FACTORS AFFECTING SIGN RETROREFLECTIVITY

Final Report

SR 514

RESEARCH

Oregon Department of Transportation

FACTORS AFFECTING SIGN RETROREFLECTIVITY

Final Report

SR 514

by

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16. Abstract

This study was undertaken to better understand the factors that may affect road sign retroreflectivity, specifically age and physical orientation. A better understanding of these factors could provide guidance to ODOT in managing its inventory of road signs. The findings showed that over a twelve-year age span, most sign retroreflectivity readings were above the minimum ODOT standard. Retroreflectivity did not vary predictably with age. There was some evidence that retroreflectivity may be affected by sign orientation (direction facing), due to the weathering effects of windblown dust and precipitation. Additional data collection in more severe climates of Oregon might provide more evidence to support this finding. The report includes recommendations for further study and for record keeping in the ODOT sign maintenance program to provide a larger body of data.

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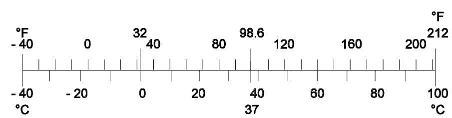
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



***** SI is the symbol for the International System of Measurement

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DISCLAIMER

FACTORS AFFECTING SIGN RETROREFLECTIVITY

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1.0 INTRODUCTION

Signs are an essential component of Oregon's transportation system, providing travelers with information to help ensure safe, orderly and predictable traffic movement. The investment in signs is substantial, estimated by the Oregon Department of Transportation (ODOT) to be more than $44,000,000 statewide. To manage this investment, ODOT needs to be able to plan for sign replacement as it becomes necessary, due to normal wear and physical damage or loss.

Signs need to be legible and the colors distinguishable at night as well as during the day. Nighttime visibility may be accomplished through external illumination, but most signs are illuminated through "retroreflection." Retroreflection occurs when light rays (e.g. from vehicle headlights) strike the surface of the sign and are redirected back toward the source of light.

Signs are constructed using various types of retroreflective sheeting, which consists of tiny prisms or spheres in a weather resistant, transparent plastic film. In the course of normal wear, the performance of signs, in terms of their retroreflectivity, may be affected by environmental conditions such as sunlight, temperature, dust and moisture.

To improve its planning process for sign replacement, ODOT needs better information on factors that may affect the service life of signs. Some ODOT maintenance districts may be replacing signs based on a perceived need before replacement is actually necessary. The purpose of this study was to investigate factors that may affect sign retroreflectivity, in order to develop criteria for appropriate sign replacement times.

1.1 RESEARCH OBJECTIVES

The objectives of this study were as follows:

1) to determine a baseline for sign retroreflectivity over time, i.e. to establish the relationship between sign age and retroreflectivity; and

2) to examine the relationship between the physical orientation of signs and retroreflectivity. As the orientation of signs vary, so does the amount of exposure to solar radiation and windblown dust and precipitation.

The study area for this project was a portion of the mid-Willamette Valley in ODOT Maintenance Region 2, as shown in Figure 1.1. The climate in this area is moderate in temperature and precipitation. Average annual maximum temperatures range from 8° to 28° C (46° to 82° F). Average annual minimum temperatures range from 1° to 11° C (33° to 51° F). Average annual precipitation is 1.04 m (41 in). Typical distribution of precipitation includes about 50 percent of the annual total from December through February, lesser amounts in the spring and fall, and very little during summer. Average cloud cover during the coldest months exceeds 80 percent, with an average of about 26 cloudy days in January. During summer, average cloud cover is less than 40 percent; more than half of the days in July are clear.

Figure 1.1: ODOT Maintenance Region 2, showing the study area

1.2 BACKGROUND

Various types of retroreflective sheeting material are used in the manufacture of roadway signs. The retroreflective material (glass spheres or prisms) may be embedded in a plastic covering (Type II sheeting), or it may be encapsulated, with an air space between the retroreflective material and the plastic covering (Type III sheeting). Type III sheeting provides much higher retroreflectivity than Type II sheeting. ODOT specifications call for the use of Type III sheeting in all signs.

1.2.1 Measurement of Retroreflectivity

The standard measure of retroreflection - the coefficient of retroreflection, R_A - is expressed in candelas per foot-candle per square foot (English units) or candelas per lux per square meter (International System of Units). The conversion from the English system to the SI system is unity: an R_A value of 100 millicandelas per foot candle per square foot in English units is equal to an R_A value of 100 millicandelas per lux per square meter in SI units. As established in the *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-85*, the coefficient R_A is described as "Specific Intensity per unit Area" or SIA (*FHWA 1985*).

Minimum specifications for retroreflective sign sheeting materials are designated by the American Society for Testing Materials, in ASTM D-4956 (*ASTM 2000*). These specifications have also been adopted by FHWA. Table 1.1 shows the ASTM standards for four different colors of Type III sheeting. Also shown in Table 1.1 are the ODOT minimum specifications for retroreflective sheeting after seven years and ten years of inservice placement (*Black 1992*). The table also shows end of service life values for signs using Type III sheeting, as recommended by FHWA (*McGee and Paniati 1998*). The ASTM and ODOT specifications served as a general guide for evaluating the retroreflectivity measurements collected in this study.

Table 1.1: Minimum retroreflectivity values for Type III sheeting

Sheeting Color	**Minimum Retroreflectivity Values (SIA) [a]**			
	ASTM D-4956 Retroreflectivity Standard	**ODOT Specification (7 yrs service)**	**ODOT Specification (10 yrs service)**	**End of Service Life (FHWA) [b]**
White	250	212	200	30-70
Yellow	170	144	136	30-55
Green	45	38	36	5-7
Red	45	38	36	5-8

[a] Values in $cd/lx/m^2$; entrance angle: -4°, observation angle: +0.2°
[b] These value ranges apply to the background colors of signs of differing size and traffic speeds.

2.0 RESEARCH METHODS

To collect data on sign retroreflectivity, a hand-held retroreflectometer was used – a RetroSign, Model 4500, manufactured by DELTA Light & Optics.[1] The instrument is designed to record and store retroreflectivity measurements of the brightness of road signs, as seen by drivers at a distance of 100 m (328 ft). Measured SIA units are displayed on an LCD panel on the instrument, and up to 1000 readings are also stored in a non-volatile memory for later retrieval.

The instrument measures retroreflectivity values at an entrance angle of –4° and an observation angle of +0.2°. Prior to taking measurements the operator is instructed to calibrate the instrument, using a reference material of known retroreflectivity, which is included with the instrument.

To measure the retroreflectivity of a sign the operator places the instrument flush against the surface of the sign face and presses the trigger. The instrument is designed to detect and automatically compensate for any external leakage of light during the measurement.

To accomplish the research objective, the following tasks were performed:

- Retroreflectivity readings were collected on 80 high intensity (Type III) signs – 20 each of red, yellow, green and white – located in the mid-Willamette Valley. Ten readings per sign were recorded. The retroreflectometer was calibrated before the readings were taken on each sign.

- The sign was washed and dried prior to any readings being taken, to detect the optimum retroreflectivity of the sign. Measurements were taken on the sign background only, not on the legend. The physical condition of signs ranged from poor to new.

- Information was also recorded on the age and predominant physical orientation of each sign (north, south, east or west). These were factors considered to have a possible effect on sign retroreflectivity.

Following the initial data collection it was found that insufficient sign data had been collected from each color at every physical orientation. Thus data for an additional 57 signs were collected to provide a more complete data set. The same methods used in the first round of data collection were followed in the second.

[1] DELTA Light & Optics, Hjortekaersvej 99, DK-2800 Lyngby, Denmark

3.0 RESULTS

3.1 MEASUREMENT VARIABILITY

3.1.1 Data Collection

The second round of data collection was found to produce readings markedly higher than those taken in the first round. The average increase in SIA values from the first to the second round ranged from 71% for red signs to 107% for yellow signs. The probable reason for this difference was that the instrument had been returned to the factory for servicing between the two data collection rounds, and adjustments to the instrument resulted in much higher readings in the second round. Test measurements of standard Type III sheeting material and repeat field measurements on a sub-sample of signs led researchers to conclude that the readings recorded in the first round were very likely to have been inaccurate.

In order to be able to use the readings from the first data collection round, a weighting factor was applied to the first round data. The weighting factor for each color of sign was derived from the average percentage difference of the second round readings compared to the first.

3.1.2 Sign Retroreflectivity

As expected, on any given sign the retroreflectivity measurements varied among the ten readings recorded, due to the variability in the reflective surface. This expected variation was the reason for specifying ten readings per sign. The average of the ten readings was used to represent the overall sign retroreflectivity.

The Coefficient of Variation (CV) is a measure of variability, which allows a comparison of variability among several data sets; it is the ratio of the standard deviation to the mean, expressed as a percent. Some signs were found to have much higher CVs than others. This variability could be considered an indicator of the uniformity of the sign retroreflectivity, hence an additional factor in gauging sign condition. Among the sign readings taken for this study, the range of CVs is shown in Table 3.1.

Table 3.1: Coefficient of Variation for retroreflectivity measurements

Sign Color	Minimum Measured CV	Maximum Measured CV
White	0.2%	28.7%
Yellow	0.9%	37.8%
Green	1.1%	18.5%
Red	2.3%	27.3%

3.1.3 Instrument Variability

The differences in readings during the course of the study also prompted researchers to examine the instrument itself to determine if readings varied due to battery charge or some other aspect of operation. Over a test period of 55 days, readings were recorded from test sheeting material while monitoring the battery level of the instrument. In each test session a set of ten readings was collected without moving the instrument, and another set of ten readings was taken from various places on the sheeting material. Based on these tests, researchers made the following observations:

- The retroreflectivity readings were probably <u>not</u> affected by the battery charge.
- The <u>variability</u> of readings was <u>not</u> affected by the battery charge.
- The variability of readings was negligible when they were taken from the same exact location on a given sign.

Thus it was concluded that the variability of readings observed in the field was likely due to actual variations in the reflective surface of the signs, not the operation of the instrument.

3.2 RETROREFLECTIVITY AND SIGN COLOR

Figure 3.1 shows the average SIA values for all signs. The retroreflectivity of white signs was the highest, with average readings ranging from 189 to 305. The average readings for yellow signs were somewhat lower, ranging from 129 to 248 (with an outlying data point at 5). The average readings for green signs ranged from 34 to 80. The SIA values for red signs ranged from 20 to 60.

For comparison purposes, Figure 3.1 also uses bars to show the minimum retroreflectivity standards established for each sign color (Table 1.1). The lower end of the range corresponds to the ODOT minimum standard at ten years of service. The upper end of the range corresponds to the ASTM standard. As Figure 3.1 shows, the overall levels of retroreflectivity measured for different sign colors were generally in the same order of magnitude as the ASTM standards. Virtually all of the readings were above the ODOT standard, and most were above the ASTM standard, with the exception of red signs.

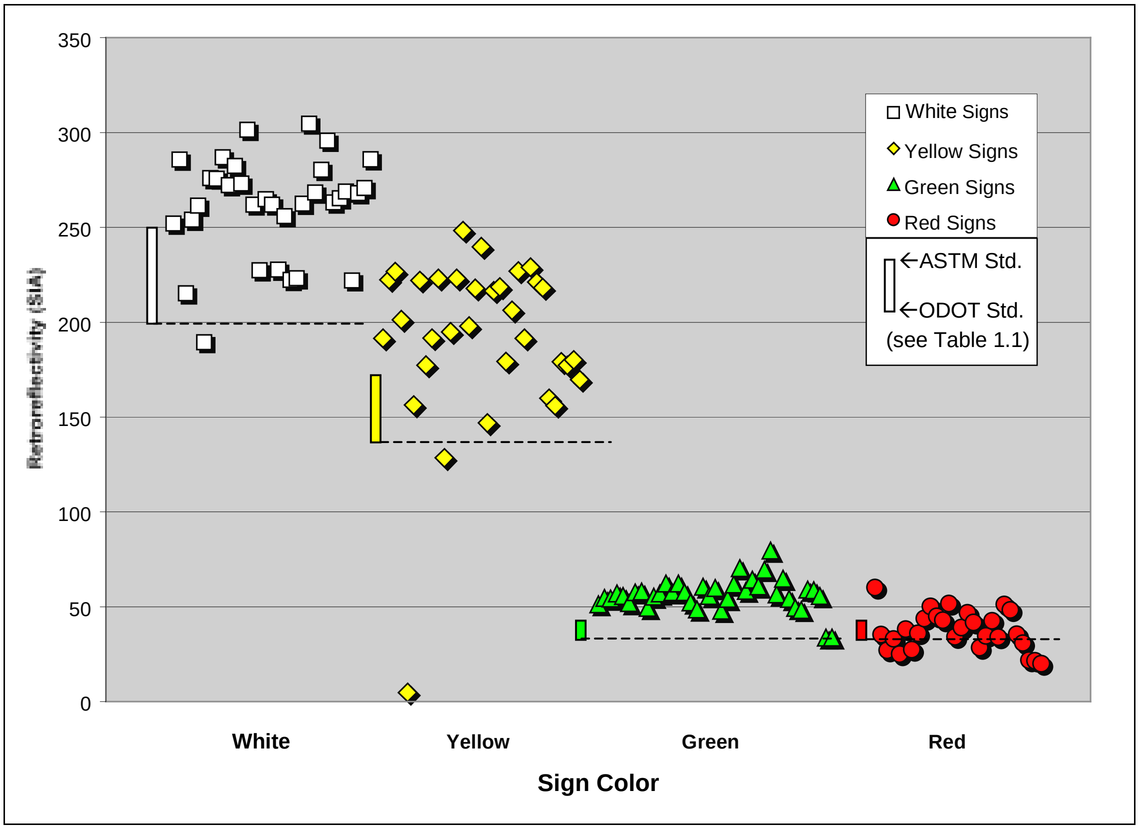

Figure 3.1: Retroreflectivity values for signs of different colors

Table 3.2 shows the comparison between the ODOT minimum values at ten years of service and the average readings by color from the sample of 137 signs. The red signs yielded the lowest average value, exceeding the ODOT standard by only 3%. The average values for signs of other colors exceeded the ODOT standard by 31% to 56% (with the exception of one data point).

Table 3.2: Comparison of sample readings with minimum ODOT values

Sign Color	Minimum ODOT Values (SIA)	Average Value from Sampled Signs (SIA)	Comparison with Minimum Values
White	200	261	+31%
Yellow	136	198 (outlyer: 5)	+46%
Green	36	56	+56%
Red	36	37	+3%

3.3 RETROREFLECTIVITY AND SIGN AGE

One might expect that as a sign ages, its retroreflectivity might decline, due to the effects of weather or other environmental conditions. To determine the relationship between sign age and retroreflectivity, the average SIA value for each sign was plotted against the installation year (ranging from 1985 to 1997). Figure 3.2 shows the results for each sign color. The trend lines show little relationship, however, between the age of signs and their retroreflectivity values.

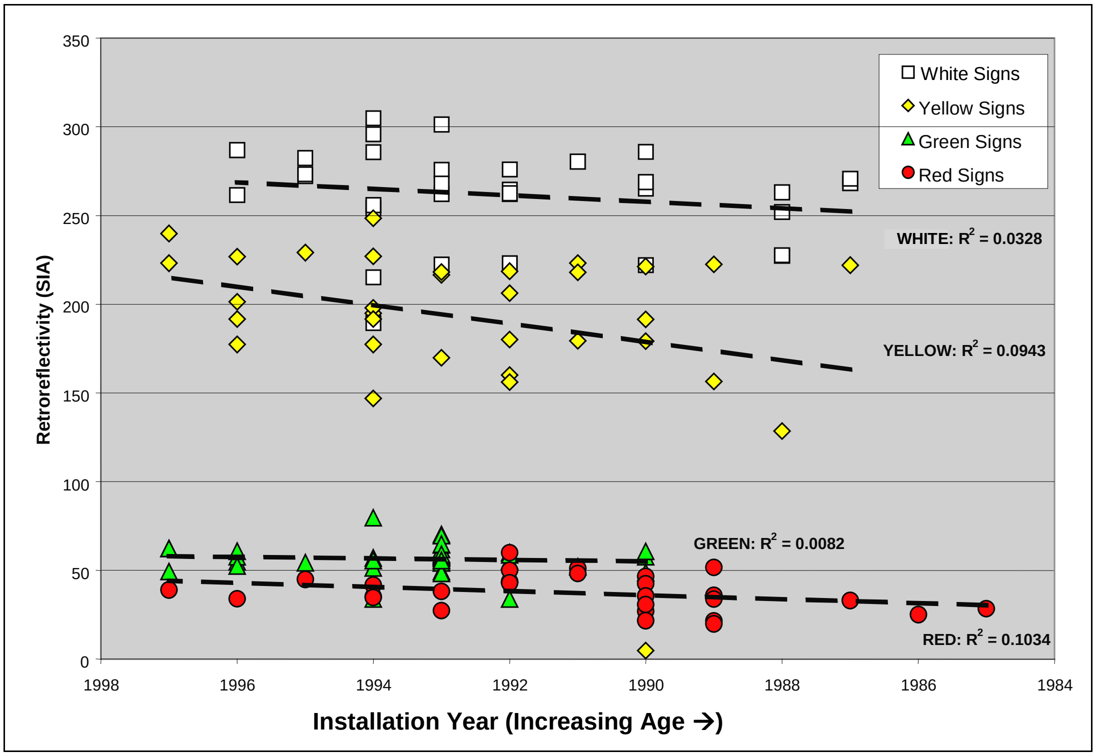

Figure 3.2: Retroreflectivity and sign age

Two factors may help explain the apparent lack of relationship. First, the age range of the signs may not have been great enough to provide a complete picture of sign performance over time. Second, the installation year data may not have been entirely reliable. A more carefully controlled investigation covering a greater time span would be needed to further explore whether any relationship exists between sign retroreflectivity and sign age.

As a sign ages, it is possible that the variability of its retroreflectivity could increase, due to surface abrasion from wind-blown dust and precipitation. Figure 3.3 shows the relationship between sign age and the Coefficient of Variation for each sign color. The analysis shows, however, that there is no clear relationship between the variability of sign retroreflectivity readings and age.

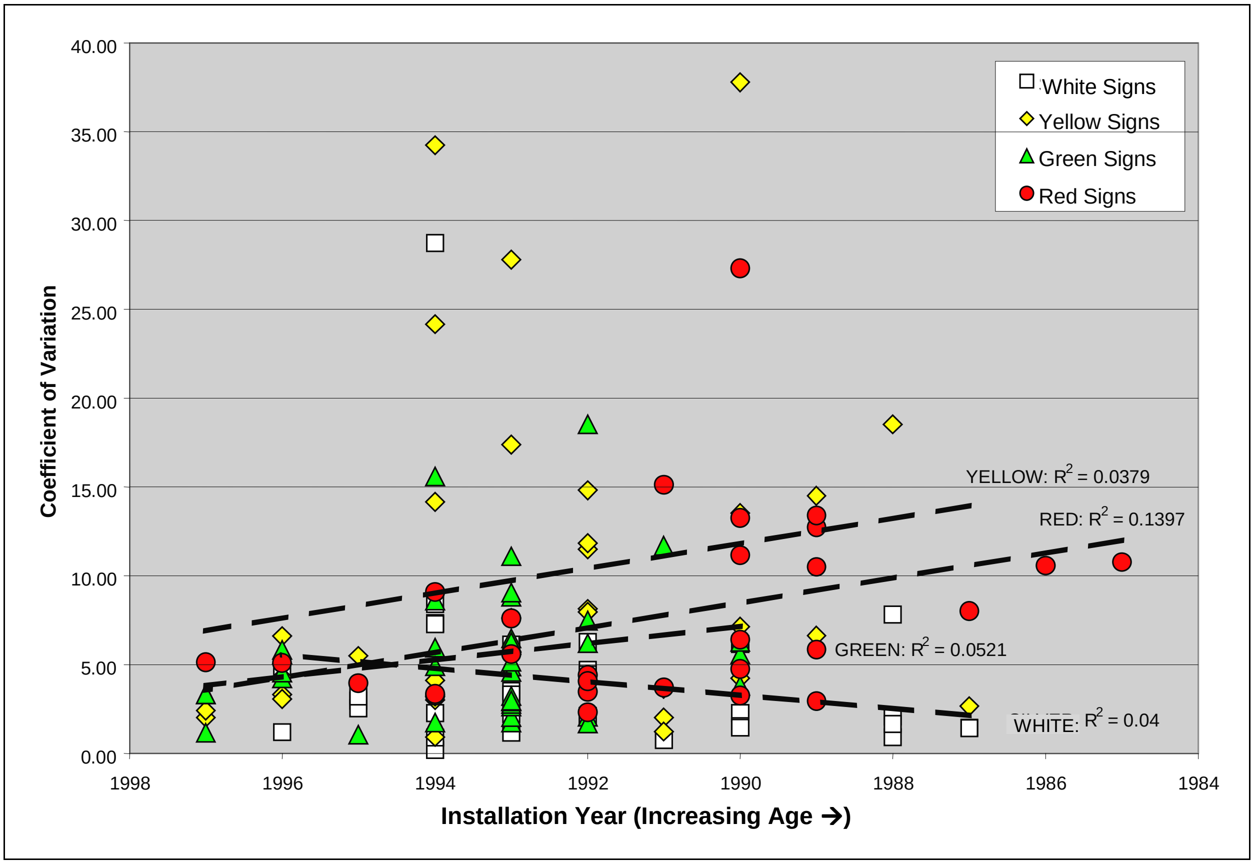

Figure 3.3: Coefficient of Variation and sign age

3.4 RETROREFLECTIVITY AND SIGN ORIENTATION

Signs with greater exposure to solar radiation or to windblown dust and precipitation might be expected to lose retroreflectivity sooner than more sheltered signs. Given the latitude of the area (approx. 45° North) and the predominant weather patterns, west-facing and south-facing signs could thus be expected to show lower levels of retroreflectivity. Figure 3.4 shows the relationship between the physical orientation of signs and their retroreflectivity. Although there was no strong trend, it appears that west-facing signs may tend to have slightly lower retroreflectivity than those facing other directions. Lower retroreflectivity for west-facing signs was recorded for three of the four sign colors – white, yellow and green. Among red signs, retroreflectivity values tended to be lowest among south-facing signs.

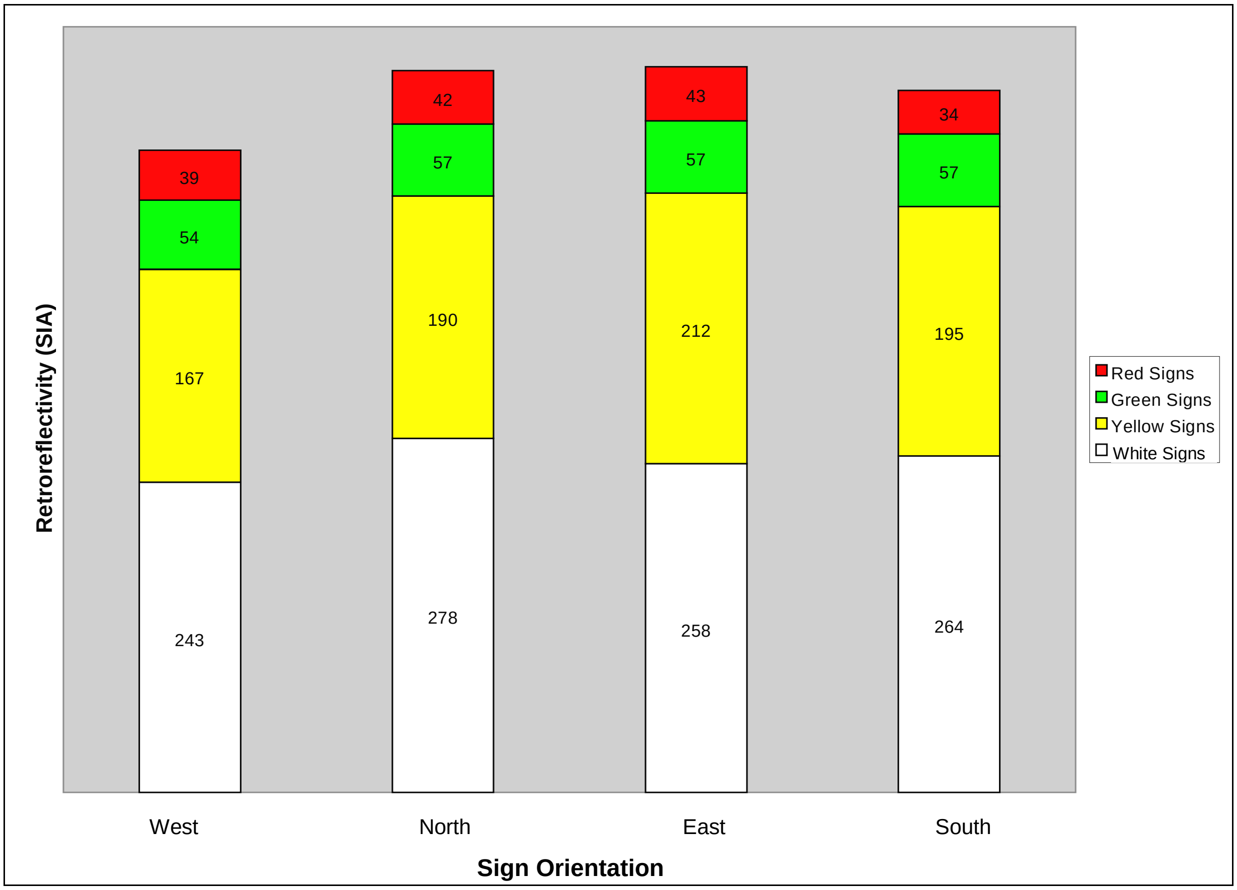

Figure 3.4: Retroreflectivity and sign orientation

The retroreflectivity variability (Coefficient of Variation) was also examined for each sign orientation. Figure 3.5 shows that, overall, west-facing and south-facing signs tended to have higher variability of readings. Yellow and white signs facing west showed higher variability than those facing other directions; red and green signs facing south showed higher variability than those facing other directions. Using retroreflectivity variability as an indicator of sign condition, this finding suggests greater weathering effects among west-facing and south-facing signs, probably due to abrasion from windblown dust, dirt and precipitation. The magnitude of these effects, however, is not great enough to produce average retroreflectivity values below the ODOT minimum standards.

During repeat field measurements to verify the second-round data, it was found that in about 19% of the cases the sign orientation had been incorrectly recorded. Thus the reliability of the field data on sign orientation is somewhat questionable. More carefully controlled additional research would be necessary to validate the finding that west-facing and south-facing signs show greater variability in retroreflectivity.

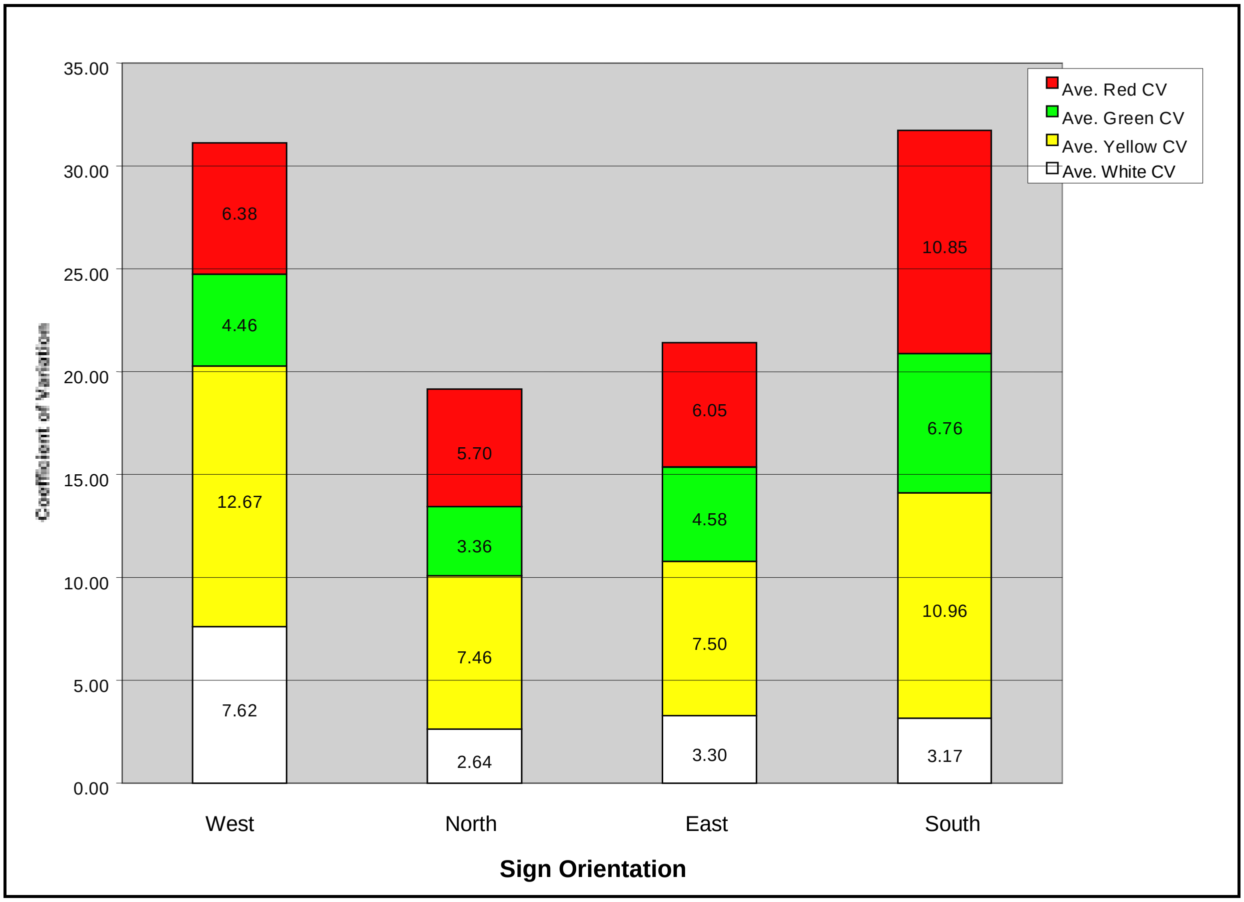

Figure 3.5: Coefficient of Variation and sign orientation

4.0 CONCLUSIONS

This study was undertaken to better understand the changes in road sign retroreflectivity over time, and to investigate factors that may affect sign retroreflectivity. A better understanding of these factors could provide guidance to ODOT in managing its road sign inventory.

The findings showed that virtually all of the signs in the sample exceeded the minimum ODOT retroreflectivity standards for an inservice period of ten years. The red signs yielded the lowest average value, exceeding the ODOT standard by only about 3%. The average values for signs of other colors exceeded the ODOT standard by 31% to 56%.

High average retroreflectivity values (compared to the ODOT minimums), coupled with the lack of any apparent relationship between retroreflectivity and age over a twelve-year period, suggests that sign retroreflectivity in the mid-Willamette Valley may not change enough over time to warrant the use of age as a factor in planning for sign replacement.

It seems likely that even if the <u>level</u> of retroreflectivity is not related to sign age, the <u>variability</u> might increase with age, as the clear plastic surface of a sign suffers the effects of abrasion from windblown dust, dirt and precipitation. The analysis of data in this study, however, shows no such relationship. It may be that more time is needed for the effects of sign weathering to have a measurable impact. The twelve-year sign age span may not have been long enough to detect weathering effects, at least in the mid-Willamette Valley environment.

In the analysis of the relationship between retroreflectivity and sign orientation, the findings suggest that west-facing and south-facing signs may have more retroreflectivity <u>variability</u>, although degradation in the average <u>levels</u> of retroreflectivity is not so evident. Thus weathering effects may indeed be a factor that at some point needs to be a sign maintenance program consideration.

Problems encountered in the data collection included highly variable readings from one data collection round to another, and questions on the reliability of some of the data on the age and the physical orientation of signs. Thus further investigation seems worthwhile on the possible relationship between retroreflectivity and independent variables such as age, physical orientation, and environmental conditions. In such an investigation, specific steps would need to be taken to address the problems cited above in order to achieve more reliable results.

The accumulation of dust and dirt on a sign will decrease its retroreflectivity. The data collected in this study, however, is only from signs that had been washed beforehand. Thus the study cannot speak to the retroreflectivity of signs as they may appear to motorists. How often signs should be washed in a maintenance program is a question to be addressed in a different study. The effects of graffiti removal cleaners and anti-graffiti coatings on sign retroreflectivity are also issues to address in future studies.

It is reasonable to conclude that the retroreflectivity of road signs oriented toward the prevailing weather patterns may be significantly affected by weathering over several years, depending on the severity of the environment. In a relatively benign environment, however, the retroreflectivity can be expected to be above the ODOT minimum after a decade or more. Further research may help to reveal how great a role weathering plays in the more severe environments of Oregon. For the time being, consideration of other hazards, such as vandalism or other physical damage, may far outweigh the hazards of weathering in a sign maintenance and replacement program.

5.0 RECOMMENDATIONS

Based upon the findings of this study, the following recommendations are made for ODOT's sign maintenance program:

- The sign location, installation date and the orientation (direction facing) should be recorded on the back of the sign and in the ODOT sign database. Future studies could then draw upon this accumulated body of data to investigate factors affecting retroreflectivity.

- Maintenance districts should consider purchasing or sharing in the use of a retroreflectometer, to collect initial readings from new signs as well as readings in periodic inspections, as feasible. At least ten shots per sign (per sheeting and legend) should be collected and stored in a database for future analysis. The data could be compared to data from nighttime inspections to determine if the contrast ratio between the background and the legend may be an indicator of sign serviceability.

- Lacking an instrument to make retroreflectivity measurements, it is worthwhile for sign crews to make a practice of recording some standard observations on the physical condition of signs as part of the maintenance program. This information could be entered into the ODOT database with the location, installation and orientation data. Where signs are reported to have poor nighttime visibility or show evidence of surface abrasion, retroreflectivity measures could be taken to establish quantitative measures of the sign condition.

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