

Maximizing Legibility of Traffic Signs in Construction Work Zones

DAVID A. KUEMMEL

The Wisconsin Department of Transportation contracted with Marquette University to research improvements in construction work zone signs. The RIGHT/LEFT LANE CLOSED and ROAD CONSTRUCTION series were selected because they are the most difficult to improve without increasing sign size above a 48-in. diamond. All signs used high-intensity retroreflective material. Twelve test signs were selected for day and night viewing by 46 observers under age 65, and 38 observers aged 65 and over. Experimental messages included rearranged legends (three to four lines) substitution of WORK for CONSTRUCTION, 18 percent stroke width increases on the inside of letters without increasing letter width, and use of Series E letters upper and lowercase [instead of all capitals as required by the *Manual on Uniform Traffic Control Devices (1)*]. The conclusion of this study was that few improvements can be made in the LANE CLOSED series without more drastic changes than those tested. In the ROAD CONSTRUCTION series, substantial improvement can be made by substituting WORK for CONSTRUCTION and increasing letter size. The 18 percent stroke-width concept resulted in no improvement and some reduction by day for younger observers. The most promising finding is the improvement possible with Series E letters because of their 20 percent increase in stroke width. Less loss of night legibility distance compared with that of day occurred with this alphabet than with any other. Further research substituting tenths of a mile for feet, which would allow larger letter size, is recommended, and field experimentation with Series E letter series under Federal Highway Administration requirements is recommended.

The Wisconsin Department of Transportation (WISDOT) has been striving for several years in its research to improve the conspicuity and legibility of its construction work zone (CWZ) signing. Several years ago, to improve conspicuity, WISDOT experimented with all high-intensity orange sheeting on state highway construction and maintenance projects. Since then, no decision has been made but contractors have begun to use high-intensity sheeting regularly, particularly on urban freeways.

Because of the brighter reflective material, WISDOT noted that new signs exhibited a phenomenon characterized as "irradiation" or "overglow," which they and others (2,3) had observed tended to reduce legibility of the signs at night, particularly in a rural setting with bright headlights. Although the improved conspicuity of high-intensity retroreflective material has obvious advantages, this research was conducted to explore how legibility could be improved, particularly for the older driver, because there is a growing population for which even current standard highway alphabets are not adequate (4). The testing was therefore limited to high-intensity materials.

Although the research project did not include a literature search, the conclusions reached by several individuals were carefully reviewed for clues to improvements that could be made in the legibility of traffic signs and the methodology for testing them.

A basic paper published by Forbes in 1939 (5) pointed out that there are two types of legibility, pure legibility where reading time is unlimited, and glance legibility, where reading times are short because of the demands of driving.

In 1977, Bernstein and Olson (6) noted that static far visual acuity was not a good predictor of the ability to read signs at night. They also concluded that legibility distances based on anything other than comprehension measures would be conservative. In a later study, Olson (2) also discussed the steps necessary for drivers in interacting with signs and pointed out the time necessary for detection, fixation, recognition, and vocalization. When signs are viewed in the glance legibility mode, this time was deemed significant by this author and led to the decision described later under methodology to use a technique closer to pure legibility on this study.

In Shepard's research in 1987 (3), the effect of irradiation with high-intensity sheeting and the apparent reduction in size of letters was noted, particularly for CWZ signing. He pointed out the difficulty of increasing the letter height and spacing within the current *Manual of Uniform Traffic Control Devices (MUTCD) (1)* requirements and how few CWZ signs could be improved if the *Standard Alphabets for Highway Signs (SAHS) (7)* requirements were followed. He therefore concentrated on increasing the stroke width (SW) of letters by 18 percent, and only on the inside dimension of the letters, based on earlier work in California and Nebraska. He reported increased legibility by night for such legends among the six test subjects. He recognized the limitations of the small subject group and suggested more extensive testing, under controlled environment, with reduced letter spacing and spacing between lines.

RESEARCH APPROACH

Because so many variables can affect the legibility of traffic signs in a highway environment, an overriding consideration throughout all the methodology was to eliminate as many variables as possible so that the results would be as closely related to differences in pure legibility as possible.

Sign Design

The work of Shepard (3) somewhat influenced the initial selection of signs to be tested. Because the project budget and

time constraints were limited, it was decided that 12 test signs could be tested under day and night conditions. Shepard's research was constrained by the current MUTCD requirements; therefore it was agreed between WISDOT and the researcher that reasonable changes in format and design, including rearranged legend, would be included in this research, even though they may require subsequent change in the MUTCD (1) or *Standard Highway Signs* (8) if they substantially improved legibility. Actual sign messages tested were proposed by the researcher and approved by WISDOT personnel monitoring the project.

Some of the test signs would include stroke width increases as recommended by Shepard. It was also decided to rearrange legends if that would improve legibility. The two most difficult CWZ sign series were selected to improve legibility. If these two could be improved, the results could also apply to other signs in terms of legibility, distance, and letter size and style. The following are examples of these two series:

RIGHT LANE CLOSED AHEAD
 CENTER LANE CLOSED AHEAD
 LEFT LANE CLOSED AHEAD
 RIGHT LANE CLOSED 1500 FT
 ROAD CONSTRUCTION AHEAD
 ROAD CONSTRUCTION 1500 FT
 ROAD CONSTRUCTION 2 MILES

Sign legends must follow the SAHS (7). If a legend size of any of these signs is to be increased, it should be expanded mathematically rather than photometrically, according to Phil Russell, formerly of the Federal Highway Administration's Office of Traffic Operations.

One alternative to improve legibility is to go to larger (60-in. diamond) signs, and this obviously allows letter size to be increased substantially but has two disadvantages: cost and inconvenience. The current 48-in. warning signs are clumsy for one person to handle. In addition, large signs are often overturned in a high wind. This researcher, with WISDOT concurrence, decided not to test signs larger than 48 in.

It was also recognized that symbolic signs can result in significant improvement but some legends cannot be symbolized (CENTER LANE CLOSED) and hence symbols were not used in this project.

A number of traditional ideas were tried first to see if improvements were even spatially possible within 48-in. diamond signs. Some of those tried were rejected because the legend was too crowded. It was decided to reject testing a substitution of tenths of a mile (decimal) for large advance distances in feet. Although they are logical, relate to odometer readings in vehicles, and would allow legend size improvement, it would have involved the introduction of another variable of unknown recognition and was therefore rejected. This concept is addressed in the Conclusion section of this paper.

In the _____LANE CLOSED_____ series, standard and rearranged legends and different letter series were selected for testing. In the ROAD CONSTRUCTION_____ series, the word CONSTRUCTION can be changed to WORK, with substantial improvements in legibility expected through increased letter size. Different letter series were also selected for testing.

It should be pointed out that WORK may be substituted for CONSTRUCTION in the revised Chapter VI of the MUTCD approved by the National Committee on Uniform Traffic Control Devices (9). New York has already tried this on freeway construction. In addition, Series E (upper- and lowercase) letters were used in this research even though not allowed in MUTCD (1) or *Standard Highway Signs* (8) for CWZ signs.

Because many of the signs are similar and were to be viewed in random order, there was concern about recognition and memory recall. It was therefore necessary to consider reversing letters or deliberately varying the sign message to ensure legibility. To do this, words similar to highway sign legends were selected. All standard signs and their test messages are shown as follows:

- Sign A "RIGHT LANE CLOSED AHEAD"—6-in. C
(Standard) TEST SAME
- Sign B Rearranged "RIGHT LANE CLOSED AHEAD"—
7-in. C TEST "RIGHT LANE CLIPPED
AHEAD"
- Sign C Rearranged "RIGHT LANE CLOSED 1500 FT"—
7-in. B TEST "READ LINE CLOSED 1500 IN"
- Sign D Rearranged "RIGHT LANE CLOSED 1500 FT"—
7-in. B + 18 percent SW increase
TEST "RIPE LINE CLASS 1600 AT"
- Sign E "Right Lane Closed 1500 Ft"—6½-in. E
TEST SAME
- Sign F "ROAD CONSTRUCTION 1 MILE"—7-in. C
TEST SAME
- Sign G "ROAD CONSTRUCTION 1 MILE"—7-in. C +
18 percent SW increase
TEST "RIDE CONSTRUCTION 1 MILL"
- Sign H "ROAD WORK 1 MILE"—7-in. C
TEST "RODE WALK 1 MOLE"
- Sign I "ROAD WORK 1 MILE"—7-in. C with 18 percent
SW increase
TEST "ROAD WOKE 1 MILL"
- Sign J "ROAD WORK 1 MILE"—8-in. C
TEST "READ WALK 1 MOLE"
- Sign K "ROAD WORK 1 MILE"—8-in. E
TEST SAME
- Sign L "Road Work 1 Mile"—8-in. E with 18 percent stroke
increase
TEST "READ WOKE 1 MALE"

Because some signs are standard and their legends expected, and others have unusual or unexpected legends, care had to be taken when comparing results. When people encounter unexpected messages they can be expected to do poorly compared with their performance when encountering expected messages. For that reason, at least one comparison among the 12 signs (signs F and H) involved the difference between standard and unexpected signs of the same letter size and series (7-in. Series C).

Sign Fabrication

The city of Milwaukee sign shop prepared the cutout letters and applied the black vinyl letters according to the design furnished by the research assistant and based on mathematical interpolations of the table for letter size and spacing of the SAHS (7).

Before application, measurements of reflective intensity were made on all reflective sign blanks that had high-intensity sheeting (Type I—Reflectivity II, Federal Specification L-S-300C) (9) made by 3M and applied by WISDOT. The blanks were all prepared from rolled goods. The orange material was all in the range of 143 to 158 SIA units (cd/ft.c/ft²), with less than a 10 percent variation in intensity across the entire blank.

Test Site Conditions

Because the greatest problem with irradiation occurs with the least background luminance (3), a location that would simulate a rural highway was needed. The inner and outer tracks at the Wisconsin State Fair Park Auto Race Track were used. The pavement luminance was measured with a United Detector Technology Model 40X light meter with a photometric filter and diffuser and pavement luminance of between 0.01- to 0.02-ft candles. The night site is shown in Figure 1a.

In order to eliminate some of the variables in nighttime viewing, a Ford Tempo 4-door rental automobile with halogen headlamps was used.

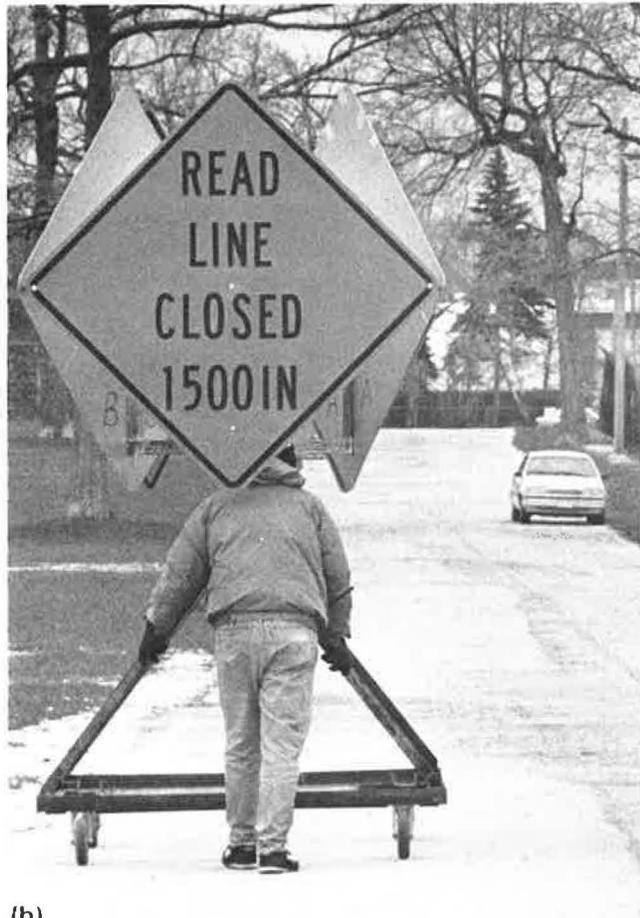
Selection of Test Subjects

An estimate of the driver population at some future design year (2020) was made based on *Accident Facts* (11) and *Transportation In An Aging Society* (4). By the year 2020 there will be more than 13 million drivers age 65 or over. Because this project was intended to improve legibility for all drivers, with particular emphasis on the older driver, older drivers were disproportionately represented in the test sample because literature sources reviewed (4) indicate that variation in visual acuity would increase with age. Sufficient sample size was needed to ensure significance because of the large variance.

The driver age groups and the desired and actual sample size are shown in the following table. Male and female differences were ignored because no sexual difference in visual acuity by age was observed. For statistical purposes, test subjects were divided into a younger group (under 65) and an older group (65 and over).

Test Age Group	Desired Size	Actual Size
18 to 44	20	22
45 to 64	20	24
65 and over	40	38

To recruit test subjects, 1,000 flyers were prepared and distributed in a variety of ways, including door-to-door distribution in some neighborhoods, windshield distribution at shopping centers, and through contacts in retirement communities, all within four miles of the test site. Also copies were distributed to retired and several current Marquette University (MU) employees.



(b)

FIGURE 1 Test sites: (a) night and (b) day, with cart.

Originally, it was expected that the testing and vision screening would take approximately 3 hr. Travel time would add several hours more, so a stipend of \$50 was set for test observers, which included any transportation costs, using \$10.00/hr as the basis. A test subject had to complete all three tests to receive the stipend. Because paid observers were being sought, no attempt was made to ensure random selection of candidates, other than excluding anyone associated with the College of Engineering at MU.

Vision Screening and Candidate Scheduling

The original charge of the sponsor (WISDOT) was to use the vision screening services of the Wisconsin Drivers License

Examiner's Officer (DLE). Wisconsin statutes require a visual acuity (V/A) of at least 20/40 in one eye for unrestricted licensing. It was agreed that all candidates anonymously pass a standard vision screening administered by the DLE.

Vision screening was administered using a OPTEC 1000 DMV vision tester regularly used in Wisconsin. Visual acuity was recorded for left and right eye only because that is the way vision screening is done in Wisconsin. Data were analyzed later according to best and worst V/A.

A failure rate of 10 percent was anticipated. Actual visual screening resulted in a failure rate of 14.7 percent. People in all age categories, including an 18 year old, failed the vision test. This was partly because DLE insisted they be tested because their license allowed them to drive. Of 93 who passed the vision screening, 84 completed all field testing.

A total of 47 females (56 percent) and 37 males (44 percent) were used as subjects. The females were more heavily represented in the under 65 age groups (72 percent) and the males more heavily represented in the over 65 age group (63 percent). Glasses were worn by 75 percent of all candidates tested.

FIELD TEST PROCEDURES

One of the first decisions made was that this test would be a static one. Because it was only to be a legibility test, the most accurate way to obtain legibility distances would be if the observer were seated in a stationary vehicle and the signs brought forward toward the observer on a sign cart. Signs involved in this study were 4 ft × 4 ft. A sign cart was therefore designed that could hold six of the large signs and would require only rotation of the signs or reversal of the cart to switch the selection of a given sign. Because 12 signs would be tested, two carts were constructed in the machine shop at the MU College of Engineering; one is shown in Figure 1b. By assigning four students to move carts, the observer time was reduced to approximately 20 min/test (day or night) for all 12 signs.

When the subjects entered the driver's seat, the recorder greeted them and oriented them to the task at hand. After orientation, and when the first sign was in place at a distance selected to be beyond the distance at which the observer with a known V/A could possibly see, the recorder inquired if the observers could read the sign, reminding them that they were not to guess.

The cart was moved forward at about 3 ft/sec until the signal was given to stop. When the sign was correctly identified, the radios were turned on and the distance estimated (distances on the course were marked every 10 ft, from 100 to 700 ft) by interpolating within the 10-ft marks. The distance was noted by the recorder on a form prepared in advance, which listed observer data and the random order of signs for that observer. Because this was legibility and not recognition distance owing to sign similarity, the results should be reviewed with that in mind.

The physical offset between sign observer, vehicle, and the center of the sign cart is shown in Figure 2 for the day and night test sites. Test signs are shown in Figures 3 through 5.

Data on sign legibility distances and observer characteristics were analyzed using the statistical SPSS software on the Uni-

versity's Vax computer system. Data on distances were rounded, because rounding the data to the next highest 10-ft increment would be logical, considering how distances were measured and recorded.

STUDY RESULTS

Mean legibility distances are shown in Figures 6 and 7 for all observers, for younger observers (under age 65), and for older observers (65 or over). The figures include the sign alphabet of each test sign to help the reader interpret results.

In Figure 6, mean legibility distances are shown for each observer group by day and by night for the five signs in the RIGHT LANE CLOSED— series (signs *A* through *E*). In Figure 7, the same mean legibility distances are shown for the ROAD CONSTRUCTION— series (signs *F* through *L*). In reviewing comparisons, the differences between legends sometimes make conclusions difficult. Wherever day and night differences were reduced by a test sign compared with a standard, it was concluded that overglow phenomena were reduced, and hence an improvement was made. Qualified conclusions on the comparisons are discussed later.

Further study results are presented by individual sign by day and night in Table 1. They include the ranges (minimum and maximum legibility distances), which show large spreads between "best" and "worst" legibility distances. These spreads are 400 to 500 ft for most signs and show the wide range of drive capabilities encountered.

A cumulative frequency analysis was run on all observer groups to determine the threshold visual acuity at which a given percentile of the observers could see at or better than that level and is reported for the signs at the 85th percentile and is also included in Table 1. Note that the 85th percentile values are much closer to the minimums than the maximums. This could very well be the result of the poor seeing ability of the test subjects. The number of test subjects with V/As at 20/40 or worse in one eye (and still passing) was 45 percent of all observers, 24 percent of younger observers, and 71 percent of older observers.

Multiple regression analysis was performed on each sign result to review linear relationships. Both distance and the log of distance were compared with age, best V/A, and worst V/A. As might be expected, the plots represented a scattered arrangement. Review of each showed that distance and age had coefficients of correlation (CC) of between 0.44 and 0.66. The CCs for distance and best V/A ranged from 0.43 to 0.59, and for distance and worst V/A ranged from 0.31 to 0.51. The equations for the straight-line relationships all had constants of from -2.0 to -4.0 ft/year of age difference, depending on the individual sign design.

Another overall analysis was performed on the differences in range of values (highest to lowest) legibility distance for all signs, for all observers, and for younger and older observers. The reason this was analyzed was because the difference between the best and worst sign was noticed by data recorders, and the difference was generally in the ratio of 1.5:1 to 2:1 (best sign over worst sign). Obviously legend style had an impact on legibility. These differences are as follows:

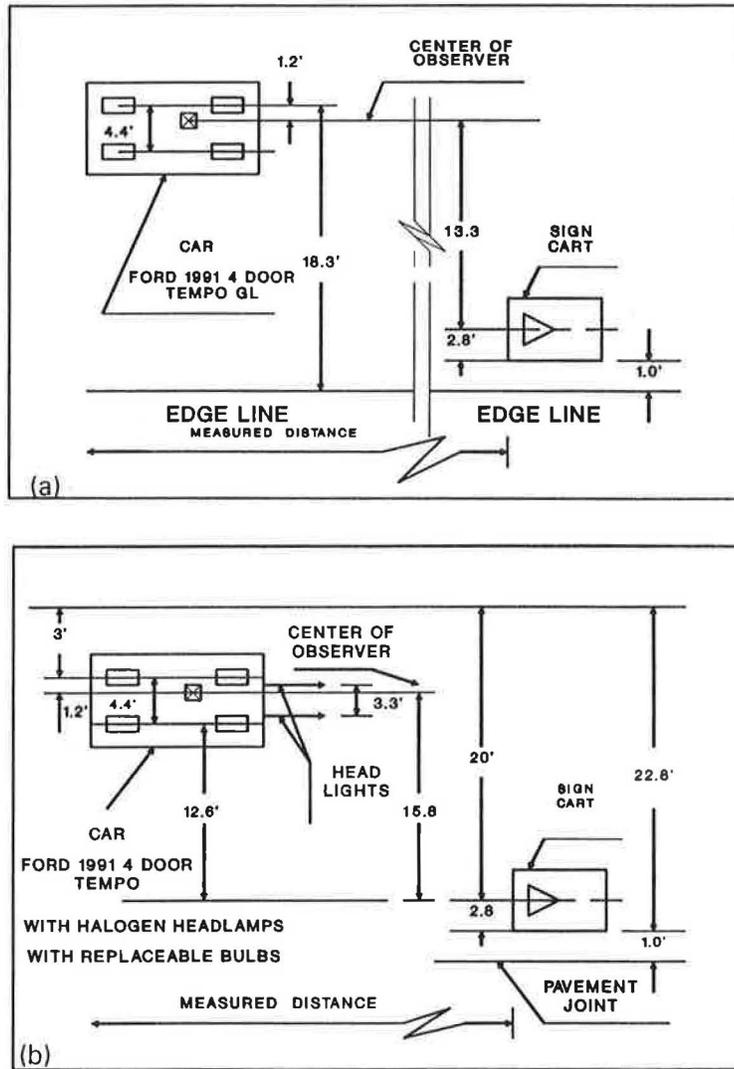


FIGURE 2 Schematic test sites: (a) day and (b) night.

Observer	Day	Night
All	202	208
Younger	224	220
Older	174	194

The differences are significant and the difference varies for young and old.

CONCLUSIONS

This study was an attempt to take the two most difficult CWZ signs and test four different concepts to improve legibility.

1. Rearrangement of legend to allow letter size increase (—LANE CLOSED— series).
2. Change from CONSTRUCTION to WORK to allow letter size increase (ROAD CONSTRUCTION— series).
3. The effect of SW increase.

4. Use of Series E (upper- and lowercase letters) currently not allowed by the MUTCD).

Other concepts (increased sign size) and use of tenths of miles instead of feet or abbreviations of words were deliberately avoided.

From study results it can be concluded that there is a large variation (range) in nighttime ability to see (read) the current standard CWZ signs (Signs A and F). The legibility distance for best and worst observers was 650 ft and 140 ft, respectively. The mean of the range of legibility distances between an observer's best and worst sign was approximately 200 ft. Changes tested in this project made a major difference in legibility distance, and not always an improvement.

Those signs that increased both letter size and SW while maintaining or increasing the standard alphabet letter series resulted in the best improvement. Increasing letter size while decreasing the alphabet series (like C to B) reduces sign

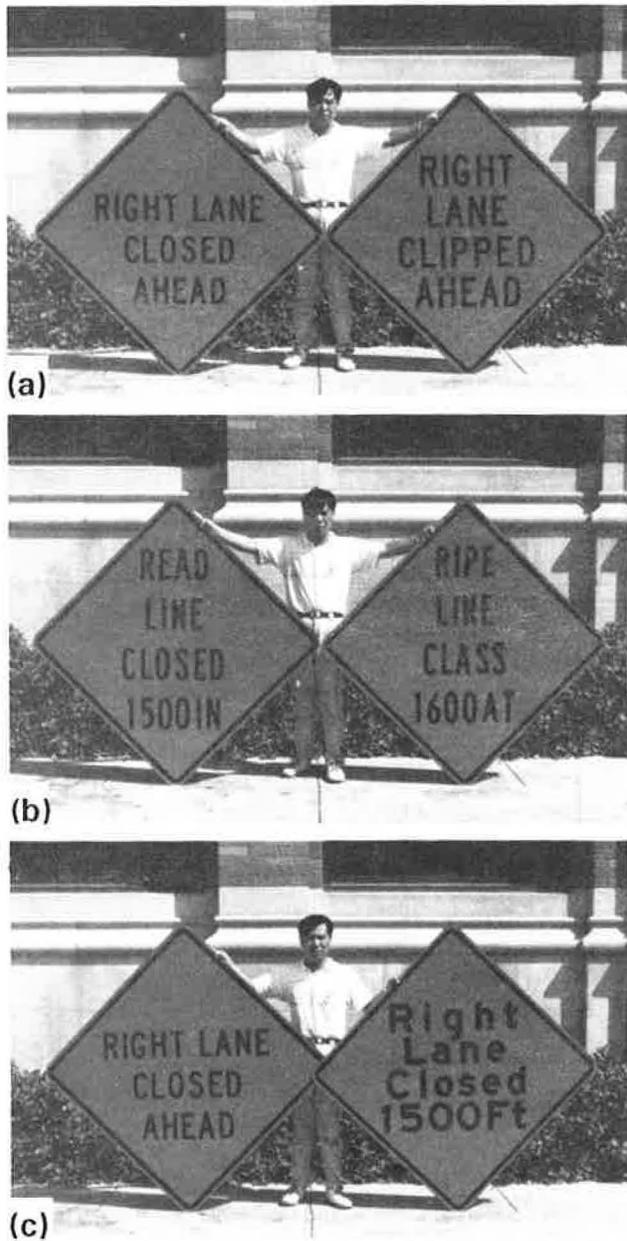


FIGURE 3 Test signs: (a) Sign A (6-in. C) and Sign B (7-in. C), (b) Sign C (7-in. B) and Sign D (7-in. B with 18 percent SW), and (c) Sign A (6-in. C) and Sign E (6½-in. E).

legibility, particularly at night. This practice is not recommended.

Effect of Stroke Width Increase of 18 Percent

The increased SW on the inside of letters without changing letter width, as recommended by Shepard (3), resulted in either no change or a decrease in legibility by day and night. This was tried on Series B, C, and E and the results were the same.

The alternative method of legend rearrangement or substitution of Series E letters with its 21 percent SW increase

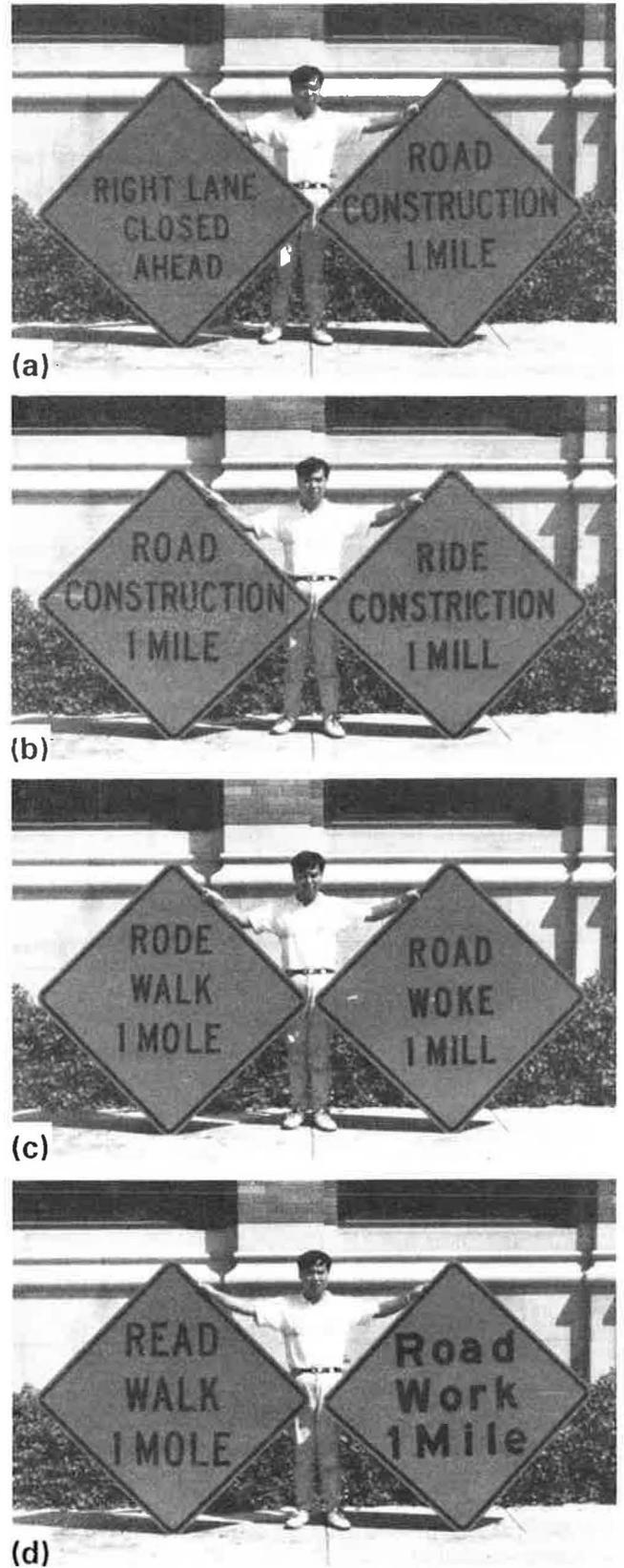


FIGURE 4 Test signs: (a) Sign A (6-in. C) and Sign F (7-in. C), (b) Sign F (7-in. C) and Sign G (7-in. C + 18 percent SW), (c) Sign H (7-in. C) and Sign I (7-in. C + 18 percent SW), and (d) Sign J (8-in. C) and Sign K (8-in. E).

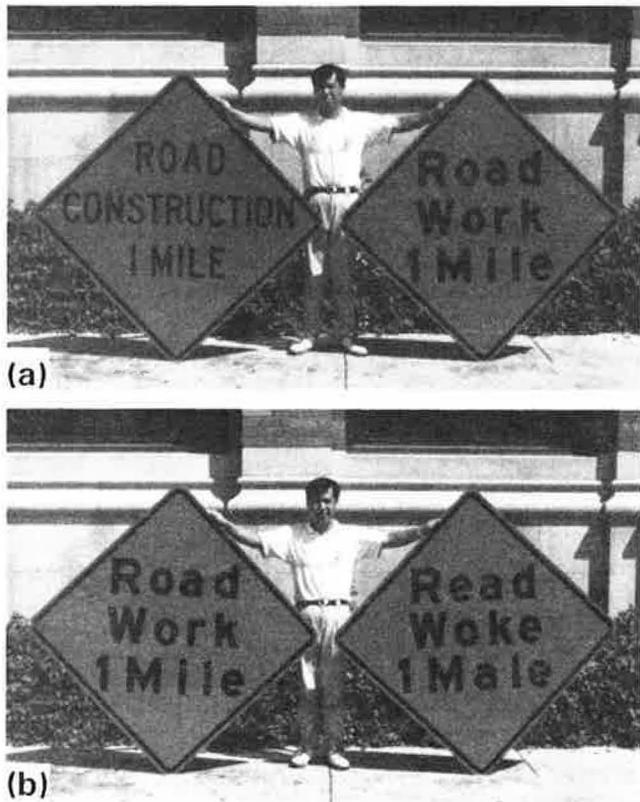


FIGURE 5 Test signs: (a) Sign F (7-in. C) and Sign K (8-in. E) and (b) Sign K (8-in. E) and Sign L (8-in. E + 18 percent SW).

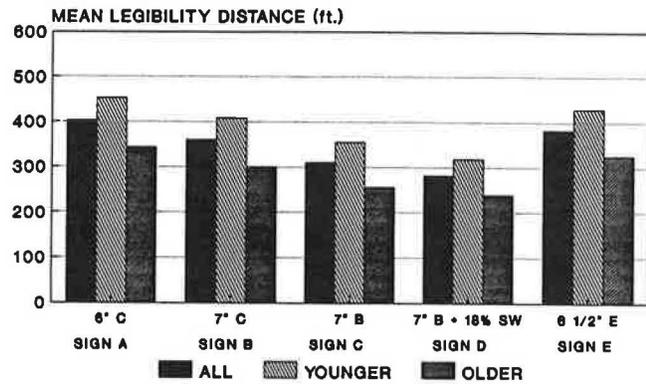
over Series C, discussed in the following section, is more promising as a way to overcome the phenomenon of overglow with brighter reflective materials.

Use of Series E Letters

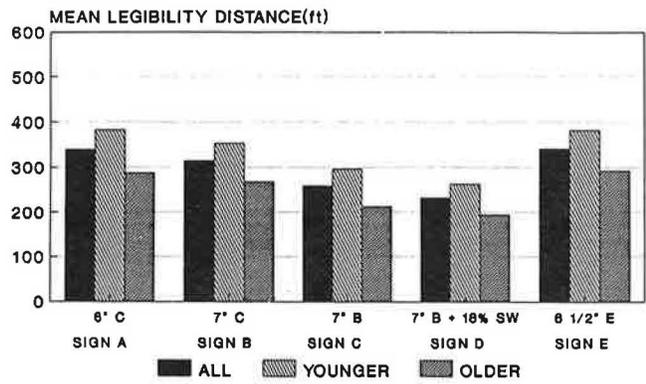
The most promising findings of this research are the use of upper- and lowercase letters, even though they are not allowed by the MUTCD. The fact that Series E has a 21 percent increase in the ratio of SW to letter height over 8-in. Series C letters and a 33 percent increase between a 6-in. Series C and 6½-in. Series E appears to overcome the overglow phenomenon and yield improved legibility by night without its reduction by day for younger observers. The comparisons of this study did not always make that clear because some signs were standard and some had changed legends. However, the reduction in nighttime legibility distance below that by day for older drivers (85 percentile) was from 0 to 13 ft (Signs E, K and L) only, whereas the reduction for current sign (A and E) was between 20 and 60 ft (night less than day). This lack of reduced legibility when considering day and night legibility distances indicates that the wider SW overcomes the irradiation or overglow phenomenon, a topic that was one of the purposes of this research.

Sign Legibility Requirements

The results point to the difficulty in bringing legibility distances up to a level at which all drivers would have a minimum



(a) LETTER SIZE



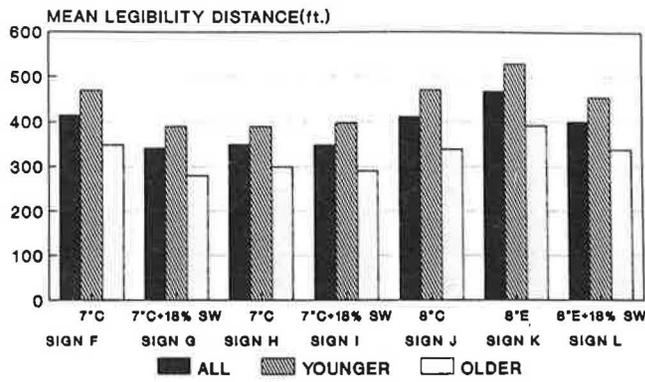
(b) LETTER SIZE

FIGURE 6 Mean legibility distances for Sign A through E: (a) day time and (b) night time.

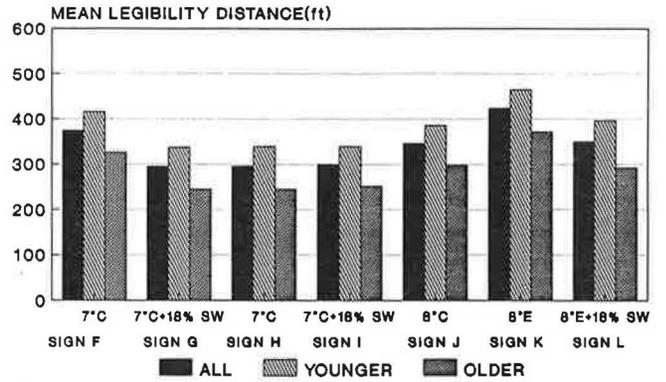
of 300 ft of distance (or about 3 sec at 55 mph) to read a sign legend. An examination of the minimum legibility distance for signs A, F and K (all standard) indicates that a relationship of 25 ft of legibility/in. is necessary for legally licensed drivers (those with at least one eye with 20/40 V/A). This means that signs with 12-in. letters would be necessary if a mathematical extension of the results for 6 in. (140 ft minimum), 7 in. (170 ft minimum) and 8 in. (200 ft minimum) letter size are indicative, and if 100 percent of the legal driving public is to be accommodated; slightly less than that called for in Howlett's formula for required visibility distance (12).

The frequency of legal drivers of all ages with V/A less than 20/20 and the legibility requirements of older drivers point to the need for new letter size requirements for all signs. The challenge is to do that through careful legend redesign to avoid signs so large that they are unmanageable and costly.

The question that needs to be resolved is how long a CWZ sign needs to be legible (in seconds) while a vehicle is approaching the sign. FHWA's program on Minimum Required Visibility Distance (MRVD) is a help. The MRVD is the distance for a driver to recognize a sign and make the maneuver required. The MRVD takes into account decision sight distance and the distance required by the MUTCD for advance posting of warning signs. The MRVD for both signs is 331 ft at 55 mph and 369 ft at 65 mph (unpublished as of 1991, FHWA data from Jeffrey F. Paniati). A comparison of these



(a) LETTER SIZE



(b) LETTER SIZE

FIGURE 7 Mean legibility distances for signs F through L: (a) day time and (b) night time.

TABLE 1 Sign Legibility Data

Sign	Observer category	Legibility Distances (feet)					
		Daytime			Nighttime		
		Minimum	85th %	Maximum	Minimum	85th %	Maximum
A	All	180	300	610	140	230	650
6" C	Younger	280	360	610	190	290	650
	Older	180	250	500	140	180	470
B	All	160	260	590	170	220	540
7" B	Younger	250	310	590	210	280	540
	Older	160	210	450	170	200	460
C	All	140	220	500	120	160	450
7" B	Younger	180	280	500	170	230	450
	Older	140	180	400	120	140	350
D	All	140	200	480	100	160	370
7" B + 18% SW increase	Younger	180	230	480	140	210	370
	Older	140	160	420	100	140	320
E	All	180	280	630	150	240	600
6 1/2" E	Younger	270	370	630	230	310	600
	Older	180	220	460	150	210	490
F	All	170	290	630	170	270	630
7" C	Younger	260	340	630	240	310	630
	Older	170	250	500	170	240	500
G	All	140	250	530	120	190	550
7" C + 18% SW increase	Younger	210	320	530	190	260	550
	Older	140	190	440	120	170	480
H	All	160	260	600	100	210	500
7" C	Younger	230	310	600	180	270	500
	Older	160	220	450	100	180	440
I	All	170	240	620	120	210	500
7" C + 18% SW increase	Younger	200	320	620	170	270	500
	Older	170	190	420	120	180	430
J	All	170	280	660	120	240	600
8" C	Younger	280	380	660	200	290	600
	Older	170	240	530	120	200	480
K	All	200	330	680	200	310	620
8" E	Younger	320	440	680	260	390	620
	Older	200	280	630	200	270	580
L	All	180	300	630	170	250	560
8" E + 18% SW increase	Younger	270	350	630	230	320	560
	Older	180	220	500	170	200	550

MRVD distances with the results of this research indicates the almost impossible tasks facing the profession.

Lane Closed Series

No substantial improvement can be made within the current MUTCD requirements and within the current 48-in. size sign. If the word AHEAD could be eliminated (Signs *A* and *B*), improvement would be possible. Use of 6½-in. Series *E* may improve legibility at night but was not proven for this sign series. Further testing is required. If distances in feet can be changed to tenths of a mile, a slight increase may result because letter size can be increased (Signs *C*, *D* and *E*).

Road Construction Series

In the second series, the results show a change from CONSTRUCTION to WORK will allow improvement in legibility without further changes in legend, and this is a significant improvement. This is best shown by comparing mean legibility distances for Sign *H* (7-in. *C*) and Sign *J* (8-in. *C*) for both day and night observations in Figure 7. More drastic changes, however, will be required to make greater improvement, which is required if the needs of all drivers are to be met, and these will require changes in national standards.

RECOMMENDATIONS

The following recommendations were made to WISDOT as a result of this research.

1. Whenever attempting legibility improvements, no decrease in alphabet series should be implemented in order to increase letter height (*C* to *B*). (Example, 7-in. Series *B* instead of 6-in. Series *C* alphabet used in Signs *B* and *C*.)
2. For the RIGHT LANE CLOSED_____ series, use of symbol signs (for most applications) will have to supplement word legend signs. For CENTER LANE CLOSED_____ series, redundancy of sign placement will have to be used if a 48-in. maximum size is to be maintained.
3. Change CONSTRUCTION to WORK in the ROAD CONSTRUCTION_____ series and increase letter size from 7-in. *C* to 8-in. *C*.
4. If irradiation or overglow is to be addressed, and a decision to use high-intensity CWZ retroreflective sheeting is made, WISDOT should pursue experimentation with Series *E* alphabet for both of the tested sign series in this research, as well as other signs in the CWZ series not tested under the procedures of FHWA.
5. Increase letter size and series for all other CWZ signs where possible, setting a sign size limit criteria as with the 48-in. sign size for warning signs.

Future Field Testing and Research

To improve the LANE CLOSED_____ series, further research to substitute tenths of a mile for feet and elimination of AHEAD

is recommended. Eliminating AHEAD allows a 33 percent increase in letters (6-in. to 8-in. Series *C*), whereas changing to decimals and Series *E* would allow an increase of 16 to 25 percent (6-in. to 7 or 7½-in. Series *E*). Both would help to overcome any irradiation phenomena.

Another more radical change would be rearrangement of the order of the three-line, four-word legend, from RIGHT LANE CLOSED_____ to CLOSED RIGHT LANE_____. This places the two-word line RIGHT LANE in the center of the diamond, allowing the legend to be increased to 8½-in. Series *C*, an increase in legend size of 2½-in. (or 40 percent). Meaning and legibility would need to be tested because the normal order is reversed.

To further improve the ROAD CONSTRUCTION series, a change to abbreviations for the word MILE in the bottom line is recommended for testing. This, in combination with the substitution of the word WORK, would allow possible letter increase to a 9-in. Series *C* or a 10-in. Series *E*, a substantial improvement over the current 7-in. Series *C* (of at least 28 percent). Legibility improvement would need to be tested.

However, the most important concept that needs further documentation is the switch to Series *E* for CWZ signs using sheetings with high-intensity retroreflective materials and its greater SW to letter-height ratio to overcome the effects of overglow at night, particularly for older drivers.

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