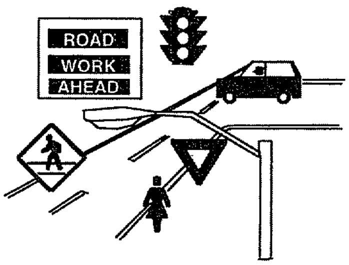
Summary Report

FHWA Traffic Safety Research Program



The FHWA Traffic Safety Research Program addresses the visibility of the roadway and its environment, and traffic control methods and devices to promote the safe and efficient movement of vehicles and pedestrians. The current emphasis areas are: the ITS program on advanced traveler information systems (ATIS), condition-responsive traffic control devices, and improved driver visibility through fluorescent materials and ultraviolet headlighting. Recent research includes recommending guidelines for the retroreflective requirements for traffic signs and pavement markings. The research is to support the programs of the FHWA's Office of Highway Safety and the Manual on Uniform Traffic Control Devices.

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MINIMUM SIGN RETROREFLECTIVE GUIDELINES

Introduction

Highway statistics reveal a nighttime accident rate that is more than three times the daytime rate. While factors such as intoxication and fatigue are partly responsible for this disparity, reduced visibility also plays a major role. Retroreflective traffic control devices are designed to help offset the lack of visual cues in the nighttime driving environment. Currently, the ***Manual on Uniform Traffic Control Devices (MUTCD)***[1] requires that signs be retroreflectorized, but no minimum in-service values are given for the level of retroreflectivity. Due to the degradation of retroreflective materials over the course of years, it is important to have a basis for knowing when to replace signs.

In the late 1980's, the Federal Highway Administration (FHWA) designated in-service retroreflectivity as the subject of a High-Priority National Program Area. The main goal of this program was to define the minimum nighttime visibility requirements for traffic control devices. The program also aimed to develop the measurement devices and computer management tools necessary to effectively implement the requirements.

A two-phased approach was taken in defining minimum retroreflectivity values for signs. On the one hand, human factors work was needed to determine drivers' needs for sign luminance for various signs and scenarios. On the other hand, analyses were needed to evaluate the likely economic implications of setting replacement values at various levels, as well as recognition of the practical requirements for implementation.

From a practical perspective, it was desirable to keep the number of required values to a minimum, e.g., to have a single value for each sign color. However, the human factors requirements for sign retroreflectivity is a highly complex problem, with numerous contributing factors. The solution to this question will depend on attributes of the sign (e.g., size, placement, sheeting material type, legend type, and color); roadway (e.g., posted speed, number of lanes); vehicle (e.g., headlight-beam patterns, headlight height); and driver (e.g., age, visual and cognitive capabilities). Consideration of all of these factors would result in minimum retroreflectivity levels for more than 500 different cases. This would obviously not be an acceptable solution.

A review of the literature found numerous studies addressing the problem; however, there was a lack of consistency in assumptions and methodologies that made it difficult to reconcile these studies with each other. Instead, FHWA chose to develop a model that would predict needed retroreflectivity on a case-by-case basis, considering all critical determining factors. Output from this model could then provide the basis for a simplified framework.

Computerized Analysis of Retroreflective Traffic Sign (CARTS) Model[2]

A three-stage model known as CARTS was developed. The CARTS model allows the user to vary numerous parameters, including type, size, and location of the sign; headlamp design and driver position; age and visual characteristics of the driver; roadway design; and traffic.

As a first stage, the CARTS model calculates the Minimum Required Visibility Distance (MRVD). The MRVD is the shortest distance at which a sign must be visible to enable the driver to respond safely and appropriately. Determination of the MRVD is based on a serial processing model, with components for the distance required for a driver to: (1) detect the presence of a sign, (2) recognize the message, (3) decide on a proper action (if necessary), and (4) make the appropriate maneuver (if necessary) prior to the sign moving out of the driver's vision.

After calculating the required MRVD for a selected sign, the model next determines the sign luminance required at the MRVD. This step makes use of a visibility model, DETECT, based on contrast threshold data. DETECT was designed to predict the distance at which a driver can detect and recognize a specified sign at a given luminance. For use in CARTS, the model was modified to predict the luminance needed for the driver to see the sign at a given distance.

Finally, the CARTS model converts the needed sign luminance to an equivalent retroreflectivity value at a standard measurement geometry. (This stage takes into account the characteristics of the sheeting material type and headlight-beam pattern, and does not involve human factors considerations.)

Framework for Minimum Retroreflectivity Values(2)

The researchers used outputs from the CARTS model to identify the critical variables affecting sign retroreflectivity and to provide insight into the levels of retroreflectivity that are required for meeting drivers' needs. Minimum retroreflectivity requirement tables were designed to provide a framework for field implementation of the requirements, with separate tables for regulatory, warning, and guide signs. The researchers estimated that the values shown in these tables would accommodate at least 75 to 85 percent of drivers.

Proposed Minimum Sign Retroreflectivity Guidelines(2)

The proposed minimum sign retroreflectivity guideline values developed from the research are presented in tables 1 through 5.

Table 1. Minimum retroreflectivity guidelines for warning signs with yellow/orange background and black legend

	Sign Size	>122 cm (48 in)	91 cm (36 in)	<76 cm (30 In)
Legend	Material Type			
Bold Symbol (see list)	All	15	20	25
Fine Symbol and Word	I	20	30	35
	II	25	35	45
	III	30	45	55
	IV & VII	40	60	70

Table 2. Minimum retroreflective guidelines for white legend on red background.

Traffic Speed	72 km/h (45 mi/h) or greater			64 km/h (40 mi/h) or less		
Sign Size	<122 cm (48 in)	91 cm (36 in)	>76 cm (30 in)	2122 cm (48 in)	91 cm (36 in)	176 cm (30 in)
Color	WR	WR	WR	WR	WR	W R
All Signs	35 8	45 6	50 8	25 5	30 5	35 5

Table 3. Minimum retroreflectivity guidelines for black or black-and-red on white background regulatory signs.

Traffic Speed	72 km/h (45 mi/h) or greater			64 km/h (40 mi/h) or less		
Sign Size	>122 cm (48 in)	76-91 cm (30-36 in)	<61 cm (24 in)	>122 cm (48 in)	76-91 cm (30-36 in)	561 cm (24 in)
Material						
I	25	35	45	20	25	30
II	30	45	55	25	30	35
III	40	55	70	30	40	45
IV & VII	50	70	90	40	50	60

Table 4. Minimum retroreflectivity guidelines for guide signs with white legends on green backgrounds.

Traffic Speed	72 km/h (45 mi/h) or greater		64 km/h (40 mi/h) or less	
Color	White	Green	White	Green
Ground-Mounted	35	7	25	5

Note: All table values are in cd/lx/m^2. Since both the legend and the background of these signs are retroreflective. a minimum contrast ratio of 4:1 should be maintained.

When both the legend and the background of these signs are retroreflective, a minimum contrast ratio of 4:1 should be maintained.

Table 5. Warning signs with bold symbols.

MUTCD Code	Sign Type
W1-1	Turn
W1-2	Curve
W1-3	Revrse Turn
W1-4	Reverse Curve
W1-5	Winding Road
W1-6	Large Arrow
W1-7	Double Arrowheads
W1-8	Chevron
W2-1	Cross Road
W2-2	Side Road
W2-4	T Intersection
W2-5	Y Intersection
W3-1a	Stop Ahead
W3-2a	Yield Ahead
W3-3	Signal Ahead
W4-1	Merge
W4-2	Lane Reduction
W4-3	Added Lane
W6-1	Divided Highway Begins
W6-2	Divided Highway Ends
W6-3	Two-Way Traffic
W8-5	Slippery When Wet
W11-2	Advanced Pedestrian Crossing
W11A-2	Pedestrian Crossing
W20-7a	Flagger Ahead

FHWA Evaluation Study[3]

A laboratory study was conducted to more fully evaluate the levels of driver accommodation provided by the proposed tables. This study measured luminance thresholds for recognition of a set of 25 representative traffic signs, for approximately 100 subjects, ages 20 to 85. Signs were scaled to half-size and were tested in static mode at viewing distances corresponding to the MRVD's for 89 km/h (55 mi/h) and 48 km/h (30 mi/h).

For each trial, subjects viewed a sign for 1 second and were asked to describe the sign message. If the subject responded incorrectly, the sign was retested in a later trial at the next highest luminance. This procedure was repeated for each sign and subject until either threshold was reached or the subject failed to recognize the sign at the highest luminance available.

As a first step in analyzing the data, a scatter plot was generated for each sign. Figures 1 and 2 illustrate some of the typical features of these scatter plots. The square data points represent data for each subject. Data for the text warning sign "Right Lane Ends" are shown in figure 1. It can be seen that, in general, older subjects require higher luminance than younger subjects in order to recognize the sign. Also, variability in the data tended to increase with subject age. These patterns were typical of the text warning signs tested. Figure 2 shows data for the right curve sign, which is typical of the bold symbol warning signs. By comparison with the text signs, even older subjects were able to recognize this bold stroke symbol sign at quite low luminance levels.

On each scatter plot, the diamond-shaped data points are values predicted by the CARTS model. It can be seen that the experimental data fall well below the CARTS predicted values. This is due, in part, to the simple nature of the experimental task, with the subject sitting quietly with all attention focused on the task, as compared with the attentional demands of the real-world driving task. Each graph also contains a horizontal line indicating the luminance value supplied by the candidate minimum retroreflectivity level recommended by the researchers. For each plot, almost all the subject data fall below this line, indicating that most of the subjects tested would be accommodated by the minimum retroreflectivity values.

A second level of analysis was necessary to estimate the percent accommodated for the driving population at large, since older drivers were deliberately over-

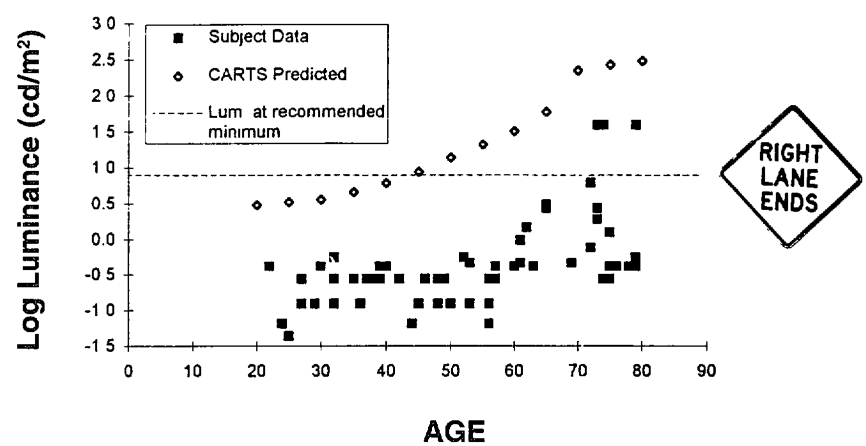

Figure 1. Luminance required to identify Right Lane Ends warning sign as a function of subject age.

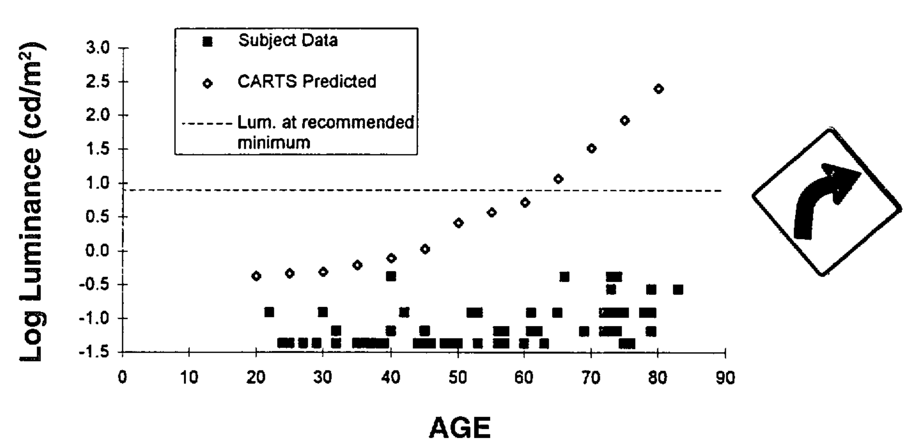

Figure 2. Luminance required to identify Curve symbol warning sign as a function of subject age.

sampled in the test sample. In order to develop an unbiased estimate, hypothetical data for each age group were generated by randomly sampling data from a normal distribution having the same mean and standard deviation as the corresponding subject age group. This was done for each sign tested. These values were compared against luminance values equivalent to the candidate retroreflectivity values. Results indicated that the recommended values would accommodate at least 90 percent of the drivers for all but three signs tested. (See tables 6 and 7.)

Table 6. Estimated percentage of drivers accommodated-warningsigns.

Curve	99
Intersection	100
Merge	100
Narrow Bridge	89
Slippery When Wet	99
Right Lane Ends	89
Bicycle	96
Pedestrian	99
Deer	100
Exit 25 mph	92
Flagger	100
Worker	98
Road Work 1 mile	96

Table 7. Estimated percentage of drivers accommodated-regulatory andguide signs.

stop	96
Yield	94
Speed Limit	97
Reduced Speed Ahead	94
No Right Turn	93
Do Not Pass	91
Keep Right	94
Do Not Enter	87
One Way	94
Route Marker	99
Guide Sign (1 line)	94
Guide Sign (2 lines)	94

Field Evaluation of Minimum Retroreflectivity Requirements(4)

To ensure that the candidate values will not require unreasonable levels of sign replacement in the field, the FHWA funded a field evaluation. There were 16 States and 9 local jurisdictions that participated in this effort.

The State and local highway agencies used retroreflectometers to measure the retroreflectivity of a representative sample of their signs according to a sampling plan provided by FHWA. Each agency was asked to report their retroreflective measures, an estimate of the number of signs that would have to be replaced under the candidate minimum levels of retroreflectivity, the cost of sign replacement, and ease of use of the hand-held retroreflectometer to collect data.

Based on the data collected by the States and local agencies that reflected the conditions in 1994, about 5 percent of the signs under State jurisdiction and 8 percent of the signs under local jurisdiction would not meet the proposed minimum retroreflectivity values and, hence, would need to be replaced. There will probably be a significant variation among the jurisdictions as to the number of signs not meeting the minimum value requirements. This variation will probably be greater among local jurisdictions than among State agencies, as the States had a higher percentage of new signs and higher grade sheeting materials.

The total cost nationally of replacing all the signs not meeting the minimum values was estimated to be about $32 million for the State agencies and $144 million for the local agencies. It is not expected that all the signs would be replaced at one time. The sign replacement rates to meet the requirements would not be significantly greater than the normal sign replacement rates. Most agencies replace their signs on an as-needed basis and, hence, many agencies won't feel any additional impact when implementing the minimum sign retroreflectivity guidelines.

Results

Final minimum sign retroreflective values developed from this research were sent from FHWA's Office of Safety and Traffic Operations Research and Development to FHWA's Office of Highway Safety. FHWA's Office of Highway Safety is issuing a proposed rule making in 1997 for minimum sign retroreflectivity guidelines to be put into the MUTCD. FHWA is publishing reports to help highway agencies implement these guidelines.

References

1. U.S. Department of Transportation. ***Manual on Uniform Traffic Control Devices,*** U.S. Government Printing Office, Washington, DC, 1988.

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4. Hugh W. McGee and Sunil Taori, ***Impact to State and Local Agencies for Maintaining Traffic Signs Within Minimum Retrorefectivity Guidelines,*** Report No. FHWA-RD-97-053, Federal Highway Administration, Washington, DC, 1997.

For More Information

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