To: RTE's Regions 1-11 Cc: RD's Region 1-11 RDE's Regions 1-11 RCE's Regions 1-11 M.O. Design M.O. Construction		*New York State* *Department of Transportation* **TRAFFIC ENGINEERING DIRECTIVE**	TED ITS 02-003

Title: PERMANENT VMS OPERATION AND TESTING REVIEWS

Distribution: ☐ Main Office ☐ Consultants ☐ Regional Office ☒ Other See Above ☐ State Police ☐ Associations	Approved: B. W. Smith, Director Traffic Engineering & Highway Safety Division Date

ADMINISTRATIVE INFORMATION. This TED transmits a "best practice" , "lessons learned experience", for informational exchange.

PURPOSE. This TED shares some of the experiences and lessons learned regarding the use, operation, and testing of permanent Variable Message Signs (VMS). It also transmits two documents from FHWA regarding message sign visibility.

BACKGROUND. Region 1 had three permanent VMS installed under a recent capital project. After the installation, visibility and legibility problems were experienced with the three permanent VMS. The signs are permanent overhead walk-in Line Matrix, 3-lines by 20-character, array hybrid High Intensity Light Emitting Diode with Reflective Flip Disks (LED-Dot) Variable Message Signs (VMS), manufactured by 3M. The signs were located along three State highways in the Capital District, I-87 southbound (south of exit 8), I-90 westbound (west of exit 8), and Alt. Route 7 westbound (west of I-787). Region 1 requested guidance from FHWA and its Eastern Resource Center.

Representatives from FHWA and NYSDOT (Region 1 and Main Office TE&HS) met to discuss and field review the VMS issue. The review consisted of visual inspections of the signs, in both day light conditions and night time conditions, at speeds experienced by the traveling public. The review group of six members provided a broad level of technical experience for reviewing the signs as well as a mixed range of eye sight capabilities.

During the daylight field review of the first VMS it was determined that while the target value was enough to detect something ahead at a great distance, the sign could not be read by all reviewers until a distance of 500 feet. After revising the lettering to a wider character spacing (from an SC2 to a SC3), all reviewers were able to read the sign at about 900 feet in accordance with the MUTCD. (These distances reflect the distance of the weakest pair of eyes on the review team.) The review continued to the other two signs, with the revised wider spacing allowing for greater legibility.

A second field review was conducted the same day at night. The increased spacing was confirmed to be the best for legibility. The lowest brightness setting was determined to be the best for legibility, creating the least amount of halo effect (lowest setting at about 40% of full brightness). Note: After installation of the signs, Region 1 realized that the software only had the capability of reducing the brightness to 80% of full brightness, and if they wanted to set the brightness level to 40%, it must be done at the hardware controls in the field controller. It is recommended that future contracts / installations of software should have the necessary control capabilities built into the software thus allowing the Operator to control the brightness from the TMC. The increased letter spacing, and the lowest brightness setting combined, provided the best nighttime legibility at 900 feet.

An additional problem required corrective action on the Region's part. The VMS originally came with a message pre-installed from the manufacturer. As the VMS were installed by the contract prior to power being available, the preset message could not be removed. Consequently the region had to "bag"the VMS for a short period of time. It is recommended that in the future, all sign shall be delivered without any preset messages.

RESPONSIBLE ORGANIZATION. **Regional TE&HS and Construction Groups.**

PERMIT TYPE. N/A

REQUIREMENTS AND GUIDELINES.

The following recommendations are offered .

1- VMS software and hardware shall support an adequate character and interline spacing.
   - the subject review indicated that three pixel between characters (SC3) worked best, along with block style lettering and single stroke font
   - in the subject review, interline spacing was fixed at one-third the character height, although a greater spacing may improve visibility even more under different conditions

2- VMS software should allow all necessary control capabilities affecting brightness to be administered from the TMC or other remote location

3- Field reviews of VMS performance and visibility should be accomplished upon the completion of the project with several reviewers of mixed ages to promote a range of eyesight capabilities.

4- It should be stipulated in the specifications that VMS should be received at the job site without any preset messages on them.

The following two documents are forwarded for information. These two documents provide information that was validated by the recent VMS sign review discussed above.

1- FHWA -RD-97-075 Summary Report - Changeable Message Sign Visibility.

2- FHWA-RD-94-077 Appendix A-Draft Design Guidelines and Operational Recommendations For CMS Visibility

CONTACT PERSON.

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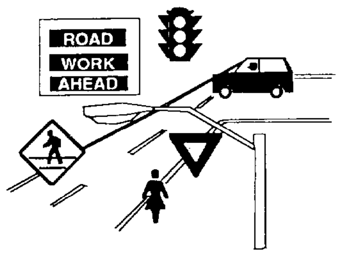
Summary Report

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 TS 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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Changeable Message Sign Visibility

Introduction

Changeable message signs (CMS's) have been used on major highways since the 1970's. However, unlike other traffic control devices, there are no nationally recognized specifications regarding the appearance of CMS's. The absence of guidelines has resulted in CMS's that display many colors, shapes, fonts, borders, and spacings. This research project addressed this issue, with the goal of providing guidelines for both the uniformity and visibility of CMS's. This research included all matrix-type CMS's capable of variable displays, whether light-reflecting, light-emitting, or a hybrid of these technologies.

Research Methodology

Subjects were recruited in three age groups: 16-40 (young), 62-73 (old), and 74+ (old-old). There were 70 to 90 subjects for each study.

Laboratory Studies: Two studies were conducted using a computer display to simulate a CMS as seen at night. The first study assessed the effects of letter width, stroke width, matrix density, contrast orientation, font, and color. The second study assessed the effects of word length, interletter spacing, interword spacing, and interline spacing.

Static Field Studies: Daytime and nighttime observations were made at distances of 275 m, 198 m, and 131 m, with signs and observers stationary. First, luminance was increased in steps from 50 to 1270 cd/m^2 to read the CMS's with letter heights of 30 and 46 cm to establish minimum luminance. Second, legibility distance was determined for CMS's with the two letter heights. Two types of displays were used—a commercially available CMS with red light-emitting diodes (LED's) and a "light box" mock-up of a CMS.

Dynamic Field Study: Six portable CMS's were located along a rural section of four-lane divided highway near State College, PA. Three-word messages (e.g., ROAD, TEST, SAFETY) were displayed on these signs. Subjects were asked to indicate when they first noticed each CMS, as well as the point at which they could first read the message.

Research Results

Subject Age: Laboratory and field studies indicated that older drivers have legibility distances 30 to 40 percent shorter than younger drivers.

Contrast Orientation: The laboratory studies showed that positive contrast (light letters on a dark background) resulted in a 20 percent improvement over negative contrast (dark letters on a light background). The night dynamic tests indicated a 29 percent improvement for positive contrast, while daytime tests found no contrast effects for either legibility or detection.

Character Proportions: The laboratory studies found small improvements in legibility from increased letter width-to-height ratio and decreased stroke width-to-height ratio. A letter width-to-height ratio of 0.8 is recommended, along with a stroke width-to-height ratio of 0.13, as shown on the next page.

APPENDIX A - DRAFT DESIGN GUIDELINES AND OPERATIONAL RECOMMENDATIONS FOR CMS VISIBILITY

OVERVIEW

The guidelines and operational recommendations for CMS visibility discussed below are the result of 2 years of intensive study. Initially, factors that most effect CMS visibility were found through a detailed critical review of the literature. Those variables that were determined to have the greatest impact on visibility were selected to undergo three levels of analysis. Level One consisted of a lab study using a computer simulation of CMS's. This stage assessed the effects of character width-to-height ratio, matrix density, font, color, contrast orientation, brightness, word length, inter-word spacing, inter-letter spacing, and inter-line spacing on the minimum letter size that observers could read. Level Two was a static field study where both a mock-up CMS, an actual CMS, and the observers were stationary. This second level of analysis measured the effects of time of day, sun position, character height, inter-letter spacing, font, and distance from the observer on minimum character brightness required for CMS legibility. The third level involved a dynamic field study using actual trailer-mounted CMS's on public roadways. Level Three assessed the influence of time of day, sun position, sign type, character brightness, contrast orientation, inter-letter spacing, and character height on the distance at which the signs could be found and read.

SCOPE

The term *CMS*, as used in this document, includes all matrix-type signs capable of variable message displays, and excludes any sign with a fixed message component such as rotating drums. The guidelines and recommendations contained in this document are applicable to any and all in-service or soon-to-be-available CMS hardware types, whether portable or permanently mounted. The capabilities of older and younger drivers are considered throughout. Several features of CMS's that may contribute to CMS visibility, however, are not included in this document. Message content issues, such as sequencing and use of symbols, were determined to be outside the scope of this report, as were treatments designed to improve conspicuity, which included the use of flashers, flashing messages, or borders. All original data reflected in these guidelines and recommendations were collected in a suburban/rural environment with low visual complexity. The applicability of the information contained in this document to urban, high visual demand situations has not been assessed.

Most attempts to improve the visibility of CMS's result in either greater initial expense, typically in the form of a larger sign, or increased maintenance costs. A formal cost-effectiveness analysis was outside the scope of this research; however, these guidelines and recommendations were written with a sensitivity to these issues. All recommendations that would result in substantial improvements in visibility distance are included. Those recommendations that appear to have a potential cost/benefit interaction are followed by some discussion of the implications.

novelty of these UV-lighted and LED signs may also prevent their recognition as traffic control devices.

Character Variables

Contrast. CMS contrast reduction is typically caused by glare reflecting off of the sign face (called veiling luminance) or insufficient brightness of the active elements. Veiling luminance is the result of sun angle or the sign's own lighting system. An appropriate black matte finish applied to the background portion of a CMS helps; however, the main reason for the loss of contrast is the reflection of light off the plexiglass sheeting used to protect the sign face. CMS's with new protective sheeting typically produce appropriate contrast levels; problems occur mainly when the sheeting is allowed to become dirty or scratched. Regular cleaning, and replacement when surfaces become excessively scratched, is highly recommended. Usually the protective sheeting can be cleaned with a mild non-abrasive detergent, warm water, and a soft cloth; however, the manufacturer's recommendations should be consulted.

The formula for determining the luminance contrast of a CMS is:

$$\frac{L_t - L_b}{L_b}$$

where:

L_t = luminance of a character module with all of the elements "on"
L_b = luminance of the character module with all elements "off"

The photometric procedure for contrast measurement is discussed below under the section entitled *Luminance*. Field contrast measurements should be conducted under the following five lighting conditions: sun directly on the sign; sun directly behind the sign; sun overhead; overcast; and at night. If the contrast falls below 5 under *any* ambient lighting condition, immediate cleaning or replacement of the protective sheeting is recommended. If the contrast is still low after the recommended maintenance procedure, the manufacturer should be consulted for the appropriate action. It may be that resurfacing of the discs is needed for reflective technologies or that diodes, lamps, or FO's need to be replaced or repaired for light-emitting technologies.

Luminance. Maintaining character luminance is perhaps the most important factor in ensuring the legibility of CMS's. Character luminance is defined as the weighted average of lighted elements and the unlighted spaces between elements. To establish CMS character luminance, measurements must be made with the character module "on" and the character module "off."

To obtain these two measurements, the aperture of a photometer is centered on a character module (figure 61). All of the elements in that module are turned on and a measurement is taken; all of the elements are then turned off and a second reading is taken. The character luminance is the difference between the on and off readings. The off reading represents the amount of light reflected by the background, glare screen, and any stray light entering the photometer.

It is possible to change the luminance of light-emitting CMS's. All currently marketed light-emitting CMS's have a range of luminances that can be either manually or automatically manipulated. Although most light-emitting CMS's are capable of the range of luminances recommended here, particularly when new, periodic field measurement using the techniques outlined above should be conducted to ensure continued optimal performance.

In daytime, light-reflecting CMS's are illuminated by the sun and are therefore dependent on the very factors that they need to overcome (i.e., sun position and ambient brightness). The only way to enhance the luminance of these signs is to increase the amount of light hitting the sign face. Except when the sun is behind the sign, however, new light-reflecting signs, or those recently cleaned and with new reflective elements, are capable of supplying the recommended values of character luminance. Although, when the elements begin to fade, neither the minimum luminances for the overcast/rain nor the washout conditions can be met.

Contrast Orientation. Contrast orientation should always be positive, that is, with luminous characters on a dark or less luminous background. Legibility distance for negative-contrast CMS's is likely to be at least 25 percent shorter than that of positive-contrast messages. Furthermore, the increased light emitted by negative-contrast CMS's has not been shown to improve detection distances. Therefore, CMS designs that only allow for a background lighter than the text should be avoided.

Font and Matrix Form. A font similar to the one shown in figure 62 is recommended. This font type was derived from several fonts currently found on in-use CMS's. However, any reasonable set of alphanumerics that provide clean lines similar to Standard Highway fonts will likely produce equivalent legibility. Improving the "resolution" of CMS characters by increasing the number of elements in a character matrix from the nominal 35 found with a 5x7 character matrix has neither a negative nor a positive effect on legibility distance of uppercase letters.

So-called "double" fonts, which attempt to provide double-stroke widths within a 5x7 matrix, should be strictly avoided (figure 63). These double fonts yield legibility distances approximately 25 percent shorter than regular fonts.

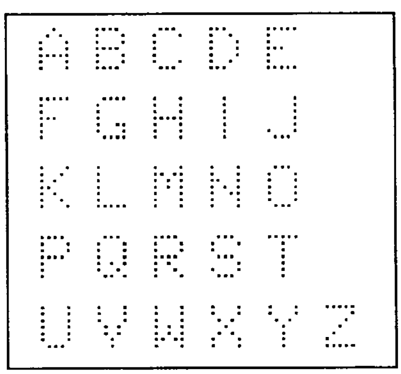

Figure 62. Recommended CMS font.

Message Components

Inter-Letter Spacing

Proportional Spacing. If a CMS has the capability of generating proportional spacing, it is recommended that three times the Standard Alphabet spacing for Series E letters be used. Proportional inter-letter spacing makes optimal use of the size of the sign, without loss of legibility, by using the shape of the letters to determine the spacing. For example, two letters with adjacent vertical contours, such as an O and a U, require a larger inter-letter spacing than does an LY combination. The reason for tripling the Standard Alphabet spacing is that CMS's, particularly at night, are very high-contrast, luminous signs with characters that blur together more readily than do those on standard signs. Even so, the largest spacings (e.g., BU) required when using this recommendation would be about 4/7 the letter height, or four elements on a 5x7 sign. The majority of the spacings would be equivalent to three elements (e.g., BC), and the rest of the spacings would be either two elements (e.g., CV) or one element (e.g., AY).

Fixed Spacing. An inter-letter spacing of 1/2 the letter height is recommended for signs that do not have the capability of proportional spacing. Applying this recommendation can increase nighttime legibility distances by 30 percent over the distances obtained with spacings of either 1/7 or 2/7 the letter height (i.e., "single element" or "double element" spacing). This improvement in legibility, however, would come at the cost of an additional 1.14 m (3.75 ft) over single-element spacing and 0.69 m (2.25 ft) over double-element spacing on signs with eight, 457-mm-high characters.

Inter-Word Spacing

Recommended inter-word spacing is dependent on inter-letter spacing. If inter-letter spacing is either proportional or 1/2 the letter height, inter-word spacing equal to letter height is recommended. For inter-letter spacing 3/7 the letter height or less, inter-word spacing equal to 5/7 the letter height is recommended.

Inter-Line Spacing

It is recommended that CMS's using more than two lines of text have an inter-line spacing of 70 percent of letter height. CMS's that use two lines of text can use an inter-line spacing as small as 20 percent of letter height without any appreciable loss in legibility. The larger inter-line spacing recommended for signs with three or more lines of text greatly enhances the legibility of the center line(s).

Hardware Components

Nighttime Lighting of "Disc-Matrix" CMS's

There are several methods currently available for nighttime illumination of the elements on non-light-emitting CMS's. The two most common techniques use either UV ("black light") tubes or discrete lamps mounted below the CMS in the manner of overhead guide signs. Both of these

Table 39. Summary of recommended character/message variables for CMS visibility.

Design Feature	Optimal	Acceptable
Color	Matching MUTCD color-coding specifications	Red, Amber/Yellow, White, Orange
Contrast	Lt-Lb/Lb>5 to 50	Lt-Lb/Lb=5
Contrast orientation	Light letters on a darker background	Light on black Light on colored
Font and matrix form	Alphanumerics that most closely approximate Standard Highway font	Any reasonable non-serif font using at least a 5x7 matrix or equivalent
Letter height	46 cm	30.5 cm if legibility < 122 m is acceptable
Width:height	W:H=0.8	W:H=0.6 to 1.0
Stroke width:height	SW:H=0.13	SW:H=0.1 to 0.18
Inter-letter spacing	Three times Standard Alphabet Series E or 1/2 the letter height	3/7 the letter height
Inter-word spacing	Equal to letter height	Equal to 5/7 the letter height
Inter-line spacing	70 percent of letter height	20 percent of letter height with two-line CMS

1 cm = 0.3937 in; 1 m = 3.281 ft