Evaluation of Sign Retroreflectivity Measurements from the VISUAL Inspection Signs and Panels (VISUALISE) System

Texas Transportation Institute

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EVALUATION OF SIGN RETROREFLECTIVITY MEASUREMENTS FROM THE VISUAL INSPECTION SIGNS AND PANELS (VISUALISE) SYSTEM

INTRODUCTION

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

- Fulfill a need,
- Command attention,
- Convey a clear simple meaning,
- Command respect from road users, and
- Give adequate time for proper response.

Sign information can be conveyed through the legend, which can be compromised of words, symbols, and arrows. Roadway users can also extract information from a sign's unique appearance as size, color, and shape are critical components. In addition to the specialized design criteria, road users need to detect signs and comprehend the message content in a timely manner in both daytime and nighttime. At night, signs not internally illuminated must be fabricated with retroreflective materials. Retroreflective materials return light back to the original source. Light from a vehicle's headlamps is reflected from the sign's surface back to the driver giving the sign an illuminated appearance.

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

The 2009 MUTCD states that an agency "shall use an assessment or management method" to maintain sign retroreflectivity. The manual does not dictate the method, but provides agencies flexibility to implement one or more method(s) that best suits their needs, expertise, and level of resources. The intent of the methods and guidance outlined in the MUTCD is to provide support to the agencies and offer them systematic procedures to maintain traffic sign retroreflectivity.

Section 2A.08 of the 2009 MUTCD offers five traffic sign methods for maintaining nighttime sign visibility and an "Other" method, which must be supported by an engineering study. The five methods are categorized as either assessment or management methods. Assessment methods evaluate the retroreflectivity of individual signs and include Visual Nighttime Inspection and Measured Sign Retroreflectivity. Management methods incorporate an expected retroreflective life period of individual sheeting materials. The management methods include Expected Sign Life, Blanket Replacement, and Control Signs. Assessment and management methods may be combined in many different ways to accommodate an agency's needs and objectives. The MUTCD description of each method is contained below.

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

The FHWA provided an array of different sign maintenance methods at the request of agencies (*2*). The various methods provide agencies a way to customize their sign maintenance policies to best fit their needs while still being in compliance with the new regulations. A recent national survey has shown that all of the methods listed above are already being used, and many are being combined as agencies determine how they can best meet the new regulations (*3*).

Measured Sign Retroreflectivity with Handheld Devices

Of all the maintenance methods listed in the MUTCD, the most objective method to maintain traffic sign retroreflectivity is measuring sign retroreflectivity. Many agencies prefer this method because it is thought to be the most protective in terms of potential tort that may result from the new MUTCD regulations (*3*). However, given the current technology to measure sign retroreflectivity, some agencies have deemed this method unacceptable. The disadvantages of measuring sign retroreflectivity with handheld devices are listed below:

- The devices cost $10,000 to $15,000 per unit and require adequate care and annual recalibration (i.e., sending the device back to the manufacturer).
- The devices must be in contact with the sign surface to take measurements.
- The devices make measurements at a prescribed geometry that is not always representative of the actual driving geometries.
- Measurements from twisted and leaning signs can result in retroreflectivity levels above the minimum MUTCD levels. However, the luminance of the sign under nighttime conditions may be less than needed for the drivers because of the non-standard geometry.
- Measuring signs is time consuming. Shoulder mounted signs can be measured at a rate of about 80 to 160 signs per day using a two-person crew.
- Measuring sign retroreflectivity exposes maintenance crews to the risk associated with working near traffic and on the roadside.
- Overhead and even some shoulder mounted signs can be out of reach, even with an extension pole connected to the handheld device.
- Each reading with a handheld device measures a maximum of a 1-inch diameter area of the sign. As signs age, the variability of readings across the sign face can increase as a function of dirt and grime on the sign face. Therefore, making handheld readings on older signs can decrease the repeatability of the measurements and ultimately add bias.
- When handheld devices are used, many agencies calibrate them with using a reducer ring, which reduces the size of the measurement aperture from 1-inch diameter to 0.5-inch diameter. The reduced ring is used to measure the legend of positive contrast signs (because of the relatively narrow stroke width). To be more efficient in the field, maintenance crews typically leave the reducer ring on to make all their measurements and avoid having to recalibrate the handheld device each time the reducer ring is used. Using the reducer ring adds measurement bias to retroreflectivity readings, especially on signs made with prismatic retroreflective materials.
- There are two types of handheld devices on the market as of summer 2012. They are typically referred to as point and annular devices (see ASTM E1709). Making measurements with these devices can lead to different results. The results can be as large

at 25 percent or more, depending on the type of retroreflectivity sheeting material and the orientation in the handheld device. Some materials are called orientation-sensitive, meaning that as they are rotated around an axis perpendicular to the face of the sign, the performance can vary. This is important because point devices are sensitive to the orientation of measurement and annular devices are not. The sensitivity varies with different as a function of the geometries. An example of the 360 degree orientation sensitivity of different ASTM D4956 materials is shown in Figure 1.

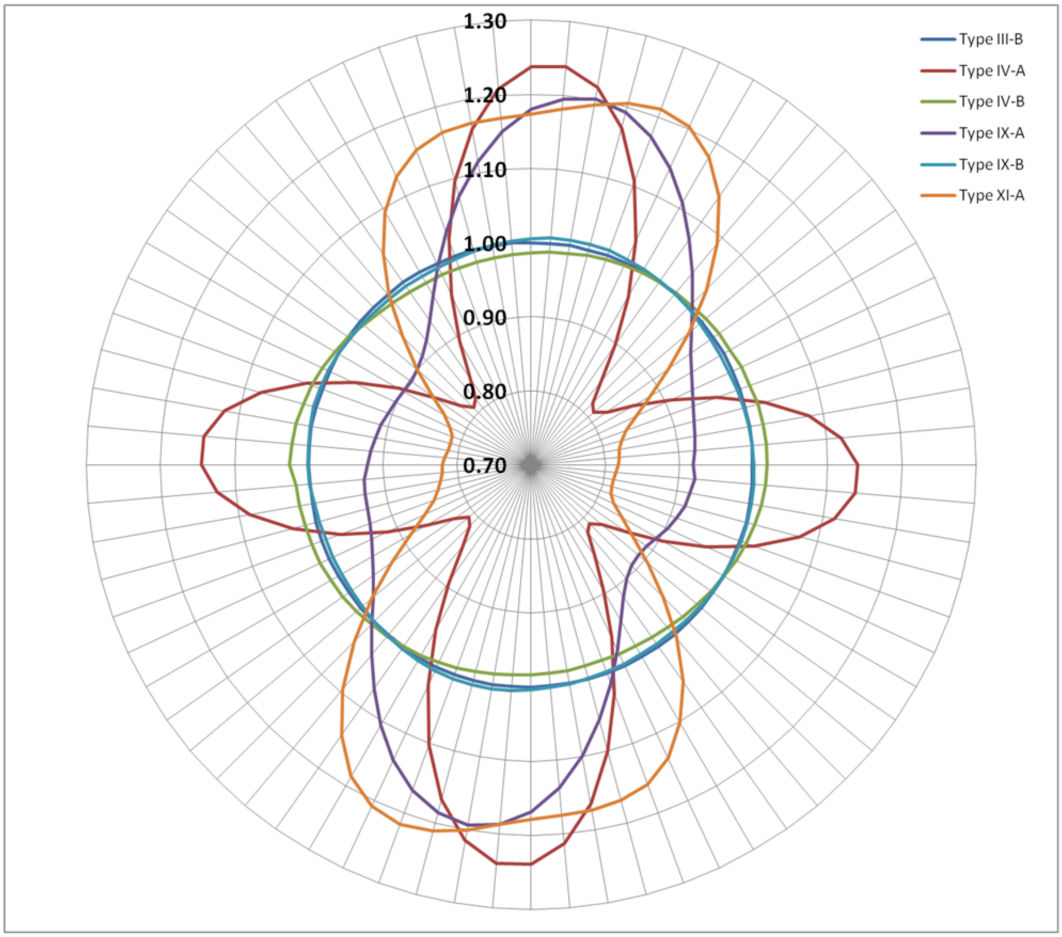

Figure 1. Rotational Sensitivity (Alpha=0.2°, Beta=4.0°)

There is practically no official information regarding the measurement bias and repeatability of handheld retroreflectometers. The Retroreflection Subcommittee of ASTM E12 (Color and Appearance) has been working on developing a precision and bias statement for two years, but nothing has officially been published yet.

In March 2011, a paper was published in the ITE Journal of Transportation that included research from Indiana used 22 stop signs and three different retroreflectometers in a laboratory test to determine the range of median bias for Type I and Type III sheeting for both the legend and background (white and red). Here is what they found:

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

They also made field measurements with the handhelds. They concluded that it is reasonable to assume that the coefficient of variation (COV) for an individual sign will be between 4 and 14 percent when using a handheld device. However, this study did not include prismatic materials and did not include the impact of using the reducer rings.

Measured Sign Retroreflectivity with Mobile Technology

Almost all of the concerns associated with the handheld measurement devices (as listed above) can be alleviated or eliminated with the ability to measure sign retroreflectivity from digital images recorded at highway speeds. In other words, using technology from a mobile platform could provide the following advantages:

- Measurements could be made while driving down the highway and therefore no equipment would have to be in contact with the sign.
- Measurements would be made at real roadway geometries rather than prescribed geometries that do not always represent the real world.
- Twisted and leaning signs would be measured as seen from the roadway perspective and can be easily identified as needing routine maintenance (straightening rather than replacement).
- Images of signs could be recorded at highways speeds, although post-processing the images would be needed. This would minimize the exposure and risk of the technicians.
- All signs can be measured, including overhead and difficult-to-reach shoulder mounted signs.
- Using image analysis, the entire retroreflective area of the sign can be measured rather than a few 1-inch diameter areas. This includes the legends and backgrounds of positive contract signs.

Over 10 years ago, the first mobile sign retroreflectivity technology was introduced. As the FHWA was working to develop minimum sign retroreflectivity levels, they were also developing the first mobile sign retroreflectivity technology. The Sign Management and Retroreflectivity Tracking System (SMARTS) van was a fully functional prototype for a mobile sign retroreflectometer van. The SMARTS van was developed by the Naval Research Laboratory (NRL) for the FHWA. A total of four units were produced (but are no longer in operation). A photo of one of the FHWA vans is shown in Figure 2.

Figure 2. One of the Four FHWA Mobile Sign Retroreflectivity Vans (circa 2002)

While the FHWA's van was an ambitious project, it was ahead of its time in many ways. The van was promoted as a prototype and in a 2001 evaluation, it was deemed too inaccurate to be useful (http://www.dot.state.ak.us/stwddes/research/assets/pdf/fhwa_ak_rd_01_01.pdf). However, the purpose of the effort was to demonstrate that technology could be implemented to measure sign retroreflectivity, and in an unpublished Highway Innovation Technology Evaluation Center (HITEC) report, the van's results were not unreasonable (note that the HITEC program is no longer in operation).

Over 10 years have passed since the FHWA's van was introduced. Since that time, the MUTCD has adopted minimum sign retroreflectivity levels and an implementation date for maintaining regulatory and warning signs has been set for June 2014. As the pending date approaches, there has been an increased amount of activity regarding the development of mobile sign retroreflectivity measurements.

SCOPE

In 2012, TTI was approached by EuroConsult Group to evaluate their technology that was built to measure sign retroreflectivity, among other things. This system is called VISUALISE and was built by a team of engineers, physicists, and statisticians and is composed of three components (1) a mobile system for data and image acquisition, (2) detection, performance, and positioning software, and (3) management and analysis software. In 2012 May, TTI evaluated their system, including the accuracy and repeatability of the retroreflective sign measurements. The VISUALISE system records images during the nighttime and then processes the images to determine retroreflectivity. The remainder of this report describes the testing that was performed and the test results.

Testing Protocol

There is neither any national specification for a mobile sign retroreflectometer nor a national test method. The testing protocol that was set up for the VISUALISE system was derived from a combination of factors. TTI has been testing retroreflectivity measurement technologies for 15 years and has experience testing the FHWA van as well as several other mobile technologies. In addition, among the unique features of the VISUALISE van is the ability to measure signs in both static and dynamic conditions. Therefore, the testing protocol that was established included the following:

- Static measurements of a variety of retroreflective signs on a closed-course facility.
- Dynamic measurements of a variety of retroreflective signs on a closed-course facility.
- Dynamic measurements along an open-road test route.

All tests were conducted with different types of signs that are typically found in the U.S. Those signs consisted of standard colors and were made of various retroreflective materials and used in various conditions of maintenance. Meanwhile, the signs were mounted as per the MUTCD (i.e., typical heights and lateral offsets) with their face perpendicular to the direction of travel. The general goal was to have signs representative of what a driver encounters on any given drive. Another general goal was to include signs with very high retroreflective performance as well as signs with very poor retroreflective performance (in order to test the dynamic range of the system).

Both the static test and dynamic closed course test were performed at the Riverside Campus of Texas A&M University. The static test verifies the performance of the system in the most controlled situation. The van was positioned at a distance of 38 m from the signs. Therefore, an observation angle is approximately equal to 0.2 degrees, since the vertical offset between the illuminator and camera was set to be 13 cm. This testing was done with an array of signs in different colors.

The dynamic testing on the closed-course facility was conducted to determine both the measurement bias of the system as well as the repeatability of the system. Since the closed course testing was conducted in a dark rural environment, additional testing was conducted on the open-road to investigate the measurement bias with all the random factors that one would expect during measurements (such as interference lighting from roadway luminaires, platooned vehicles, opposing vehicles, and roadside development).

Static Test Results

The static testing was straightforward. The test van was positioned at a distance of 38 m from the signs in order to attain the observation angle of 0.2 degrees. Six signs were measured, in six available colors: white, red, green, blue, yellow and orange, as shown in Figure 3. The sign retroreflectivity was measured by the van at a night. Each reading required less than one minute. The entire operation required less than an hour of testing. The recorded van's readings were compared with those from a calibrated handheld retroreflectometer. The handheld measurement was conducted right before the static testing. The comparison results of the static testing are summarized in Table 1.

Figure 3. Signs for the Static Test

Table 1. Comparison Results of Static Testing

Type of Material	Color	Average Handheld Measurement (n=4),cd/lx/m^2	Van Measurement, cd/lx/m^2	Actual Difference in Measurements, cd/lx/m^2
Beaded	Blue	25	26	1
Beaded	Red	43	47	4
Beaded	White	335	303	-32
Prismatic	Green	126	105	-21
Engineer Grade	Yellow	75	70	-5
Prismatic	Orange	281	315	34

The static measurements demonstrate the capability of van's dynamic range. In this study, the signs were measured at least four times with a handheld retroreflectometer conforming to ASTM E1709. The average of these measurements was assumed to be the true retroreflectivity of the sign. This averaged handheld value was used as a baseline to compare the van measurements. From Table 1, the errors of the six signs are all less than 20 percent of the handheld measurements. In addition, the apparent errors were high when the retroreflectivity levels were high. At least from a compliance point of view, it is interesting to see how the van did when measuring signs on the low end of retroreflectivity, or near the minimum levels in the MUTCD. Overall, the static results were impressive and showed promise but the technology was really built on the ability to measure signs in a dynamic situation.

During the static testing, as the signs were measured from the same position of the van, the beta angles for each sign are different, ranging from 0 to -5 degrees. The beta angle is more commonly called the entrance angle. In the prescribed geometry of handheld devices, beta is set at 4 degrees. However, the combination of an alpha angle of 0.2 degrees and a beta angle of 4 degrees is rarely seen in the field. The van testing distance is based on achieving the observation angle of 0.2 degrees but measures retroreflectivity at the resulting beta angle, depending on the sign offset and twist. The sensitivity of entrance angle is shown in Figure 4 for different retroreflective materials. For static testing, the beta angle ranged from 0 to -5 degrees and does not have a significant effect. However, when the beta angle is much larger than standard 4 degrees, the real retroreflectivity can be significantly different from the ones measured by the handheld retroreflectometer.

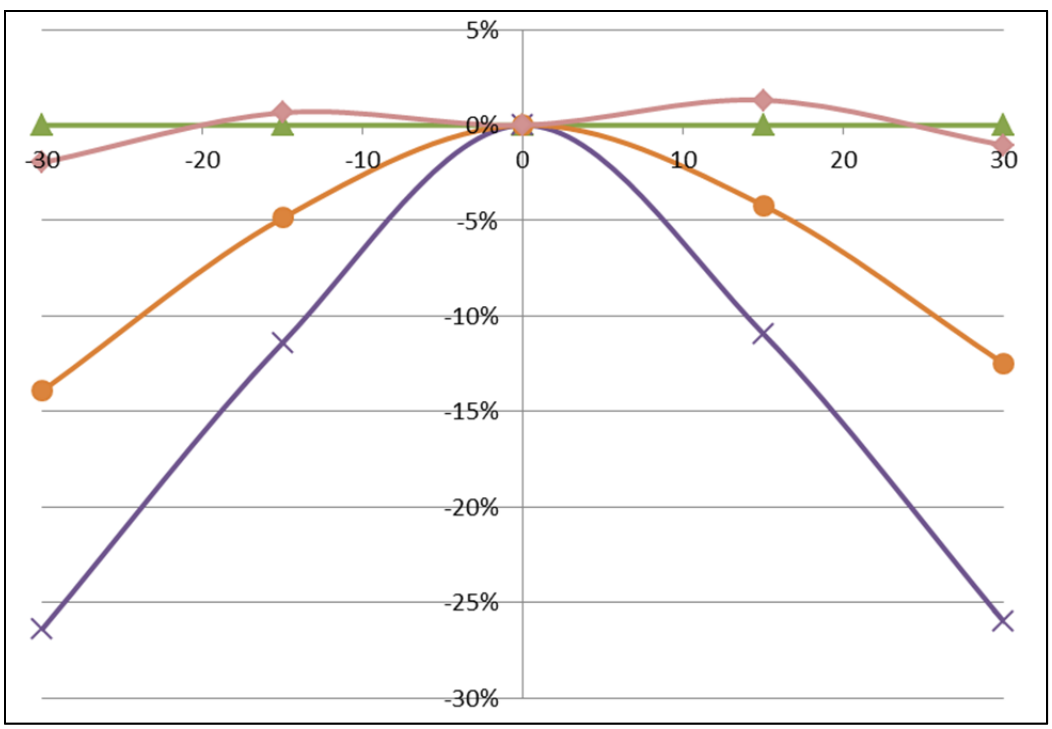

Figure 4. Sensitivity of the Beta Angle as a Function of Sign Twist

Comparisons of static results, as well as the dynamic results, were made at similar epsilon angles. As indicated in Figure 1, the effect of the epsilon angle can be significant for some retroreflective materials. Therefore, in order to achieve a constant epsilon angle for the van (i.e., epsilon angle keeps constant with the change of the relative position between the van and signs), the positions of vehicle equipment were adjusted. The illuminator and camera were set in the same plane parallel to the sign face, which lead to the epsilon angle as 0. It needs to be pointed out that this setting is different from other mobile systems. Accordingly, the comparisons were made with handheld readings corresponding to the epsilon angle equal 0, which eases the comparisons between mobile and handheld measurements at the same epsilon angle, especially for the variable geometries of signs in the open-road test. It is also important to note that a handheld retroreflectometer was used in this study. The handheld retroreflectometer was of the "point instrument" type, as described in ASTM E1709.

Dynamic Closed-Course Test Results

The dynamic closed-course testing consisted of 28 different but typical signs one would normally encounter. The signs were mounted at the both side of a runway at Riverside Campus of Texas A&M University. The layout of the signs is shown in Figure 5. The testing van was driven on the runway along the designated lane with a typical lateral offset of 20 feet. The driving speed was between 40 mph and 46 mph.

Figure 5. Signs for Closed-Course Testing

A list of the signs, their sheeting type, and the average handheld retroreflectivity readings are shown in Table 2. For these signs, we assessed measurement bias and repeatability. As the static test, the average of handheld measurement was assumed to be the true retroreflectivity of the sign. The bias is the difference between the van measurement and the averaged handheld value. The repeatability as used herein is the ability of the VISUALISE van to obtain identical readings of the signs making multiple passes. Repeatability shows whether the VISUALISE van produces consistent readings when the conditions of the measurement are unchanged. It is important to note that due to the trade-off between accuracy and wide dynamic range of the mobile system, signs with retroreflectivity higher than 700 cd/lx/m^2 were not included in the analysis. Regarding management of minimum retroreflectivity levels, the upper range of 700 cd/lx/m^2 was not considered a concern as the minimum levels in the MUTCD are much lower. A simple comparison of the sign background measurements is shown in Figure 6.

Table 2. Sign Used for Dynamic Closed-Course Testing

ID	Sign Legend	Type	Color	Average Handheld Measurement (n=4), cd/lx/m^2	
				Background	Legend
001	STOP	Prismatic	Red/White	175.8	922.8
002	PAVEMENT ENDS	Beaded	Yellow/Black	97.2	
003	DO NOT ENTER	Beaded	Red/White	9.1	72.0
004	NO PASSING ZONE	Beaded	Yellow/Black	69.9	
005	STOP	Engineer Grade	Red/White	9.8	70.7
006	SPEED LIMIT 55	Beaded	White/Black	333.3	
007	SN2	Beaded	Green/White	67.8	349.0
008	SN1	Prismatic	Green/White	149.8	819.0
009	SPEED LIMIT 55	Prismatic	White/Black	663.0	
010	STOP	Engineer Grade	Red/White	9.1	123.3
011	pedestrian crossing	Beaded	Yellow/Black	165.5	
012	DO NOT ENTER	Beaded	Red/White	34.5	273.0
013	NARROW BRIDGE	Beaded	Yellow/Black	26.2	
014	STOP	Engineer Grade	Red/White	21.4	231.0
015	SQUARE LARGER	Prismatic	Orange/Black	242.8	
016	SPEED LIMIT 45	Prismatic	White/Black	925.5	
017	STOP	Prismatic	Red/White	104.5	578.0
018	SPEED LIMIT 55	Beaded	White/Black	288.5	
019	Farmer	Prismatic	Brown/White	40.4	391.0
020	curve ahead	Prismatic	Yellow/Black	250.8	
021	pedestrian crossing	Prismatic	Yellow/Black	541.8	
022	chevron	Prismatic	Yellow/Black	65.0	
023	arrow	Prismatic	Yellow/Black	325.3	
024	CARBON	Prismatic	Blue/White	42.6	374.8
025	SPEED LIMIT 55	Prismatic	White/Black	1194.5	
026	STOP	Beaded	Red/White	31.3	292.8
027	SPEED LIMIT 55	Engineer Grade	White/Black	91.9	
028	Enough Silent	Prismatic	Yellow/Black	525.3	

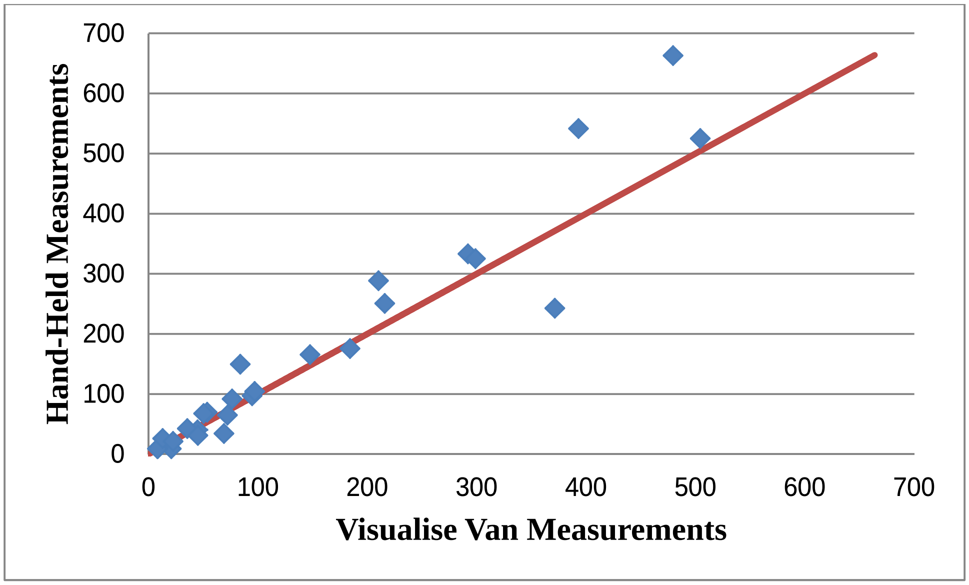

Figure 6. Comparison of Background Retroreflectivity Measurements (cd/lx/m^2)

Overall, the average percent difference between the measurements was 1 percent and the average actual difference was 18.7 cd/lx/m^2. Similar to the static testing results, the largest differences were observed on for the signs with very high retroreflectivity (e.g., greater than 350 cd/lx/m^2). As mentioned before, for retroreflectivity much higher than the minimum MUTCD levels, the larger differences on the high end are not deemed to be major issues. In addition, the measurements from the VISUALISE van are generally lower than handheld measurements, which indicates the van provides more conservative values.

In many ways, measuring the sign background is easier than the sign legend (with positive contrast signs) because there are many additional pixels of information in a digital image to analyze. In fact, measuring the legend is so difficult that some mobile technologies only offer services to measure sign backgrounds. However, the VISUALISE system claims to be able to measure the legend retroreflectivity of positive contrast signs. Figure 7 shows a comparison of the sign legend measurements from the handheld retroreflectometer and the VISUALISE van.

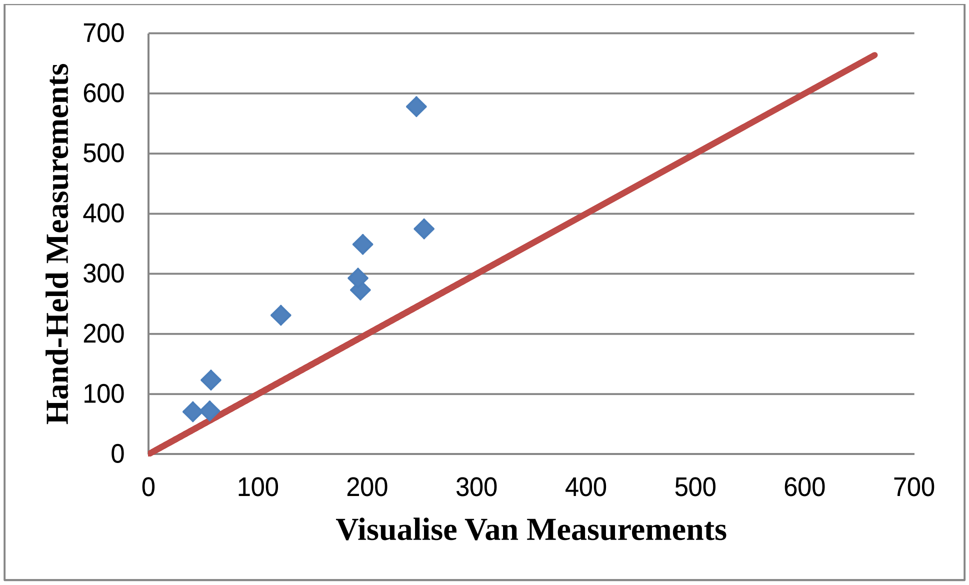

Figure 7. Comparison of Legend Retroreflectivity Measurements (cd/lx/m^2)

Overall, measurements of legends from VISUALISE van were lower than the handheld measurements. The average percent difference between the measurements was 40 percent and the average actual difference was 112.3 cd/lx/m^2, which are much larger than those for the background retroreflectivity measurements. It is as expected since the generally narrow font on a sign makes the measurement of legends hard to be accurate. The signs with the largest differences were made of prismatic retroreflective materials. In general, the prismatic retroreflective materials appear to be associated with the largest differences in measurements regardless of whether the measurements were of the sign background or legend.

As mentioned, the repeatability of the VISUALISE system was also tested on the closed-course. Three sets of dynamic data were recorded in order to test the repeatability of the mobile system. Figure 8 shows the cumulative distribution of the results for both the handheld and VISUALISE van measurements (the COVs for background and legend were combined together) graphically. For VISUALISE van measurements, the median COV was about 4 percent, and the 85th percentile COV was about 6 percent. While, for handheld measurements, the median and 85th percentile COVs are 6 percent and 24 percent, respectively. In addition, in earlier reported research, the median and 85th percentile COV for handheld readings on in-service signs were about 6.5 percent and 15 percent. Therefore, based on the results reported herein, the VISUALISE van measurements are even more repeatable than handheld measurements. The differences can be explained by the potential caveats of using handheld devices as described starting on page 3.

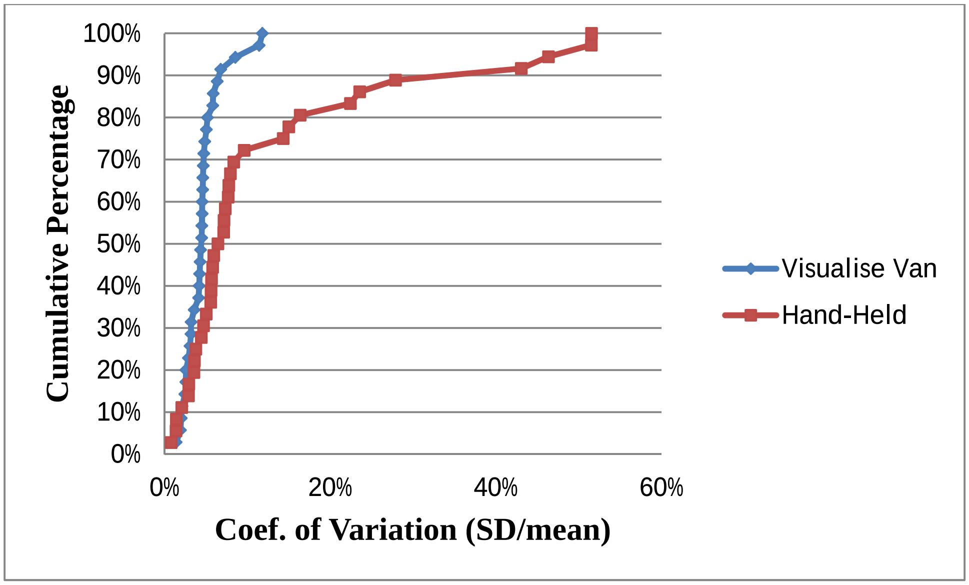

Figure 8. Cumulative Percentage of COV of Mobile VS. Hand-Held Measurements

The COV for each sign and each type of measurement (i.e., background versus legend) is shown in Figure 9 for the mobile measurements. The range of COV for the background was between 1 percent and 12 percent, while the range was between 2 percent and 7 percent for the legend. The highest COV for a background was on a NO PASSING ZONE warning sign made with high intensity beaded retroreflective material. The highest COV for a legend was on a prismatic guide sign with the word DO NOT ENTER, which might be explained by the very narrow font (0.3-inch in this case). In contrast to the reported COV from handheld retroreflectometers, these mobile COV are better, not only in terms of the median and 85th percentile COVs as mentioned above, but also for the range of both of the background and legend measurement. For handheld measurements, the range of COV was between 1 percent and 52 percent for either background or legend, which was much wider than the range for mobile measurements. This is a promising finding given the challenges of measuring sign legends.

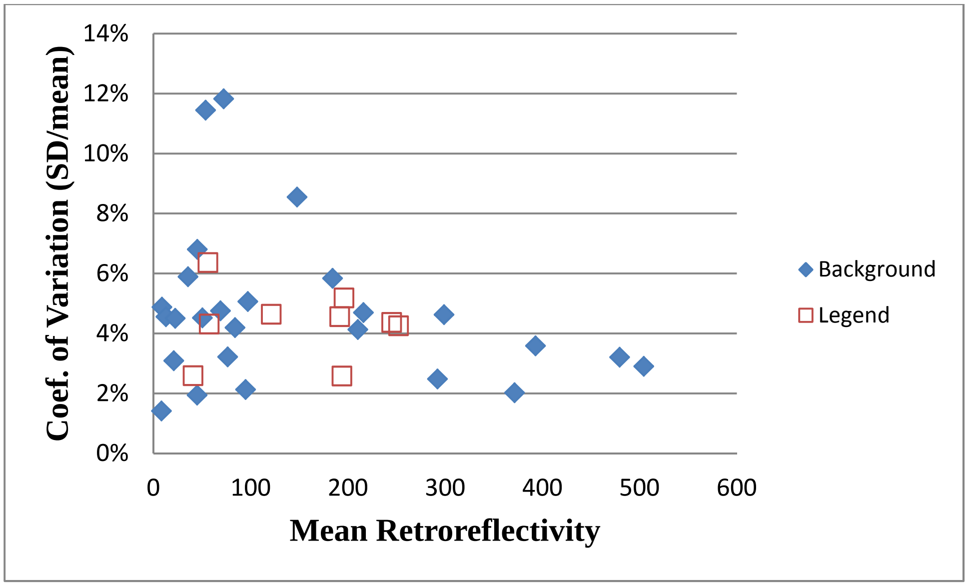

Figure 9. COV of Mobile Legend and Background Measurements

Open Road Test Results

The VISUALISE van was driven a 12-mile route starting from the interchange of SH21 and SH6, at a speed between 40mph and 55mph. They traveled west-southwest on SH21 then turned left on Silver Hill Road, a county-maintained road). Then they turned left on SH47. The last sign they measured was at the gore of the Villa Maria Rd. The route is shown below in Figure 10 with images of the 82 signs that were measured.

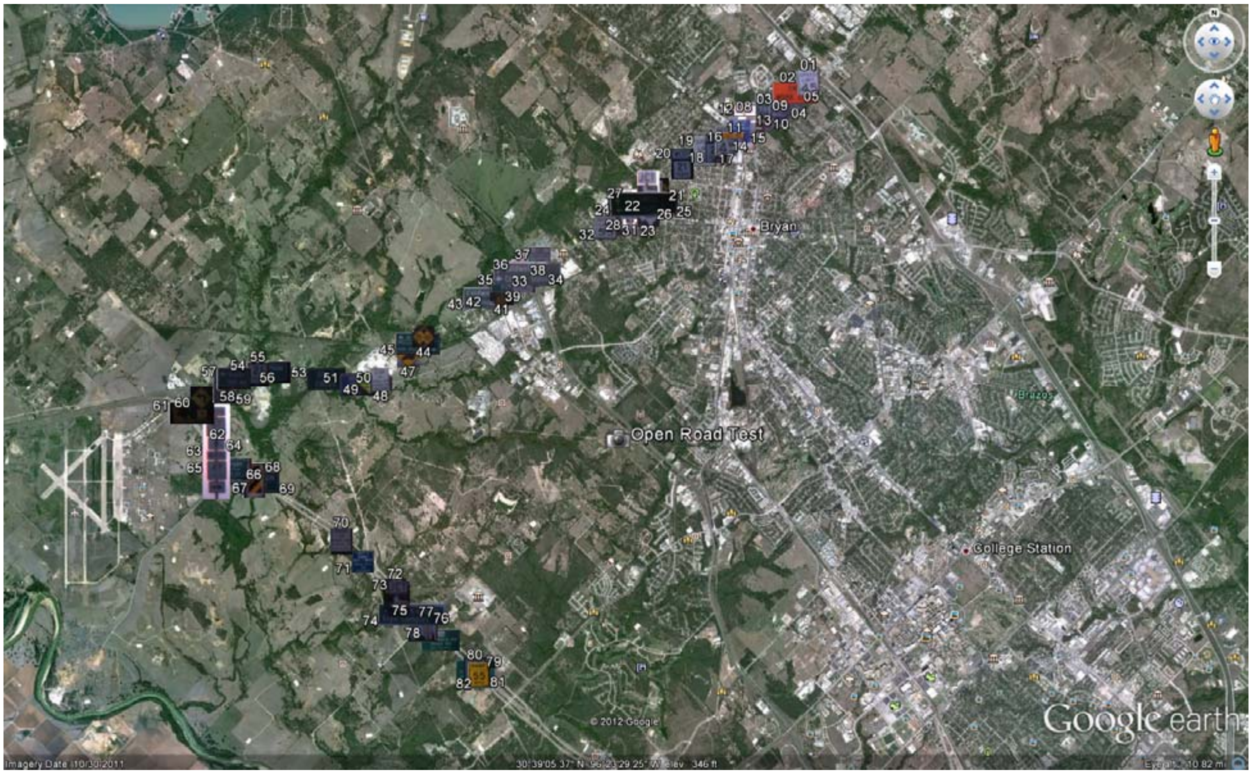

Figure 10. Route of Open-Road Testing

The data from the VISUALISE measurements included background and legend retroreflectivity levels as well as sign color. TTI research assistants measured the same signs with a calibrated handheld retroreflectometer, in accordance with ASTM E1709. Only 61 out of the 82 signs were measured by the handheld retroreflectometer as some of signs were temporarily set on the road when the van was running for the test, and some of the guide signs were too high to reach for the handheld measurement. Therefore, the mobile and handheld retroreflective measurements were then compared based on the measurements from the 61 signs.

Overall, the results from the mobile system were lower than the handheld device which was consistent with the result of dynamic closed-course test. However, this is not surprising since the mobile system measures signs in-situ rather than at a *standard* geometry. The mobile system is designed to make retroreflectivity measurements at an observation angle as close to 0.2 degrees as possible, but the entrance angle can be different from 4 degrees, depending on the roadway geometry, sign position, lean, and twist. One way to think about this difference is that the mobile system measures signs as drivers experience them while the handheld devices measure signs in accordance to a standardized test method.

The mobile background measurements were, on average, 2 percent lower than the handheld measurements, while the mobile legend measurements were 13 percent lower than the handheld measurements. Figure 11 shows for each sign background color how the mobile and handheld measurements compared. Overall, the linear fit is good with an R-squared value of 0.9552, when the slope is 0.9997 and the intercept is 10.445. However, the MUTCD minimum retroreflectivity levels for sign backgrounds do not go above 75 cd/lx/m^2, so Figure 12 was created to better show the comparisons at these lower retroreflectivity levels. As seen in Figure 12, a large difference was observed on for both signs in brown, which was as expected as brown signs were not used during the calibration process.

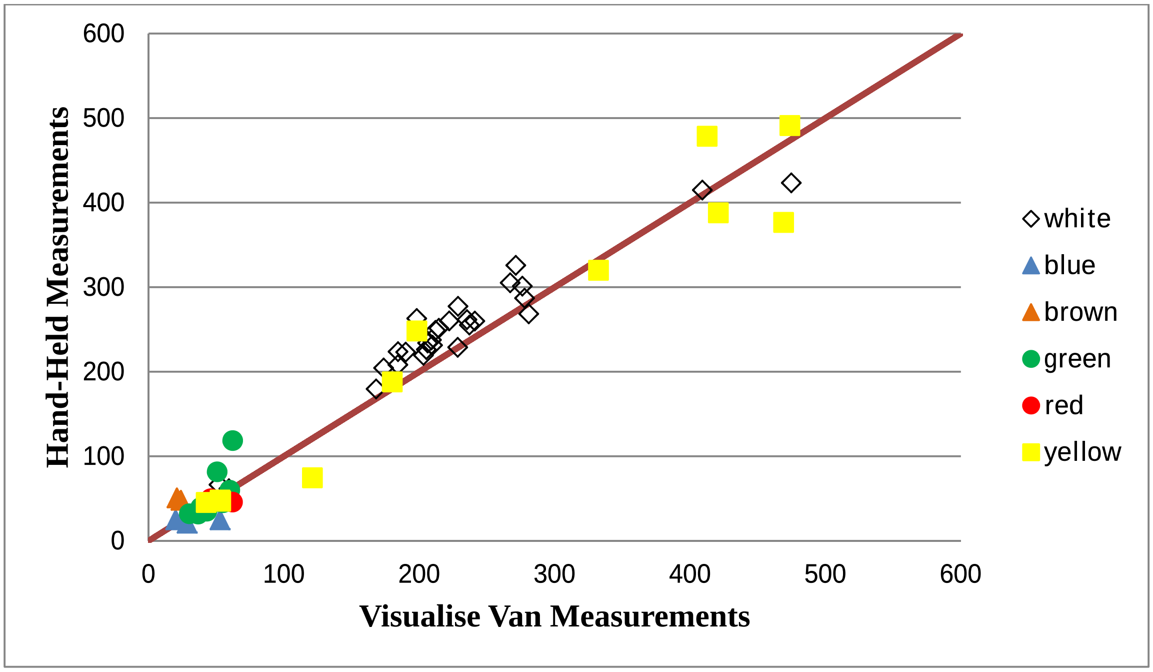

Figure 11. Comparison of Background Measurements (cd/lx/m^2)

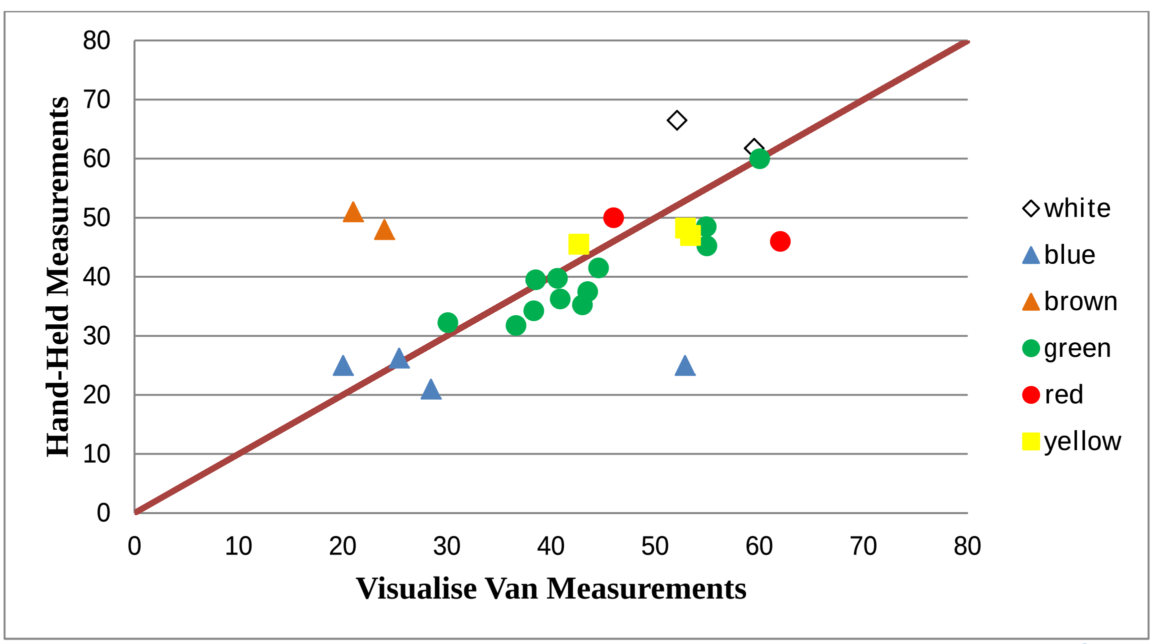

Figure 12. Close-Up of Comparison of Background Measurements (cd/lx/m^2)

Figure 13 shows a comparison of the legend measurements. There were 14 of 22 signs with legends having handheld measured retroreflectivity levels greater than 700 cd/lx/m^2 which is much higher than the FHWA required minimum levels.

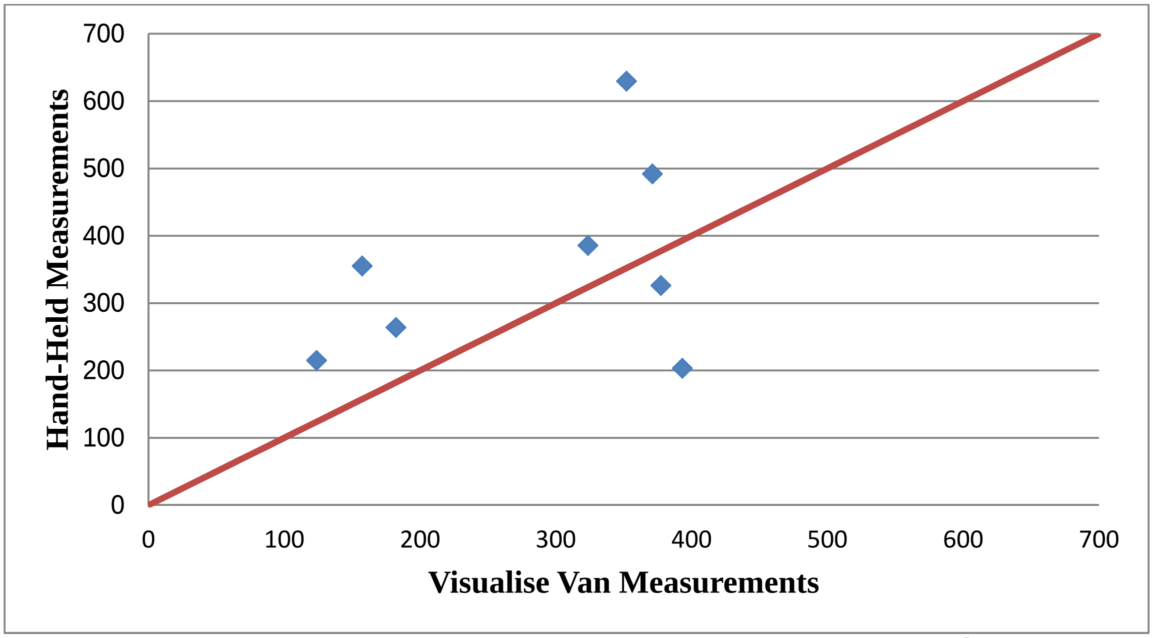

Figure 13. Comparison of Legend Measurements (cd/lx/m^2)

FINDINGS

This report includes a description of the testing of VISUALISE mobile sign retroreflectivity measurement capabilities. Other features of the VISUALISE's service such as measuring sign size and accurately locating sign position were not assessed within this effort. This effort assessed the measurement bias and repeatability of sign retroreflectivity measurements made on a closed-course testing facility and along an open-road route.

The static test results were conducted on a closed-course facility to determine the accuracy of the real-time retroreflectivity measurements. The van includes this feature as a calibration and demonstration mode only. The results of the static testing showed that at the lower end of retroreflectivity, where FHWA has set the minimum maintained retroreflectivity levels in the MUTCD, the static measurements provide a range that one would expect taking measurements with a handheld device. As the retroreflectivity increases, the range of reported retroreflectivity from the van increases, but the difference is not as critical since these retroreflectivity levels are much higher than the FHWA minimum maintained levels. For the same reason, retroreflectivity higher than 700 cd/lx/m^2 cannot be measured appropriately by the VISUALISE system is not deemed as a major issue.

Dynamic testing along a closed-course route was performed to assess the van's measurement bias and repeatability. The measurement bias regarding background measurements was less than 1 percent, meaning that the measurements from the van were on average less than 1 percent from the handheld measurements. The legend measurements from the van were on average about 40 percent from the handheld measurements.

The median COV was about 4 percent, and the 85th percentile COV was about 6 percent for mobile measurements. For handheld measurements, the median and 85th percentile COVs are 6 percent and 24 percent, respectively. In addition, in earlier reported research, the median and 85th percentile COV for handheld readings on in service signs was about 6.5 percent and 15 percent, respectively. These numbers show that the variability of measurements can be even lower with the VISUALISE mobile system compared to handheld measurements.

The open-road testing is what really counts, however. A total of 61 signs were measured with a handheld retroreflectometer and compared to the mobile measurements. The mobile background measurements were 2 percent lower than handheld measurements and the mobile legend measurements were 13 percent lower than handheld measurements. The larger differences were most evident on the signs with high retroreflectivity levels.

Regarding the differences in the mobile and handheld measurements, the open-road findings with lower mobile measurements is actually an indication that the system is probably functioning as it should. Theoretically, it is really not possible for a mobile system to produce the exact same retroreflectivity levels as a handheld device. The key difference is that the handheld devices are built to specific geometries but those geometries are not simultaneously common with typical roadway cross-sections, roadway alignments, and sign positions. In most cases, non-contact measurements from in-situ will provide slightly lower results than contact devices measuring the same signs. However, if working properly, a mobile measuring system will provide a better representation of how the signs are working at night, and this is ultimately the most important item here.

The two areas that were consistently a challenge for the VISUALISE mobile system were signs with small and narrow legends and signs made with prismatic retroreflective materials. However, these challenges are not isolated to the mobile systems. Signs with narrow legends that are retroreflective are harder for handheld measurements too. A reducer ring is needed on the handheld devices, which requires recalibrating the device and accepting higher levels of measurement uncertainty (although they have not been formally documented). In addition, signs made with prismatic retroreflective materials can provide a somewhat misleading perspective on the performance of the sign because of the sensitivity of these materials to measurement geometries (as illustrated in Figure 1 and Figure 3). Measurements made from the roadway, such as those made from the VISUALISE system, can provide a better realization of how the sign is seen from the perspective of the nighttime driver.

CLOSING REMARKS

By establishing minimum retroreflectivity levels in the MUTCD, the FHWA set minimum visibility criteria for traffic signs. Ideally, the FHWA would not have used retroreflectivity as the metric but luminance. However, measuring luminance in the field is not an easy effort and until recently required quite specialized equipment. Retroreflectivity was chosen by the FHWA as a convenient way to set the minimum visibility standards. While convenient, it has limitations such as the geometry under which it needs to be measured.

For now, however, retroreflectivity measurements are used to establish minimum maintenance levels for traffic signs in the U.S. Based on the results reported herein, the VISUALISE system appears to be a viable tool for measuring traffic sign retroreflectivity for compliance with the minimum maintenance requirements in the MUTCD.

REFERENCES

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