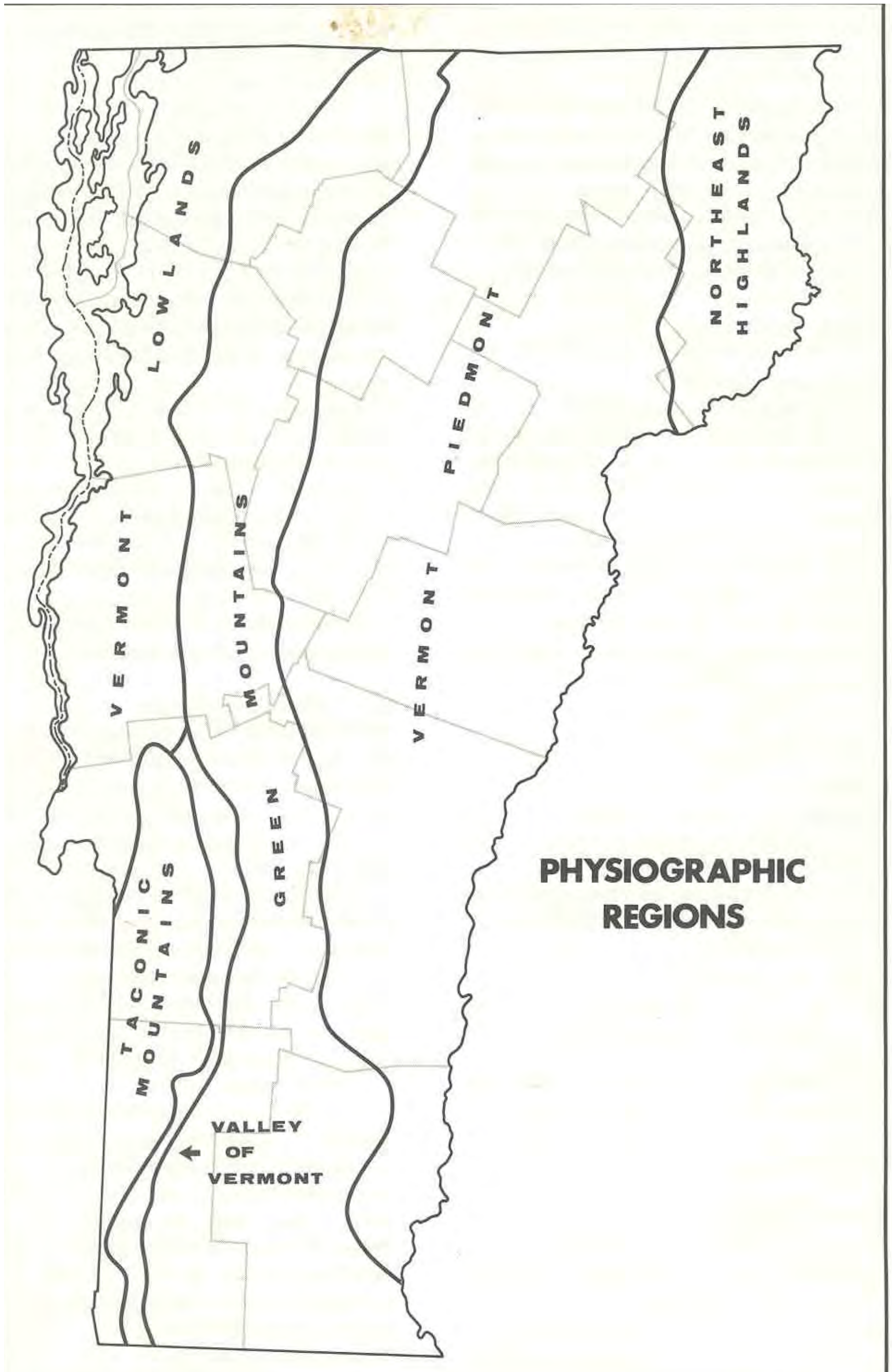


Figure B-2: Physiographical regions of Vermont (*16*).

Appendix C

Table C-1: Life Expectancy Table.

Type 3					
Graph	**Line**	**Trend Type Selection**	**Equation**	**R^2**	**Life Expectancy (years)**
Overall Color	Green	Linear	y = -0.8538x + 135.16	0.0359	11.73
Overall Color	Green	Log	Y = -37.804Ln(x) + 234.66	0.0366	27.82
Overall Color	Green	Exp	y = 93.821e-0.0047x	0.0393	32.51
Overall Color	Red	Linear	y = -0.3629x + 72.891	0.0266	15.13
Overall Color	Red	Log	Y = -13.737Ln(x) + 107.55	0.016	125.81
Overall Color	Red	Exp	y = 58.998e-0.0053x	0.0224	33.52
Overall Color	Yellow	Linear	y = -1.23999x + 284.39	0.0771	15.75
Overall Color	Yellow	Log	Y = -78.828Ln(x) + 525.81	0.1275	34.85
Overall Color	Yellow	Exp	y = 240.53e-0.003x	0.0323	43.63
Overall Color	White	Linear	y = -2.1282x + 408.64	0.0586	14.04
Overall Color	White	Log	y = -130.27Ln(x) + 790.7	0.1288	24.56
Overall Color	White	Exp	y = 374.32e-0.0059x	0.0618	28.43
Manufacturer Green	A	Linear	y = -0.0838x + 59.788	0.0038	534.46
Manufacturer Green	A	Log	Y = -0.6662Ln(x) + 58.342	0.001	18 Octillion
Manufacturer Green	A	Exp	y = 54.315e-0.0009x	0.0045	119.14
Manufacturer Green	B	Linear	y = -0.9291x + 182.62	0.0292	180.41
Manufacturer Green	B	Log	Y = -4.0872Ln(x) + 161.64	0.0019	3.8 Quadrillion
Manufacturer Green	B	Exp	y = 135.29e-0.0032x	0.0027	57.28
Offset - 3M	6ft x 6ft	Linear	y=-4.3938x+63.058	0.3362	10.94

Green					
Offset - 3M Green	6ft x 6ft	Log	y=-13.057Ln(x)+62.663	0.2234	38.49
Offset - 3M Green	6ft x 6ft	Exp	y=73.139e-.1281x	0.3821	12.37
Offset - 3M Green	30ft x 7ft	Linear	y=1.5798x+41.903	0.1734	-17.03
Offset - 3M Green	30ft x 7ft	Log	y=10.791Ln(x)+32.492	0.1198	0.2
Offset - 3M Green	30ft x 7ft	Exp	y=43.242e.028x	0.1477	-37.81
N vs. S - 3M Green	North	Linear	y = -1.419x + 62.458	0.0508	33.45
N vs. S - 3M Green	North	Log	y = -5.389Ln(x) + 63.315	0.0321	7828.18
N vs. S - 3M Green	North	Exp	y = 60.39e-0.0236x	0.0562	59.02
N vs. S - 3M Green	South	Linear	y = -0.9124x + 50.382	0.224	38.78
N vs. S - 3M Green	South	Log	Y = -2.1695Ln(x) + 49.156	0.115	6,877,183.50
N vs. S - 3M Green	South	Exp	y = 50.483e-0.0203x	0.2187	59.78
Type 9					
Graph	**Line**	**Trend Type**	**Equation**	**R^2**	**Life Expectancy (years)**
3M YG vs. Y	YG	Linear	y = -9.5203x + 454.88	0.2624	42.53
3M YG vs. Y	YG	Log	Y = -17.867Ln(x) + 441.15	0.116	3,218,931,927
3M YG vs. Y	YG	Exp	y = 457e-0.0239x	0.2842	92.58
3M YG vs. Y	Y	Linear	y = 5.5979x + 256.84	0.0789	-36.95
3M YG vs. Y	Y	Log	y = 27.131Ln(x) + 246.68	0.2325	0.0007
3M YG vs. Y	Y	Exp	y = 250.48e0.0258x	0.1122	-62.46

Table C-2: Correlation Table of Important Variables in Determining Sign Sheeting Replacement.

Results			
Type	**Color**	**Variable**	**Correlation**
3	Green	Time	Y
		Color	Y
		Condition	Y
		Manufacturer	Y
		Offsets	Y
		Orientation	N
		Type A or B	N
		AADT	N
		Wind	N
3	Red	Time	Y
		Color	Y
		Condition	Y
		Manufacturer	Y
		Offsets	N/A
		Orientation	N
		Type A or B	N/A
		AADT	N/A
		Wind	N/A
3	Yellow	Time	Y
		Color	Y
		Condition	Y
		Manufacturer	Y
		Offsets	N/A
		Orientation	N
		Type A or B	N/A
		AADT	N/A
		Wind	N/A
3	White	Time	Y
		Color	Y
		Condition	Y
		Manufacturer	Y
		Offsets	N/A
		Orientation	N
		Type A or B	N/A
		AADT	N/A
		Wind	N/A
9	YG	Time	Y
		Color	Y
		Condition	Y

		Manufacturer	Y
		Offsets	N/A
		Orientation	N
		Type A or B	N/A
		AADT	N/A
		Wind	N/A
9	**Yellow**	Time	Y
		Color	Y
		Condition	Y
		Manufacturer	Y
		Offsets	N/A
		Orientation	N
		Type A or B	N/A
		AADT	N/A
		Wind	N/A

Appendix D

Survey Questions

1. What are your current procedures for sign replacement? (before the FHWA minimum requirements and replacement methods came out)

2. Has your state chosen a method of replacement to conform to the new FHWA requirement?

3. If yes, what method was chosen? Is it one of the FHWA suggested methods, combination of methods or something different?

4. What were or are the factors in choosing a method for sign replacement in your state?

5. If a study is underway what methodology procedures are being used?

6. What date do you project for choosing a method?

7. Does your state currently have a sign inventory as part of your asset management program?

8. If so, will you be utilizing this as part of your replacement strategy?

Table D-1: State Survey Results.

Survey Responses								
State	State							
	1	2	3	4	5	6	7	8
AZ	Replace on a cycle (2010 - $4million per year)	Yes.	Combination of replacement cycles and inventory.	Funding and simplicity.	No.	N/A	Currently working on the inventory. Expected to finish this summer.	Yes.
CA	Visual nighttime inspection.	Yes.	Expect no changes in current method.	Maintain current method.	No.	N/A	Maintained on a district basis in 12 different offices.	Looking into how to establish and maintain an inventory.
DE	Blanket replacement and as projects are implemented.	Yes.	Blanket replacement, Nighttime visual inspection, sign retroreflectivity.	Blanket replacement when funding is available. Nighttime used to spot check.	No.	Currently active.	Yes for overhead and I-beam mounted signs, not for ground mounted signs.	Yes, currently used for forecasting replacement costs.
IL	Route sign inspections, based on condition	Yes.	Blanket replacement, based on county or route every 15 years.	Cost.	No.	N/A	Yes but maintaining the inventory is difficult due to reduced	Yes, planning on implementing a different inventory

							staff.	program.
LA	Ground mounted signs = 10 years. Overhead signs = 15 years.	Yes.	Manage signs by age only.	Some service life data is available but more is needed from manufacturers. Considering using expected service life curves.	N/A	N/A	No but are planning to establish one. Currently the value of an inventory does not justify the cost.	N/A.
ME	Each region is responsible for the assessment and replacement of signs.	Yes.	Life-cycle method. Awaiting decisions from other New England states.	Life cycle method seems most appropriate.	No.	N/A	Inventory is out of date and is not electronic. Hoping to use MATS in the future.	Hopefully. Also considering inclusion of replacement in repaving projects.
MN	Replacing Type III signs with Type IX since March 1999 on a 12 year cycle. In August 2005 switched to DG3 sheeting.	Yes.	Expected sign life on a projected time frame of 15 years for prismatic sheeting types. Also a NTPEP test deck is located here and is tested annually.	Past experience in combination with determining the most cost effective method of sign replacement.	No.	N/A	Implementing the SignCAD SignTRACK inventory system for all signs on state highways. It is anticipated that this will take several years to update.	Possibly.

MS	District offices maintain signs on a 7-10 year cycle on all state roadways except the Interstate system which is maintained by Traffic Engineering on a 10 year cycle. An inventory is in place and aids in determining how many signs to replace annually.	Yes.	Life expectancy and blanket replacement methods.	The inventory has been in place for five years and have been using this method since then.	No.	N/A	Yes and are presently in discussions on how to update the system and possibly migrate to a new database structure.	Yes.
MO	Annual sign log inspections were performed, looking at every sign on the entire system. The inspections alternated between day inspection one year and night inspections the next. Not successful due to subjectiveness of the inspectors.	Yes.	3 Major Steps: 1) Setting a sheeting type. Upgraded to Type IV for permanent sheeting and Type VII for work zones. 2) Develop inventory. 3) Adopt a management method based on replacement cycle of 10	Requiring the higher sheeting type will automatically raise the initial retroreflectivity values well above the minimums. The inventory will help in managing what signs to replace and when. As the inventory is populated, it is expected that a true life expectancy will alter the current	No.	N/A	Yes as mentioned previously.	Yes and random annual nighttime inspections will also be performed to validate the replacement plan based on the inventory.

			years.	replacement cycles over time.				
NE	Nighttime inspection for retroreflectivity, faded signs, and when damaged.	Yes.	Current nighttime inspection and some retroreflectivity measurements.	Policy has been in place for several years. Seems logical to keep this going.	No.	N/A	No, but discussed it several times.	N/A.
NC	Daytime and nighttime visual inspections.	No.	Currently in an evaluation process of the most effective and efficient methods to comply.	Leading method is visual inspection coupled with using retroreflectivity readings for borderline signs.	Y/N - Preliminary stages will require central research on expected sign life and a survey of field personnel.	TBD	No.	N/A.

NY	Ground mounted signs were replaced on 12 year cycles but due to limited funding cycles have moved to 15 to 16 years. Annual sign contracts exist to address corridors and specific signs.	No.	In reviewing process. Expect a combination of methods (corrider replacement, life cycle, and nighttime inspection, test deck) will be chosen.	Using retroreflectometers for measured sign retroreflectivity will not be an option due to costs.	No.	TBD - Before Summer 2009.	No - Currently in process of developing an inventory using Cartegraph. Estimate 750,000 signs on the state system. A number of regions have developed systems using dBase, Access, Excel, etc.	Yes.
OR	Combination, including: nighttime inspection, complaints and/or damage, construction projects, and funding.	No.	Hoping that the maintenance group will form a task group to evaluate the situation and make a recommendatio n. Research has proposed a study to evaluate alternatives and associated	Cost, equipment and staff needed, time involved, effectiveness, consistency between districts, time to implement, and whether existing procedures will comply.	Not yet.	None yet.	Software has been available to all districts for 15 years but usage is not mandatory. Over the last 2 years, a "basic inventory" has been produced at a statewide	Hoping to make this the starting block for their replacement strategy. Retroreflectivity values and condition are documented in the basic inventory.

			costs.				level.	
TN	Originally, interstate signs were replaced on a 12 year cycle and all others were random by county. This ended several years ago due to budget constraints.	No.	Currently reviewing how to comply with the new requirements.	Most likely a combination of retroreflectivity readings and cycle replacements based on the costs.	No.	N/A	The existing inventory is several years old. A new contract to collect data is about to start. Looking at the cost of retroreflectivity readings as part of the process to see if it is something that would fit into budgeting.	If it fits within the budget.
TX	All signs are inspected twice a year for position, damage, legibility, structural distress, general condition. One inspection is at night, using two people.	No.	Leaning toward nighttime inspection with calibrated signs.	Cost, feasibility, current practice.	Yes, project 0-6408 Develop a Statewide Sign Maint. Program is underway and hopefully will begin in September 2009.	2012	No, but some of the smaller maintenance sections have created spreadsheet based inventories.	N/A.

VA	Visual inspections (day and night), conducted by 5 regional offices.	No.	Looking at visual inspections with measured readings for signs that are questionable.	Expected sign life and blanket replacement is not reliable due to large inventory and inaccurate documentation. Control signs are too labor intensive. Visual inspections will be chosen and those signs that are suspected to be below the minimums will be continually measured for retroreflectivity.	No.	None yet.	Not a full inventory is in place. All overhead signs were done as part of a structural inspection program. 5 regional offices have functionally complete inventories. Working to develop using video graphic tools for interstate signs.	Unsure, but most likely.
WV	Overhead signs = 12 to 15 yrs by contract and statewide maintenance handles these signs if damaged. All other signs are	Yes.	Replacement based on age.	Due to large inventory of signs, this method is most cost effective for the state.	No.	N/A.	Some districts use various inventory methods. For roadways renovated by contract, plans are used as	Spoken with 3M about using their sign asset mgmt. software. This would be used for the district shops initially

	handled by district sign shops with varying strategies.						the inventory.	and if proven successful spread statewide.
WI	Signs replaced on a 12 year cycle but is difficult to maintain due to funding and manpower.	Yes.	Blanket replacement and control signs.	Practical methods and easy implementation.	Yes - control signs.	In place.	Yes - Cartegraph Sign View, started in 1999 now totally 302,000 signs.	Yes - critical to replacement strategy.