Assessment of Sign Retroreflectivity Compliance for Development of a Management Plan

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The *Manual on Uniform Traffic Control Devices* (MUTCD) specifies minimum retroreflectivity requirements that include an obligation for agencies to develop a strategy for maintaining compliance. States were given a deadline of January 1, 2012, for the implementation of an assessment or management plan, which led to an increased emphasis on sign asset management. However, a new rule was submitted to the *Federal Register* to extend and modify the deadlines. With budget considerations, it is important that a transportation agency implement an assessment or management plan that is efficient and provides compliance with the standards required by the MUTCD. The development of an efficient plan requires knowledge of the overall condition of an agency's assets as well as unique considerations regarding its performance. Through a review of previous data collection efforts, this paper details the development of a data collection strategy for assessing the performance of traffic signs maintained by the Utah Department of Transportation (DOT). Agency operations, site selection, and attribute collection were all considered during the development of a collection plan for an agency where limited inventory and installation data were available. Retroreflectivity measurements were taken for 1,433 Utah DOT signs. This sample provided a snapshot of current compliance and assisted in the selection of an asset management plan for maintaining sign retroreflectivity. Results from the study showed that the Utah DOT's signs were well over 90% compliant with the MUTCD standards and preliminary management strategies were presented to address vandalism and other damage.

Establishment of standards for minimum levels of retroreflectivity for traffic signs was first directed by the Congress to the Secretary of Transportation in 1992. This congressional mandate established the foundation for the adoption of new language in the second edition of the 2003 *Manual on Uniform Traffic Control Devices* (MUTCD). The necessity for a sign management program comes from the necessity to comply with the MUTCD standards, as well as a need to efficiently allocate maintenance funds.

The MUTCD currently contains the mandate that by the year 2012, "Public agencies or officials having jurisdiction shall use an assessment or management method that is designed to maintain retroreflectivity" (*1*) at a level that is at or above the minimum retroreflectivity levels that are provided. However, a new rule has been proposed to modify the current retroreflectivity regulations. As guidance, the MUTCD provides five assessment and management methods for complying with this mandate. These methods are

1. Visual nighttime inspection,
2. Measured sign retroreflectivity,
3. Expected sign life,
4. Blanket replacement, and
5. Control signs.

Methods 1 and 2 are classified as assessment methods and Methods 3, 4, and 5 are classified as management methods for complying with the minimum retroreflectivity level standards. Each assessment or management method is designed to maintain the minimum retroreflectivity levels shown in Figure 1.

Agencies are required to ensure that all traffic signs in their jurisdiction that are not explicitly excluded in the MUTCD are in compliance with these standards. Currently the signs must be compliant by the year 2015 for regulatory, warning, or post-mounted guide signs and by the year 2018 for street sign names and overhead guide signs. At this time, it has been proposed that the MUTCD be amended to remove these compliance dates, but the minimum levels to be maintained are to remain for regulatory and warning signs. With budget considerations and constraints, it is important that transportation agencies select a management or assessment method that will best meet the agencies' compliance needs while doing so in the most efficient manner possible. Each individual method requires varying types and degrees of agency resources and carries its individual costs in ensuring an acceptable degree of overall compliance.

Selecting an appropriate management or assessment method to efficiently maintain sign retroreflectivity requires an understanding of the conditions and factors unique to a particular agency. Additionally, it is important to understand the degree of current overall compliance with minimum standards when policy is established to manage any of an agency's assets. To facilitate this, it is imperative that agencies collect information regarding the state and condition of their assets.

The objective of this research is to provide a data collection and analysis procedure that will assist in the development of a sign asset management strategy to comply with the minimum retroreflectivity levels stipulated in the MUTCD. The purpose of data collection is to provide a quantitative assessment of overall compliance with minimum retroreflectivity levels, which will give guidance in the

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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
	W*; G ≥ 7	W ≥ 120; G ≥ 15			Post-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 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.

FIGURE 1 Minimum retroreflectivity levels.

selection of a management method to ensure future compliance. The data collected are analyzed to provide insight regarding the current state, performance, and special considerations relating to the Utah Department of Transportation's (DOT's) sign assets. This paper provides details of the data collection effort and analysis of the collected data and then shows how the data collected influenced the sign management strategy for the Utah DOT.

BACKGROUND

Each assessment or management method requires some degree of understanding of an agency's sign assets and how they are performing over time. Beyond just meeting the minimum retroreflectivity conformance criteria, sheeting performance, damage rates, maintenance, and overall visibility should all be considered in the development of a sign asset management program.

In the past, the majority of data collection efforts for the retroreflectivity of traffic signs have been focused on understanding how the retroreflectivity of traffic signs deteriorates (*2–4*). For development of an asset management strategy to comply with the then proposed minimum levels of retroreflectivity of signs in North Carolina, a study was performed that reviewed various approaches to managing retroreflectivity (*5*). The work focused on the collection of retroreflectivity data and its use in the evaluation of the effectiveness of current inspection methods as well as the potentials of implementing various management strategies. The field data collection portion of the project was concerned with field inventories and compliance as well as the effectiveness of various methods of maintaining retroreflectivity. Collecting data with this focus provided a framework by which cost analyses and operational performance may be evaluated.

Research performed for the Louisiana Department of Transportation and Development evaluated data collection procedures concerning the use of computer-based technologies including geographic information system, Global Positioning System (GPS), and inventory equipment (*6*). Key attributes were collected to allow for assessment of the possibility of performing larger-scale inventories. The collection area was selected for its widely varied functional road classification as well as variation in the commercialization of its regions. The data collection procedure was designed to provide a basis for future analyses and to assist in future decision making.

There have been other data collection efforts for which the data collection methodology was explicitly designed in order to achieve specific goals. These goals range from assisting with the management of retroreflectivity to modeling the deterioration of retroreflectivity over time. Researchers at Purdue University collected retroreflectivity measurements for 800 Type I and Type III signs for which sign age was known over a 20-year period. The data were collected for the development of survival curves for Type I and Type III sheeting. The resultant curves were to assist in the determination of replacement costs and assessment cycles in the management of the retroreflectivity of traffic signs. The results were limited though, because not all Type I and Type III sheeting is alike and cannot be combined for failure prediction (*7*).

In studying in-service Type III high-intensity traffic signs in Texas, researchers developed a collection plan that included sampling procedures to account for sign densities and varying site conditions (*8*). The collection focused on regional areas that displayed distinctive characteristics. This study did not provide a data collection procedure to assess overall conformance with minimum standards. However, such targeted attribute collection will provide a basis to evaluate special considerations relevant to an agency's assets.

Pierce County in Washington State found that a sign inventory that included retroreflectivity measurements proved useful in assisting with the selection of a sign management strategy (*9*). The county found that the data collected were beneficial for managing the traffic signs. Additionally, the inventory provided an approximation of the control group size needed to maintain a desired degree of reliability in estimating the representation of the overall population. For other agencies, retroreflectivity measurements have been found to be instrumental in assisting in evaluating compliance with required minimum standards (*10*). Such an inventory provides significant assistance in identifying issues with the performance of assets currently in use.

The collection of field data is the first step in the development of an efficient management plan. Past experience has proven that the proper selection of samples, procedural methodology, and attribute collection are crucial in efforts to identify performance and compliance issues within an agency's assets. Great care must be taken in the development of a data collection procedure to ensure that potential issues may easily be identified and that results of the collection may be utilized for planning and policy making.

METHODOLOGY OF DATA COLLECTION

A sign management program is needed to comply with the MUTCD standards. Limited budgets and resources provide challenges for state DOTs to allocate their maintenance funds efficiently. The allocation of limited resources must be based on the analysis of various options and trade-offs and decisions must be made with quality information (*11*).

To develop a data collection plan that facilitates a transportation agency's need to manage assets efficiently, special consideration must be taken in the development of a data collection strategy. The purpose of data collection is to provide a quantitative assessment of overall compliance with minimum retroreflectivity levels, which will give guidance in the selection of a management method to ensure future compliance. In the development of the data collection procedure, it is important to include considerations that can directly affect the selection, methodology, and procedure of a particular plan. These considerations include agency operations, site selection, sign attribute selection, and procedural methodology.

Agency Operations

Understanding the operational procedures of an agency is instrumental for evaluating the feasibility of asset management options as well as providing a context for data collection. The use of prior inventory efforts and an understanding of data management procedures within the Utah DOT provided key information for developing a collection strategy. Recent efforts by the Utah DOT in developing a central database for transportation assets proved beneficial. The database provided information including an inventory of sign retroreflectivity conducted between 1999 and 2001.

Site Selection

Collection sites were selected to be representative of signs within the state to provide an overall snapshot of compliance and conditions present within different geographic areas. It is critical that the sample provides the best representation possible of the overall population given the resources available. The structure of the Utah DOT consists of four administrative regions.

Each region is subdivided into maintenance stations where maintenance is overseen at the local level. In Utah, maintenance strategies are directed and overseen at the region level. As noted in the Texas study (*8*), there can be difficulty in establishing a sample set that is truly representative of the overall condition of signs because sign densities vary greatly and costs must be considered in establishing a sample set. In the case of the Utah DOT, with maintenance efforts varying greatly by region and individual maintenance sheds, it was important to provide a representative sample.

To establish an overall sample, sign data were collected for locations that were representative of each region. From a review of previous inventory efforts within the state, junction areas between state routes were identified as containing among the highest densities of traffic signs. For this reason, routes were selected that had a high junction density. Along with the high sign density, junctions also contained a wide variety of sign color. To better represent the variation of maintenance and construction activities between stations and regions on highway segments, signs of every color were collected at intervals of 5 to 15 mi. The survey team, who based the decision on sign density and geographic conditions present along the route, determined the intervals. Because canyon routes represent unique situations in Utah and contained high densities of signs, data were collected every 5 mi, whereas data on rural roads were collected every 15 mi. These intervals were used to provide an adequate representation of the overall sign population.

Sign Attribute Selection

To analyze and determine special considerations unique to Utah concerning sign asset management, specific attribute data were collected for signs. All data were recorded with a handheld GPS unit that included a customized data dictionary to enter information. Attributes recorded in the handheld GPS unit included background color, sheeting type, retroreflectivity measurements, orientation, mount height, offset, installation date, and major and minor damage. Identification of sheeting types was accomplished with FHWA's identification guide (*12*). Retroreflectivity measurements were taken with the use of a Delta RetroSign Model 4500 retroreflectometer. The Model 4500 illuminates the sign at a –4° angle with the angle of observation being 0.2°. In addition to recording information in the handheld GPS unit, photographs were taken of every surveyed sign and linked to the data to further classify any damage or vandalism.

To classify damage issues of the signs and the associated effects on retroreflectivity, five damage categories, shown in Figure 2, were

FIGURE 2 Damage categories: (*a*) bending damage, (*b*) peeling damage, (*c*) vandalism, (*d*) cracking damage, and (*e*) other damage types.

used during the collection process. Damage categories included bending, peeling, vandalism, cracking, and other, defined as follows:

- Bending damage described signs with significant portions of bent sheeting, which caused light to be reflected away from its origin;
- Peeling damage applied to the legend of a sign peeling off of the background sheeting;
- Vandalism, the most diverse category of damage, included damage caused by paintballs, bullet holes, beer bottle impacts, stickers, and graffiti;
- Cracking damage, only present on Type I sheeting signs, consisted of the retroreflective background cracking and degrading over time; and
- Other referred to forms of damage such as fading, tree rubbing, and tree sap.

Installation Data

Because of the limited installation data, additional effort was made to collect sign data where installation information was known. Since 2008, the Utah DOT has mandated that all signs placed into the field have an installation sticker on both the front and back of the sign. Typically the sticker on the front of the sign has a transparent background with a black legend for the year it was installed, whereas the back contains the month and year of installation and the company that constructed the sign. Although mandatory since 2008, compliance with this policy was not consistently adopted by the stations and contractors installing signs for the Utah DOT.

Collection Procedure

After a few preliminary trails, it was determined that the data collection would be performed by a three-man team to increase safety and efficiency of the data collection process. For increased efficiency, each man would have a specific task to complete for the various sign attributes. Researcher one was the driver of the vehicle and was in charge of loading and unloading the ladder as well as taking retroreflectivity measurements. Researcher two was the front seat passenger and was in charge of entering data into the handheld GPS unit. Researcher three was in charge of taking photographs and sign measurements. The sign survey process was broken up into three sequential stages: (*a*) setup, (*b*) measurement, and (*c*) teardown.

As the member of the research team took the retroreflectivity measurements, the other members of the team began to enter attributes of the sign into the GPS unit. Following this survey process, the research team was able to measure on average 15 signs per hour, which is comparable to previous collection projects (*5*). This average included the time spent traveling between sign locations. In the case of a full sign inventory where sign densities were much higher, this collection rate would likely prove much higher. It is also possible to increase this rate by reducing the number of attribute measurements per sign.

DATA ANALYSIS

The research team measured a total of 1,433 signs, spanning Utah DOT's four regions. The sample size was approximately 1.5% of the 95,000 signs that the Utah DOT currently maintains. White and yellow signs make up the majority of the surveyed signs. Table 1 shows a summary of surveyed signs divided among the Utah DOT's four regions.

In accordance with ASTM E1709-09, four measurements for both the retroreflective background and legend, if applicable, were taken for each sign. These four measurements were averaged to determine the sign's overall retroreflectivity per the ASTM standard. During the measurement of each sign, special considerations were taken to ensure that the retroreflectometer was held vertical and steady against the sheeting and measurements were taken at the same four areas regardless of sign damage. Figure 3 shows box-and-whisker plots for each sign type collected across all four Utah DOT regions. The vertical lines that traverse the plots are the minimum retroreflectivity levels for each sheeting background type and color.

MUTCD Compliance

One goal of this research was to take the Utah DOT's limited sign inventory and installation data and assess the current compliance rate for the new MUTCD's minimum retroreflectivity levels. For the compliance rates presented within this research, signs were only rejected if the retroreflectivity was below minimum retroreflectivity levels. Although damage was reported and categorized, a sign was never rejected purely based on damage alone. Table 2 shows the compliance rate for the surveyed signs by sheeting type and color.

TABLE 1 Surveyed Sign Summary

	Signs by Color and Type																				
	Red				White					Yellow					Green					
Region	III	III HIP	IX	XI	I	III	III HIP	IX	XI	I	III	III HIP	IX	XI	I	III	III HIP	IX	XI	Total
One	4	2	2	0	44	107	17	23	0	17	91	3	23	0	4	96	5	5	0	443
Two	12	13	7	0	0	6	35	19	8	1	15	6	6	1	0	4	8	6	1	148
Three	7	4	1	3	20	73	3	4	10	11	50	4	12	14	4	46	21	13	7	307
Four	86	12	4	13	13	100	18	21	9	7	81	35	26	8	7	58	4	18	15	535
Total	109	31	14	16	77	286	73	67	27	36	237	48	67	23	15	204	38	42	23	1,433

NOTE: HIP = high-intensity prismatic.

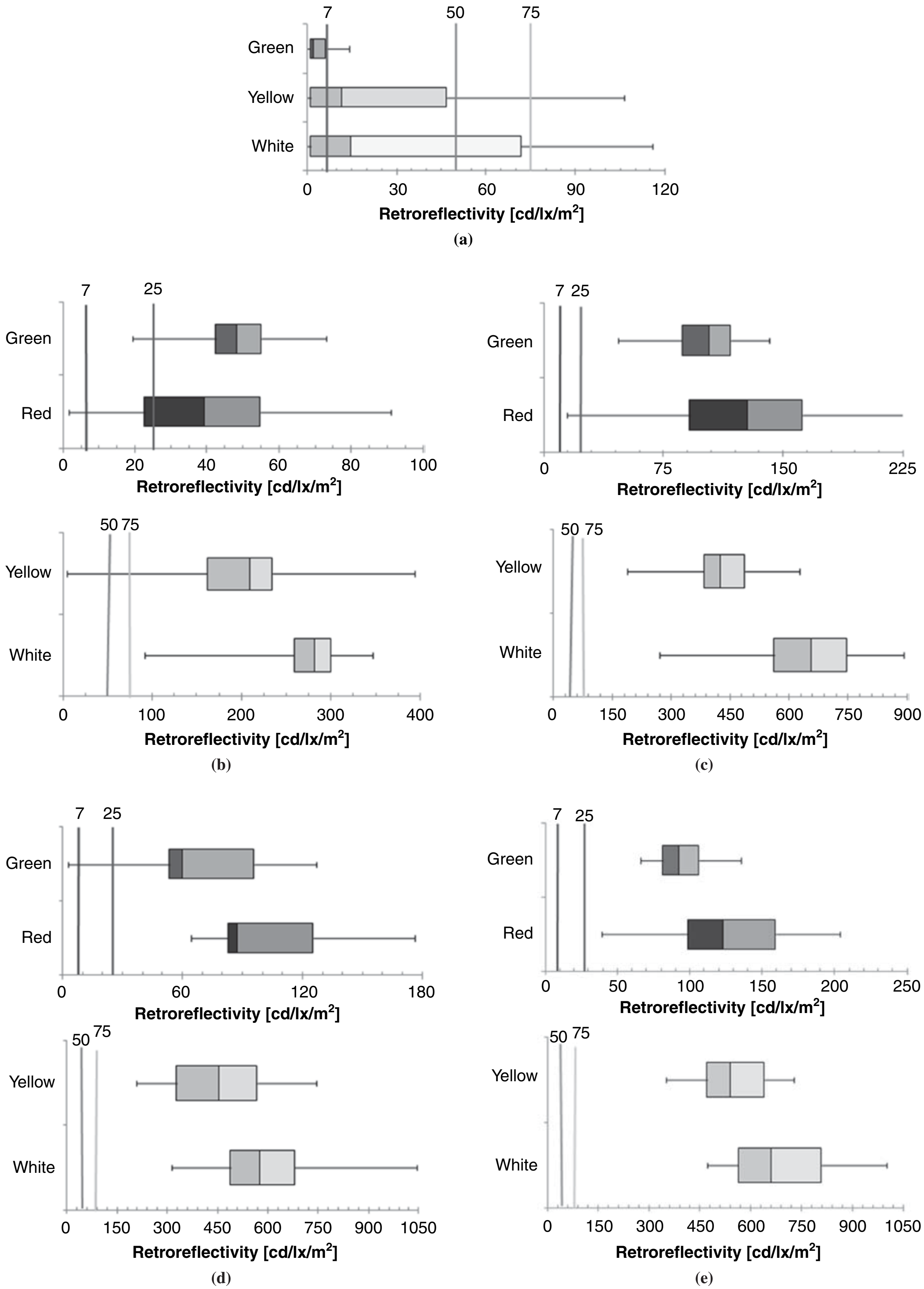


FIGURE 3 Retroreflectivity box-and-whisker plots by sheeting type and color: (*a*) Type I, (*b*) Type III, (*c*) Type III HIP, (*d*) Type IX, and (*e*) Type XI.

TABLE 2 Compliance Summaries

	Sheeting Type					
Color	I	III	III HIP	IX	XI	Rejected (%)
Red	0	6	0	0	0	4
White	46	0	0	0	0	9
Yellow	33	20	0	0	0	13
Green	9	3	2	5	0	6
Rejected (%)	69	3	1	3	0	

The vast majority of all rejected signs were Type I and Type III. Although there were seven rejections of Type IX sheeting, all of which were green, five were caused by legend retroreflectivity and the remaining two were caused by special causes. For the six rejected red signs, one was a stop sign and the remaining five were exclusion signs. For the overall sign sample population, the failure rate was 9%.

Type I Signs

The Utah DOT began phasing out the use of Type I sheeting because of its low levels of retroreflectance and corresponding short service life. At the completion of the survey period, there were no Type I red sheeting signs surveyed. A comparison with a retroreflectivity study conducted in 1999, which indicated that there were 177 red signs in service in Regions 1 and 3, shows the concerted effort by the Utah DOT to remove Type I signs.

The mean retroreflectivity level for Type I signs in the surveyed sample set was 36 candelas per lux per square meter (cd/lx/m^2), which is well below the minimum level of 50 cd/lx/m^2. Sixty percent of all Type I white signs failed, which is triple the rate calculated from measurements taken in the 1999 study. White Type I signs had a high rate of cracking damage, which is likely the root cause for the increase in failures. Although the majority of Type I white signs are most often noncompliant, there are a few examples that still perform well. In the surveyed sample population, Type I white signs were usually used for route identifications and speed limit signs.

Yellow Type I signs had the highest failure rate of any Type I sign color, with 80% having retroreflective measurements below the minimum levels. This is an increase in the 77% failure determined from the 1999 retroreflectivity study. Yellow Type I signs had a high rate of vandalism and had mean retroreflective measurements at a third of the minimum level.

Green backgrounds made up the smallest percentage of Type I sheeting, with only 15 being measured during the sign survey. Similar to the other Type I background colors, green had a mean measurement of 4 cd/lx/m^2, which is below the minimum retroreflective level. Seventy-five percent of the survey sample measured below the minimum level.

Type III Signs

The Utah DOT Type III signs were performing well with only 3% failing. Values for Type III red signs ranged from 12 to 91 cd/lx/m^2 with a mean of 38 and a standard deviation of 21. Of 111 signs collected, there were only six failures. The failures were all old sheeting with visible damage and fading.

Of 204 Type III green signs measured, only two signs were found to be failing. Values measured ranged from 19 to 73 cd/lx/m^2 with a mean of 48 and standard deviation of 9. Few issues were found with the Type III green population, with the only exceptions being signs that exhibited extreme fading and cracking.

The Type III yellow sample set contained the highest degree of variability, with measured values ranging from 5 to 394 cd/lx/m^2. The mean measurement of the Type III yellow signs was 194 and the standard deviation was 72. The majority of failed signs exhibited either extreme damage, weathering, or vandalism. Of all signs evaluated, yellow sheeting was roughly three times more likely to display vandalism than any other sheeting. Damage was often visible from bullet holes, paintballs, and projectiles thrown from vehicles such as glass bottles.

From the samples collected, there were no Type III white sheeting failures. Observed values ranged from 91 to 394 cd/lx/m^2 with a mean of 275 and standard deviation of 36. The Type III population is performing extremely well with respect to compliance, with the majority of signs well above the minimum required standards.

The Type III high-intensity prismatic (HIP) population, though small, was performing well within the state. Type III red values ranged from 15 to 225 cd/lx/m^2 with a mean of 122 and a standard deviation of 52.7. White values ranged from 270 to 890 cd/lx/m^2 with a mean of 646.8 and standard deviation of 142.4. Yellow values ranged from 189 to 627 cd/lx/m^2 with a mean of 434.6 and standard deviation of 86. Green values ranged from 47 to 141 cd/lx/m^2 with a mean of 101.2 and a standard deviation of 20.3.

Type IX and Type XI Signs

Types IX and XI are the newest sheeting in the Utah DOT's overall sign population. Aside from a few exceptions with Type IX green sheeting, Type IX and Type XI sheeting were performing well beyond the minimum required levels. The mean and standard deviation for Type IX green was observed at 72.6 and 29.79 cd/lx/m^2, respectively. The green Type IX signs that exhibited low values were a result of a construction issue when Type IX green sheeting was overlaid on Type IX white sheeting with the legend being cut from the green overlay. Signs with this construction exhibited extreme peeling problems and low retroreflectivity values in relatively new signs. There were no failures recorded for signs with red, white, or yellow backgrounds for either Type IX or Type XI. The values for these sheeting types did vary greatly within sample populations.

Prismatic Sheeting Variance

When collecting the sample sign data, inspectors noted a great degree of variation in the measurement of many recently placed traffic signs that used prismatic sheeting. This tremendous variation was evident in a review of the plots for signs for which installation dates were known. Because the tracking of sign installation data is a relatively new procedure for the Utah DOT and has taken some time for implementation, there were few samples with known sign installation data. Despite the small data set with known installation dates, an extreme degree of variation is clearly evident in signs that were recently placed, as seen in Figure 4. These measurements were for signs that did not display signs of damage.

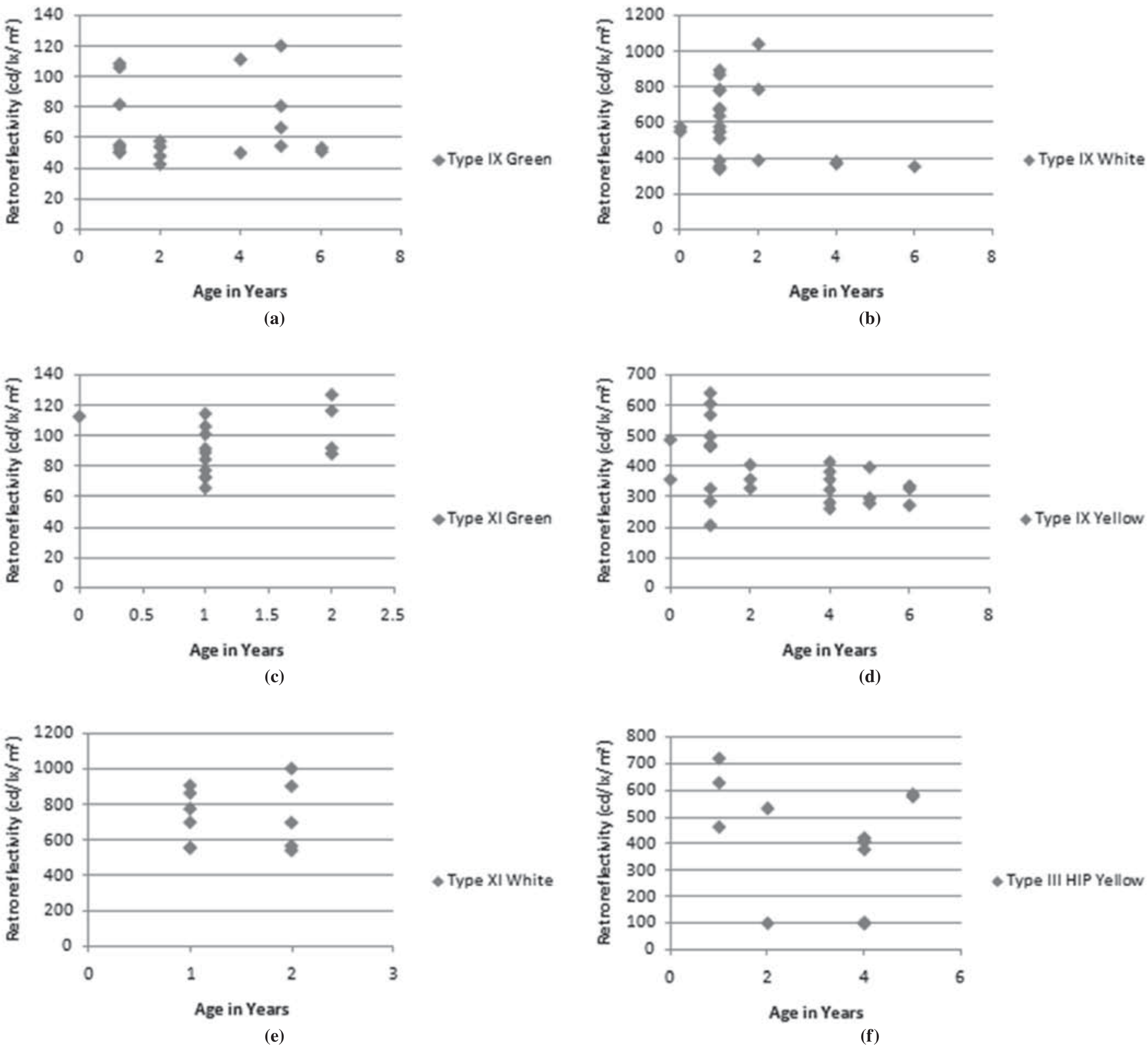


FIGURE 4 Retroreflectivity measurements of prismatic sheeting with installation dates.

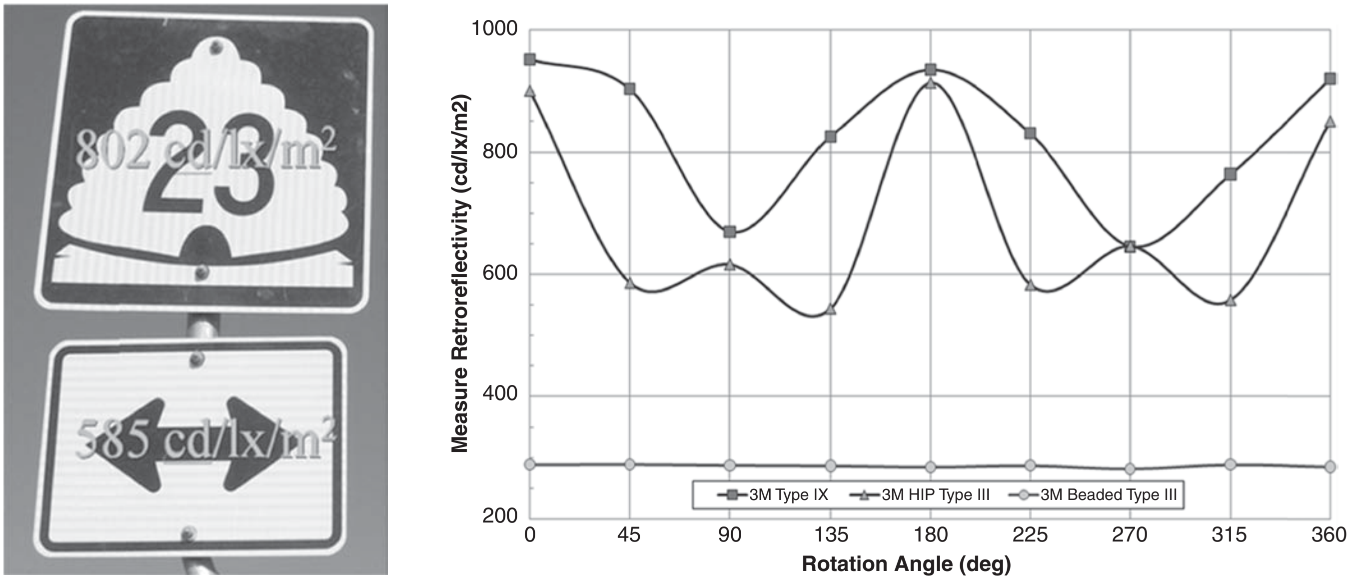
The greatest ranges of measurements were seen in Type IX, Type XI, and signs with white and yellow backgrounds. Table 3 provides an example of the range of values of measurements recorded by researchers for Type IX and Type XI signs that were placed within 1 year of inspection and had no visible damage or weathering.

Further evaluation of these signs identified a possible explanation for this variation regarding an issue of inefficiency with the construction of many of the Utah DOT's newly placed traffic signs. The problem is the rotational sensitivity of the sheeting used for a large majority of signs placed within recent years. Although the sheeting that was used by the Utah DOT for many of its new signs is designed to be usable at any orientation, because of the use of cube corner retroreflection the sheeting is most effective when placed at a specific orientation. The range of values measured varies greatly depending on the orientation with which the sheeting was placed, with much sheeting not being

TABLE 3 Type IX and Type XI Placed Within 1 Year

	Retroreflective Measurements (cd/lx/m^2)				
Type	Color	Mean	SD	Low	High
IX	Green	78	23	51	109
IX	Yellow	455	141	208	643
IX	White	597	188	898	338
XI	Green	88	16	338	898
XI	White	725	149	554	904

NOTE: SD = standard deviation.



(a) (b)

FIGURE 5 Rotational sensitivity example.

placed optimally. This issue was discovered primarily for Type III HIP, Type IX, and Type XI sheeting that was oriented at varying degrees in signs throughout the state. This issue is further exaggerated when measurements are taken with a point retroreflectometer. Figure 5 shows an example of the range of values possible for sign construction with sheeting in varying conditions when sign sheeting is placed at varying orientations. The measurements were taken from three types of white sheeting currently being used by the Utah DOT. Figure 5 also shows the signs at 0° and 90° orientations.

Similar distributions were found for other Type IX and Type XI sheeting currently being used by the Utah DOT. Sheeting placement in varying orientations was found for all background color types. The majority of yellow signs constructed of any type of prismatic sheeting within the Utah DOT were found to be placed at a less than optimal orientation.

Damage and weathering are of particular concern in the development of an asset management strategy to maintain compliance with minimum retroreflectivity requirements. Even small amounts of damage that is visible during the daytime can have a large effect on the sign's ability to convey messages under nighttime conditions. The overall percentage of damaged signs varied greatly by region and environment. Damage was classified as being either major or minor, depending on the overall effect of the message of the sign. Major damage included any degree of damage on the sign face that affected the legibility of the sign. Tables 4 and 5 show a summary of damage rates throughout the Utah DOT's regions.

CONCLUSION

With deadlines approaching for compliance with the MUTCD retroreflectivity requirements, this research was intended to provide a data collection strategy to assist with state DOT planning and policy development. With budgetary constraints, it is imperative to utilize a strategy that will provide both efficiency and compliance. To develop an efficient asset management strategy, there must be an understanding of how a particular agency's assets are performing and what conditions are present that are affecting the overall performance and life of the assets. For this reason, particular emphasis is given to the procedure and methodology used in data collection for this purpose. It is important to gather the necessary information in a manner that provides an overall representation of the agency's assets.

Previous experience informed the data collection strategy of this project, and the experiences of the research team helped inform the future data collection procedures as well as the ability to highlight issues previously unknown to the Utah DOT, such as the rotational

TABLE 4 Damage Rates by Region

	% Damaged (All Types)		% Vandalized	
Region	Major	Minor	Major	Minor
One	30	18	12	5
Two	5	14	1	5
Three	26	34	12	12
Four	12	22	6	9

TABLE 5 Damage Rates by Color

	% Damaged (All Types)		% Vandalized	
Color	Major	Minor	Major	Minor
Red	13	25	5	12
White	18	17	6	8
Yellow	17	27	16	10
Green	14	19	5	3

sensitivity of the signs. Many unique conditions and situations that directly affected traffic sign management were found through the data collection procedure. As these considerations were identified and incorporated into the process, the continuing insight provided for a better overall understanding of how the sign assets were performing.

The sample sign survey provided a valuable assessment of overall compliance with the MUTCD minimum retroreflectivity requirements. Reviewing the data also identified issues with the Utah DOT's sign construction and management that were previously unseen. The use of a methodology that included the collection of sign and sight condition attributes provided the information necessary to develop a retroreflectivity management plan that considers the Utah DOT's own assets and the most economical and feasible steps to ensure compliance. Outside of Type I sheeting used by the state, the majority of the Utah DOT's assets are currently in compliance with the new MUTCD standards (91%). With the complete removal of Type I signs, the percentage of compliant signs would increase to 97%.

The data collected throughout the state, and the results from analysis of the data from this project, may now be used in the development of the plan. The high percentages of damaged signs, as well as limited installation and service life performance data currently available to the Utah DOT, indicate that an assessment method, either visually or through measurements, will best serve for maintaining retroreflectivity compliance until further information is available. The compliance rates of various sheeting types provided for quick assessments of alternatives for bringing the DOT's current assets into compliance with MUTCD standards. Given the high failure rate of Type I signs within the state, an initial blanket replacement of all Type I signs and tracking the performance of the replacements would be beneficial. The data collected also provide for operational changes that may result in greater efficiency and performance of the Utah DOT's assets. A carefully planned and standardized procedure for data collection provides results that give stakeholders a better overall understanding of the trends that affect varied maintenance and materials usage practices in the different regions of the state. Dividing collection proceedings in this manner allowed for better understanding and facilitated data collection that better represented the overall population. This information will be used to develop plans for the maintenance and coordinated replacement of signs for the state.

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