Traffic Sign Retroreflectivity Measurement Using Human Observers

WA-RD 140.1

Final Report
December 1987

Washington State Department of Transportation
in cooperation with the
United States Department of Transportation
Federal Highway Administration

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16. ABSTRACT

This report is an investigation of the current methodology used to evaluate traffic sign retroreflectivity under actual highway conditions. The report consists of three parts: a literature survey, a questionnaire, and the training and analysis of human observers to rate traffic sign retroreflectivity.

The literature survey and questionnaire concluded that human subjectivity judgment is almost exclusively used to evaluate traffic sign retroreflectivity. Instruments are not used for large inventories because of cost and computer-based sign management systems are in the early stages of development and not used. The questionnaire also revealed that few states have any policy for sign replacement.

The main objective of the research was to assess the accuracy of using human observers to evaluate traffic sign retroreflectivity. Observers were trained to rate warning and stop sign retroreflectivity in two experiments. After the training the observers evaluated signs on two highway courses. The observer sign ratings and the sign rating calculated using a retroreflectometer were incorporated into a decision model to replace or not replace a sign based on the sign condition and environment. The individual observers made correct decisions on 74 percent of the warning signs and 75 percent of the stop signs.

The literature survey and questionnaire concluded that at present there is no method of sign review other than the trained observer that is suitable for large sign inventories. The experiments have demonstrated that a trained observer is a valuable part of a sign maintenance program. Agencies will have to continue to rely on observers' judgments for some time to come.

Key words: sign reflectivity measurement

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TRAFFIC SIGN RETROREFLECTIVITY MEASUREMENT USING HUMAN OBSERVERS

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DISCLAIMER

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EXECUTIVE SUMMARY

Driving at night is a difficult task with a fatality rate per mile three times higher than driving in daylight. Improvement in the nighttime guidance of the driver is likely to improve driver performance. The majority of today's traffic signs are made with retroreflective material for nighttime legibility. As signs age, their retroreflective ability decreases, accompanied by a decrease in effectiveness. An effective method of periodically inspecting traffic signs is important to ensure highway safety.

The Federal Highway Administration (FHWA) is currently investigating the addition of performance standards for retroreflective traffic signs to the Manual on Uniform Traffic Control Devices (MUTCD).[1] The implementation of retroreflectivity standards would create a need for an accurate, reliable and cost-effective method to evaluate the retroreflectivity of traffic signs along the highway. This research project was designed to assess the current methodology of traffic sign retroreflectivity inspection and the accuracy and usefulness of using trained observers to evaluate retroreflectivity.

This research project composed of three parts: a literature survey, a questionnaire, and the training and analysis of the observers.

A literature survey and the questionnaire sent to the 50 state transportation agencies showed that instruments to evaluate traffic sign retroreflectivity are accurate but not used on a large scale because of the time required to use them. An instrument that would be suitable to evaluate the retroreflectivity of a large inventory of traffic signs has not been developed and may not be developed for several years. A computer-based sign management system may prove to be satisfactory provided adequate weathering data and several other factors, including accurate records of sign replacement, can be obtained. At present the human observer is almost exclusively used to evaluate sign retroreflectivity, but is of unverified accuracy.

A summary of the survey questionnaire is included as Table ES-1. Eighty-five percent of the states responded to the questionnaire, indicating a very high interest in the subject of traffic sign retroreflectivity. The major findings are the following:

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[1]The Federal Register, April 26, 1985.

- few states (15) have any policy for sign replacement;
- 23 states supplement visual inspection, most using retroreflectometers;
- most states (31) do not have any plans to modify their inspection procedures, indicating that current procedures are adequate; and
- only nine states are planning or performing research related to sign retroreflectivity.

The main objective of the research, to assess the accuracy of the trained observer in evaluating traffic sign retroreflectivity, was accomplished in a series of experiments. Seventeen observers were trained to rate warning and stop signs, first in a dark gymnasium and then from a stationary car on a straight-level section of road. The observers rated a series of signs on a scale of 0 to 4 (by whole numbers, 4 being best) that were placed on a sign post from 100 to 300 feet away. After the training the observers were driven on two highway courses in which they rated 130 traffic signs.

The primary results of the highway experiments are the comparisons of the observer rating of the signs and the rating of the signs calculated by using the retroreflectometer. The observer rating was incorporated into a decision model to replace or to not replace the sign based on the visual complexity of the sign environment. Figure ES-1 is a breakdown of the highway experiment results by sign type. A and D are the correct decisions to replace and to not replace a sign, respectively. B is the incorrect observer decision to replace a sign when it should have remained in place and C is the incorrect observer decision to let a sign remain in place when it should have been replaced. The observers were correct on 74 percent of the warning signs and on 75 percent of the stop signs. The observers correctly rated a high percentage of the signs.

The literature survey and questionnaire led to the conclusion that at present there is no method of sign review other than the trained observer that is suitable for a large sign inventory. The experiments have demonstrated that a trained observer is a valuable part of a sign maintenance program. Agencies will have to continue to rely on observers' judgments for some time to come.

Table ES-1. Survey Questionnaire Summary

State Surveyed	Questionnaire Returned	Written Policy	Supplement Visual Inspection	Plans to Modify Sign Inspection Procedures	Future or Current Research
Alabama	Y	N	Y[3]	N	N
Alaska	Y				
Arizona	Y		N	Y	Y
Arkansas	Y				
California	Y				
Colorado	Y	Y[2,4]	N	Y[5]	
Connecticut	Y	Y[6]	N	N	Y[5]
Delaware	Y	N	Y[7]	N	N
District of Columbia					
Florida					
Georgia	Y	Y[8]	Y[1]	Y[2,3]	N
Hawaii	Y				
Idaho	Y	Y[9]	Y[2]	N	N
Illinois	Y	N	Y[4]	N	N
Indiana	Y	N	Y[2]	N	N
Iowa	Y	N	Y[2]	N	N
Kansas	Y	N	Y[3]	Y[10]	N
Kentucky	Y	N	N	N	Y[5]
Louisiana	Y	N	N	Y[11]	N
Maine	Y	N	N	Y[12]	N
Maryland					
Masssachusetts	Y	N	N	Y[13]	Y[14]
Michigan	Y	N	Y[2]	N	N
Minnesota					
Mississippi	Y	N	Y[2,15]	N	N
Missouri	Y	Y[1]	N	N	N
Montana	Y	N	Y[3]	N	N
Nebraska	Y				
Nevada					
New Hampshire					
New Jersey	Y				
New Mexico	Y	N	Y[2]	Y[16]	N
New York	Y				
North Carolina	Y	N	N	Y[17]	Y[5]
North Dakota	Y	N	Y[2,3]	N	N
Ohio	Y				
Oklahoma	Y				
Oregon					
Pennsylvania					
Puerto Rico	Y				
Rhode Island	Y	N	N	Y[18]	N
South Carolina	Y	N	Y[2]	N	N

Table ES-1. Survey Questionnaire Summary (Continued)

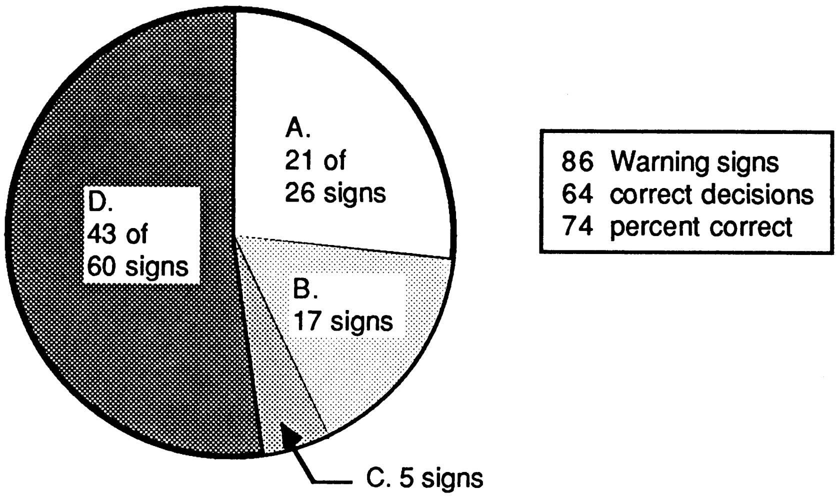
State Surveyed	Questionnaire Returned	Written Policy	Supplement Visual Inspection	Plans to Modify Sign Inspection Procedures	Future or Current Research
South Dakota	Y	N	Y[2,3]	Y[2]	Y[5]
Tennessee	Y				
Texas	Y				
Utah	Y	N	Y[2]	N	N
Vermont	Y	N	N	N	Y
Virginia	Y	Y[19]	N	N	Y[20]
Washington	Y	N	N	Y[10]	Y
West Virginia	Y	N	Y[2]	N	N
Wisconsin	Y	Y[21]	Y[2]	Y[10]	N
Wyoming	Y	Y[22]	N	N	N

Notes:

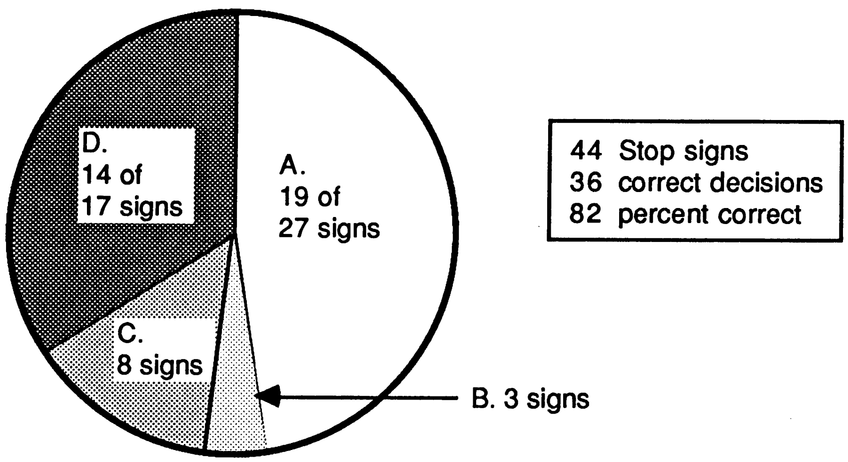
1. Policy is based on daytime and nighttime inspection frequencies
2. Use reflectometer for field checks
3. Use material patches for field checks
4. Use retro-reflectometer for training or special studies
5. Field weather deck
6. Policy is based on annual nighttime surveillance program
7. Retro-reflectometer used in maintenance and construction projects
8. Retro-reflectivity warranty for reflective sheeting
9. Policy is based on highway service levels and subjective retro-reflectivity performance
10. Formalize inspection frequency, procedure, and/or inspection criteria
11. Use remote reflectometer developed at Louisiana Technical University, 1974
12. Plan to institute a program to inventory and computerize the installation date of signs
13. Perform nighttime visual inspections
14. Field evaluation of various combinations of reflective sheeting and button copy
15. Use Q-beam (spotlight) for daytime reflectivity checks
16. More shop inspections for contract sign vendors and more reflectivity readings on construction projects
17. A study committee has proposed a maintenance standard which includes annual night inspections
18. Adding personnel and increasing sign surveillance and assigning responsibility areas to sign crews
19. Signs should be considered for replacement when the reflectivity falls below 50 percent of the original brightness
20. A level-of-service document is currently being developed
21. The color of the sign background shall be readily detectable using the upper beams as follows:

color	distance
red, yellow, white	500 feet
green, blue	300 feet
brown	no standard

22. Based on manufacturers' data and our experience



WARNING SIGNS



STOP SIGNS

LEGEND

Individual Observer	Replaced		Not Replaced	
Decision Model	Replace	Do Not Replace	Replace	Do Not Replace
	A (correct)	B (incorrect)	C (incorrect)	D (correct)

Figure ES-1. Warning and Stop Sign Replacement, Individual Observer.

CHAPTER 1
INTRODUCTION AND STUDY OBJECTIVES

INTRODUCTION

Driving at night is much more difficult than driving in daylight. A driver's visual acuity, contrast sensitivity, distance judgment, and color discrimination are all impaired by the relative darkness of the night driving environment. Accident statistics compiled by the National Safety Council for the 20 years from 1965 through 1984 indicate that 56 percent of all traffic fatalities occur at night. The fatality rate on a mileage basis for nighttime is more than three times that of daytime. A driver's night vision characteristics and lack of adequate visual guidance information are significant factors in the greater accident and fatality rates at night (1). Improvement in the nighttime guidance of the driver is likely to improve driver performance. Therefore, an effective method of periodically inspecting traffic signs is important to ensure road safety.

The majority of today's traffic signs are made with retroreflective material for nighttime legibility. As signs age or are covered with road dirt, their retroreflective decreases, accompanied by a decrease in effectiveness. The Federal Highway Administration (FHWA) is currently investigating the addition of performance standards for retroreflective traffic signs to the Manual on Uniform Traffic Control Devices (MUTCD) (2). The MUTCD at present states:

> "Regulatory and warning signs, unless excepted in the standards covering a particular sign or group of signs, shall be reflectorized or illuminated to show the same shape and color by both day and night" (3).
>
> All traffic signs should be kept in proper position, clean and legible at all times. Damaged signs should be replaced without undue delay. . . . To assure adequate maintenance, a suitable schedule for inspection, cleaning and replacement of signs should be established (4).

Agencies are responsible for establishing their own criteria and maintenance schedule for sign replacement.

The implementation of retroreflectivity standards would create a need for an accurate, reliable and cost-effective method to review traffic signs in the field. The use of observers is the most common, least complicated, fastest, and most cost-effective way to evaluate the retroreflectivity of traffic signs; however, minimal research has been done to verify the accuracy of this method. This research project was designed to assess the current methodology of traffic sign inspection and the accuracy and usefulness of using trained observers.

STUDY OBJECTIVES

This research project had two primary objectives. The first objective was to review all available literature on maintaining retroreflective traffic signs and survey all state transportation agencies to learn about the methodologies employed in making retroreflective judgments on highway signs. The second objective was to determine how accurately an observer can be trained to rate the retroreflectivity of traffic signs in a highway environment.

CHAPTER 2
LITERATURE SURVEY

In January 1986, Edward McCormack of the Washington State Transportation Center (TRAC), located on the University of Washington campus, published a paper entitled "Measuring Traffic Sign Reflectivity: A Literature Survey." The survey summarized all the available research and information on the methods used to measure traffic sign retroreflectivity. Appendix B contains his survey.

McCormack's literature survey describes three methods for examining the retroreflectivity of traffic signs:

- human observers,
- measuring instruments, and
- a combination of instruments and observers.

Human observation is probably the most widely used method for evaluating sign retroreflectivity in the field. This method is the simplest, but little evaluation on the accuracy of this technique is found in the literature.

A number of studies have evaluated the accuracy of portable measuring systems. All of the measuring systems are quite accurate in their determination of sign retroreflectivity; however, using them can be cumbersome and slow.

The study on the combination of instruments and observers was primarily concerned with the detection distance for a sign. This method required a secondary data analysis, which could become time-consuming and confusing.

In summary, McCormack found that although the use of instruments to evaluate traffic sign retroreflectivity is fairly well documented and has been shown to be accurate, instruments are seldom used for field evaluation of sign retroreflectivity because of the amount of time they require. On the other hand, the use of human observers for the field evaluation of traffic sign retroreflectivity is widespread but is of unverified accuracy. He recommended that the accuracy of a human observer be further examined.

A recent research report by Mace (5), not included in McCormack's literature survey, evaluated three methods of measuring sign performance, and two other methods were incidentally associated with the study. The following paragraphs are brief descriptions of the five methods employed.

1. **Comparison Standard**. Subjects attached a strip with four patches of reflective sheeting, each with a different brightness level, to a sign face. They then judged the closest match between the sign and the patches from a distance of 60 feet, illuminating the sign with a flashlight held next to their eyes.

2. **Electroluminescent Panel**. An electroluminescent (EL) panel was color matched to the federal specifications for yellow engineering grade sheeting and was adjustable for six levels of brightness. Sign-mounted and vehicle-mounted procedures were tested. The sign-mounted procedure was similar to the comparison standard technique described above. For the vehicle-mounted procedure the panel was mounted on the hood of the car. Both trials were from a stationary vehicle at a distance of 300 feet from the sign. The subjects sat in the car and compared the panel to one of the six panel settings.

3. **Legibility**. For this procedure, a passenger in a vehicle determined the legibility distance of the sign using a distance measuring instrument (DMI).

4. **Incidental Methods**. A Pritchard photometer (Method 4) and a Retrotech retroreflectometer (Method 5) were used to establish baseline and ground truth measures of luminance and retroreflectivity.

The results of the tests showed high correlation using either the EL panel or the test patches on the sign. With the EL panel mounted on the vehicle, the correlation dropped to 0.30. The legibility method had unaccountable errors and was not recommended.

A summary table comparing the five methods across a number of criteria was included in the report. Of the methods that proved to be accurate and consistent, the time per measurement varied from two to ten minutes for the retroreflectometer; five to ten minutes for the comparison standard; ten to 20 minutes for the EL panel; and ten to 30 minutes for the photometer. None of these methods could be economically used for large-scale sign measurement.

In another section of the research report by Mace, knowledgeable subjects drove a test route and evaluated signs, deciding whether to replace or not replace them. The subject drivers' replacement decisions were then compared to replacement decisions made by six different replacement strategies in a sign maintenance management system. The study showed excellent agreement between the test subjects' decisions and model strategies for warning signs. However, for regulatory and other signs the agreement was not as good. This portion of the study showed that knowledgeable observers are able to make replace/not-replace decisions with some accuracy with no formal training.

The Traffic Control Devices Handbook describes a method of evaluating the retroreflectivity of traffic signs based on the amount of time they are visible (legible) to the observer traveling at the speed limit:

> "Signs that are visible for two seconds, or less, should be replaced as soon as possible. Signs that are visible for three seconds are considered borderline and should be scheduled for replacement. Signs that are visible for four or more seconds are usually considered acceptable" (3).

The literature survey showed that instruments to evaluate traffic sign retroreflectivity are accurate but not used on a large scale because of the cost they required. An instrument that would be suitable to evaluate the retroreflectivity of a large inventory of signs has not been developed and may not be developed for several years. A computer-based sign management system may prove to be satisfactory, provided adequate weathering data and several other factors can be obtained. At present the use of the human observer is widespread but still of unverified accuracy. This report will begin to assess the accuracy of the trained observer.

CHAPTER 3
QUESTIONNAIRE

The study team mailed a questionnaire on May 23, 1986, to each of the 50 states, the District of Columbia and Puerto Rico. The purpose of the questionnaire was to obtain specific details of the policies and procedures used in maintaining retroreflective traffic signs. The answers to the questions might also provide information that would be useful in training observers for the experiment.

Eighty-five percent, or 44 states, responded to the questionnaire. The summarized results are based entirely on the answers received. All percents and other ratios refer to the answers on the 44 returned questionnaires.

The main findings are summarized below.

QUESTIONNAIRE SUMMARY

- Six states had written, maintained performance standards for retroreflective sheeting material:
  - **Arizona** -- signs are replaced when not adequate as determined by nighttime visibility checks
  - **Colorado** -- signs are replaced when major damage occurs, legibility is impaired by the fading of the letter message or symbol, or nighttime reflectivity is impaired
  - **Georgia** -- policy is based on performance warranty
  - **Idaho** -- policy is based on highway service levels and subjective retroreflectivity performance
  - **Virginia** -- signs are considered for replacement when reflectivity falls below 50 percent of original brightness
  - **Wyoming** -- policy is based on manufacturers' data and their own experience

- Most other states that had written or unwritten policies based their policies on how often signs should be reviewed.
- Eight states used an installation date in their sign inventories as a priority to replace signs.
- Thirty-five states put either an installation date or fabrication date on their signs.
- Most states reviewed signs for replacement at least once a year.
- Sign inspectors were responsible maintenance and traffic personnel (usually both).
- Thirty-five states used both day and night visual inspections; thirty-five states used a combination of moving and stationary vehicles.
- Retroreflectometers or material patches were only used as a supplement to visual inspection; Mississippi also used a spotlight during daylight hours.
- A few states said they were able to make some general correlations between sign face characteristics and retroreflectometer readings; most states responded no.
- One-third of the respondents washed signs with varying frequency.
- Thirty-one states did not and 13 states did have plans to modify their existing sign inspection procedures. Modifications and changes included hiring more personnel, improving record keeping, improving training, taking more retroreflectometer measurements, using material patches, decreasing or formalizing review frequencies, and formalizing inspection criteria and procedures.
- Only ten states claimed to be performing or planning research related to sign retroreflectivity in 1986. The most common research was the setting up and monitoring of field weather decks for sign material evaluation. One state was working on the development of a retroreflectometer; one state was field evaluating various combinations of sign sheeting materials for legends and backgrounds; one state was working with accelerated weathering; and another state was developing a level of service document. One state also thought that present research was adequate.

QUESTIONNAIRE DETAILS

QUESTION 1

Do you have an existing policy or retroreflective performance standard for traffic sign replacement?

Yes __15__ No __29__

If answer is yes, is your policy or standard

Written? __9__ Unwritten? __5__

Time related? __2__ Contract related? __0__

Other?______________

Describe the policy:

Out of the 44 responses only 15 states had any policy for sign replacement. The policy was written in nine states, not written in five, and one state did not say. In two states the policy is time-related and in no state is it contract-related. Some of the comments on this question included, "Signs are under constant surveillance by maintenance personnel, law enforcement officers, and others for problems."

The policy in most states was related to how often signs should be reviewed, with most replacement decisions based on subjective judgments. Two states replaced signs at about 50 percent of their new retroreflectivity, again based on subjective judgment. One state based its replacement policy on detectability distance, with different distances for different colored background. In the two states with time-related policies, the first state's policy was based on manufacturers' claims and their own experience, again using subjective judgment; the other state, Georgia, used a performance warranty for sign material with replacement values as shown in Table 3-1. Idaho maintained its signs at different service levels of subjective retroreflectivity for different levels of highways (see Table 3-2).

Table 3-1. Georgia Performance Warranty.

DEPARTMENT OF TRANSPORTATION
STATE OF GEORGIA

SUPPLEMENTAL SPECIFICATION

Modification of the Standard Specifications dated September 15, 1977

SECTION 913 – REFLECTORIZING MATERIALS

Delete 913.01 as written and substitute the following:

913.01 REFLECTIVE SHEETING: Type I – Enclosed Lens and Type II – Encapsulated Lens Sheeting:

The reflective sheeting shall be of Type I – Enlosed Lens consisting of spherical lens elements enbedded within transparent, weatherporoof plastic film having a smooth, flat outer surface, or Type II – Encapsulated Lens consisting of spherical lens elements adhered to a synthetic resin and encapsulated by a flexible, transparent, weatherproof plastic film having a smooth, flat outer surface. The sheeting shall have a protected, precoated adhesive backing and conform to one of the three levels of reflective intensity as specified by the Engineer.

A. Reflective Intensity

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M. Performance Warranty

The contractor or bidder shall transfer to the Department a performance warranty for Type I Enclosed Lens or Type II Encapsulated Lens reflective sheeting issued by the manufacturer. These warranties shall be in addition to all other certifications and/of warranties required by this specification and shall cover the full replacement cost including material and labor. Included in these warranties will be a provision that it is subject to such transfer. In addition to the above requirement the manufacturer's warranty shall provide for the following applicable requirements and statements.

Reflective sheeting processed, applied to sign blank materials, and cleaned, shall perform effectively for the number of years stated in Table V of this specification, as determined by the Department. The reflective sheeting will be considered unsatisfactory if it has deteriorated due to natural causes to the extent that: (1) the sign is ineffective for its intended purpose as defined in Article 913.01 K., or 2 (2) the average night-time reflective brightness is less than that specified in Table V.

Table 3-1. (cont.)

TABLE V EFFECTIVE PERFORMANCE LIFE

SHEETING TYPE AND COLOR			Average Minimum Candle Power per Foot Candle per Square Foot (1) at 0.2° Divergence and -4° Incidence	Effective Performance Life – Years
(FP-85 Type II Engineer Grade)				
White	Type I	Level A	35	7
Yellow	Type I	Level A	25	7
Brown	Type I	Level A	0.5	7
Orange	Type I	Level A	12	5
Red	Type I	Level A	7	7
Dark Red	Type I	Level A	7	7
Green	Type I	Level A	4	7
Blue	Type I	Level A	2	7
(FP-85 Type I)				
White	Type I	Level B	25	5
Yellow	Type I	Level B	12	5
Orange	Type I	Level B	6	3
Red	Type I	Level B	5	5
Green	Type I	Level B	3	5
Blue	Type I	Level B	2	5
(FP-85 Type III High Intensity)				
White	Type II		200	10
Yellow	Type II		132	10
Orange	Type II		56	3
Red	Type II		28	10
Green	Type II		24	10
Blue	Type II		12	10

Note (1) Candlepower measurement shall be made following sign cleaning

Table 3-2. Idaho Retroreflectivity Performance Levels.

TRAFFIC SERVICE LEVELS

The attached map identifies four Levels of Traffic Service approved for routes on the State Highway System not covered by a separate city or county maintenance agreement. These levels are based on the average daily traffic volume, accident rate, and physical features of each route. Stratifying the highway system according to these criteria will result in more efficient and effective use of limited resources.

This Directive is effective immediately with full implementation expected by January 1, 1986. Maintenance Supervisor will conduct annual reviews to ensure compliance.

	Level 1	Level 2	Level 3	Level 4
Signing	Replace signs when reflectivity/legibility is noticeably deteriorating. See Mtce Manual 5-321.	Replace signs when reflectivity/legibility is marginal. See Mtce Manual 5-321.	Replace when legibility is marginal. See Mtce Manual 5-321.	Same as Level 3

Levels of Service are intended to be minimum guidelines; they are not meant to preclude a more rigorous maintenance program. Sound engineering judgment should dictate the detailed application of this directive. Stated time limits are intended to apply to temporary repair, i.e. the use of plastic striping tape, wooden luminaire poles, porta rail, flashing signals, etc. when permanent repairs are not feasible within the given time limits.

QUESTION 2

		Yes	No
2.	Do you maintain a sign inventory?	26	18
	Does your inventory have an installation date for signs?	18	8
	Do you use the installation date as a priority to replace signs? 8	10	
	Describe any other uses your sign inventory serves in the replacement of signs:		

Twenty-six out of the 44 respondents maintained a sign inventory in all or part of their states, with 18 maintaining an installation date in the inventories (one state only kept dates on its interstate guide signs); only eight states used the installation date as an indicator for sign replacement. Most states that commented on the uses of their sign inventory used the inventory to keep track of the exact location of their signs so they could be replaced and relocated easily if missing. Some states also kept track of support types, relationship to highway and types of backing material. A few states used their inventories for budget data. One state said it was developing a sign management automated system which would have design life incorporated to predict a replacement schedule.

QUESTION 3

		Yes	No
3.	Do you put an installation date on each sign?	31	9

Thirty-one respondents put an installation date on each sign. Four states put a fabrication date on the sign.

QUESTION 4

How often do you inspect signs for possible replacement?

Year 11 Month 2 Other 22

Does your inspection include stop signs on county roads and city streets?

Yes 30 No 13

Do you also inspect signs for proper location?

Yes 37 No 6

This question uncovered a wide range of frequencies of sign review. Eleven states reviewed signs yearly and seven states reviewed signs every six months. Five states' review period varied; four states were under constant surveillance; two states reviewed signs monthly; two performed sign maintenance as needed; and one state each reviewed signs every three months, spring and fall, one to two years, and on a five-year schedule. Some states alternated day and night reviews. One state reviewed signs on a six-month schedule and also had a sign maintenance crew that completely reviewed, replaced and rechecked signs statewide, county by county, with about a three-year cycle length. Probably most states' signs are under constant surveillance from the public, law enforcement officers and maintenance personnel, and some states' replies reflected this while some states only considered formal review in their responses.

Thirty states reviewed the stop signs on county roads at their intersections with state highways and 37 checked sign location in their reviews.

QUESTION 5

Who makes the inspection determination to replace signs? Are they from a traffic engineers office (district level) __5__ or a maintenance technician (from a maintenance area) __8__ or both __31__? What are their official titles?

Title____

Title____

In five states, district traffic personnel reviewed signs for replacement; maintenance office personnel in eight states reviewed signs; and the remaining 31 responding states had both district and maintenance personnel review signs for replacement.

The titles of the sign reviewers were primarily maintenance foreman or sign supervisor and district traffic engineer. The titles indicated someone with responsibility.

QUESTION 6

What methods do you use to evaluate sign reflectivity?

Visual inspection

Daytime __4__ Nighttime __4__ Both __35__

Stationary (if so, distance) __varies__ feet

Moving vehicle __9__ (if so, how fast) __various__ mph

Combination of stationary and moving __30__

Do you supplement visual inspection with

	Yes	No
Material patches of known reflectivity?	5	39
A retroreflectometer?	17	27

If so, what manufacturer and model? ______________________________

Please describe in more detail the methods used above:

This question was aimed directly at obtaining information on the "nuts and bolts" of sign inspection methodology. Thirty-five states said that they used both day and night inspections, with four states each doing only nighttime or only daytime inspections. Thirty states used a combination of both moving and stationary vehicles, nine states used only moving inspections, and one state used only stationary inspections.

The stationary distances from the sign face to evaluate retroreflectivity varied considerably, with two states at the sign face, one state at ten feet to 100 feet, one state said 100 feet per inch of copy height, one state said 25 feet to 200 feet, two states said 200 feet, one state said various distances, and one state listed 600 feet, 300 feet, 100 feet, and five feet.

The vehicle speeds for evaluating sign retroreflectivity also varied. Ten states said they traveled at the speed limit and one state said they traveled at 85 percent of the speed limit. The speeds of the other nine states that reported speeds were mostly in the 30 to 40 mph range, with one state at 45, one at 25, one less than 20, and one state at five mph.

The second part of the question was designed to gain information on how states supplement visual inspection. Five states said they use material patches of known retroreflectivity, but only North Dakota went on to describe how they used the material plates: the material plates had 40 percent of the acceptance standard retroreflectivity, and any sign with retroreflectivity lower than that was replaced. Seventeen states owned retroreflectometers, with 15 being manufactured by Advanced Retro Technology, Inc. (formerly Gamma and Retrotech). Most states used their reflectometer for spot checks or studies, with no state claiming to use a retroreflectometer on a regular basis. Mississippi used what the respondent called a Q-beam light during daylight hours. The Q-beam was described as a 200,000 candle power light which was shone on the sign. The sign reviewer placed his or her eyes above the light, and defects or deterioration in a sign face would become evident. No observation distance was reported. A similar method of using the sun and a mirror was also uncovered in the course of the study. The accuracy of these two techniques is unknown.

QUESTION 7

---

7. What specific indicators of deterioration do you look for on a sign face?

Physical Defects		Reflectivity Defects	
All	Peeling	All	Faded colors
All	Delamination	29	Dirt
All	Cracking	All	Insufficient reflectivity
All	Vandalism	____	Other
____	Other		

Are you able to correlate sign face characteristics with reflectivity measurements? If so, describe:

This question was directed at finding out exactly what kind of deterioration sign reviewers looked for on a sign face. Almost every responding state looked for the physical defects of peeling, delamination, cracking, and vandalism. Other physical defects included bending, changes in color, and fading stencil ink.

Under the heading "Reflectivity Defects," all states looked for faded colors and insufficient retroreflectivity while, only 29 states looked for dirt (maybe not considering this a defect). Other retroreflectivity defects included cell breakdown, vapor coat fade in high intensity sheeting, and dark streaks and blotches caused by premature failure.

No state claimed it was able to correlate sign face characteristics directly with retroreflectometer readings. About half of the states did not even attempt to do so. The states that were able to make some general correlations stated that a deteriorating surface, sheeting showing contamination marks and dullness, and darkening or graying of white or yellow is frequently a sign of low retroreflectivity. One state said that users of the retroreflectometer may develop a feel for what a sign will read by visual inspection.

QUESTION 8

		Yes	No
8.	Is washing signs part of your maintenance program?	16	28
	How often do you wash signs? _8_ year ____ month		
	Is washing done before inspection?	1	15
	If you do not wash signs, do you feel the environmental factors (rain) are able to keep the sign face clean enough? _17_	10	

In response to this question 16 states said they wash signs. Six states washed signs as necessary, eight states washed signs yearly, one state's washing frequency varied, and one state washed signs every two years. In one state washing was done as an interstate summer job. Only one state said it washed signs before inspections. Seventeen states did and ten states did not believe that environmental factors kept signs clean enough. One state said its climate is conducive to clean signs.

QUESTION 9

---

9. Do you have any plans to modify your existing sign inspection procedures? If so, what are they?

Thirteen states had plans to modify their existing sign inspection procedures by

Arizona -- developing its own retroreflectometer

Colorado -- implementing new sign maintenance management program

Georgia -- using a retroreflectometer and material patches more frequently

Kansas -- increasing the frequency of sign inspections

Louisiana -- using a remote retroreflectometer developed at Louisiana Technical University in December 1974 by Tom Williams, Professor of Electrical Engineering, for the Louisiana Department of Highways in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

Maine -- instituting a program to inventory and computerize the installation date of signs

Massachusetts -- performing nighttime visual inspections

New Mexico -- conducting more shop inspections for contract sign vendors and more reflectivity readings on contract projects

North Carolina -- conducting annual nighttime inspections

Rhode Island -- adding personnel, increasing sign surveillance and assigning responsibility areas to sign crews

South Dakota -- using a retroreflectometer to supplement visual inspections

Washington -- formalizing frequency and inspection criteria to assure consistency

Wisconsin -- giving better advice to district crews on what signs of deterioration to look for on a sign face and requiring a log of inspection activity

QUESTION 10

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10. Is your state currently performing or planning future research related to sign reflectivity? If so, please describe:

Ten states were performing or planning future research related to sign reflectivity:

- Arizona --developing its own retroreflectometer
- Colorado, Connecticut, Kentucky, North Carolina, and South Dakota -- planning field weather decks
- Massachusetts -- performing a field evaluation of various combinations of reflective sheeting and/or button copy
- Vermont -- studying retroreflective sheeting material on signs and other traffic control devices under FHWA Category II
- Virginia -- developing a level-of-service document
- Washington -- conducting this study

QUESTION 11

---

11. Please list any other comments you may have related to sign replacement.

This question was a catch-all question that produced many unrelated responses. The responses are listed below by state.

Alabama. "It is felt that signs that perform and are in compliance with the Alabama MUTCD is an importance function of the department."

Arizona. "Most of our replacements for retroreflectivity are in groups due to similar installation dates. We have developed techniques which help us perform these tasks (especially on large signs) more efficiently."

California. "Caltrans believes our current policy of review by experienced, dedicated personnel is more than adequate."

Georgia. "Need small, cheap pocket retroreflectometer."

Iowa. "We try to maintain our signs in relatively good condition to avoid tort liability problems and for respect by motorists."

Mississippi. "Sign replacement on routes other than interstate is under the jurisdiction of the districts. Statewide interstate sign maintenance and replacement is under the traffic control safety division."

Nebraska. "I feel that signs should be replaced as they reach a pre-determined life. The pre-determined life should be determined by past test experience. For example, seven to eight years for engineering grade and ten to 12 years for high intensity. Special problems would be caught by monthly visual inspection."

New Jersey. "Old aluminum signs are returned to central sign shop and shipped to a vendor who reclaims the aluminum blank. Reclaimed signs are used to fabricate new signs."

New Mexico. "We have an active problem of overlaying (refurbishing) large guide signs in the field."

North Dakota. "Signs are replaced when districts observe signs that they feel are not reflective, vandalized, or have been struck by vehicles and damaged sign facing."

Ohio. "We are currently considering various methods of overlay and full sign replacement."

Oklahoma. "We also have a sign maintenance crew that completely reviews, replaces, and rechecks all signs within a county, one county at a time. At this time, the amount of time lapse from one scheduled maintenance review to the next is about three years."

Rhode Island. "We are currently using federal funds to pay for "knockdowns" as damage to safety hardware, we plan to expand our program for upgrading on a system/project basis."

Texas. "Generally there are insufficient maintenance funds available to replace signs."

Washington. "We believe it is imperative to develop an acceptable method of visually inspecting signs without instrument measurements.

Wisconsin. "Sign replacement for small signs is on an as-needed basis. More liberal replacement of large guide signs resulting in group replacement is developing due to economics in contracting, etc."

QUESTION 12

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12. Would you please send a copy of your state's response to the ten questions formulated by the FHWA concerning the retroreflective performance of traffic control devices (FHWA Docket No. 85-18)?

Nineteen states sent copies of their responses to the FHWA's ten questions. In addition to the states' responses, copies of the replies of several organizations and committees were obtained. The organizations and committees were the following:

1. National Safety Council Response to Advance Notice of Proposal Amendments to the Manual on Uniform Traffic Control Devices, December 23, 1986;
2. National Committee on Uniform Traffic Control Devices Task Force Report, January 8, 1986. This report includes the written responses from an ITE circulation of the Federal Register notice and also the Hearing Record of an ITE hearing, held on August 21, 1985, as a part of the 55th ITE annual meeting in New Orleans. The report also includes the results of a survey, of the 50 states, circulating the same ten questions among its membership;
3. National Committee on Uniform Traffic Control Devices Task Force Report on Retroreflectivity, Advisory Ballot Summary, April 9, 1986.

The responses to the FHWA's questions are summarized as follows:

- Most states felt that maintained standards or guidelines are needed for retroreflectivity of traffic control devices.
- Research to correlate drivers' needs and retroreflectivity requirements is necessary.
- No practical method of traffic sign retroreflectivity measurement exists for a large sign inventory.

- Research is needed to develop a practical instrument to measure retroreflectivity before standards are implemented.
- The cost-effectiveness of standards is unknown.

<u>QUESTION 13</u>

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13. If you would like a copy of the completed report, please check (__). Send report to the following:

Name____

Title____

Mailing Address

____

____

____

Forty-two states requested copies of the finished report.

CHAPTER 4
METHODOLOGY

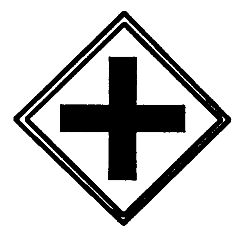
EXPERIMENTAL DESIGN

The primary objective of this research was to assess the accuracy of a human observer in determining levels of highway sign retroreflectivity in a highway environment. To accomplish this goal a series of experiments were conducted using impartial observers to rate the retroreflectivity of traffic signs. The results were then analyzed.

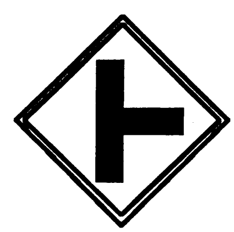
Traffic signs come in a variety of colors and sizes depending on what message the sign is to convey to the motorist. Signs fall into two categories depending on how they are made. A sign can have a legend and background of reflective material, or reflective background and a non-reflective legend.

Traffic signs also vary in how critical they are to the motorist, depending upon the consequences to the motorist of not responding to the signs' messages. Not stopping at a stop sign could result in serious injury while not responding to a "do not litter" sign could result in a fine, but would not be a life and death mistake.

Stop Sign (R1-1)



Cross Road Sign (W2-1)



Side Road Sign (W2-2)

Figure 4-1. Laboratory and Controlled Highway Experiment Signs.

To have evaluated all colors and combinations of colors would have been time consuming and somewhat repetitive. Therefore, two types of signs were selected for the experiments: the stop sign and the warning sign (see Figure 4-1). These sign types are of high relative importance; they are commonly used, so an adequate supply could be obtained for the experiments; and they are of both sign types, some having a reflective legend and background and others have a non-reflective legend. If observers could be trained to distinguish levels of retroreflectivity for these sign types they could probably be trained for the other colors.

Sign reflectivity experiments were performed under three conditions. The first set of experiments took place in Edmundson Pavilion at the University of Washington. The second set took place outdoors on the University of Washington campus under controlled highway conditions. The third set took place in two parts on state highways under actual highway conditions. All experiments were done in darkness.

Laboratory Experiment

The laboratory experiment in Edmundson Pavilion (see Figure 4-2) was set up to minimize variables by controlling ambient light, geometrics and other environmental conditions. Observers sat in chairs with their eye height at the design driver's eye height of 3.5 feet (7). Two seven-inch-diameter, sealed beam headlights were placed in front of them to simulate the relationship between the driver's eyes and an automobile's headlights. The headlights were aligned similarly to automobile headlights in accordance with the Society of Automotive Engineers' (SAE) specifications. Signs of known retroreflectivity were placed on a sign post with the bottom of the sign at seven feet. Observers marked their judgments on rating sheets using a small flashlight to see. The experiment simulated a car parked on the shoulder with the driver observing the sign. The offset distance from the right headlight to the sign post was eight feet. Two observation distances, 100 and 200 feet, were evaluated. The size of the laboratory limited the observation distance to a maximum of 200 feet.

The observers were divided into four groups for the laboratory experiment. Groups met either Monday-Wednesday or Tuesday-Thursday at 9:00pm-11:00pm or 10:00pm-12:00am. Each group

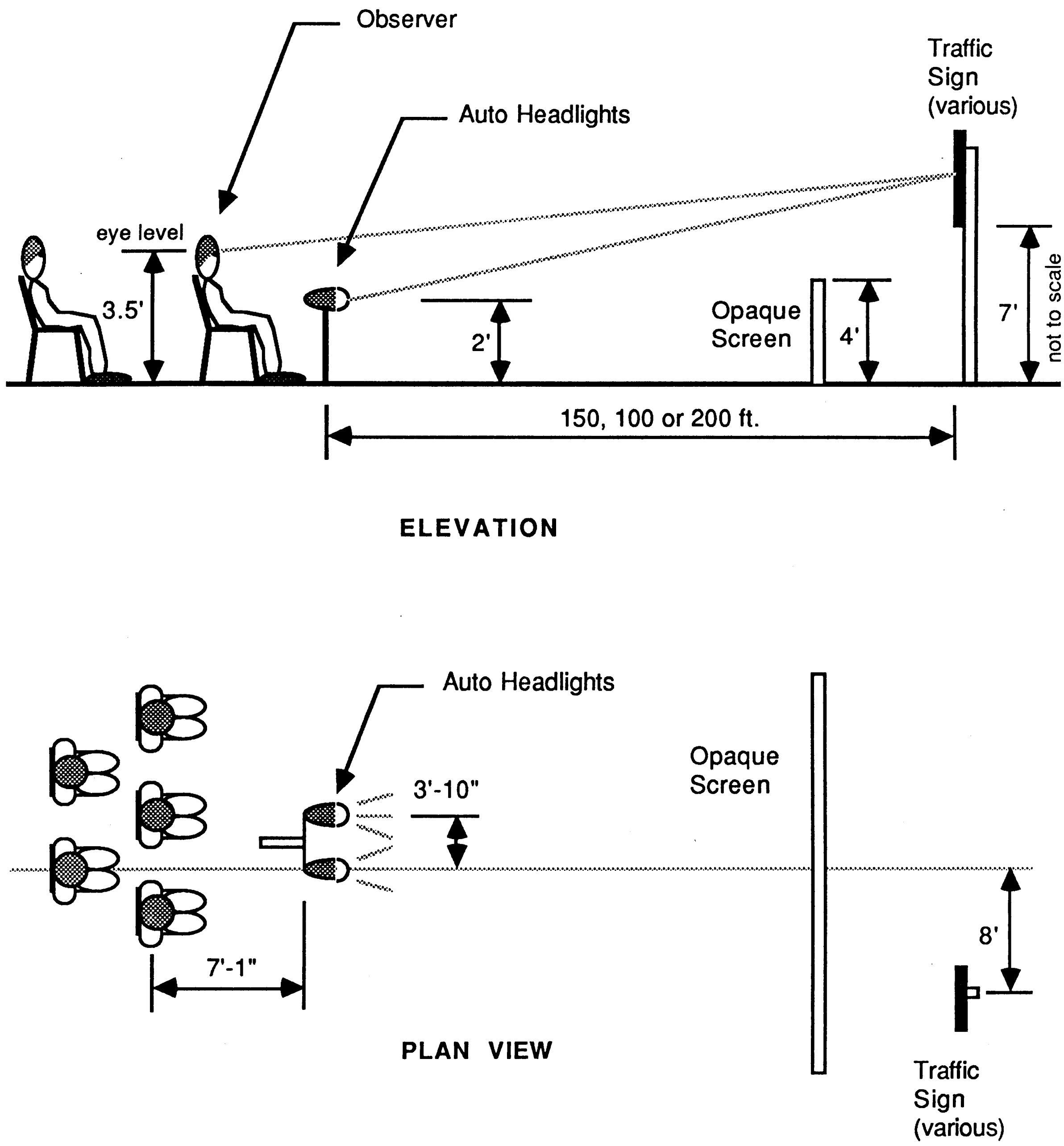


Figure 4-2. Laboratory Experiment.

participated in three sessions in the laboratory. The first two sessions were at an observation distance of 150 feet. The third session consisted of 50 observations at 100 feet and 50 observations at 200 feet.

Controlled Highway Experiment

The controlled highway experiment on the campus (see Figure 4-3) was performed similarly to the lab tests. Observers for this test sat in a stationary automobile on approximately level ground and used the same method of recording the sign ratings. The same set of signs used in the laboratory experiment were used again. The signs were observed at three distances: 100, 200, and 300 feet. The offset distance from the side of the car to the sign post was eight feet. The experiment simulated highway conditions, including ambient light, geometrics and viewing through the windshield. The same groups also observed signs in three sessions for the controlled highway experiment. In the first session, subjects observed at distances of 100 feet and 200 feet. Subjects observed from distances of 200 feet and 300 feet in the second and third sessions. Forty sign observations were made from each distance.

The controlled highway experiments were done when it was not raining. The controlled highway experiments were logistically more difficult than the laboratory experiments. The sky was not dark enough to begin observations until 9:45pm, limiting the time available. The wind, combined with the observers being inside the vehicles, made communication difficult.

Highway Experiment

The highway experiment (see Figure 4-4) was conducted on parts of three state highways under rural (SR 900 and SR 901) and urban (SR 522) conditions. The highway sections were selected for convenience and it is not known if they represent typical highways. Observers were driven along the highways and evaluated signs from moving and stationary vehicles.

The rural course consisted of two types of highway. The beginning and end was a two-lane arterial through a residential area with street lights on power poles spaced unevenly at about 500 feet apart. The middle portion of the course was a rural arterial which was totally dark except for one intersection and one sign at the turn-around point, which were in areas illuminated by street lights.

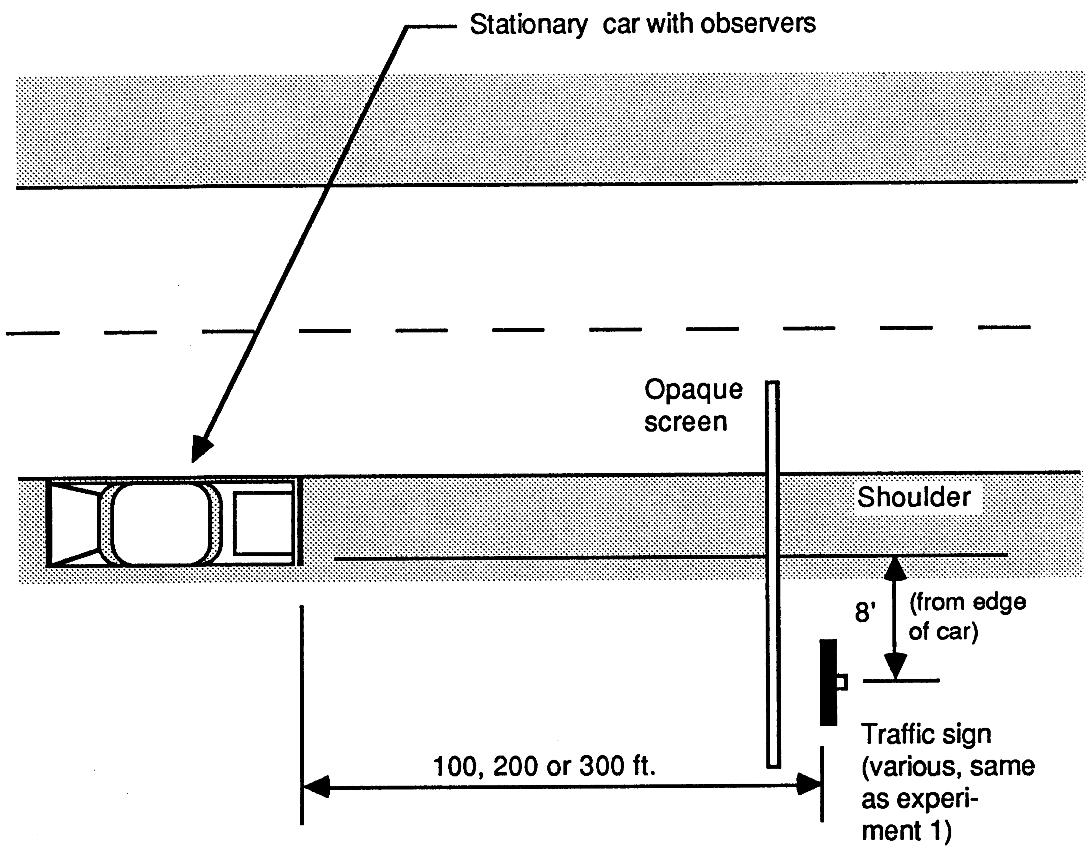


Figure 4-3. Controlled Highway Experiment.

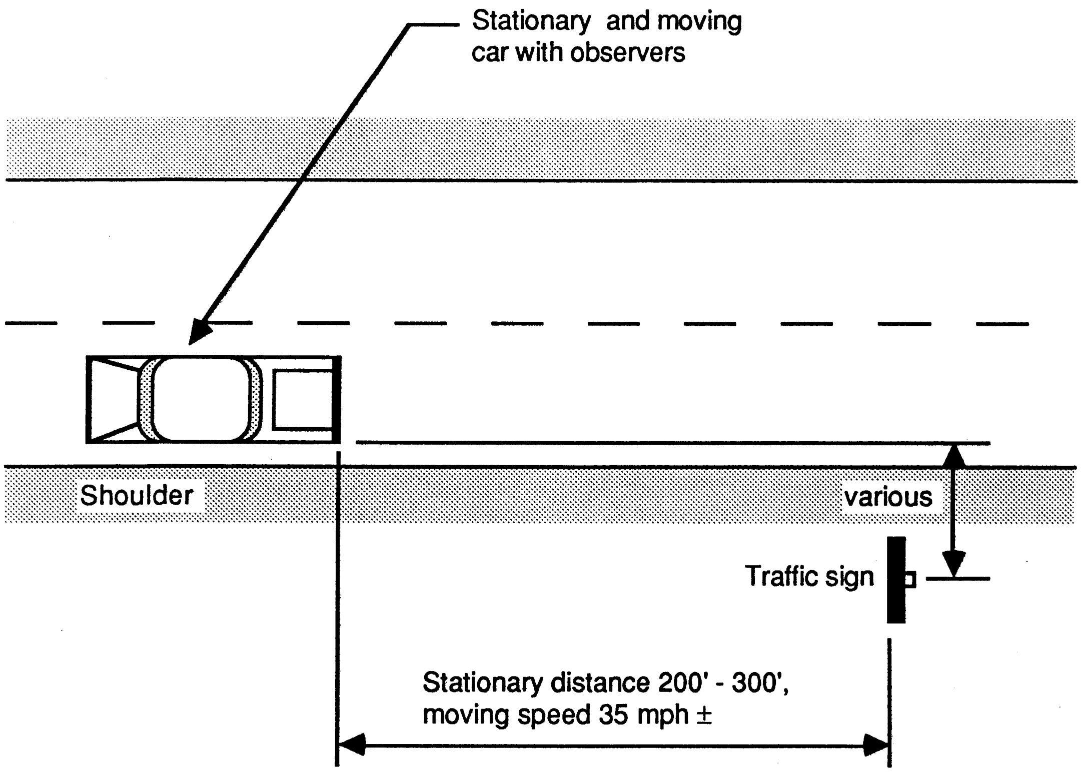


Figure 4-4. Highway Experiment.

The urban course was primarily on a four-lane, undivided urban arterial. The course went through areas of commercial development but also included some sections that were undeveloped and dark. The turn-around point and the few signs on either side of this point were on a four-lane, divided highway (freeway).

During the experiments, a driver and three observers rode in a car. Each observer had a clipboard with a rating sheet, a small flashlight and a writing instrument. In one direction, the driver stopped the vehicle approximately 200 to 300 feet from the warning signs, trying to duplicate the controlled highway relationship between the car and sign. In the return direction the vehicles were driven past the warning signs at the speed limit or about 35 miles per hour, whichever speed was slower. The stop signs on county roads and city streets intersecting the state highways were evaluated using the same method for both directions. The controlled highway relationship was duplicated as best as possible considering roadway geometrics and other factors. Evaluating stop signs from a moving vehicle was not possible as the vehicle had to stop at the sign.

The method of using the same observers on the same night to evaluate signs from a stationary and a moving vehicle minimized the experimental variables, including ambient light conditions, observer inconsistency from one day to the next, automobile headlight differences and any other factors. Both of the highway courses had numerous directional changes so that observations were in all directions for both the stationary and moving vehicle portions.

The highway experiments were done under good weather conditions.

SIGN RETROREFLECTIVITY SCALE

The objective of the experiments was to determine if a human observer could be trained to accurately rate traffic sign retroreflectivity. During the training period a series of signs were shown to the observers and they rated them based on a retroreflectivity scale. The literature included various studies in which observers rated background complexity, determined legibility distances, observation distances and other sign-related observations. However, all studies were from a driver's perspective of a sign. This study was from a trained maintenance person's or traffic engineer's perspective, and for this reason a retroreflectivity scale for use in sign maintenance had to be developed.

The study team considered two alternative ways for the observers to rate sign retroreflectivity. The first alternative was to establish an arbitrary level of acceptable retroreflectivity. Observers would then either reject or accept signs. The main concern with this method was the establishment of an acceptable level of retroreflectivity, which would probably have differed from any level adopted in the future. An acceptable level of retroreflectivity adopted in the future might have also varied by sign and situation. The difference in acceptable retroreflectivity levels would have cast some doubt on the results.

The second alternative was to establish categories of retroreflectivity and have observers rate signs into these categories. This method was selected because it would allow for some variability in maintained retroreflectivity standards and also it would show how well observers could rate signs into categories based on retroreflectivity levels. Essentially, the experiment would entail calibrating the observers to a retroreflectometer.

According to Fincham, "The eye is uncapable of making an absolute measurement of the amount of light entering it; the eye can look at two sources and estimate that one appears 'brighter' than the other if there is sufficient difference between them, but cannot form a reliable judgment as to by how much they differ" (8). For this reason the rating categories were fairly large. The research team decided that a scale of five categories was enough; observers rated signs on a scale from 0 to 4.

The scale was described to the observers as 0 being the worst a sign could be and 4 being a brand new sign. Category 1 signs were described as having low retroreflectivity or some other defect that would make the sign ready for replacement. Category 2 signs were described as signs which had an "adequate" amount of retroreflectivity and looked ok. They might also have some defects but not defects detrimental to the function of the sign. A Category 3 sign was described as a sign that had good retroreflectivity. The scale actually was three categories with the 0 and 4 classifications for the exceptionally bad or good signs, respectively.

Warning Signs

A sign retroreflectivity scale for warning signs was established based on the minimum and maximum retroreflectometer readings for yellow engineer grade reflective sheeting and a study by Mace (9). The boundaries between the five categories of the 0-4 scale were established in the following manner. The boundary between 0 and 1 was set at a specific intensity per unit area (SIA) value of 6 candelas per square per foot-candle (cd/ft^2/fc). All the signs below this level looked extremely dark. The boundary between 1 and 2 was set at an SIA value of 18 based on the Mace findings that signs degraded to this value provided adequate luminance for low complexity sites. The boundary between 2 and 3 was established at SIA 36, based on the Mace finding that this value provided adequate recognition distance for speeds below 35 mph. The boundary between 3 and 4 was set at SIA 70, based on the reasoning that all the warning signs the study team had measured with SIAs above this value were new. The federal acceptance level of SIA 50 for new engineer grade yellow sheeting falls in the middle of Category 3.

This report does not address high intensity or super engineer grade yellow sheeting because WSDOT does not use these types of sheeting material.

Stop Signs

The rating scale for stop signs was established based on the SIA of the legend and the internal contrast of the sign. Stop signs are made of one of three types of reflective sheeting: Type II, IIB and III. The federal specification FP-85, in section 635, "Temporary Traffic Control" (page 565) (10), allows the different types of sheeting to degrade to 75 percent for Type II, 50 percent for Type IIB, and 50 percent for Type III of the acceptance level for new material. Because of this, two separate scales were set up (however, as it turned out observers could not tell what type of sheeting the signs were made of, so in reality rating was done on one scale). Sivak and Olson (11) summarized several studies on sign luminance and concluded that the recommended optimal legend-background contrast for signs to be 12:1.

Retroreflectivity for the Type III, silver-gray, high intensity sheeting used in stop signs varies from an SIA over 250 for a new sign to 0 for a completely "dead" stop sign. This range was divided into equal parts of 50 SIA, setting the boundary between 1 and 2 at an SIA of 125 or 50 percent of the acceptance level, the boundaries between 2 and 3 and 3 and 4 50 and 100 SIA higher, and the boundary between 0 and 1 50 SIA lower. U-shaped curves were drawn with the bottom of the U at these boundary levels and centered on a white/red ratio of 12:1. The width of the bottom of the U was first based on judgment and later in the study on observer feedback. Figure 4-5 shows the rating scale for Type III sheeting.

A similar scale was set up for combining both Type II, engineer, and Type IIA, super engineer, grade stop signs. The retroreflectivity for this scale varied from above the acceptance level of 150 SIA for the super engineer grade to 0 SIA for a worn-out stop sign. The highest rating for a super engineer grade stop sign was only three, because a new, super engineer grade stop sign had a white SIA value considerably lower than that of a high intensity stop sign. The scale was then set up in increments of 50 SIA, with the boundary between 1 and 2 at 75 SIA and the boundaries between 2 and 3 and 1 and 0 above and below. Figure 4-6 shows the rating scale for Type II and Type IIA sheeting.

SIGNS

Collection

To conduct the laboratory and controlled highway experiments, a collection of signs representing the range of retroreflectivity were needed. The signs were obtained from the Washington State Department of Transportation's District 1 office in Seattle. The used sign "pile" was picked through, and all signs with potential for testing were sorted and measured. These signs were primarily of low retroreflectivity (they were worn out). New signs, with high retroreflectivity, were obtained from the WSDOT sign shop in Yakima through District 1. Signs with midrange retroreflectivity levels were still in service along the highways. To obtain midrange signs, the study team measured signs along state highways 202, 900, and 901 near Issaquah, Washington, and had the signs needed for the experiment taken down. These were rural, two-lane highways and the study team's measuring activity was relatively

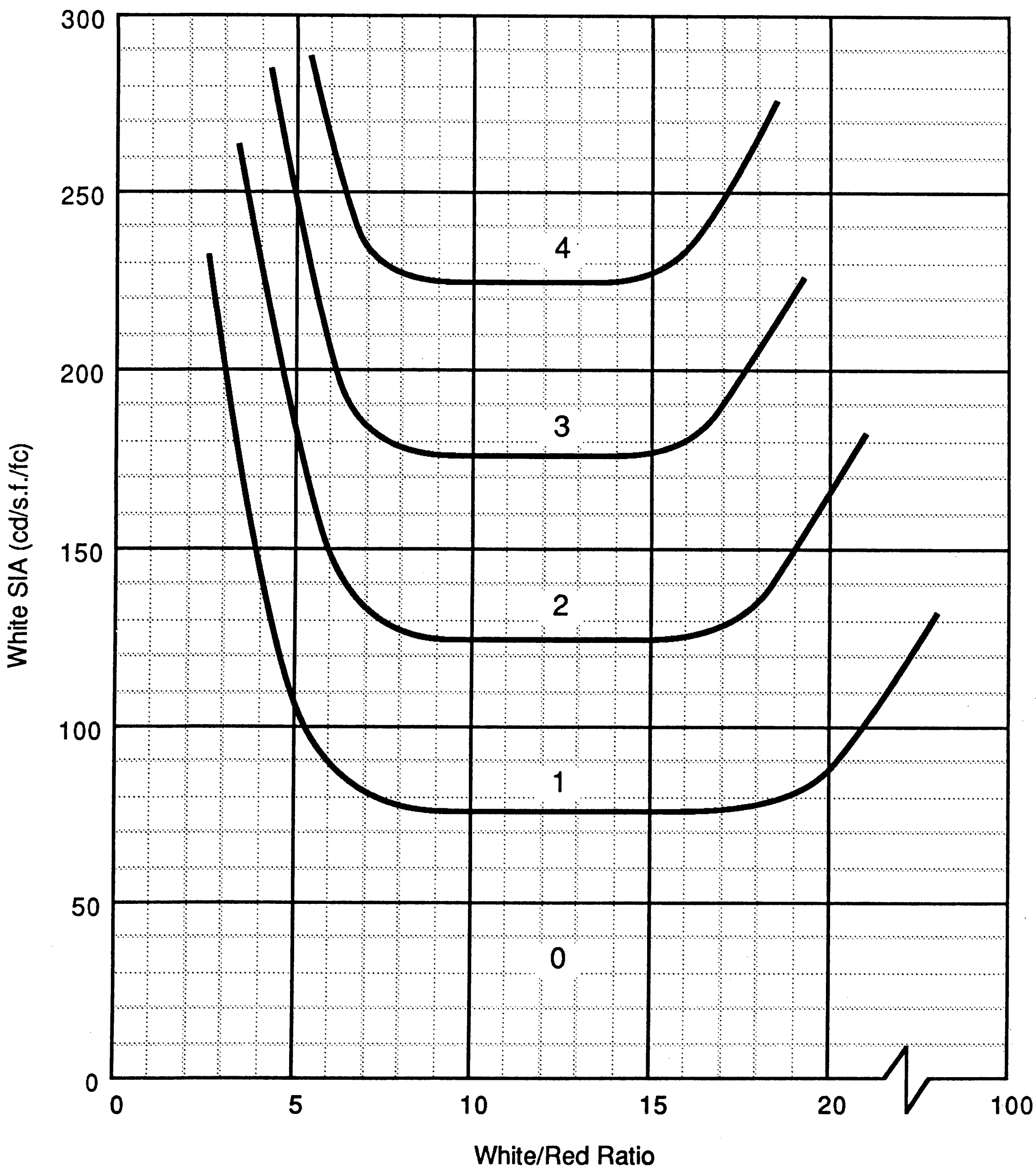


Figure 4-5. Stop Sign Rating Scale – High Intensity Sheeting.

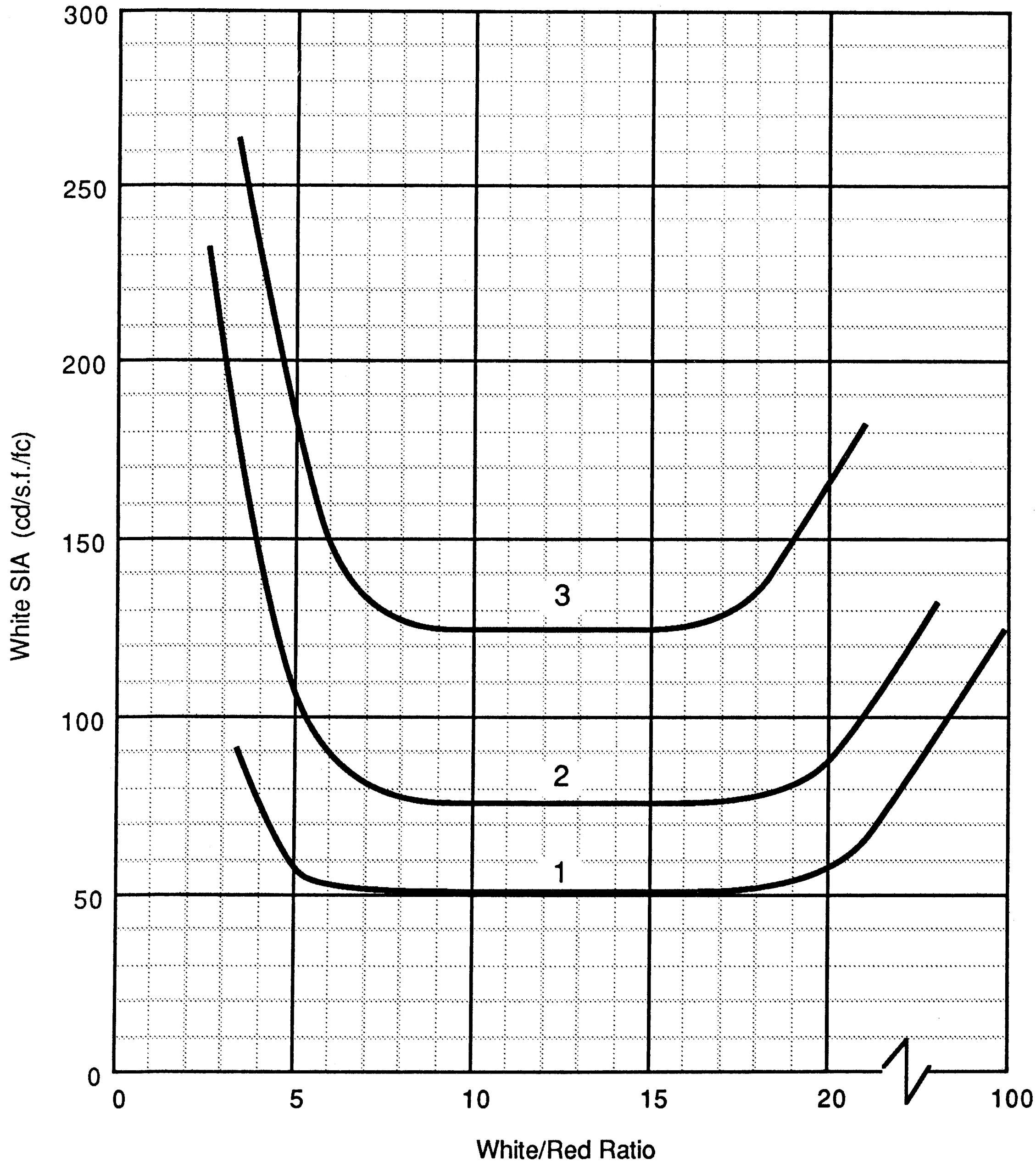


Figure 4-6. Stop Sign Rating Scale – Engineer and Super Engineer Sheeting.

safe. The signs were not too large (primarily 30" by 30"), and there were enough signs to select examples throughout the range of retroreflectivity. These highways were also the closest state highways on which signs were under state instead of city jurisdiction.

Appendix D contains a list of all the warning and stop signs used in the laboratory and controlled highway experiments. The collection of signs selected for the retroreflectivity experiments had a uniformly degraded retroreflectivity and as few defects as possible. The collection was hand picked and for this reason somewhat different than what would normally be found on the highway. In other words, this was a rare collection of signs because they had not been excessively bent, shot up, painted or otherwise vandalized and were cleaned so that observers would be rating solely their retroreflectivity.

The signs used in the highway experiments were signs that were in place on the highways. Appendix D contains a list of all the signs and their environmental conditions. On the rural course some signs were partially cleaned, and one warning sign was discarded for this reason. Six stop signs and one warning sign on the rural course were replaced with new signs to obtain signs for the laboratory and controlled highway experiments. One stop sign was totally obscured by brush and was discarded.

<u>Measurement</u>

The sign retroreflectivity measurements were accomplished with a Model 910F Retro Tech reflectometer that was on loan from the Washington State Department of Transportation Materials Laboratory in Tumwater. The model 910F conforms to ASTM, GSA and FHWA requirements. The observation angle, the angle between the light source and observation point, was 0.2 degrees. The entrance angle, the angle between the perpendicular line to the sign face and light source, was -4 degrees as in FP-85, the WSDOT standard specifications and other state specifications. The optical head was mounted on an extendable pole to allow the study team to measure signs up to 14 feet from the ground. The optical head was placed directly against the sign face so ambient light was blocked out and readings could be taken under any light condition. An individual reading took about five seconds.

The retroreflectivity over a sign face is dependent on many variables, such as the sign's manufacture, location, environment and posted direction. To account for this variability, five

$$ORU = \frac{\sum_{j=1}^{NC} \sqrt{\sum_{i=1}^{n} (X_A - X_O)^2}}{NC}$$

where NC = number of categories in which signs were observed

X_A = actual sign rating

X_O = observer sign rating

n = number of signs observed in a category

The difference between the actual sign rating, X_A, and the observer sign rating, X_O, varied between zero and a maximum of four for the 0 and 4 categories; zero and three for Categories 2 and 3; and zero and two for Category 2. The scale was set up so that if an observer correctly rated all the signs in every category his or her ORU was zero; if an observer incorrectly rated all the signs in every category by the maximum possible amount, his or her ORU was 3.2 for the five warning and stop sign categories. The ORU for each observer varied between these limits. If an observer rated all signs in all categories by one rating off his or her ORU was one.

The ORU for all of the observers at every session was calculated and plotted on a graph (see Figure 5-1). Figure 5-1 shows a dot for each observer's ORU, along with the mean and standard deviation of the ORUs for each session. The observation distance as well as whether the car was moving or stationary for rating the warning signs in the highway experiment is also listed.

The improvement of the observers can be seen from left to right, starting with the laboratory experiment then the controlled highway experiment and finally the highway experiment. As the figure shows, the observers did not dramatically improve throughout the experiments. The mean and standard deviation of the ORUs exhibited a general downward trend for the laboratory and controlled highway experiments. This trend indicated an increase in accuracy and consistency for the observers. However, some of the signs had recognizable defects, and some improvement could be attributed to the observer's

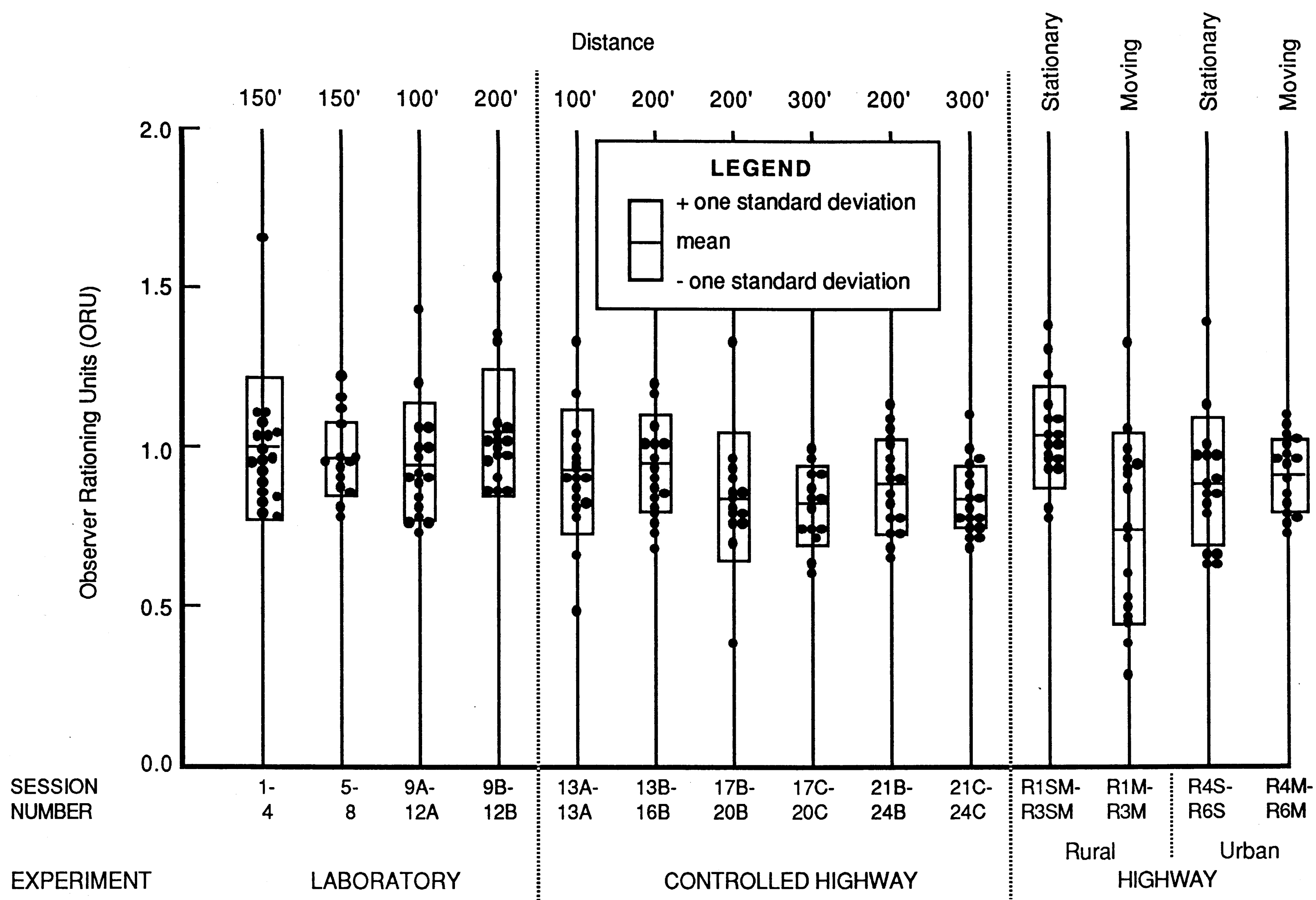


Figure 5-1. Observer Accuracy.

familiarization with the signs. Some observer boredom was also evident towards the end of the controlled highway experiment, which could also have affected the results.

The ORU mean was fairly constant through the laboratory experiments at about 1.0, decreasing to 0.85 for the last two controlled highway experiments.

The ranking order of the observers was analyzed to try and determine if some observers were consistently better than others. No consistency could be determined. The observers reached their optimum accuracy after two or three sessions and further improvement was not possible. Another factor to be considered is uncertainty near division lines. In other words, because the division lines between the categories had to be set at some point, signs that rated a 2 might have been close to rating either a 1 or a 3.

The final analysis of the observers also shows that the ORU mean and standard deviation did not change much between the controlled highway and the highway experiments considering any of the 200 or 300 foot distances or the stationary or moving observations. The standard deviation was high for one road session but the mean was the lowest. Observers in this session seemed to be separated into two groups. One group was average, with respect to the other sessions, while one group was much better than average.

Traffic signs at night should be visible to all drivers. The amount of light required to see at the same level of brightness increases with age. For this reason some researchers have suggested that older people, or even people with poor vision, should review signs for replacement. This factor was not addressed in this study; the oldest observer in the study was only 43 years old. Based on the ORUs in Figure 5-1 it does appear that the observers base their decisions on the relative amount of luminance to their eye. If acceptable levels of retroreflectivity for older drivers were established through studies it is possible that people with good vision could be trained to distinguish those retroreflectivity levels.

HIGHWAY EXPERIMENT ANALYSIS

The major objective of this study was to determine how well a trained observer can evaluate warning and stop sign retroreflectivity under highway conditions based on judgments made with available luminance (the headlights illuminating the sign are considered to be a constant). The experiments in the laboratory and on the controlled highway were simply the training ground for the observers. Observers in these experiments rated signs under conditions that were ideal. The distances, geometrics and ambient light conditions, as well as the signs, were all controlled and as consistent as possible. In the highway experiments all of these factors varied from one sign location to the next. Observers used their training under actual highway conditions.

The primary results of the highway experiments were the comparisons of the observers rating of the signs and the rating of the signs calculated by using the retroreflectometer. The observers' and the retroreflectometer ratings were then incorporated into a decision model to replace or not replace the sign, based on the Mace criteria for warning signs and the FP-85 criteria for stop signs. The replacement retroreflectivity level for both types of signs was based on visual complexity for each sign location. Signs would be replaced if a sign on a rural road with dark conditions rated a 1 and if a sign in an area illuminated by street lights and/or commercial lights rated a 2. A sign with a rating of 3 would remain in place under all conditions. The use of these criteria essentially reduced the scale from one of five categories to only three. The 0 and 4 ratings became special cases of the 1 and 3 ratings, respectively. The 0 and 4 ratings were valuable in the training period to show observers how bad or good a sign could be.

The 17 observers rated the signs on the two road courses using the 0-4 rating scale. To obtain one value to be used in the decision to either replace or not replace a sign, the median judgment of the observers was used. Tracing the observers' accuracy in Figure 5-1 reveals that the observers' ORU remained in a group, with the observers' order changing within the group. The median judgment of the observers then represented the most likely rating a trained observer would give a sign. The consistency of the observers would be represented by the frequency distribution of the observers' observations for each sign category.

The observer median rating combined with the replacement criteria discussed earlier in Chapter 4 in the section "Sign Retroreflectivity Scale" resulted in one of four possible decisions. The observers' decision to replace or not replace a sign either agreed or disagreed with the decision model to replace or not replace the sign based on the true retroreflectometer rating of the sign. Two of the four decisions would have been correct -- the observers could have replaced the sign in agreement with the decision model or they could have let the sign remain in place in agreement with the decision model. The two incorrect decisions by the observers would have had differing consequences. A decision by the observers not to replace a sign that was scheduled for replacement by the decision model would have created an unsafe condition for the driver and increased liability for the agency. The decision to replace a sign unnecessarily would have created an additional expense for the highway agency.

The rural highway experiment contained 76 signs. Of the 56 warning signs, 13 were correctly replaced, 32 were correctly left in place, nine signs (of which five signs had defects) were replaced that should not have been replaced, and two signs were not replaced that should have been replaced. Of the 20 stop signs, seven were replaced correctly, nine were correctly left in place, two (both had defects) were replaced that should not have been replaced, and two were not replaced that should have been replaced.

In the urban highway experiment a total of 54 signs were rated, 30 warning and 24 stop signs. Nine of the warning signs were correctly replaced, 13 were correctly left in place, six signs were replaced that should not have been replaced and two signs were not replaced that should have been replaced. Of the 24 stop signs rated, 14 were replaced correctly and six were left in place correctly, no signs were replaced that should not have been and four signs were not replaced that should have been replaced.

Table 5-1 summarizes the decisions of the observers and the decision model for the highway experiments. The table is broken down by warning and stop signs as well as by rural and urban experiments. The table shows that of the 130 signs in the highway experiment, the observers' median ratings and the decision model were in agreement on 103 signs or 79 percent of the total. Seventeen signs (15 warning and two stop) were replaced that should have remained in place. Of these signs, ten had noticeable defects including dirt, dents, bends and one sign face had also been "reconditioned." These signs represented the percentage of signs that are replaced before their service life for reasons

Table 5-1. Highway Experiment Results.

Observers Decision	Replace		Do Not Replace	
Decision Model	Replace	Do Not Replace	Replace	Do Not Replace
<u>Warning Signs</u>				
Rural				
Number of Signs	15	0	0	41
Median	13	9	2	32
Individual	13	10	2	31
Urban				
Number of Signs	11	0	0	19
Median	9	6	2	13
Individual	8	7	3	12
Total Number of Signs	26	0	0	60
Median	22	15	4	45
Individual	21	17	5	43
<u>Stop Signs</u>				
Rural				
Number of Signs	9	0	0	11
Median	7	2	2	9
Individual	6	2	3	9
Urban				
Number of Signs	18	0	0	6
Median	14	0	4	6
Individual	13	1	5	5
Total Number of Signs	27	0	0	17
Median	21	2	6	15
Individual	19	3	8	14
<u>Combined</u>				
Total Number of Signs	53	0	0	77
Median	43	17	10	60
Individual	40	20	13	57

other than insufficient retroreflectivity. Ten signs (four warning and six stop) were not replaced when they should have been replaced. Of these signs, two warning signs' retroreflectivity was near the top of their categories and was rated in the next higher category and not replaced.

The median judgment of the 17 observers, while representing the most likely rating a trained observer would give a sign, does not represent the accuracy of a single observer rating the series of signs. The accuracy of the observers varied within the group. An observer may have rated one sign low and the next high. This inconsistency among observers was averaged in the median decision. In actual practice, agencies would use one or two observers to make sign replacement decisions. For this reason the accuracy of the single observer was also investigated. Table 5-1 also lists the average sign replacement decisions for the 17 observers in each of the four possible rating decision categories. The observers as individuals were in agreement with the decision model on 97 of the 130 signs or were correct on 75 percent of the signs. The trained observer as an individual is only slightly less accurate than the group.

Figures 5-2, 5-3, and 5-4 were constructed to determine at what levels of retroreflectivity signs were being replaced in the highway experiments. In Figure 5-2, the range of retroreflectivity for the warning signs is broken down into sub-categories within the limits of each rating category. The figure is also separated into two graphs for the two different replacement levels. The number of signs in each sub-category is shown as well as how many signs in each sub-category were replaced. The graphs show that of the 17 warning signs in the 0 and 1 categories (SIA below 18), at the two replacement levels, 16 signs (94 percent) were replaced. The observers were very accurate in replacing warning signs at this level. Thirteen (76 percent) of the 17 signs scheduled for replacement in the 2 category were replaced. The graphs also show the unnecessary replacements. At replacement level 1 six unnecessary sign replacements are scattered throughout the remainder of the scale. At replacement level 2, nine unnecessary sign replacements are distributed throughout the three and four range. This shows that when a sign is to be replaced at level 2, more signs will be replaced unnecessarily. Category 2 is a catch-all category in which the "O.K." signs are rated. Dirt, sign defects and poor geometry contribute heavily to good signs being rated lower.

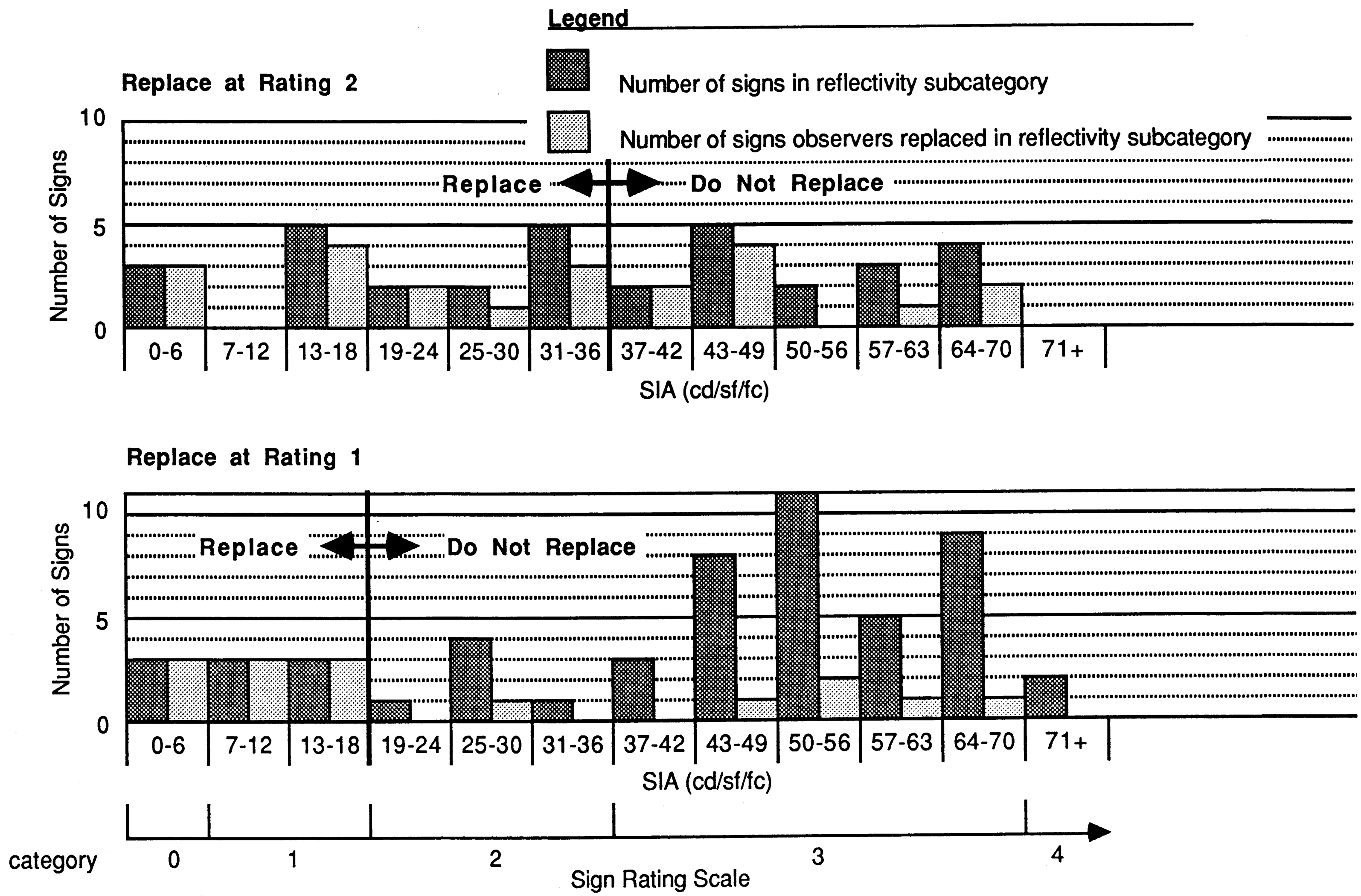
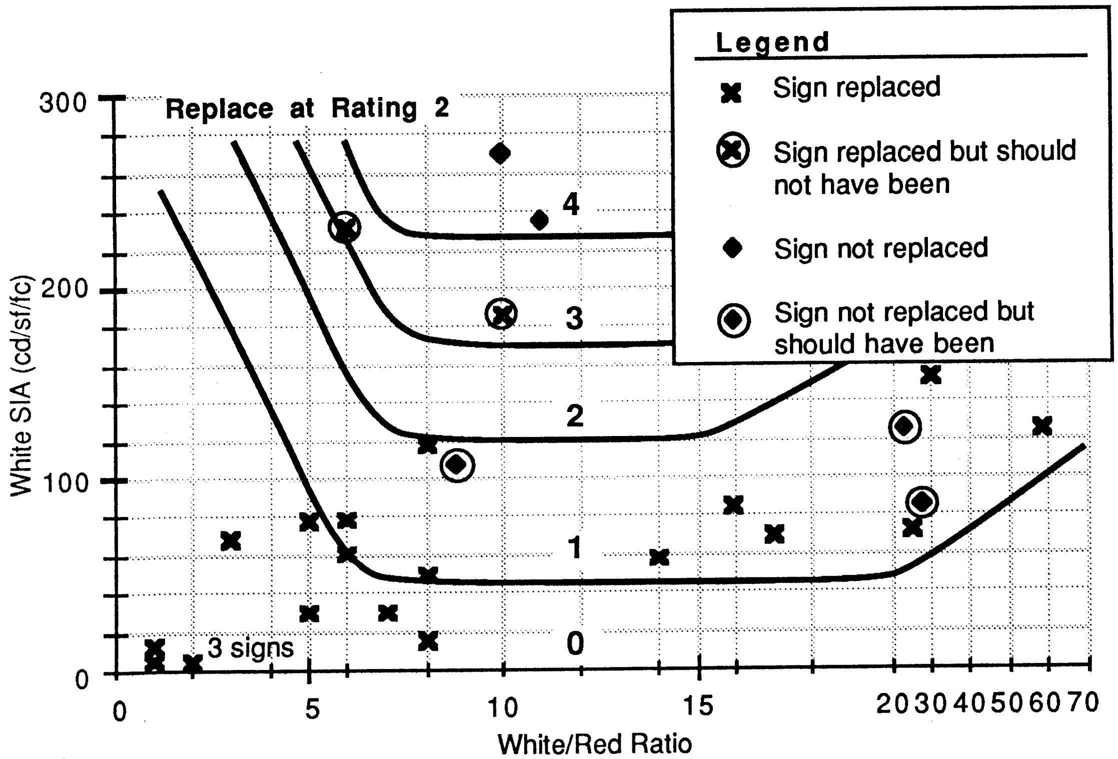


Figure 5-2. Warning Sign Replacement at Ratings 1 & 2 Observer Median



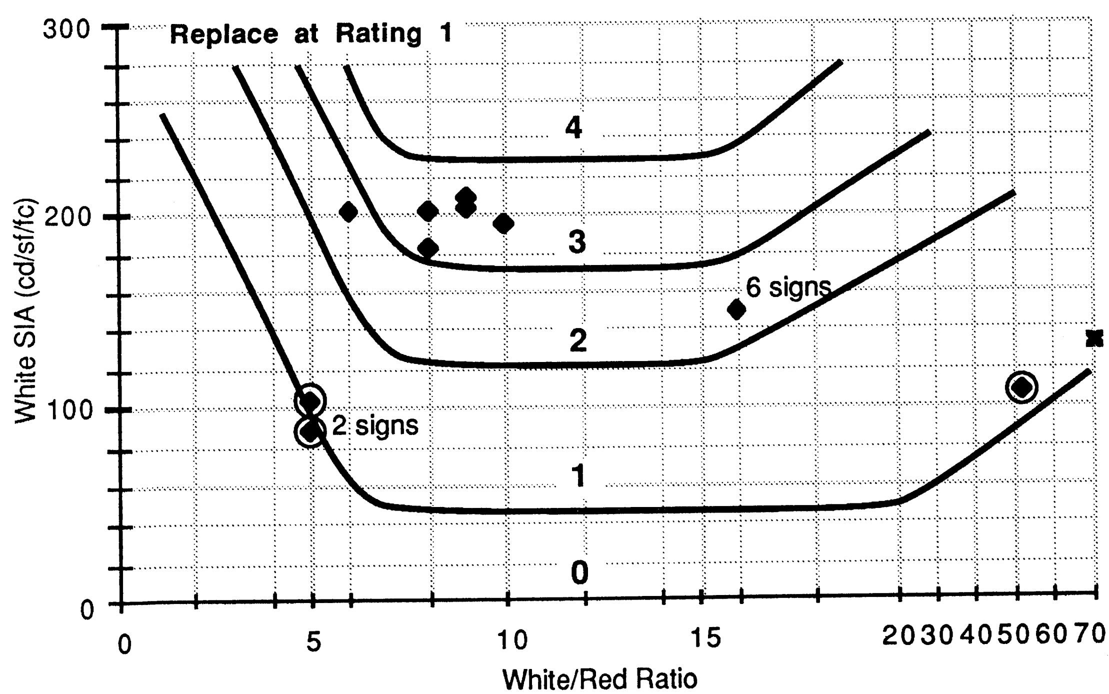


Figure 5-3. Stop Sign Replacement at Ratings 1 & 2 Observer Median (White Retro-reflectivity).

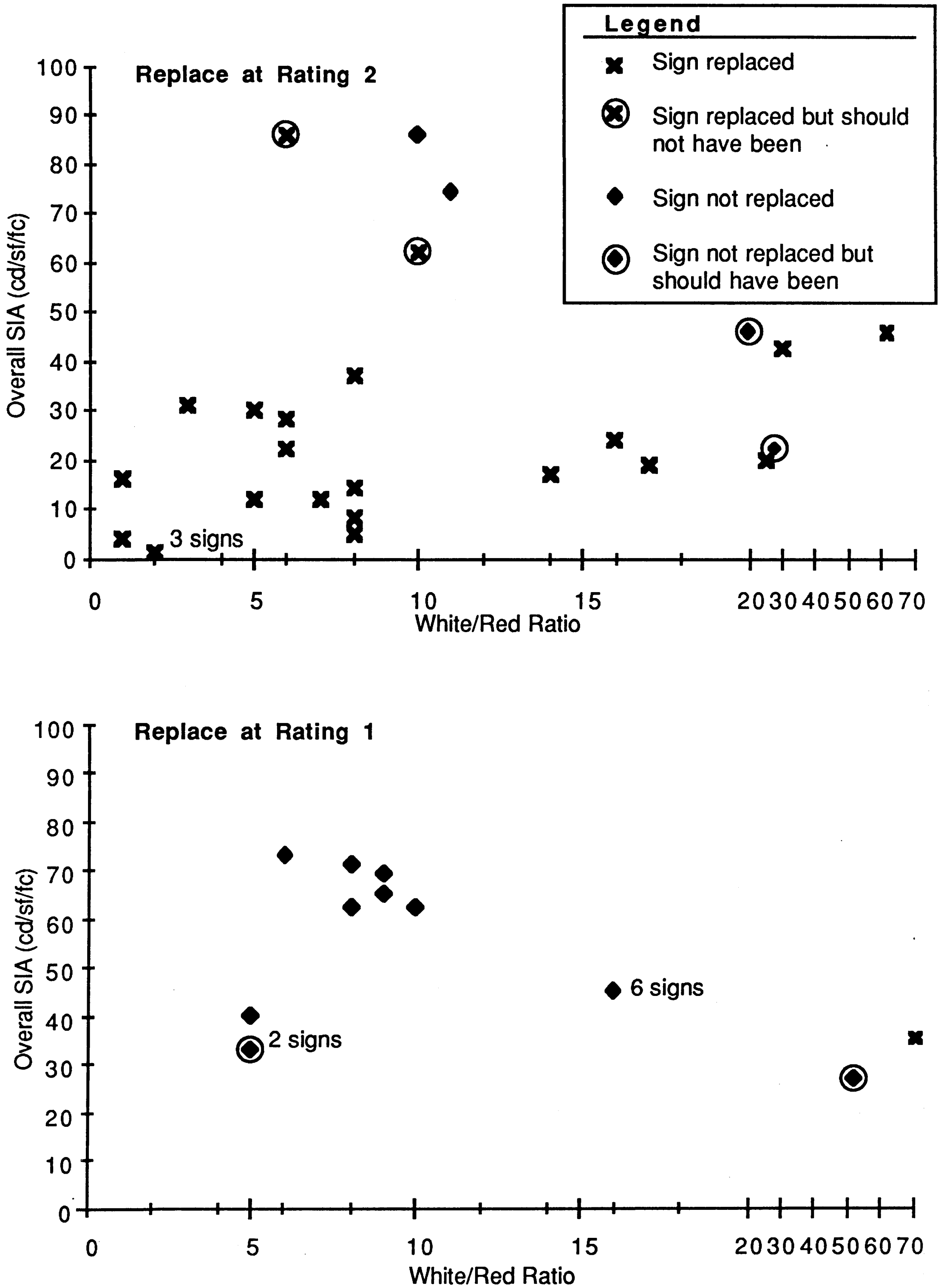


Figure 5-4. Stop Sign Replacement at Ratings 1 & 2 Observer Median (Overall Retro-reflectivity).

Figures 5-3 and 5-4 represent the observers' decisions about the stop signs in the highway experiments. The figures are separated into two graphs for the two replacement levels and show the same results in different ways. Figure 5-3 is a plot of the observers' decisions using the same scales as the rating graphs, the SIA of the white on the vertical axis and the white/red ratios on the horizontal axis. Figure 5-4 is a plot of the observers' decisions with the overall SIA (see Appendix A for definition) of the sign on the vertical axis and the white/red ratios on the horizontal axis.

Figure 5-3 and Figure 5-4 at replacement level 1 show that signs with an SIA of the white over 80 and an overall SIA over 30 remained in place. The one sign that was removed had a high contrast (the red looked black). The lower limit for replacement could not be established because all the signs with low SIAs were in the replacement level 2 graph.

Figures 5-3 and 5-4 at replacement level 2 show that observers generally replaced all stop signs below a white SIA of 100 or an overall SIA of 40. Two signs with high overall SIAs and good contrast ratios were replaced unnecessarily. When signs are replaced at the 2 level a sign has to be very good to remain in place.

The sign replacement decision based on the observers' median sign rating does not account for the frequency distribution of the observer ratings for each sign. The frequency distribution is important to agencies because most agencies use only one or two observers for sign review. The consistency of individual observers would be represented by the frequency distribution of the observers' ratings for the signs in each category. A frequency distribution with a correct mean and a small standard derivation would indicate high accuracy and consistency.

Figures 5-5 and 5-6 show the frequency distributions of the observer ratings for the warning and stop signs, respectively. These figures were based on the individual observation so apply to both the median as well as individual replacement decisions. In Figure 5-5, the observer frequency distributions for stop signs in each category were plotted. The vertical scale is based on the range of SIA of the warning sign. The frequency distributions for each category clearly show a correlation between the observer's ratings and the sign ratings calculated based on retroreflectometer readings. The observers

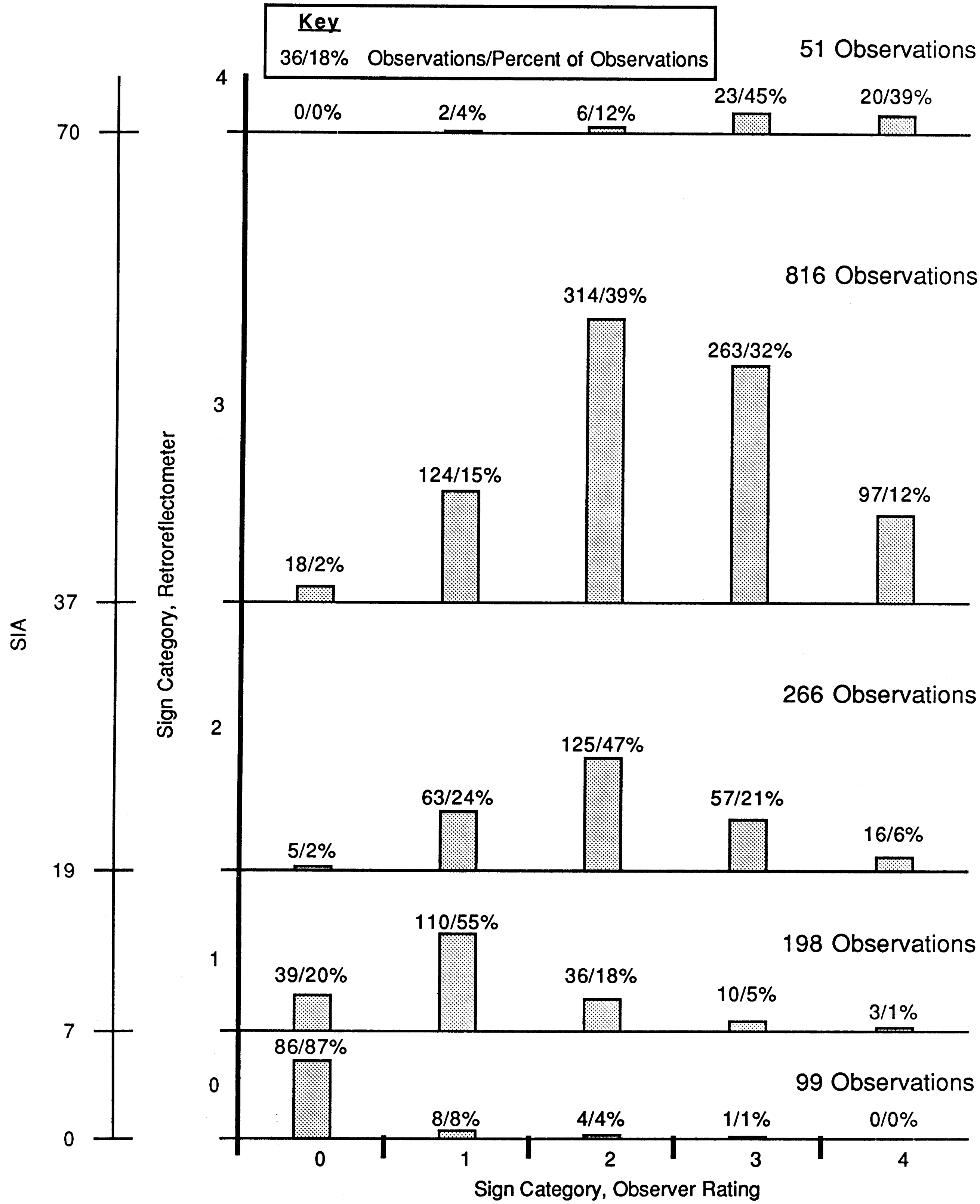


Figure 5-5. Frequency of Observer Sign Rating Responses Compared to Sign Rating and SIA (Specific Intensity per unit Area) of Warning Signs.

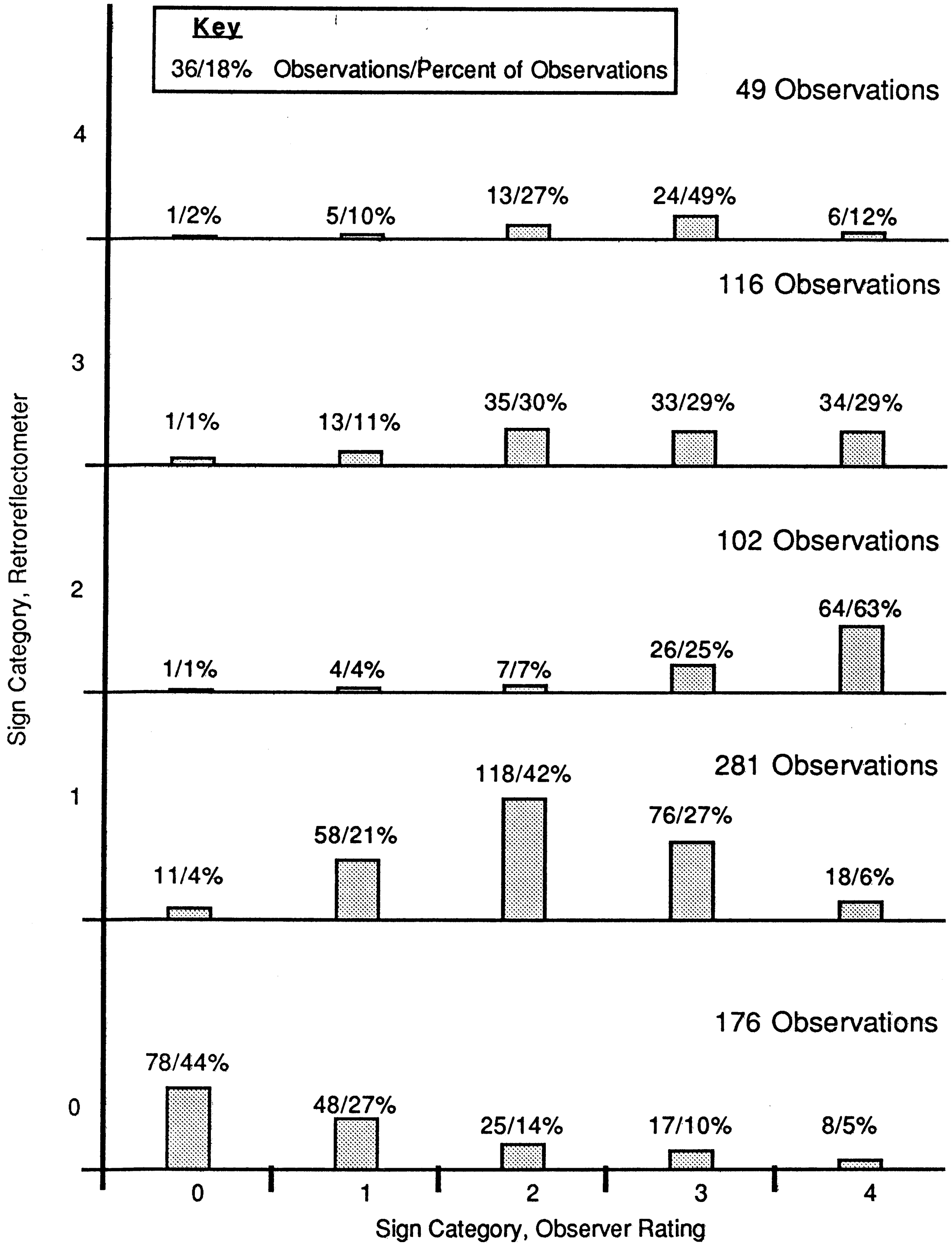


Figure 5-6. Frequency of Observer Sign Rating Responses Compared to Stop Sign Ratings.

were very accurate rating signs in the 0 and 1 categories; observers can easily have the "bad" signs removed. The frequency distribution of the observer's ratings for signs in the 2 category shows about 50 percent of the ratings at the 2 level with about 22 percent of the ratings either one rating category higher or lower. The frequency distributions for the 3 category shows the mean observation to be about 2.4 with a fairly wide spread. Eighty percent of the ratings of the signs in Category 4 were about equally split between ratings 3 and 4 with a small percentage of the signs being rated 0, 1 or 2.

The figure generally shows observers have a high accuracy and consistency for signs rating 0 or 1, the frequency distribution for signs in category 2 is fairly wide, and the frequency distributions for signs in categories 3 and 4 tend to be a little on the low or conservative side. Observers generally rate good signs a little lower than they should probably due to poor geometries or other factors.

Figure 5-6 shows the frequency distributions of the observer's ratings for the stop signs in each rating category. The correlation between the observers ratings and the calculated ratings is not as strong as for the warning signs. Observers were able to rate stop signs in the 0 category with some consistency but did tend to rate somewhat high. Signs in the 1 category were rated in all categories with 42 percent rated into the 2 category; about 25 percent rated into each of categories 1 and 3; and remaining 10 percent of the observations evenly split into categories 0 and 4. The majority of signs in categories 2,3 and 4 were rated about evenly into categories 2,3 and 4 with a small percentage at either 0 or 1.

The frequency distributions of the observer ratings for the stop signs were dependent upon the stop sign rating scale. Improvements to the rating scale as discussed in the section Sign Rating Scales, p.55, may increase observer consistency.

Sign Rating Distance

Observers rated signs from four distances in the laboratory and controlled highway experiments to determine an optimum rating distance. The observation distances were 150 feet in the first two sessions, 100 feet and 200 feet in the next two sessions and 200 and 300 feet in the last two sessions. A comparison of the mean ORUs in Figure 5-1 does not indicate any distance being statistically better than another.

In the highway experiments, observers rated the warning signs from both stationary and moving vehicles. The stationary vehicle tried to duplicate the controlled highway conditions as best possible while the moving vehicles drove at the speed limit or 35 mph, whichever was slower. Again the ORUs in Figure 5-1 do not indicate that either method is statistically better.

These results seem to indicate that the human eye is not sensitive to differences in sign luminances over the range of distances measured or from a stationary or moving vehicle. A possible reason for the lack of sensitivity could be that the available luminance remains fairly constant over the different distances. At a distance of 200 feet a sign may have a lower luminance than the same sign at 300 feet because the headlight aim directs a brighter part of the beam towards the sign at the greater distance. The observation angle is also reduced, increasing the available luminance. These factors can overcome the attenuation of the head lamp at the greater distance. This conclusion agrees with Figure 18 in a study done by L.F. King and H. Lunenfeld (12). The figure is a plot of available luminance versus distance for a shoulder mounted sign.

ECONOMICS OF USING AN OBSERVER

Economically, what do the observers cost the highway agency when they remove signs that could remain in place or let signs that should be removed remain in place? The study team performed an economic analysis on the signs in the two highway experiments. The analysis was based on the median observer replacement decision. It was also not known if the 130 signs in the highway experiment represented signs along a typical highway, so the analysis should not be applied to the other highways.

The Washington State Department of Transportation warning and stop signs are manufactured in a central sign shop in Yakima. The costs for a screened 30-inch by 30-inch warning sign and a stop sign are $21.44 and $28.44, respectively.

The signs that were replaced unnecessarily had been in place for some period of time. To account for the years of sign life that were lost, a deterioration model based on the useful life of the sign was used. Mace (13) uses a useful sign life of seven years for engineering grade sheeting and 12 years for high intensity sheeting. At the end of seven years the sheeting material retains 50 percent of its initial retroreflectivity (measured by SIA) and is totally dark after 14 years. The signs are assumed to deteriorate in a linear fashion. Sixteen signs would have been replaced unnecessarily in the study: 14 warning signs made of engineering grade sheeting and two stop signs made of high intensity sheeting.

The useful sign life lost was calculated using the SIA of the signs. Forty-five and ten years of sign life would have been lost for the warning and stop signs, respectively. The sign life lost for these signs would have cost the agency $164.00. Sign posts were assumed to be good.

To replace these 16 signs under average conditions would have required two sign technicians and a truck for one day. The current WSDOT labor charge including overhead is $17.00/hour. Truck rental is $11.00/hour. Using these costs, the daily charge becomes $360.00

The total cost for the unnecessary sign replacement becomes $524.00. The labor estimate could be reduced by about 50 percent if the costs were prorated over the sign life. Not considered in the analysis was the sign life gained when warning signs are allowed to degrade to an SIA of 18, three years beyond their life expectancy, or the salvage value of the aluminum.

The decision by the observer to allow a sign that should have been removed to remain in place would have incurred an additional liability for the agency and created a potential hazard for the motorist. The economics of this decision are difficult to compute. Neither the agency nor the motorist suffer any economic loss until a motorist has an accident. After an accident the cost to both the motorist and agency can be quite high.

RETROREFLECTOMETER VERSUS HUMAN EYE

A Retrotech 910F was used to measure the retroreflectivity of the signs used in the experiments. While the Retrotech 910F was easy to use and reliable, certain discrepancies between how a retroreflectometer sees a sign and how a human sees a sign became evident. The Retrotech 910F was designed to be placed directly on the sign face and measure the retroreflectivity of a circular area 20-25 mm in diameter. For a 30-inch by 30-inch warning sign, the total area is 900 square inches (ignoring corner rounding), by taking five measurements a total area of 3.92 inches is measured (approximating 25mm to 1 inch). The measured area is only 0.4 percent of the total area. A great majority of the vandalism and other problems are not measured.

Another problem is that the retroreflectometer sees bent signs as flat, and signs that are severely dented or damaged cannot be properly measured (in a normal situation they would just be replaced).

The observer actually sees the luminance of the entire sign and this is sometimes quite different than the retroreflectometer. The author's experience is that a thin uniform layer of dirt on a sign does not have as much of an effect on the retroreflectometer reading as one would think. The dirt also tends to be heaviest at the bottom of the sign. Anything thrown at the sign tends to streak or stick on in blotches and is often not measured. If any part of the sign is cleaned this also makes the sign look blotchy. Either the entire sign must be cleaned or none of it cleaned. One sign was discarded in the highway experiment because only parts of it had been cleaned.

SIGN RATING SCALES

Warning Sign Rating Scale

The warning sign rating scale was satisfactory. While the signs seemed to degrade gradually from one category to another, at the point where the SIA reached about 18, the sign would degrade rapidly. This was the point where all signs were replaced in the study.

Stop Sign Scale

Figure 5-7, Stop Sign Rating Scale, All Sheeting Material, shows the final stop sign rating lines for all the sheeting materials. Upon completion of the experiments a closer examination of the stop sign rating system was performed. The objective of the examination was to evaluate exactly how the observers were rating the signs. First the average rating for each sign was calculated. These values were then placed on two separate graphs. The first graph was similar to the original scale with the SIA of the white and the white/red ratio. The second graph had the overall SIA of the sign on the vertical axis and the white/red ratio on the horizontal axis. The study team believed that contour lines of equal rating could be drawn and would indicate more closely how observers were rating the signs. Definite contour lines could not be drawn on the graphs, but several conclusions could be drawn from the graphs. On

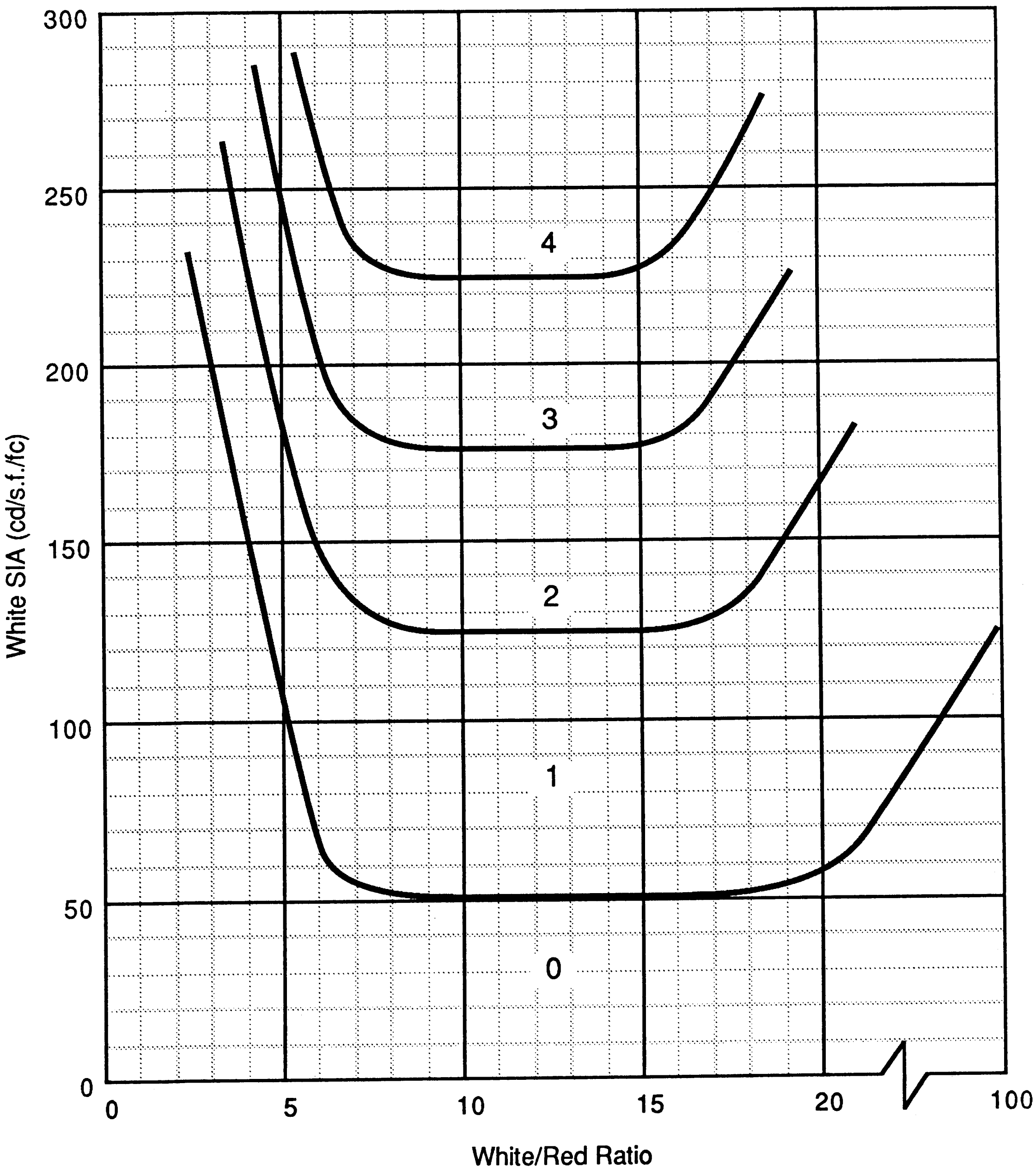


Figure 5-7. Stop Sign Rating Scale – All Sheeting Material.

both graphs a 0-1 contour line could be drawn with some confidence. Other contour lines on both graphs were inconclusive.

The graphs showed that observers can generally rate stop signs based on contrast and retroreflectivity. Signs with low retroreflectivity and good contrast were rated lower than signs with the same contrast but higher retroreflectance, and signs with low contrast were rated lower than signs of equal retroreflectivity but closer to optimal contrast. Only one sign with a good white SIA (135) and a high contrast (75:1) was used in the study. Observers rated this sign lower than signs of equal retroreflectivity but closer to the optimal contrast ratio. One finding that did become clear was that observers consistently rated a new engineering grade stop sign high, in spite of low SIA of the white (compared to a new high intensity sign) and low specific retroreflectivity. The white/red ratio of the sign was close to optimal at 9:1 and the face, of course, looked new. For these reasons the sign was rated higher.

The stop sign rating scale used in this study was the first of its type. If the study team were to redesign the scale, some changes would be made. One scale would be applied to all types of sign sheeting material. The vertical axis of the scale would be based on the one thing all stop signs have in common: how well they perform their job, or recognition distance. The horizontal axis would be again the white/red, internal contrast ratio.

Juan Morales (14) is currently finishing a study on stop sign retroreflective requirements in which he obtains a relationship between recognition distance (the distance from the sign where the driver recognizes the sign and understands the meaning or command associated with it) and the overall SIA of the sign. In his study he also determines that an overall SIA of over 40 does not improve the sign's recognition distance. The observers in these experiments could not tell the difference between a new high intensity, a new super engineer or a new engineering grade stop sign with overall SIA values of 74, 46 or 20, respectively, when displayed separately.

The overall retroreflectivity value for a sign must be used in conjunction with the white/red ratio. The three signs with the highest overall retroreflectivity used in the study (82-84) were worn out, high intensity signs in which the red had faded, exposing the silver-white sheeting and thus causing the high readings.

The Morales study also indicates that a stop sign can have a very low overall retroreflectivity and still perform its function. The average observer rating for the majority of signs used in this study and all the signs on the highway courses that had an overall SIA of 20 was below 1 or they were all replaced. A sign with an overall SIA of 20 in Morales' study has a minimum recognition distance of 279 feet under ideal viewing conditions. Some of the stop signs that were in place on the highway course had overall SIA values as low as one but were functioning correctly (if there were an accident problem the sign probably would have been replaced). This was probably because of driver expectancy in a given situation.

Any new stop sign rating scales should be based on performance (similar to the warning sign rating scale) and internal contrast and not whether the sheeting material has 50 percent or 75 percent of its initial acceptance retroreflectivity.

CHAPTER 6
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The literature survey and the questionnaire sent to the 50 state transportation agencies showed that instruments to evaluate traffic sign retroreflectivity are accurate but not used on a large scale because of the cost required to use them. An instrument that would be suitable to evaluate the retroreflectivity of a large inventory of traffic signs has not been developed and may not be developed for several years. A computer-based sign management system may prove to be satisfactory provided adequate weathering data and several other factors, including accurate records of sign replacement, can be obtained. This data collection may also require several years. At present the human observer is almost exclusively used to evaluate sign retroreflectivity, but is of unverified accuracy.

A summary of the survey questionnaire sent to the states is included as Table 6-1. Eighty-five percent of the states that responded to the questionnaire indicated a very high interest in the subject of traffic sign retroreflectivity. The major findings are the following:

- few states (15) have any policy for sign replacement;
- 23 states supplement visual inspection, most using retroreflectometers;
- most states (31) do not have any plans to modify their inspection procedures, indicating that current procedures are adequate; and
- only nine states are planning or performing research related to sign retroreflectivity.

The main objective of the report, to assess the accuracy of the trained observer in evaluating traffic sign retroreflectivity, was accomplished in a series of experiments. Seventeen observers were trained to rate warning and stop signs, first in a dark gymnasium and then from a stationary car on a straight-level section of road. The observers rated a series of signs on a scale of 0 to 4 (by whole numbers) that were placed on a sign post from 100 to 300 feet away. After the training the observers were driven on two highway courses in which they rated 130 traffic signs.

Table 6-1. Survey Questionnaire Summary

State Surveyed	Questionnaire Returned	Written Policy	Supplement Visual Inspection	Plans to Modify Sign Inspection Procedures	Future or Current Research
Alabama	Y	N	Y[3]	N	N
Alaska	Y				
Arizona	Y		N	Y	Y
Arkansas	Y				
California	Y				
Colorado	Y	Y[2,4]	N	Y[5]	
Connecticut	Y	Y[6]	N	N	Y[5]
Delaware	Y	N	Y[7]	N	N
District of Columbia					
Florida					
Georgia	Y	Y[8]	Y[1]	Y[2,3]	N
Hawaii	Y				
Idaho	Y	Y[9]	Y[2]	N	N
Illinois	Y	N	Y[4]	N	N
Indiana	Y	N	Y[2]	N	N
Iowa	Y	N	Y[2]	N	N
Kansas	Y	N	Y[3]	Y[10]	N
Kentucky	Y	N	N	N	Y[5]
Louisiana	Y	N	N	Y[11]	N
Maine	Y	N	N	Y[12]	N
Maryland					
Masssachusetts	Y	N	N	Y[13]	Y[14]
Michigan	Y	N	Y[2]	N	N
Minnesota					
Mississippi	Y	N	Y[2,15]	N	N
Missouri	Y	Y[1]	N	N	N
Montana	Y	N	Y[3]	N	N
Nebraska	Y				
Nevada					
New Hampshire					
New Jersey	Y				
New Mexico	Y	N	Y[2]	Y[16]	N
New York	Y				
North Carolina	Y	N	N	Y[17]	Y[5]
North Dakota	Y	N	Y[2,3]	N	N
Ohio	Y				
Oklahoma	Y				
Oregon					
Pennsylvania					
Puerto Rico	Y				
Rhode Island	Y	N	N	Y[18]	N
South Carolina	Y	N	Y[2]	N	N

Table 6-1. Survey Questionnaire Summary (Continued)

State Surveyed	Questionnaire Returned	Written Policy	Supplement Visual Inspection	Plans to Modify Sign Inspection Procedures	Future or Current Research
South Dakota	Y	N	Y[2,3]	Y[2]	Y[5]
Tennessee	Y				
Texas	Y				
Utah	Y	N	Y[2]	N	N
Vermont	Y	N	N	N	Y
Virginia	Y	Y[19]	N	N	Y[20]
Washington	Y	N	N	Y[10]	Y
West Virginia	Y	N	Y[2]	N	N
Wisconsin	Y	Y[21]	Y[2]	Y[10]	N
Wyoming	Y	Y[22]	N	N	N

Notes:

1. Policy is based on daytime and nighttime inspection frequencies
2. Use reflectometer for field checks
3. Use material patches for field checks
4. Use retro-reflectometer for training or special studies
5. Field weather deck
6. Policy is based on annual nighttime surveillance program
7. Retro-reflectometer used in maintenance and construction projects
8. Retro-reflectivity warranty for reflective sheeting
9. Policy is based on highway service levels and subjective retro-reflectivity performance
10. Formalize inspection frequency, procedure, and/or inspection criteria
11. Use remote reflectometer developed at Louisiana Technical University, 1974
12. Plan to institute a program to inventory and computerize the installation date of signs
13. Perform nighttime visual inspections
14. Field evaluation of various combinations of reflective sheeting and button copy
15. Use Q-beam (spotlight) for daytime reflectivity checks
16. More shop inspections for contract sign vendors and more reflectivity readings on construction projects
17. A study committee has proposed a maintenance standard which includes annual night inspections
18. Adding personnel and increasing sign surveillance and assigning responsibility areas to sign crews
19. Signs should be considered for replacement when the reflectivity falls below 50 percent of the original brightness
20. A level-of-service document is currently being developed
21. The color of the sign background shall be readily detectable using the upper beams as follows:

color	distance
red, yellow, white	500 feet
green, blue	300 feet
brown	no standard

22. Based on manufacturers' data and our experience

The primary results of the highway experiments are the comparisons of the individual observer rating of the signs and the rating of the signs calculated by using the retroreflectometer. The individual observer rating was incorporated into a decision model to replace or to not replace the sign based on the retroreflectivity of the sign and visual complexity of the sign environment. Figure 6-1 is a breakdown of the highway experiment results by sign type. A and D are the correct decisions to replace and to not replace a sign, respectively. B is the incorrect observer decision to replace a sign when it should have remained in place and C is the incorrect observer decision to let a sign remain in place when it should have been replaced. The observers were correct on 74 percent of the warning signs and on 75 percent of the stop signs. The observers correctly rated a high percentage of the signs.

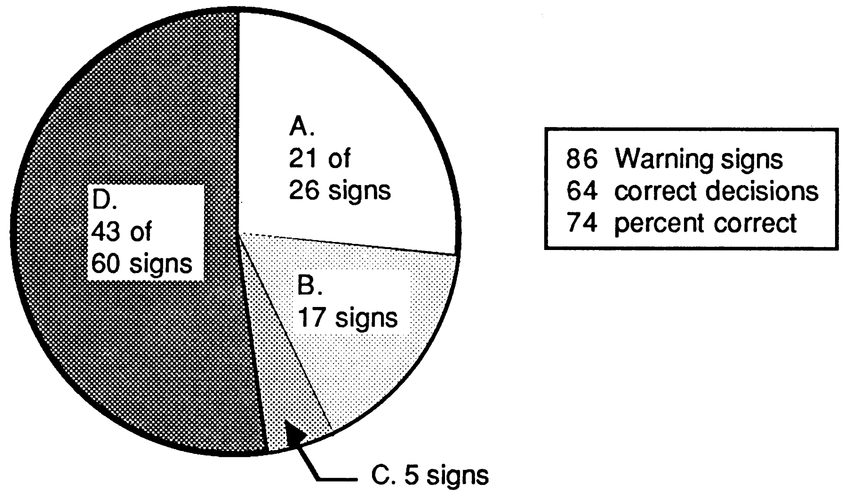
The literature survey and survey questionnaire indicated that at present there is no method of sign review other than the trained observer that is suitable for a large sign inventory. The retroreflectometer, while extremely accurate and consistent, overlooks many factors important to the driver. The experiments have shown that a trained observer is a valuable part of a sign maintenance program. The trained observer sees a sign in the same way that a driver sees a sign. Agencies will have to continue to rely on observers' judgments for some time to come.

CONCLUSIONS

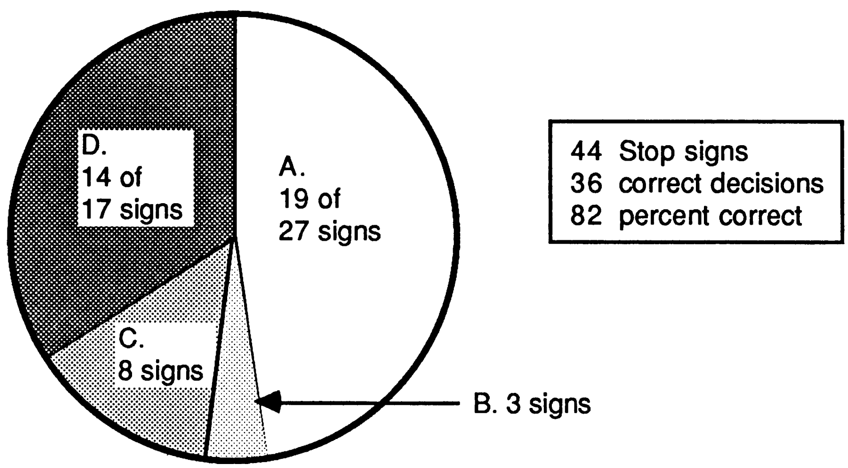
Figure 5-1, Observer Accuracy, demonstrates that the observers used in the study were all about equal. The observer can easily tell a "good" sign from a "bad" sign, but because of the category division lines and other variables, including the sensitivity of the eye, the observer cannot be totally accurate. The people used in the study all had good vision, most were in their 20s, but two were in their early 40s. The observer progress shown in Figure 5-1 shows that most people with good vision can be trained in a few hours to rate traffic signs.

The trained observer can make accurate and reliable decisions to replace signs. Several factors encountered in the study would improve their accuracy:

- observers should be used in pairs -- one to drive the vehicle and one to keep records;
- the approach to a sign should be clear of obstructions;



WARNING SIGNS



STOP SIGNS

LEGEND

Individual Observer	Replaced		Not Replaced	
Decision Model	Replace	Do Not Replace	Replace	Do Not Replace
	A (correct)	B (incorrect)	C (incorrect)	D (correct)

Figure 6-1. Warning and Stop Sign Replacement, Individual Observer.

- nighttime observations should be made under favorable weather conditions (also for the safety of the observers);
- straight, level approach geometrics;
- the sign should be plumb and approximately 90 degrees to the observer;
- dirty signs should be cleaned;
- the observer should be used in conjunction with a sign management system which includes the installation date and the life expectancy of the sign;
- a comprehensive daylight review should be performed prior to the nighttime review;
- the trained observer should be used as the final check after the obvious corrections to the signs on a highway have been made;
- the trained observer should be familiar with sign criticality; and
- signs rating 2 could also be checked with a retroreflectometer for final replacement decision.

Sign maintenance will cost agencies more money but it is necessary to decrease nighttime accidents and agency liability.

The study team observed many stop signs in all states of serviceability. An incidental conclusion was that the thickness of the transparent red ink on a new stop sign makes a considerable difference in the appearance of the sign at night. The light reflected through the red ink must travel through the ink twice. If the ink is too thick, even the red on a brand new sign will look black at night.

RECOMMENDATIONS

1. The trained observers should be fully evaluated before undertaking research to develop an "expensive" retroreflectometer to evaluate traffic sign retroreflectivity.
2. Agencies should design a training program to instruct people who are currently making sign replacement decisions. Training would make sign replacement more uniform throughout a jurisdiction and create safer highways for the motorist. Instruction of observers would demonstrate that agencies are actively training personnel to inspect signs. Observer training, in

combination with regular day and night inspection, substantiated with record-keeping indicating that effective remedial action is taken in a timely manner, would be the key elements in a tort action.

3. The sign maintenance management system (SMMS) does show promise. The SMMS would be especially valuable for large signs in areas where vandalism is not a factor.

4. A sheeting material test deck or certain key signs would be an excellent way to input sign life into a SMMS which would assist the observer in replacement judgments.

5. Several states maintain their signs at different levels of retroreflectivity for different classifications (speeds) of highways. Sign criticality could also be considered in sign replacement. These policies may be good ways to stretch limited funds.

6. The last recommendation is incidental to the study. The transparent red ink used on stop signs should have a specified thickness. At the present time the only requirement for the application of the ink is that it is put on uniformly and that borders are clear and sharp. With this specification agencies will be able to control the internal contrast ratio of the sign.

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APPENDIX A
DESCRIBING RETROREFLECTION

APPENDIX A
DESCRIBING RETROREFLECTION

RETROREFLECTION DEFINITIONS

Retroreflection -- reflection in which radiation is returned in directions close to the direction from which it came, this property being maintained over wide variations of the direction of the incident radiation.

Retroreflector -- a surface or device from which, when directionally irradiated, a relatively large portion of the reflected radiation is retroreflected.

Retroreflective Element -- one optical unit which by refraction or reflection, or both, produces the phenomenon of retroreflection.

Retroreflective Device -- a complete device, ready for use, consisting of one or more retroreflective elements.

Retroreflective Material -- a material that has a thin continuous layer of small retroreflective elements on or very near its exposed surface.

Retroreflective Sheeting -- a retroreflective material preassembled as a thin film ready for use.

PHOTOMETRIC DEFINITIONS

Photometry is concerned with the quantity of light that is emitted from point sources (headlights), is recieved on a surface (sign) and is emitted or re-emitted from that surface (luminance).

In Photometry engineers differentiate between the following quantities:

(1) the amount of light emitted by a point source, the luminous flux and luminous intensity;

(2) the amount of light received on a unit area of a surface in a given position; that is, the illumination or illuminance of the surface; and

(3) the amount of light emitted or re-emitted per unit area of a surface; that is the luminance of the surface. This was formerly called the brightness of the surface.

The Photometric terms defined below are used to specify the performance of retroreflective materials. Luminous Flux, F, the rate of flow of light from a source. The unit of this is the lumen (lm).

Luminous intensity, I, the concentration or density of luminous flux per unit solid angle in a given direction. The unit of luminous intensity is the candela (cd.), formerly the candle, and luminous intensity is often referred to as candle-power.

Illumination, E, at any point of a surface receiving light is the density of the luminous flux at that point, or the flux divided by the area of the surface, when the latter is uniformly illuminated. The unit is the lumen per square foot (lm/ft^2), the illumination of a surface normal to the direction of the light one foot from a source of one candle-power. This unit was formerly called the foot-candle.

Luminance, L, the light emitted per unit area of a surface. The luminance in a given direction of a surface emitting light is the luminous intensity, I, measured in that direction divided by the area of this surface projected perpendicular to the direction considered. The unit of luminance is the foot-lambert, the luminance of a surface emitting a flux of one lumen per square foot.

Specific Intensity, SI, is the ratio of luminous intensity of a surface to the normal illuminance. The units are candelas per foot candle (cd/fc).

Specific Luminance, SL, the ratio of the luminous intensity of the projected surface to the normal illuminance at the surface on a plane normal to the incident light, expressed in candelas per square foot per foot candle (cd/sq.ft. 1fc).

Specific Intensity per Unit Area, SIA, is the ratio of the luminous intensity of the surface to the normal illuminance and to the area of the retroreflective surface. Its units are candelas per footcandle per square foot (cd/fc/sq.ft.).

Although SL and SIA represent the same quantity, SIA should be used when the surface being measured has some area. SL is used to measure a "point", where the area is negligible.

Overall SIA, the overall SIA for the stop sign obtained by weighing the white (24 percent) and the red (76 percent) SIAs by area.

GEOMETRICAL SYSTEM

The geometrical coordinate system used to describe retroreflection was developed by the Subcommittee on Retroreflection of Committee 2.3 on Materials of the International Commission on Illumination (Commission International de l'Eclairage, CIE). The following terms are directly applicable to this study:

Reference Center, a point on or near a retroreflector which is designated to be the center of the device for the purpose of specifying its performance.

Illumination Axis, a line segment from the reference center to the light source.

Observation Axis, a line segment from the reference center to the receptor.

Observation Angle, α, the angle between the illumination axis and the observation axis. The observation angle is always positive and in the context of retroreflection is restricted to small acute angles.

Reference Axis, a designated line segment from the reference center which is used to describe the angular position of the retroreflector.

Entrance Angle, β, the angle from the illumination axis to the reference axis. The entrance angle is usually no larger than 90 degrees, but for completeness its full range is defined as $0. < \beta < 180$ degrees.

APPENDIX B:
EDWARD McCORMACK'S LITERATURE SURVEY

MEASURING TRAFFIC SIGN REFLECTIVITY: A LITERATURE SURVEY

by

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Final Report
Research Project Y-2811
Task 5

Prepared for
Washington State Transportation Commission
Department of Transportation

January 1986

SUMMARY OF PURPOSE

The majority of today's traffic signs are reflectorized for nighttime legibility. However, as signs are or are coated with road dirt their reflectivity abilities decrease. Therefore, an effective method for periodically inspecting signs is important to ensure road safety. This report discusses the existing methods for measuring traffic sign reflectivity and proposes research to explore and further refine the available techniques.

SUMMARY OF FINDINGS

Three basic methods of measuring sign reflectivity are found in the literature. The simplest and probably the most common involves the use of human observers to evaluate traffic signs. However, this observation method is of uncertain accuracy. Another method includes the use of portable reflectivity measuring instruments, which are accurate but are often slow and cumbersome. The last method combines the use of instruments with observers but is probably of limited use when a large number of signs require inspection. The table below summarizes the methods reviewed. Because the use of observers is the least complicated and fastest way to inventory traffic signs, this report recommends that research be conducted to assess the accuracy and usefulness of this method.

Measurement Method	Special Equipment Needed	Stop Required at Each Sign	Limited to Use at Night	Accuracy Verified
Observer	No	Varies	Yes	No
Instrument	Yes	Yes	No, Generally	Yes, Generally
Observers and Instruments	Yes	No	Yes	No

BACKGROUND

In order for traffic control signs to be as legible to motorists at night as during the day, the Manual on Uniform Traffic Control Devices (1978) requires reflectorization of most non-illuminated traffic signs. As a result, the majority of traffic signs are made with a reflective material so they can be illuminated by vehicle headlights. Unfortunately, signs' reflective abilities are diminished by aging and by road dirt coating them. Illegible signs can cause accidents and can potentially lead to liability problems. Therefore the Transportation and Traffic Engineering Handbook (1976) recommends yearly inspections to determine if signs are ready for replacement or washing.

METHODS

The literature contains three methods to examine the reflectivity of traffic signs. They involve the following:

- human observers,
- measuring instruments,
- or a combination of instruments and observers.

The following section discusses a number of these techniques applied to measurement of traffic signs in the highway environment.

Human Observers

A survey of several states' Departments of Transportation (Washington, California, Idaho, and Oregon) indicated that they use visual nighttime inspection of traffic signs. This is the least complex method to measure sign reflectivity and probably the most commonly used. No information on the accuracy of this technique was found in the literature.

Another observer-based method used to evaluate the reflectivity of traffic signs (Williams 1974) involves placing a standard test material on the sign and using a light, at night, to illuminate the sign. An observer then must decide if the sign appears to be at least as bright as the standard. No evaluation on the accuracy of this technique was found in the literature.

<u>Portable Measuring Systems</u>

In a laboratory, quantification of a sign's reflectivity is readily possible. While it is more difficult in the field, portable reflectivity measurement instruments are available. A number of studies have been concerned with such instruments.

Rector (1968) attempted to simulate the geometrics of roadway viewing and illumination in designing a portable photometer to measure the reflectivity of sign material. The readings from the photometer were compared to readings from both a standard laboratory darkroom tunnel reflectivity test and rankings by human observers responding to nighttime highway environments. The night test involved observers sitting in a stationary automobile looking at sign samples of five traffic colors which were illuminated by the vehicle's left headlights. As seen in Exhibit 1, the correlation, at a 95 percent confidence level, between the photometer, the visual ranking and the darkroom test were fairly high, with the value of R in most cases close to 1.0. Rector concluded that the photometer provided close agreement with human observers and traditional darkroom analyses. Exhibit 2 shows the two piece portable photometer which is small enough to be convenient to use. While the photometer was only used in the dark, Rector indicated that the possibility existed to modify the instrument for use in daylight.

Exhibit 1

Simple Correlation Coefficients[1]
Photometer vs. Visual Ranking and Darkroom

Item	Sign Colors Silver	Yellow	Red	Green	Blue
0.2 deg divergence:[2]					
Visual ranking	0.87	0.78	0.98	1.00	0.99
Darkroom	0.98	0.99	0.99	0.99	0.97
0.5 deg divergence:[3]					
Visual ranking	1.00	0.90	1.00	1.00	1.00
Darkroom	0.98	0.89	0.99	0.99	0.82
Sample Size	6	5	5	4	6

1. Corrosion coefficient for sample sizes for 95 percent confidence level.
2. Corresponds to a viewing distance of 600 feet.
3. Corresponds to a viewing distance of 300 feet.

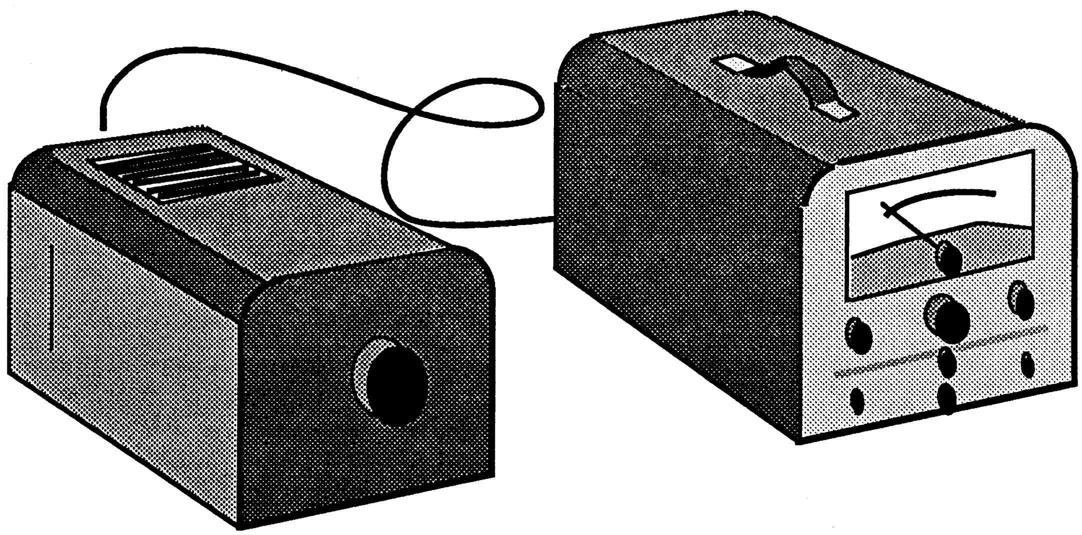

Exhibit 2
Portable Photometer

Williams (1974) presents a detailed technical discussion on how a portable retro-reflectometer was successfully constructed. The instrument was designed with a built-in lamp so it was usable in both daylight and at night. Readings on a set of test signs were taken both at night and during the day to show that the instrument functioned was independently from ambient light. The instrument's readings showed minimal variation in different lighting conditions. More variation was present as the instrument was tested at various distances from signs. However, Williams felt the reflectometer could measure signs with sufficient accuracy to determine whether or not the signs were in satisfactory condition. The instrument's dimensions where approximately 30" by 22" by 6" and it was mounted on a heavy duty tripod.

Williams notes that each reflectivity measurement required about five minutes and felt it probably would not be economically feasible to measure more than a small percent of the signs in any jurisdiction. Williams indicates that a sensible use of his instrument would involve the use of random samples and statistical procedures in order to determine the factors which cause sign deterioration. Such information could be used to develop a traffic sign maintenance schedule.

Malasheskie (1979) evaluated a commercially available portable retro-reflectometer (Gamma Scientific Model 910B) and determined that it was both accurate and rugged enough for field use. The retro-reflectometer was field tested in a variety of lighting conditions, temperatures and relative humidities. Readings from the portable instrument were compared to those from a precision laboratory instrument. In all cases the two instruments' values, at a 95 percent confidence level, showed a correlation coefficient (R-value) of .94 or greater.

This instrument required calibration by the color of the sign and also needed physical contact with the sign being measured.

Webb (1977) constructed a portable retro-reflectometer and briefly evaluated its accuracy. The instrument was designed to make daytime field measurements of traffic signs and other reflective traffic control devices. The limited evaluation of the instrument consisted of measuring the reflectance of five different color samples of sign material. The reflectance of the samples had previously been measured in laboratory conditions. The maximum variability of the portable retro-reflectometer from the laboratory values was 2.7 percent. The instrument was in two parts and designed to be lightweight enough to be easily portable.

Youngblood (1971) mounted a telephotometer (i.e, a photometer with a telescope) on a tripod above and behind the driver's seat in an automobile and measured the brightness of signs both at night and during the day. The photometer was calibrated against a standard material from the National Bureau of Standards and shown to average + or - 2.5 percent from the standard value. The vehicle was stopped at various distances from the target sign and measurements were taken. This method did not require leaving the vehicle but needed at least two operators and required stops on the roadway shoulder at pre-painted reference marks. Youngblood was interested in quantifying the brightness of recently installed signs in the the highway environment and specifically avoided a number of variables such as sign age which could be related to sign deterioration. The research methodology did, however, effectively measure different levels of sign reflectivity.

Combined Observer and Instrument Measurement

Hills (1972) developed a method to measure the detection distances of signs at night by using a specially equipped automobile and observers. The automobile was equipped with a twin channel tape recorder. On one channel was a velocity measuring instrument which was coupled to the speedometer. The other channel was connected to a microphone. The observer held a two button response box. When a traffic sign was initially detected the subject pressed one button. The second button was pressed when the sign was passed. Concurrent with this, the observer was instructed to verbally describe the sign. A laboratory analysis of the tape allowed for identification of each sign and its detection distance. While the purpose of the research was to measure signs' legibility distance, Hills also determined that aging and dirt accumulation reduced sign legibility distances by 30 percent or more. This discovery indicates that legibility distance might be an adequate surrogate for reflectivity. This method advantageous in that it can be done on the move. A disadvantage is that the method is dependent on correctly decoding and interpreting a tape. This could be difficulties if large numbers of sign were examined.

EVALUATION

As seen in a summary table (Exhibit 3), each sign reflectivity measuring method has advantages and disadvantages. Measuring sign reflectivity using an observer is perhaps the simplest and fastest way to evaluate the reflectivity of a traffic sign in the field. Rector, (1968) in his review of a portable photometer, had observers make simple, relative intensity evaluations and compared the results to a laboratory and portable photometer. As discussed earlier (Exhibit 1), the observers' values correlated fairly closely with those of the instruments.

Measurement Method	Special Equipment Requirements	Stop Required for Each Sign	Limited to Use at Night	Accuracy Verified
Observer				
• Visual Inspection	None	No	Yes	No
• Comparison with Standard Test Strip	Standard Test Strip	Yes	Yes	No
Instrument				
• Photometer (Rector)	Photometer	Yes	?	Yes
• Retroreflectometer (Williams)	Retroreflectometer	Yes	No	Yes
• Retroreflectometer (Webb)	Retroreflectometer	Yes	No	Yes
• Retroreflectometer (Malasheskie)	Retroreflectometer	Yes	No	Yes
• Telephotometer (Youngblood)	Telephotometer/ Pavement Marks	Yes	Yes	No
Observer with Instrument				
• Sign Detection Distance (Hills)	Specialy Equipped Vehicle	No	Yes	No

Exhibit 3

Summary of Measurement Method

Unfortunately, little information is available on how effectively a visual inspection detects inadequately reflectorized signs in the highway environment. Using a standard test material on each sign, while more accurate than a simple visual examination, would be very time consuming because it would method require stopping at each sign. Furthermore, both observer based methods need to be done at night when safety and overtime pay become a consideration.

The methods which require portable instruments use of an instrument reduces the subjectivity which occurs with observers, and many of the instruments can be used during the day. However, their utilization can be cumbersome and slow. Several of the photometers needed either physical contact with the sign or a stationary tripod. Youngblood's use of a photometer mounted in a car, while more convenient then most instrument-based measurement techniques, still required stopping and pre-painted reference lines.

The use of distance measuring instruments combined with human judgment, as performed by Hill is advantageous in that it can be done from a moving vehicle and some quantification is possible. This method has the drawback of requiring a secondary laboratory analysis which could be bogged down by large amounts of data.

A statistical sampling method, as suggested by Williams, based on a sign's age, location and sheeting material possibly could be used in conjunction with any of the methods discussed above. Statistical information might allow the creation of a schedule to identify the date at which a sign would have a high probability of needing replacement. Any statistical program would have to recognize that signs often need replacement due to unpredictable factors such as being knocked over and bullet holes. If a statistical procedure could deal with such problems it could streamline the traffic sign inventorying process.

RECOMMENDATIONS

Research is needed to investigate methods to effectively measure traffic sign reflectivity. The need for such methods will probably increase in the future. Nettleton (1984), in a multi-year study of sign weathering, noted that reflectivity measurement become more important as traffic signs' structural lives increase due to better materials and application techniques.

Since a typical transportation agency is responsible for thousands of traffic signs, the use of reflective instruments would be time consuming and probably not economically feasible. The least costly method for inventorying traffic sign reflectivity is visual inspection from a moving vehicle. Unfortunately the accuracy of an observer in such a situation is generally unknown. Further research is recommended to determine if observers can effectively inventory traffic sign reflectivity.

STUDY DESIGN

The author proposes that research is needed to determine the accuracy of using visual inspections to locate "bad" traffic signs. The research would use observers to examine a number of traffic signs in both a laboratory and a highway environment. The observers' abilities to discriminate sign reflectivity within the standards currently being developed by the Institute of Transportation Engineers (1985) would be assessed. The observers' accuracy would be determined by comparing their results to readings from a precision reflectivity measuring instrument. An investigation would also be conducted on methods to enhance observer accuracy. Use of techniques such as portable or vehicle mounted calibration displays would be evaluated. Additionally, the proposed research would survey the sign inspection techniques used by a number of transportation agencies across the country. Promising observer-based methods would be evaluated.

A breakdown of the proposed research would be as follows:

Task 1 - Determine observer accuracy in laboratory conditions.

Task 2 - Determine observer accuracy in highway environment.

Task 3 - Survey sign inspection techniques used by a variety of transportation agencies.

Task 4 - Evaluate promising methods.

Task 5 - Develop recommendations and report.

If researchers found that observers could an not adequately identify the reflectivity of traffic signs then further investigation into the use of instrument-based inspection techniques would probably be warranted. Regardless of the actual inspection method used, it would be valuable to examine the factors which cause the deterioration of a sign's reflective ability and to attempt to develop statistical methods to identify when a sign would need inspection. Such knowledge could be used to guide the development of sign inspection programs.

BUDGET

Approximately $15,000 would be needed to investigate the visual inspection of traffic sign reflectivity. A breakdown of the proposed budget would be as follows:

Salaries	$3,000
Equipment	4,000
Supplies	2,000
Overhead, etc.	6,000
Total Estimated Research Cost	$15,000

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APPENDIX C
EXPERIMENT DATA

APPENDIX C
EXPERIMENT DATA

LABORATORY EXPERIMENT

The headlight system used in the laboratory consisted of two, seven-inch-diameter sealed beam headlights mounted on a plywood stand. The system was powered by an eight-month-old Sears Die Hard LT battery with a rating of 550 cold cranking amps. A battery charger was connected to the battery during the experiment. The charger showed a charge rate of about two to four amps indicating, that the charger was supplying the needed amperage and the battery was not draining.

To establish the headlight height from the ground, the width and also the distance from the headlights to the observers' eyes, 50 random vehicles were measured along 15th Avenue N.E in Seattle. The dimensions were then averaged and the headlights set accordingly. The height of the headlights was set at two feet, two inches, the width from center to center was three feet, ten inches, and the distance from the headlights to the driver and front seat passengers eyes was about seven feet (see Table C-1).

The seven-inch sealed beam headlights were selected because they were readily available in a wrecking yard and were easily mountable on the plywood stand. The light pattern of the headlight has remained constant for quite a long time, the only difference between the round, seven-inch sealed beam and the square, quartz-halogen headlights on the cars used in the controlled highway and highway experiments was in intensity. Figure 5-1 in the text indicates that the observers improved in the experiments in which they were in the vehicles. The choice of headlights did not make much difference.

Table C-1. Headlight Measurement Samples.

No.	Distance Apart	Height	Distance to Eyes	No.	Distance Apart	Height	Distance to Eyes
1	4'-0"	2'–1-1/2"	7'-0"	26	3'-5"	2'–1-1/2"	7'-3"
2	3'-10"	2'–5-1/2"	7'-4"	27	3'-8"	2'-1"	7'-5"
3	4'-0"	2'-3"	7'	28	3'-10"	2'-4"	6'-5"
4	5'-2"	2'-7"	7'	29	3'-7"	2'-2"	6'-8"
5	4'-1"	2'-0"	7'-8"	30	3'-5"	2'–1-1/2"	7'-1"
6	3'-4"	2'-3"	7'-4"	31	3'-5"	2'-3"	6'-9"
7	3'-9"	2'-3"	7'-7"	32	4'-0"	2'-1"	7'-0"
8	4'-0"	2'-1"	7'-4"	33	3'-8"	1'-11"	6'-8"
9	4'-3"	1'-10"	8'-1"	34	3'-5"	2'-1"	7'-1"
10	4'-7"	2'-5"	7'-5"	35	3'-10"	2'-4"	7'-7"
11	3'-7"	2'-0"	6'-11"	36	3'-9"	2'-0"	7'-4"
12	3'-7"	2'-3"	7'-5"	37	3'-5"	1'-11"	6'-11"
13	3'-5"	2'-1"	6'-0"	38	4'-6"	2'-1"	7'-11"
14	3'-5"	2'-4"	7'-6"	39	4'-8"	2'-2"	7'-7"
15	3'-3"	2'-1"	6'-10"	40	4'-0"	2'-1"	7'-10"
16	4'-7"	2'-2"	7'-7"	41	3'-6"	2'-1"	7'-7"
17	4'-6"	2'-1'	8'-3"	42	4'-3"	2'-0"	7'-4"
18	3'-8"	2'-3"	6'-8"	43	3'-8"	2'-1"	6'-3"
19	4'-4"	2'-2"	8'-0"	44	4'-2"	2'-3"	6'-10"
20	3'-3"	2'-1"	6'-8"	45	4'-6"	2'-2"	6'-10"
21	3'-9"	2'-4"	3'-10"	46	3'-10"	2'-0"	6'-10"
22	3'-2"	2'-2"	7'-3"	47	3'-3"	2'-2"	7'-0"
23	6'-0"	2'-9"	7'-2"	48	3'-7"	2'-1"	7'-0"
24	3'-4"	2'-0"	7'-9"	49	3'-3"	2'-2"	7'-2"
25	3'-7"	2'-1"	7'-1"	50	3'-6"	2'-1"	7'-3"

Average Distance Apart = 46.2" ~ 3'-10"
Average Height = 25.9" ~ 2'-2"
Average Distance to Eye = 85.4" ~ 7'-1"

The study team considered using a rectifier system to power the headlights but was advised against this by Professor David L. Johnson in the electrical engineering department. His reasoning was that when 110 Volts ac are converted to 12 Volts dc the result always has a slight ripple. It might not be noticeable but it is there.

The sign post used in the laboratory and controlled highway experiment was portable and free standing. The post consisted of a two-by-four with a piece of conduit mounted on the front which would slide up and down the post. A bolt was installed at the top of the conduit which ran in a track formed by two oak boards. Signs were hung on the bolt when the bolt was about seven feet high. The conduit was then pushed up the post until the bottom of the sign was seven feet from the ground. The base for the post was basically a cross with adjustable props which enabled plumbing of the post. This post system worked well, enabling signs to be changed in about 20 seconds. It also prevented sign changers from having to go up and down stairs in the dark.

The opaque screen placed in front of the sign post was simply two to four feet by eight feet sheets of plywood painted flat black. The screens prevented the observers from seeing the signs when the headlights were shining directly on them at ground level. The screens were supported by a table which gave the sign changers a place to write down the order of sign presentation.

The observers sat in folding chairs. Their eye height was measured to be about 3.5 feet making, any height adjustment unnecessary. They were given a clipboard with a rating sheet (see Figure C-1), a small penlight flashlight and a pencil. This system worked satisfactorily.

NAME__________ OBSERVER NO.__________

DATE__________ SESSION__________

Sign	Rating	Sign	Rating	Sign	Rating	Sign	Rating
1		26		51		76	
2		27		52		77	
3		28		53		78	
4		29		54		79	
5		30		55		80	
6		31		56		81	
7		32		57		82	
8		33		58		83	
9		34		59		84	
10		35		60		85	
11		36		61		86	
12		37		62		87	
13		38		63		88	
14		39		64		89	
15		40		65		90	
16		41		66		91	
17		42		67		92	
18		43		68		93	
19		44		69		94	
20		45		70		95	
21		46		71		96	
22		47		72		97	
23		48		73		98	
24		49		74		99	
25		50		75		100	

Figure C-1.
Laboratory and Controlled Highway Experiment Rating Sheet

CONTROLLED HIGHWAY EXPERIMENT

The controlled highway experiment was conducted using the same set of signs, the same sign post, and the same observer groups, and the observers used the same rating sheets and system for marking down their ratings.

The vehicles used were typical of vehicles that maybe used for reviewing signs. When the controlled highway experiments began, only seventeen observers remained in the study. In the one group with five people, three people sat in the back seat; otherwise, two people sat in the front seat and two people sat in the back seat of the vehicles.

The experiment was conducted in two separate locations. In both locations the approach to the sign was straight and the service road was as level as possible. There were some minor inconsistencies in the road. The conditions were as dark as possible, with only a few lights in the far distance behind the sign (no lights were directly behind signs).

HIGHWAY EXPERIMENT

The highway experiment was conducted similarly to the controlled highway experiment. A maximum of three observers sat in the vehicles (one as front seat passenger and two in the back seat). Observers used the same clipboards and flashlights to record their ratings. The rating sheets for the highway experiments listed every sign by number, type, location and size. They also had a line for comments. This listing was somewhat similar to a sign log that would be used under actual conditions. A copy of the rating sheets is included as Figures C-2 and C-3.

Name______________________________ Observer Number____________

Date______________________________ Session______________________

Sign No.	Description	Size	Rating	Comments
1.	Curve Warning Right	30 x 30	____	______________________
2.	Pedestrian Crossing	48 x 48	____	______________________
3.	Stop Sign	30 x 30	____	______________________
4	School Bus Stop Ahead	30 x 30	____	______________________
5.	Stop Sign	30 x 30	____	______________________
6.	Stop Sign	30 x 30	____	______________________
7.	Reverse Turn Warning	30 x 30	____	______________________
8.	Pedestrian Crossing	48 x 48	____	______________________
9.	Curve Warning Left	30 x 30	____	______________________
10.	Stop Sign	30 x 30	____	______________________
11.	Stop Sign	30 x 30	____	______________________
12.	Pedestrian Crossing	30 x 30	____	______________________
13.	School Advance Warning	30 x 30	____	______________________
14.	School Crossing	30 x 30	____	______________________
15.	School Crossing	30 x 30	____	______________________
16.	Stop Sign	30 x 30	____	______________________
17.	Stop Sign	30 x 30	____	______________________
18.	Deer Crossing	30 x 30	____	______________________
19.	Curve Warning Right	30 x 30	____	______________________
20.	Winding Road Warning	30 x 30	____	______________________
21.	Truck Crossing	30 x 30	____	______________________
22.	Curve Warning Left	30 x 30	____	______________________
23.	School Bus Turn Around Ahead	30 x 30	____	______________________

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Figure C-2.
Rural Highway Experiment Rating Sheet

Name____________________________________ Observer Number______________

Date_____________________________________ Session______________________

Sign No.	Description	Size	Rating	Comments
24.	Curve Warning Left	30 x 30	___	________________
25.	Curve Warning Right	30 x 30	___	________________
26.	Cross Road Warning	30 x 30	___	________________
27.	Stop Sign	30 x 30	___	________________
28.	Curve Warning Right	30 x 30	___	________________
29.	Curve Warning Right	30 x 30	___	________________
30.	Curve Warning Left	30 x 30	___	________________
31.	School Advanced Warning	30 x 30	___	________________
32.	Cross Road Warning	30 x 30	___	________________
33.	Stop Sign	30 x 30	___	________________
34.	Stop Sign	30 x 30	___	________________
35.	Winding Road	30 x 30	___	________________
36.	Side Road Warning	30 x 30	___	________________
37.	Stop Sign	30 x 30	___	________________
38.	Curve/Cross Road Warning	30 x 30	___	________________
39.	Stop Sign	30 x 30	___	________________
40.	Curve Warning Right	30 x 30	___	________________
41.	Side Road Warning	30 x 30	___	________________
42.	Curve Warning Left	30 x 30	___	________________

Figure C-2.
Rural Highway Experiment Rating Sheet (Continued)

Name________________________________ Observer Number______________

Date________________________________ Session________________________

Sign No.	Description	Size	Rating	Comments
51.	Curve Warning Right	30 x 30	____	________________________
52.	Side Road Warning	30 x 30	____	________________________
53.	Stop Sign	30 x 30	____	________________________
54.	Curve Warning Right	30 x 30	____	________________________
55.	Stop Sign	30 x 30	____	________________________
56.	Side Road Warning	30 x 30	____	________________________
57.	Winding Road Warning	30 x 30	____	________________________
58.	Reverse Curve Warning	30 x 30	____	________________________
59.	School Advance Warning	30 x 30	____	________________________
60.	Cross Road Warning	30 x 30	____	________________________
61.	Stop Sign	30 x 30	____	________________________
62.	Curve Warning Left	30 x 30	____	________________________
63.	Curve Warning Left	30 x 30	____	________________________
64.	Cross Road Warning	30 x 30	____	________________________
65.	Curve Warning Left	30 x 30	____	________________________
66.	Stop Sign, Straight and Left	30 x 30	____	________________________
67.	Stop Sign, Right	30 x 30	____	________________________
68.	School Bus Turn Around Ahead	30 x 30	____	________________________
69.	Curve Warning Right	30 x 30	____	________________________
70.	Truck Crossing	30 x 30	____	________________________
71.	Winding Road Warning	30 x 30	____	________________________
72.	Curve Warning Left	30 x 30	____	________________________
73.	Signal Ahead Warning	48 x 48	____	________________________

Figure C-2.
Rural Highway Experiment Rating Sheet (Continued)

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Name________________________________ Observer Number______________

Date________________________________ Session________________________

Sign No.	Description	Size	Rating	Comments
74.	Stop Sign	30 x 30	____	______________________
75.	Stop Sign	30 x 30	____	______________________
76.	Right Lane Ends	30 x 30	____	______________________
77.	Stop Sign	30 x 30	____	______________________
78.	Lane Drop Sign	30 x 30	____	______________________
79.	School Advanced Warning	30 x 30	____	______________________
80.	School Crossing	30 x 30	____	______________________
81.	Stop Sign	30 x 30	____	______________________
82.	Pedestrian Crossing	30 x 30	____	______________________
83.	School Crossing	30 x 30	____	______________________
84.	Reverse Curve Warning	30 x 30	____	______________________
85.	Pedestrian Crossing	48 x 48	____	______________________
86.	Curve Warning Left	30 x 30	____	______________________

Figure C-2.
Rural Highway Experiment Rating Sheet (Continued)

Name____________________ Observer Number__________

Date____________________ Session__________

Car Number____________________ Seat Position__________

Sign No.	Description	Size	Rating	Comments
1.	Stop, 147th	30 x 30	____	__________
2.	Side Road Warning	30 x 30	____	__________
3.	Stop, 153rd	30 x 30	____	__________
4.	Stop, 155th	30 x 30	____	__________
5.	Signal Ahead	36 x 36	____	__________
6.	Signal Ahead	36 x 36	____	__________
7.	Stop, 41st	30 x 30	____	__________
8.	Side Road Warning	30 x 30	____	__________
9.	Stop, 65th	30 x 30	____	__________
10.	Side Road Warning	30 x 30	____	__________
11.	Side Road Warning	30 x 30	____	__________
12.	Side Road Warning	30 x 30	____	__________
13.	Curve Warning, Left (Mod.)	36 x 36	____	__________
14.	Stop Sign	30 x 30	____	__________
15.	Signal Ahead	30 x 30	____	__________
16.	Overheight Detector	30 x 30	____	__________
17.	Overheight Vehicle	48 x 48	____	__________
18.	13 ft. 6 inch	30 x 30	____	__________
19.	Stop, Bothell Landing	30 x 30	____	__________
20.	Curve Warning, Right	30 x 30	____	__________
21.	Curve Warning, Left	30 x 30	____	__________
22.	Stop, Woodinville Drive	30 x 30	____	__________
23.	Lane Merge	48 x 48	____	__________

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Figure C-3.
Urban Highway Experiment Rating Sheet

Name________________________________ Observer Number______________

Date________________________________ Session______________________

Car Number__________________________ Seat Position________________

Sign No.	Description	Size	Rating	Comments
51.	Lane Merge	48 x 48	___	___________
52.	Left Lane Ends	48 x 48	___	___________
53.	Lane Drop	48 x 48	___	___________
54.	(Left) Curve Warning, Right	48 x 48	___	___________
55.	(Right) Curve Warning, Right	48 x 48	___	___________
56.	Right Arrow	96 x 48	___	___________
57.	13 ft. 6 inch	30 x 30	___	___________
58.	Turn Warning, Left	30 x 30	___	___________
59.	Overheight Detector	30 x 30	___	___________
60.	Stop When Flashing	48 x 48	___	___________
61.	13 ft. 6 inch	36 x 36	___	___________
62.	Stop, Bothell Landing	30 x 30	___	___________
63.	Signal Ahead	30 x 30	___	___________
64.	Signal Ahead	30 x 30	___	___________
65.	Stop, Orbreck	30 x 30	___	___________
66.	Stop, Hall Road	30 x 30	___	___________
67.	Curve Warning, Right	30 x 30	___	___________
68.	Stop	30 x 30	___	___________
69.	Stop	30 x 30	___	___________
70.	Stop, 67th	30 x 30	___	___________
71.	Stop, 65th	30 x 30	___	___________
72.	Stop, 63rd	30 x 30	___	___________
73.	Stop, 62nd	30 x 30	___	___________

Figure C-3.
Urban Highway Experiment Rating Sheet (Continued)

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Name________________________________ Observer Number______________

Date________________________________ Session______________________

Car Number___________________________ Seat Position_________________

Sign No.	Description	Size	Rating	Comments
74.	Stop, 60th	30 x 30	____	______________________
75.	Signal Ahead	48 x 48	____	______________________
76.	Stop, 47th	30 x 30	____	______________________
77.	Stop, Brookside	30 x 30	____	______________________
78.	Stop, Bothell Way	30 x 30	____	______________________
79.	Stop, 38th	30 x 30	____	______________________
80.	Stop, 155th	30 x 30	____	______________________
81.	Stop 149th	30 x 30	____	______________________

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Figure C-3.
Urban Highway Experiment Rating Sheet (Continued)

OBSERVER

The ad placed in the University of Washington Daily on June 25, 1986, and the notice posted on bulletin boards on the University of Washington campus to obtain the observers used in the study are included as Figures C-4 and C-5, respectively.

The observers were required to sign the consent form in Figure C-6.

A typical sheet that was used to show the observers were rating signs is shown in Figure C-7 for warning signs and C-8 for stop signs. The figures have the sign rating on the left and the session number along the bottom. The observer mean for each category is shown by a dot and number. When two distances were observed in one night the A, B, C for laboratory experiment and controlled highway experiments represented 100, 200 and 300 feet, respectively; the S and M in the highway experiments represented the stationary or moving observations to rate the warning signs.

... month study using a new ... ...nt. Three clinic visits involved. Physical exam, ... smear, lab work, study medication—FREE OF CHARGE. Remuneration: $50 for transportation, parking, baby sitter, and other expenses. For more information call Mary Jo Levinski, R.N., 232-1400, University of Washington School of Medicine.

Male and female participants between the ages of 21 and 55 wanted for traffic sign reflectivity study. Must be available between 9 p.m. and 1 a.m. weeknights. Participants' vision must be corrected to 20/30. Compensation will be $5/hour for an estimated 16 hours. For more information contact Ed Lagergren at 545-2644, University of Washington Department of Civil Engineering, Transportation Center.

DRINKERS willing to stop for 2 weeks. Psychology experiment on cognitive—perceptual effects of moderate drinking. Must be UW student, 21 or older, experienced with alcohol but no history of legal, medical or abuse-related problems with alcohol or drugs. $20 for completion of experiment. Ca...

p.m.

Typi...

Letters.
Eastsk...
Nights.
Kath...

Figure C-4.
University of Washington <u>Daily</u> Advertisement

HELP WANTED

Male and female participants needed for traffic sign reflectivity study. Must be available between 9:00 p.m. and 12:00 p.m. weeknights. Participants vision will be examined. Pay will be $5.00 per hour for an estimated 16 hours. For more information contact:

Ed Lagergren at 545-2644,
University of Washington,
Department of Civil Engineering,
Transportation Center.

June 24, 1986

Figure C-5.
Bulletin Board Announcement

UNIVERSITY OF WASHINGTON
CONSENT FORM
SIGN REFLECTIVITY EXPERIMENTS

Principal Investigator
Dr. G. Scott Rutherford
Associate Professor
Department of Civil Engineering
Telephone: 545-2481

Associate Investigator
Mr. Edwin A. Lagergren
Graduate Student
Department of Civil Engineering
Telephone: 545-2644

INVESTIGATOR'S STATEMENT

Purpose and Benefits

Traffic sign reflectivity decreases with age. This research is designed to assess the accuracy and usefulness of using observers to determine the levels of reflectivity of traffic signs. If research shows that a human observer can adequately assess sign reflectivity levels it will save transportation agencies from having to adopt more expensive methods of sign review as well as increasing highway safety.

Procedures

You will be given an eye examination (no drugs will be administered) and then classroom instruction on detecting levels of reflectivity. Following this instruction, you will participate in some or all of the following experiments.

1. Lab experiment. The experiment will be conducted in Edmundson Pavilion. You will visually rate traffic sign reflectivity from several distances. Time required: three-two hour sessions.

2. Controlled highway experiment. You will visually rate traffic signs from inside a stationary vehicle from several distances. Time required: three-two hour sessions.

3. Highway experiment. You will visually rate traffic sign reflectivity in a highway environment. You will be driven on a test course set up on a state highway. You will remain in the vehicle at all times. Time required: one-three hour session.

Reflectivity ratings will be written on a provided form.

All experiments and instruction will be conducted between the hours of 9:00pm and 1:00am weeknights. All experiments will be conducted between June 30 and August 14, 1986.

Figure C-6.
Observer Consent Form

Risks, Stress or Discomfort

Risks will be similar to normal daily activities. The greatest potential risk will be during the highway experiment which will involve riding in a vehicle at night and stopping along the highway to review signs from inside the vehicle. The vehicle will be equipped with a flashing beacon for safety and you will not have to get out of the vehicle.

Other Information

Your identity will remain confidential. Only the named investigators will have access to your data. You are free to refuse to participate and to withdraw at any time without penalty or loss of benefits to which you are otherwise entitled. For participation in the research, you will be paid $5.00 per hour paid in accordance with the University of Washington payroll.

________________________ ________
Signature of Investigator Date

SUBJECT'S STATEMENT

The research described above has been explained to me, and I voluntarily consent to participate in this research. I have had an opportunity to ask questions and understand that future questions I may have about the research or about subjects' rights will be answered by one of the investigators listed above.

________________________ ________
Signature of Subject Date

cc: Subject
Investigator's file

Figure C-6.
Observer Consent Form (Continued)

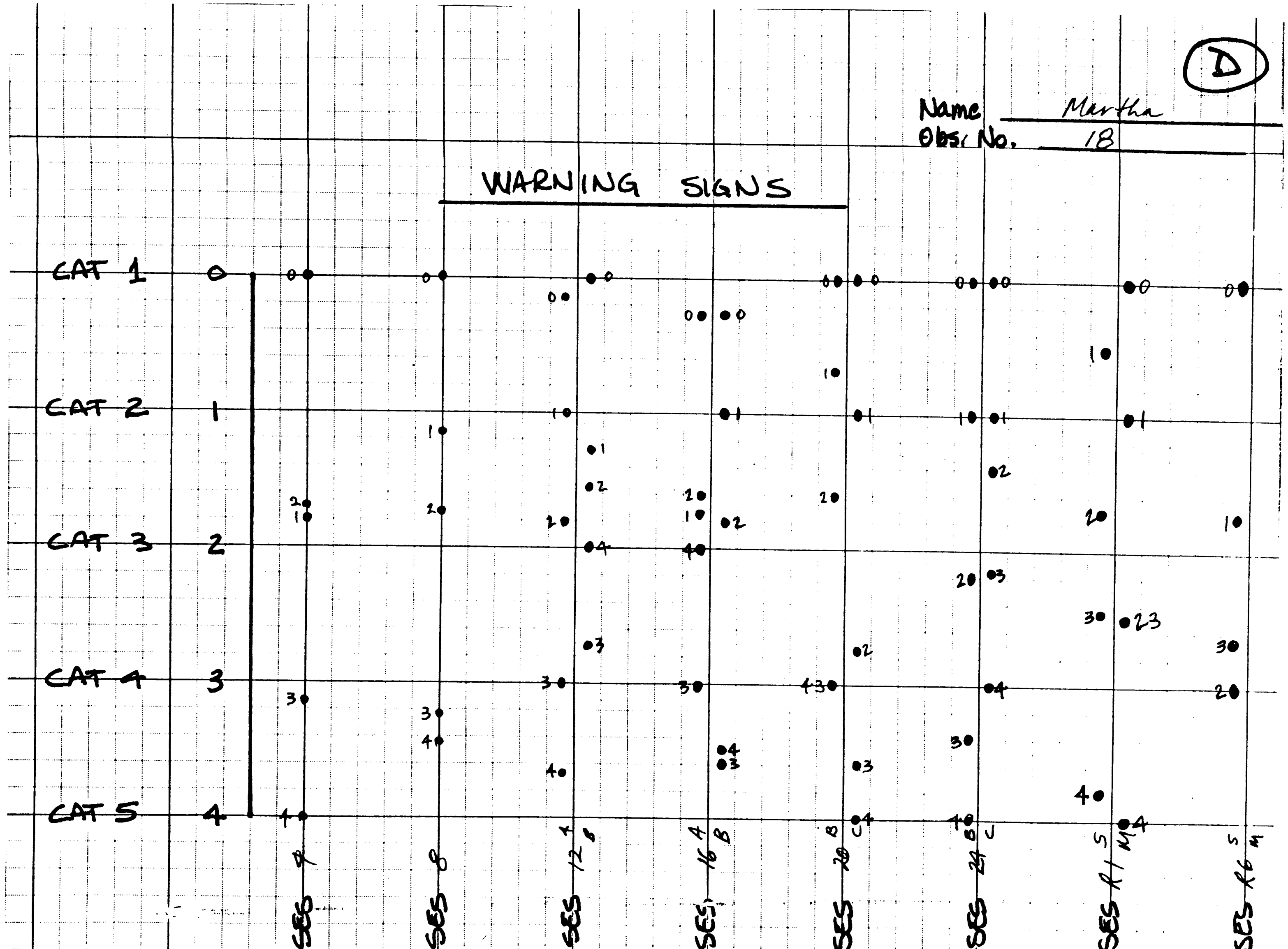

Figure C-7.
Warning Sign Observer Mean

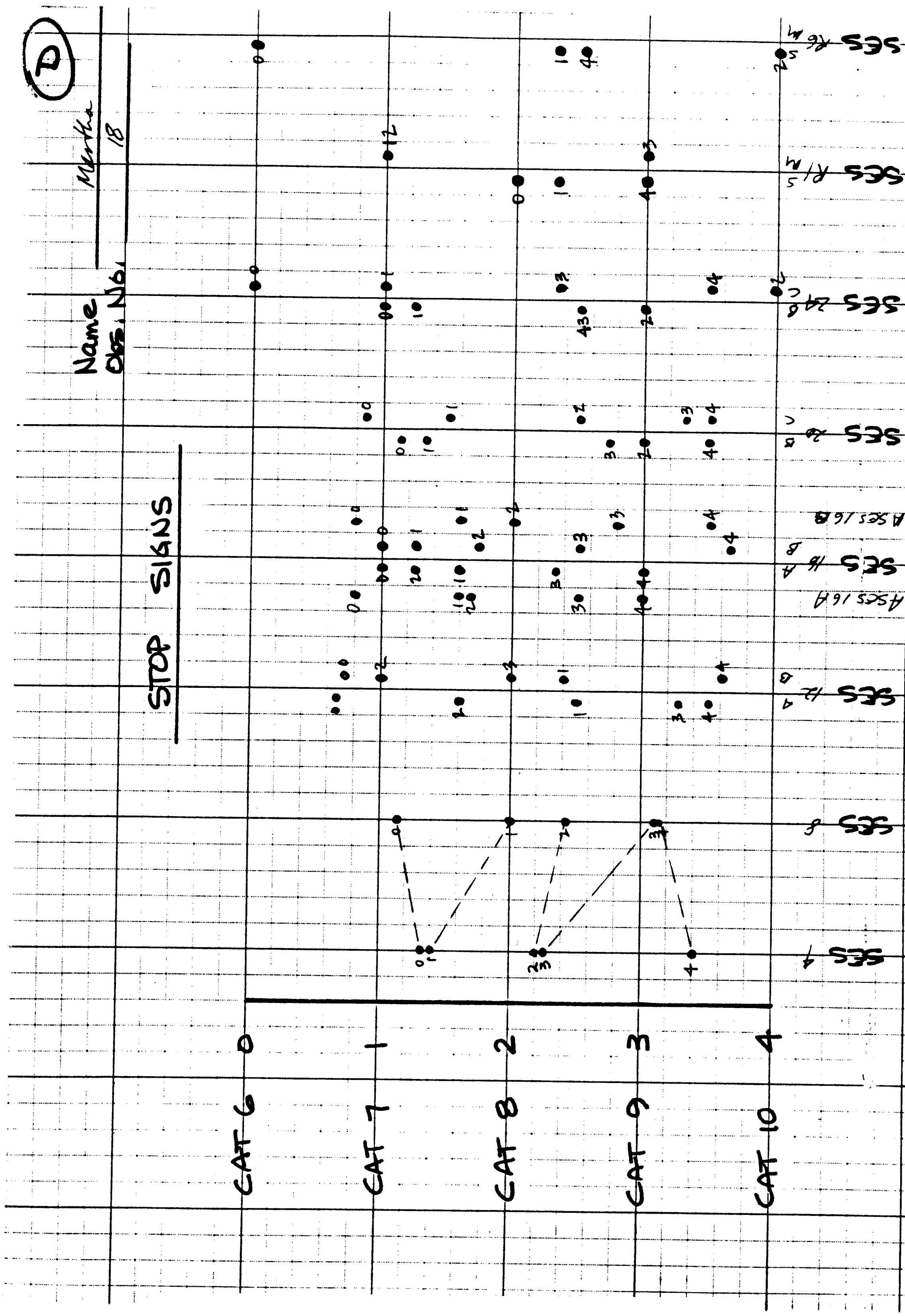

Figure C-8.
Stop Sign Observer Mean

APPENDIX D
SIGN DATA

Table D-1. Laboratory and Controlled Highway Experiments, Warning Sign Data.

Sign No.	MUTCD Code	SIA	Rating	Decimal Rating
1	W2-1	6	0	0.97
2	W2-2	49	3	3.42
3	W2-1	32	2	2.76
4	W2-2	30	2	2.69
5	W2-2	65	4	4.00
6	W2-2	31	2	2.70
7	W2-1	68	4	4.09
8	W2-1	29	2	2.59
9	W2-1	5	0	0.80
10	W2-2	0	0	0.00
11	W2-1	59	3	3.76
12	W2-2	56	3	3.66
13	W2-2	11	1	1.42
14	W2-1	14	1	1.72
15	W2-2	24	2	2.36
16	W2-2	52	3	3.53
17	W2-2	60	3	3.79
18	W2-2	53	3	3.56
19	W2-2	1	0	0.23
20	W2-2	10	1	1.36
21	W2-1	42	3	3.19
22	W2-2	20	2	2.12
23	W2-1	20	2	2.11
24	W2-1	16	1	1.83
25	W2-1	10	1	1.37

Notes

1. All signs are 30" x 30"

Table D-2. Laboratory and Controlled Highway Experiments, Stop Sign[2] Data.

Sign No.	Type[1]	White, SIA	Red, SIA	White/Red Ratio	Overall SIA	Rating	Decimal Rating
50	H	233	23	10 :1	74	4	4.10
51	H	3	8	0.3 :1	7	0	0.00
52	H	180	50	4 :1	82	1	1.10
53	E	69	5	14 :1	21	1	1.23
54	E	32	4	8 :1	11	0	0.70
55	E	0	0	0 :0	0	0	0.00
56	E	48	5	10 :1	15	1	1.00
57	E	37	9	4 :1	16	0	0.65
58	H	91	14	6 :1	33	1	1.30
59	E	94	3	31 :1	25	1	0.92
60	H	23	7	3 :1	11	0	0.26
61	E	41	0	100 :1	10	0	0.40
62	H	165	56	3 :1	83	0	0.70
63	SE	136	2	68 :1	34	1	0.90
64	H	5	24	0.2 :1	19	0	0.00
65	E	41	4	10 :1	13	0	0.90
66	H	230	28	8 :1	77	4	4.05
67	SE	160	9	18 :1	46	3	2.30
68	H	187	51	4 :1	84	1	1.10
69	E	13	4	3 :1	6	0	0.20
70	H	205	31	7 :1	73	3	3.30
71	H	185	18	10 :1	59	3	3.20
72	E	62	7	9 :1	20	1	1.20
73	E	113	22	5 :1	44	2	1.10
74	SE	175	30	6 :1	65	3	2.40
75	H	186	23	8 :1	63	3	3.20
76	H	238	13	18 :1	68	3	3.60
77	H	151	10	15 :1	44	1	2.50[3]
78	H	131	9	15 :1	39	2	2.10
79	E	63	4	16 :1	18	1	1.17

Notes

1. H = High Intensity
   SE = Super Engineer grade
   E = Engineer grade

2. All signs are 30" x 30"

3. Sign had visible streak and was rated 1

Table D-3. Highway Experiment Warning Sign Data

Rural Course

Sign No.	MUTCD Code	Size[1]	SIA, Yellow	Rating	Decimal Rating
	Stationary Observation				
101	W1-2R		25	2	2.38
102	W11A-2	48x48	32	2	2.78
104	S3-1		45	3	3.30
107	W1-4L		28	2	2.56
108	W11A-2	48x48	14	1	1.67
109	W1-2L		48	3	3.40
112	W11A-2		46	3	3.33
113	S1-1		13	1	1.58
114	S2-1		70	4	4.20
115	S2-1		67	4	4.00
118	W11-3		30	2	2.67
119	W1-2R		48	3	3.40
120	W1-5		22	2	2.22
121	W1-6		62	3	3.87
122	W1-2L		47	3	3.37
124	W1-2L		62	3	3.87
125	W1-2R		65	3	3.97
126	W2-1		68	3	3.95
128	W1-2R		57	3	3.70
129	W1-2R		68	4	4.00
130	W1-2L		68	4	4.00
131	S1-1		53	3	3.57
132	W2-1		64	3	3.93
135	W1-5		49	3	3.43
136	W2-2		53	3	3.57
138	W1-2L		78	4	4.60
140	W1-2R		51	3	3.50
141	W2-2		38	2	2.90[2]
142	W1-2L		51	3	3.50

Notes

1. All signs are 30" x 30" unless otherwise specified.
2. Sign rated lower based on appearance.

Table D-3. (cont.)

Rural Course

Sign No.	MUTCD Code	Size[1]	SIA, Yellow	Rating	Decimal Rating
	Moving Observation				
151	W1-2R		33	2	2.83
152	W2-2		61	3	3.83
154	W1-2L		10	1	1.33
156	W2-2		40	3	3.13
157	W1-5		55	3	3.63
158	W1-4R		30	2	2.67
159	S1-1		53	3	3.57
160	W2-1		38	2	2.90[2]
162	W1-2L		47	3	3.37
163	W1-2L		55	3	3.63
164	W2-1		50	3	3.46
165	W1-2L		57	3	3.70
168	S3-1		55	3	3.63
169	W1-2R		57	3	3.70
170	W11-6		0	0	0.00
171	W1-5		29	2	2.61
172	W1-2L		45	3	3.30
173	W3-3	48x48	74	4	4.40
176	W9-1		15	1	1.75
178	W4-2		36	2	2.99
179	S1-1		0	0	0.00
180	S2-2		1	0	0.17
182	W11A-2		44	3	3.26
183	S2-1		0	0	0.00
184	W1-4L		10	1	1.33
185	W11A-2	48x48	39	3	3.10
186	W1-2L		20	1	1.90[2]

Notes

1. All signs are 30" x 30" unless otherwise specified.
2. Sign rated lower based on appearance.

Table D-4. Urban Highway Experiment Warning Sign Data.

Urban Course

Sign No.	MUTCD Code	Size[1]	SIA, Yellow	Rating	Decimal Rating
	Stationary Observation				
202	W2-2		0	0	0.00
205	W3-3	36x36	64	3	3.93
206	W3-3	36x36	66	3	3.95
208	W2-2		34	2	2.89
210	W2-2		45	3	3.30
211	W2-2		46	3	3.33
212	W2-2		12	1	1.50
213	W1-2L	36x36	49	3	3.43
215	W3-3		34	2	2.89
216	W(SPL)		51	3	3.50
217	W(SPL)	48x48	62	3	3.87
218	W(SPL)		18	1	1.99
220	W1-1R		15	1	1.75
221	W1-1L		52	2	2.90[2]
223	W4-1	48x48	49	3	3.43

Notes

1. All signs are 30" x 30" unless otherwise specified.
2. Sign rated lower based on appearance.

Table D-4. (cont.)

Urban Course

Sign No.	MUTCD Code	Size[1]	SIA, Yellow	Rating	Decimal Rating
	Moving Observation				
251	W4-1	48x48	51	3	3.50
252	W9-1	48x48	66	3	3.95
253	W4-2L	48x48	26	2	2.44
254	W1-2R	48x48	17	1	1.92
255	W1-2R	48x48	13	1	1.58
256	W1-6	96x48	66	3	3.95
257	W(SPL)		63	3	3.90
258	W1-1L		2	0	0.33
259	W(SPL)		63	3	3.90
260	W(SPL)	48x48	67	3	3.96
261	W(SPL)	36x36	21	2	2.17
263	W3-3		54	3	3.60
264	W3-3		40	3	3.13
267	W1-2R		16	1	1.83
275	W3-3	48x48	54	3	3.60

Notes

1. All signs are 30" x 30" unless otherwise specified.

Table D-5. Rural Highway Experiment, Stop Sign Data.

Rural Course

Sign No.	Type[1]	Size[2]	White, SIA	Red, SIA	Ratio	Overall SIA	Rating	Decimal Rating
103	H		139	2	70:1	35	0	1.17
105	E		82	3	27:1	22	1	1.14
106	E		67	4	17:1	19	1	1.20
110	E		60	10	6:1	22	1	1.00
111	E		40	5	8:1	14	0	0.80
116	E		79	15	5:1	30	1	1.00
117	SE		155	10	16:1	45	3	2.60
127	SE		155	10	16:1	45	3	2.60
133	E		57	4	14:1	17	1	1.10
134	SE		155	10	16:1	45	3	2.60
137	SE		155	10	16:1	45	3	2.60
139	E	36x36	104	2	52:1	26	1	1.00
153	H		210	23	9:1	69	3	3.70
155	H		201	32	6:1	73	3	3.38
161	H		232	37	6:1	86	3	4.00
166	SE		155	10	16:1	45	3	2.60
167	SE		155	10	16:1	45	3	2.60
174	H		192	20	10:1	62	3	3.30
175	E		125	20	63:1	46	2	1.00
177	E		71	3	24:1	20	1	1.10
181	H		207	27	8:1	71	3	3.60

Notes

1. H = High Intensity
   SE = Super Engineer grade
   E = Engineer grade

2. All signs are 30" x 30" unless otherwise specified.

Table D-6. Urban Highway Experiment, Stop Sign Data.

Urban Course

Sign No.	Type[1]	Size[2]	White, SIA	Red, SIA	Ratio	Overall SIA	Rating	Decimal Rating
201	H		235	22	11:1	74	4	4.10
203	E		123	5	25:1	34	2	1.40
204	E		76	12	6:1	28	1	1.20
207	H		270	26	10:1	86	4	4.50
209	E		3	4	1:1	4	0	0.00
214	E		82	5	16:1	24	1	1.40
219	E		16	16	1:1	16	0	0.10
222	E		82	17	5:1	33	1	0.95
262	E		62	21	3:1	31	0	0.60
265	E		103	20	5:1	40	2	1.00
266	E		84	16	5:1	33	1	1.00
268	SE		103	11	9:1	33	2	1.80
269	H		196	19	10:1	62	3	3.40
270	E		2	1	2:1	1	0	0.00
271	E		16	2	8:1	5	0	0.30
272	E		2	1	2:1	1	0	0.00
273	E		34	5	7:1	12	0	0.70
274	E		24	3	8:1	8	0	0.50
276	H		200	22	9:1	65	3	3.50
277	E		32	6	5:1	12	0	0.58
278	H		110	14	8:1	37	1	1.80
279	H		180	24	8:1	62	3	3.00
280	E		2	1	2:1	1	0	0.00
281	SE		157	5	31:1	42	2	1.80

Notes

1. H = High Intensity
   SE = Super Engineer grade
   E = Engineer grade

2. All signs are 30" x 30" unless otherwise specified.

Table D7. Rural Highway Experiment, Sign Environment.

Sign No.	Placement[1]	Approach		Obstruction			Lighting		
		Level	Curve	None	Partial	Full	Dark	StreetLight	Commercial
101		X		X				X	
102		X			X			X	
103			X		X		X		
104			X		X			X	
105			X		X			X	
106		X			X			X	
107		X		X				X	
108		X		X			X		
109		X		X			X		
110		X	X		X			X	
111			X			X		X	
112			X	X				X	
113		X		X				X	
114			X	X				X	
115			X	X				X	
116		X		X				X	
117		X			X		X		
118		X		X			X		
119		X		X			X		
120		X		X			X		
121			X	X			X		
122		X		X			X		
123				X			X		
124			X	X			X		
125		X		X			X		

Notes: [1] Right unless otherwise specified

Table D7. (cont.).

Sign No.	Placement [1]	Approach: Level	Approach: Curve	Obstruction: None	Obstruction: Partial	Obstruction: Full	Lighting: Dark	Lighting: StreetLight	Lighting: Commercial
126		X		X			X		
127			X	X			X		
128		X		X			X		
129		X		X			X		
130			X	X			X		
131		X		X			X		
132			X	X				X	
133			X	X					X
134		X		X			X		
135		X		X			X		
136			X	X			X		
137		X		X			X		
138		X		X			X		
139			X	X			X		
140		X		X			X		
141			X	X			X		
142			X	X			X		
151		X		X				X	
152		X		X			X		
153			X	X			X		
154			X	X			X		
155		X		X			X		
156		X		X			X		
157		X		X			X		
158			X	X			X		
159		X		X			X		
160			X	X			X		

Notes: [1] Right unless otherwise specified

Table D7. (cont.).

Sign No.	Placement [1]	Approach: Level	Approach: Curve	Obstruction: None	Obstruction: Partial	Obstruction: Full	Lighting: Dark	Lighting: StreetLight	Lighting: Commercial
161		X		X				X	
162		X		X			X		
163		X		X			X		
164		X		X			X		
165		X		X			X		
166		X		X			X		
167			X		X		X		
168		X		X			X		
169		X		X			X		
170		X		X			X		
171			X	X			X		
172			X	X			X		
173		X		X			X		
174		X				X		X	
175		X		X				X	
176		X		X				X	
177			X	X				X	
178		X		X				X	
179		X		X				X	
180		X		X			X		
181			X	X			X		
182		X		X				X	
183		X		X				X	
184		X			X		X		
185			X	X				X	
186		X		X				X	

Notes: [1] Right unless otherwise specified

Table D8. Urban Highway Experiment, Sign Environment.

Sign No.	Placement[1]	Approach		Obstruction			Lighting		
		Level	Curve	None	Partial	Full	Dark	StreetLight	Commercial
201		X		X				X	
202		X		X				X	
203			X	X				X	
204			X	X					X
205		X			X		X		
206			X		X		X		
207			X		X				X
208		X			X		X		
209			X	X				X	
210		X		X				X	
211		X			X			X	
212		X			X		X		
213		X		X			X		
214			X	X				X	
215		X		X					X
216			X	X				X	
217			X	X				X	
218			X	X				X	
219			X	X				X	
220		X		X				X	
221		X		X				X	
222			X	X			X		
223		X		X			X		

Notes: [1] Right unless otherwise specified

Table D8. (cont.).

Sign No.	Placement [1]	Approach		Obstruction			Lighting		
		Level	Curve	None	Partial	Full	Dark	StreetLight	Commercial
251		X		X			X		
252		X		X			X		
253	L	X		X			X		
254	L		X	X			X		
255			X		X		X		
256	S	X		X			X		
257			X	X				X	
258		X		X			X		
259		X		X				X	
260		X			X			X	
261		X		X				X	
262			X	X				X	
263		X		X				X	
264		X		X				X	
265		X		X			X		
266			X	X			X		
267		X		X				X	
268			X	X				X	
269			X	X			X		
270		X		X					X
271		X			X			X	
272			X	X				X	
273			X	X				X	
274			X		X			X	
275		X		X			X		

Notes: [1] Right unless otherwise specified
L = Left
S = Straight ahead

Table D8. (cont.).

Sign No.	Placement [1]	Approach		Obstruction			Lighting		
		Level	Curve	None	Partial	Full	Dark	StreetLight	Commercial
276			X	X			X		
277		X		X				X	
278			X		X			X	
279			X	X			X		
280			X		X			X	
281		X			X			X	

Notes: [1] Right unless otherwise specified

APPENDIX E
IMPLEMENTATION

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IMPLEMENTATION

This study on how well a person can be trained to judge the retro-reflectivity of traffic control devices could be used as a valuable tool by transportation agencies. A training course could be set up to certify the people who judge signs for replacement at the present time. With this certification program, agencies would be able to demonstrate that they were actively training personnel to review signs. This certification, in combination with regular day and night sign inspection, substantiated with record keeping indicating that effective remedial action is taken in a timely manner, would be two key elements in a tort action.

The training course could probably be given in one evening (four hours) to people who are already familiar with traffic sign replacement. The course would consist of instruction under both light and dark conditions. First, people would be shown signs with all types and colors of sheeting with different levels of retroreflectivity under lighted conditions. The people would be able to see the indicators of aging and see what to look for on signs in the field. Next, people would be put through a training session similar to the controlled highway experiment. They would receive instruction under dark conditions using the color chips and different signs. After the instruction they would observe a series of 20 signs for each color material (possibly less for brown and blue) and rate the signs. The data would then be analyzed, and if the person rated signs in the range with the observers in the study they would be certified.

The certification would assume that the people would replace signs with the same accuracy that the observers did in the highway experiments.

APPENDIX F
STOP SIGN OVERALL SIA REPLACEMENT

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STOP SIGN OVERALL SIA REPLACEMENT

After the data collection for this research was completed, the study team received a copy of Juan Morales's report, "Retroreflective Requirements for Traffic Signs: A Stop Sign Case Study." The report uses regression analysis to develop a relationship between the overall SIA of stop signs and their recognition distance. The study team wanted to see if the observers would be more accurate if the signs were rerated based on the Morales study.

The study team set up a rating system for stop signs based on overall SIA. The Morales report found that the recognition distance of a stop sign does not appreciably increase with an overall SIA above 20. The team set the boundary between the 2 and 3 at an overall SIA of 20. The boundary between 1 and 2 was then arbitrarily set at 10. The internal contrast range of the sign was kept at about the same optimum range between 6:1 and 18:1. This new scale can be seen in Figure F-1. The 0 and 4 ratings were omitted as they are special cases of categories 1 and 3, respectively.

The results of the rating scale can be seen in Table F-1. The individual observer's accuracy did improve slightly from 75 to 77 percent overall. Nine more signs were scheduled to remain in place using the new rating system.

One interesting difference was noted in the results between the two rating systems. The number of signs in the two incorrect categories were reversed. The rating system based on overall SIA had fewer signs not replaced that should have been replaced and replacement signs that should not have been replaced. This system would tend to reduce the liability of having signs remain in place beyond their useful life.

Table F-1. Stop Sign Rating Scale Comparison.

Observers' Decision	Replace		Do Not Replace	
Decision Model	Replace	Do Not Replace	Replace	Do Not Replace
Warning Signs				
Rural				
Number of Signs Original Rating System	9 6	0 2	0 3	11 9
Number of Signs Overall SIA Rating Sys.	7 5	0 3	0 2	13 10
Urban				
Number of Signs Original Rating System	18 13	0 1	0 5	6 5
Number of Signs Overall SIA Rating Sys.	11 10	0 4	0 1	13 9
Total				
Number of Signs Original Rating System	27 19	0 3	0 8	17 14
Number of Signs Overall SIA Rating Sys.	18 15	0 7	0 3	26 19

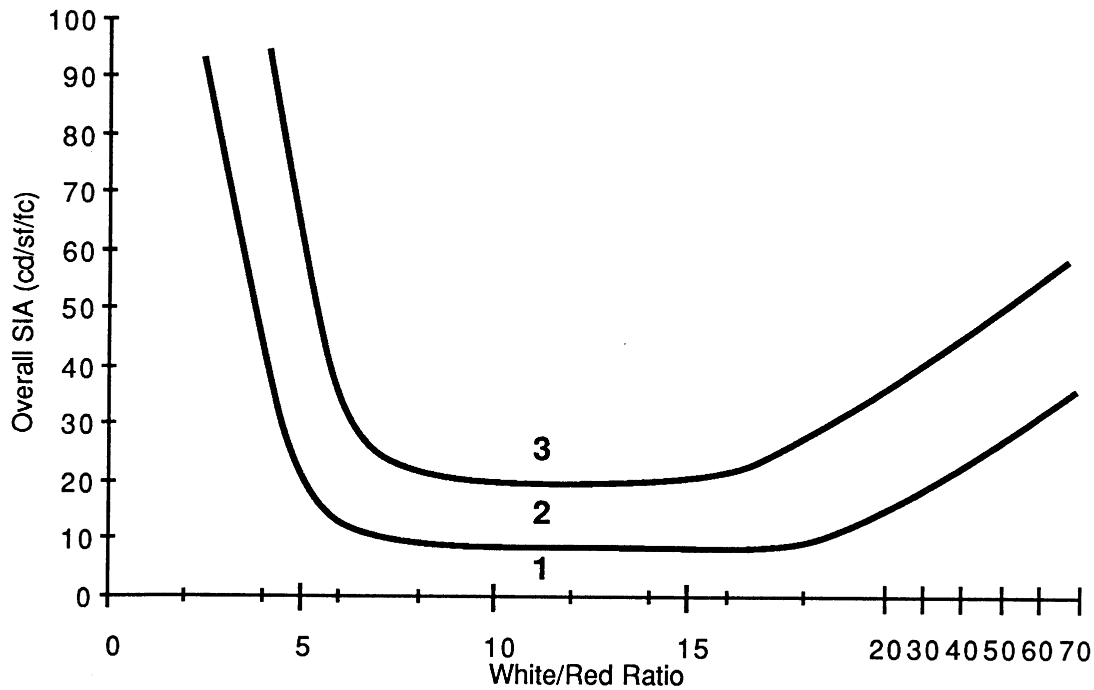

Figure F-1. Overall SIA Stop Sign Rating Scale.