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Research Review

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ELECTRONIC MESSAGE CENTER RESEARCH REVIEW

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13. Abstract: Electronic Message Centers (EMCs) are signs that are self-illuminated, primarily through the use of LEDs, and are capable of displaying static and dynamic images. Used for decades in public-sector transportation, these signs have recently become popular for roadside use by the commercial sign industry, however questions remain regarding their effectiveness as commercial signs (in terms of visibility and comprehensibility) and potential traffic safety implications. This paper reviews the research literature on these issues, and provides details on sign characteristics that could optimize EMC effectiveness. However, while there are many scientific studies evaluating EMCs used for transportation, there are few that specifically address commercial EMC applications. Future research projects to specifically evaluate the safety and effectiveness of EMCs for commercial use are recommended.	
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INTRODUCTION

The Electronic Display Manufacturers Association (EDMA, 2004) defines electronic message centers (EMCs) as signs that are “controlled via electronic communication. Text and graphic information is created on a computer using a software program … that allows the end user to be as creative or as reserved as they like. The sign can be used to display static messages only, static messages changed by a computer-generated transition from one message to the next, moving text, animated graphics and, in some applications, television-quality video (these displays can show live video, recorded video, graphics, logos, animations and text).” EMCs are also known as video billboards, electronic billboards, and electronic message displays. For the purposes of outdoor advertising, EMC manufacturer and distributor Lightvision Media Network of Vancouver has characterized EMCs as, "Where television meets outdoors" (Brill, 2002).

Although typical transportation applications are restricted to the use of static letters and, in rare instances, select symbols, the Federal Highway Administration (FHWA) defines EMCs as “programmable displays that have the capability to present a large amount of text and/or symbolic imagery. Some [EMCs] present images in realistic motion and in a large variety of colors” (FHWA, 2001). In the transportation community, where much of the research on these signs has been conducted, they are called changeable, dynamic, or variable message signs (CMS, VMS, or DMS, respectively). While there are numerous uses for EMCs that range from streaming video boards, through outdoor advertising, on-premise information, and finally traffic advisory, to the extent possible this paper will refer to three distinct sign types: *CMS* for transportation applications; *on-premise EMC* for commercial or civic announcement signs, and *off-premise EMC* for “billboard” or outdoor advertising signs. The terms “commercial EMC” and “EMC” will be used in generic boundary-crossing discussions.

A recent FHWA memorandum (Paniatti, 2003) included the statement, “While CMS can be a very effective method of providing information to motorists, [given the time constraints of a driving audience] they can convey only a limited amount of information and may not be the safest or most effective method in many cases.” Lightvision Media (among other off premise EMC manufacturers) see the prime location for these devices as “very high traffic, slow moving (road bottlenecks) spots such as merging lanes or bridge or tunnel entrances that slow down passing vehicles" (Brill, 2002). This conceptual disparity is part of what has made the commercial roadway application of EMCs so contentious.

The original objective of this paper was to synthesize a review of existing literature on the effectiveness and safety of EMCs used as on-premise and off-premise commercial signs. The intent was to provide a resource for the EMC industry and to identify gaps in the research that could be bridged by further investigation. Unfortunately, there has been little research conduced specifically on commercial EMCs; and therefore, the synthesis is based mainly on the results of static and dynamic highway sign research and basic human factors concepts. The fundamental lessons learned from these studies concerning highway sign effectiveness and safety will be applicable to EMCs, however commercial and highway sign messages and sign characteristics differ significantly, therefore, it is highly recommended that the findings reported on herein be verified by further research using commercial EMCs.

For the purposes of this paper, EMC *effectiveness* is defined as the visibility and comprehensibility of EMC messages, and EMC *safety* is defined as the potential of these signs to distract roadway users, which could possibly contribute to an increase in motor vehicle crashes in the vicinity of the signs. The effectiveness analysis consists primarily of non-commercial EMC research (i.e., CMS), while the safety review is based on the limited literature that has addressed EMCs specifically and the somewhat larger database on commercial signs in general. An annotated bibliography can be found in Appendix A.

HOW EFFECTIVE ARE EMCs?

The ability of an EMC to effectively communicate with roadway users is a function of its capacity to communicate visual information quickly, as signs on the roadway are typically read by drivers in a series of short (less than one second) glances. If the target audience is pedestrians, motor vehicle passengers, or drivers of vehicles stopped in traffic or at an intersection, the time allotted for this “communication” would be longer. All of the research uncovered for this paper addressed the needs of vehicle operators driving in “free flow” conditions at normal operating speeds. The potential need for research on audiences other than vehicle operators in free flow conditions (e.g., pedestrians, passengers) is discussed at the end of this paper. In lieu of any direct research on the visual communication strengths and weaknesses of commercial EMCs, this analysis relied heavily on published reports on static highway signs and changeable message signs used by public sector transportation agencies. The following section addresses variables that impact the effectiveness of all highway signs and should be applicable to the optimization of EMC communication.

How much information is too much?

Knowledge of how people assimilate visual information is critical to understanding the amount of information that can be effectively displayed on any individual roadway sign. Basic data on how quickly people read sign content (either text or pictures) while operating a motor vehicle should drive sign content limits. To find that type of data, the literature on human reading capacity was surveyed. Proffitt, et al. (1998) reported 250 words per minute (4.2 words per second or one word every quarter second) as the average "normal" reading speed for adults. Research on highway sign reading, however, provides evidence that it takes drivers anywhere from 0.5 to 2.0 seconds to read and process a single sign word. Studies that have evaluated a concept known as "optimum acuity reserve" (i.e., the ratio between the smallest legible copy and the optimal print size for reading) explains some of the disparity between "normal" reading speed of above size-threshold text (such as a book) and the time it takes to read a sign while driving, which often begins at the smallest size/largest distance at which the words just become readable. Optical character recognition research has demonstrated that the fastest reading speeds result from print size that may be as much as four times size threshold (Bowers and Reid, 1997; Yager, et al., 1998; Lovie-Kitchin, et al., 2000). In fact, in their reading rate calculations Yager, et al. (1998) used 0.0 words per minute as a basic assumption for reading speed at size threshold.

Psychological factors play an important part in sign reading speed. McNees and Messer (1982) found that the time it takes to read a sign depends, among other things, on how much time the driver has to read it (i.e., signs are read faster when it is necessary to do so). They also found that as reading speed increases so do errors (the well known speed/accuracy tradeoff). Proffitt, et al. (1998) stated that longer words need to have a larger letter height than shorter words and that short, standard messages with symbols, using mixed case letters and no abbreviations, are easier and more likely to be read by passing motorists. In general, Proffitt, et al. (1998) suggested that drivers are more likely to read signs if doing so requires little effort and if the sign content is brief text or symbols.

Dudek (1991) recommended a minimum exposure time of "one second per short word…or two seconds per unit of information" for unfamiliar drivers to read changeable message signs. In a study conducted by Mast and Balias (1976), the average time spent reading advance static guide signs (signs before the exit) was 3.12 seconds and the average time spent reading exit direction signs was 2.28 seconds; these researchers did not specify the number of words on the signs. Also without specifying the number of sign words, McNees and Messer

(1982) concluded that, “a cut-off of approximately 4.0 seconds to read any [static] sign was critical for safe handling of a vehicle along urban freeways.” In another study of static traffic signs, Smiley, et al. (1998) found that 2.5 seconds was sufficient for 94 percent of their subjects to accurately read signs that contained three destination names; however that performance level dropped to 88 percent when the signs displayed four or five names. Specifically looking at changeable message signs in a laboratory environment, Dudek and Ullman (2002) (also reported in Ullman, 2001) found that flashing a message to attract driver attention significantly increased the time motorists needed to read the sign. These researchers also found that flashing only one part of a message not only increased reading time, but also reduced the retention of the message on the rest of the sign. These researchers recommended that messages exceeding the information capable of being transmitted on a single CMS screen or frame should be avoided if possible.

In the section on CMS message content in the federal Manual on Uniform Traffic Control Devices (MUTCD), the FHWA made the following recommendations:

- The message should be as brief as possible.
- Signs should be limited to not more than three lines with not more than 20 characters per line.
- No more than two displays should be used within any message cycle.
- When a message is longer than two phases, additional changeable message signs should be used.
- Each display should convey a single thought.
- When abbreviations are used, they should be easily understood.
- The entire message cycle should be readable at least twice by drivers traveling the posted speed, the off-peak 85th-percentile speed, or the operating speed. (USDOT, 2003)

While it is unrealistic to expect a single minimum time to allow all drivers to read and understand any sign, the research on sign reading speed discussed above indicates that signs displaying one word could be comfortably read and comprehended in approximately 1.0 second, signs with two to three words could be read in 2.5 seconds, and signs with four to eight words in 4.0 seconds.

What effect does driving have on sign reading?

In addition to reading signs, drivers must also watch the road and perform other driving tasks. Using calculations from McNees' and Messer's (1982) research on overhead static guide signs, for drivers to have 4.0 seconds of sign reading time, a sign would have to be legible for 10.0 seconds. This results from adding 2.0 seconds for sign clearance time (when the sign is at too great an angle to be read comfortably) and 8.0 seconds divided equally between 4.0 seconds of sign reading and 4.0 seconds for other driving tasks. In looking at static highway signs mounted on the road shoulder, Smiley, et al. (1998) provided less conservative estimates. These researchers allowed for 0.5 seconds clearance time and a 0.5 seconds glance back at the road for every 2.5 seconds of sign reading (based on eye movement research by Bhise and Rockwell, 1973). This would require a 1.5 second legibility distance for 1.0 seconds of sign reading, 3.0 seconds of legibility distance for 2.5 seconds of sign reading, and 5.0 seconds for 4.0 seconds of sign reading. This is assuming that the driver begins to read the sign as soon as it becomes legible.

Allowing an additional 1.0-second for sign acquisition after it becomes legible, and to achieve a reasonable level of acuity reserve, an appropriate legibility distance for signs displaying one word would be 2.5 seconds, two to three words would be 4.0 seconds, and four to eight words would be 6.0 seconds. (Translating that to distance at 55 mph would require these signs to be legible at 200, 325, 485 feet, respectively.) The United States Sign Council (USSC, 2003) offers guidelines designed to assist in quantifying the legibility factors discussed above and simplifying the process for computing the size of the average static commercial sign in a motorist oriented environment. Unfortunately, no research or standards has yet to address the speed at which motorists can assimilate the type of dynamic television-style graphics that EMCs are capable of displaying.

How large should EMC letters be?

In a study of CMS for the FHWA, Garvey and Mace (1996) reported that letter height has the greatest impact on the distance at which a sign can be read. Unlike other critical sign visibility variables, such as contrast and luminance, legibility distance continues to improve with increases in letter height; there is no practical asymptote. There are, however, real world limitations on sign size, and there is also research that reports optimum letter heights for fastest normal reading speeds above which performance declines (Raasch and Rubin, 1993).

Legibility Index (LI) is a measure of the furthest distance at which a sign can be read as a function of letter size, and in English units is expressed in feet per inch of letter height (ft/in). In the current Manual on Uniform Traffic Control Devices the FHWA uses a legibility index of 40 where each inch of letter height is assumed to provide 40 feet of legibility distance (a sign with 12 inch tall letters would be legible 480 feet away). The MUTCD does mention, however, that "Some research indicates that a ratio of one inch of letter height per 33 feet of legibility distance could be beneficial." (USDOT, 2003). Some of those research results were based on the outcomes of several roadway evaluations of CMS. For example, Upchurch, et al. (1992) and Garvey and Mace (1996) found that LIs for CMS on the order of 35 ft/in would accommodate "average" older and younger observers. Indeed, Garvey and Mace found that even larger letters might be required to accommodate all drivers as LIs dropped to 22 for the bottom 15 percent of younger drivers and 17 for the poorest performing 15 percent of older drivers. In a study of static commercial sign legibility conducted under "real world" conditions, Zineddin, et al. (2005) confirmed these findings and actually found that in certain high complexity sites, the LI dropped to as low as 7 ft/in.

In a study of CMS visibility, Colomb, et al. (1991) wrote that words on an 80 mph (117 ft/sec) roadway should have a letter height of 16 inches, as the authors contend that this would allow seven words to be read before the driver passed the sign. This is consistent with the review of reading time and LI discussed above (if a LI of 35 is used for the 16 inch letters, then legibility distance would be 560 feet, and at 117 ft/sec this would allow 4.8 seconds to read the sign, a time that falls between the 4.0 seconds to read three words and the 6.0 seconds to read four to eight words). Other research that has specifically evaluated CMS contends that "under perfect conditions, a driver with 20/20 vision traveling during the day at 62 mph on a freeway reading 14-in letters has about nine seconds during which sign text is legible" (Mast and Ballas, 1976 in CTC & Associates, 2003). The MUTCD states that CMS letters should be a minimum of 10.6 inches and increased to 18 inches if speeds are greater than 55 mph.

Research conducted on static outdoor advertising content has yielded similar results. Coetzee (2003) reported that three-foot high text should be legible at about 1,600 feet (an LI of about 44). This author wrote that text height should be between 12 inches and three feet, as the larger number appropriately restricts sign viewing to approximately 1,600 feet and the smaller number ensures that the sign can be read before the viewing angle is too large for the driver to comfortably read the sign.

Using "bit" values defined by the South African Government where:

- Words up to 8 letters = 1 bit,
- Words > 8 letters = 2 bits,
- Numbers to 4 digits = 0.5 bits,
- Numbers 5–8 digits = 1 bit,
- Symbol/Abbreviation = 0.5 bits, and
- Logo/graphics = 2 bits,

Coetzee (2003) calculated typical reading times for static outdoor advertisement as a function of amount of information and level of distraction (D) for two roadway complexities (Table 1). This author recommended a maximum of 12 bits of information for signs with about 1500 feet of legibility distance.

Table 1. Typical reading times for outdoor advertising signs

N (bits)	T (D=1.25)	T (D=1.5)
3	0.9 sec	1.1 sec
6	2.1 sec	2.6 sec
8	2.9 sec	3.5 sec
12	4.5 sec	5.4 sec

People read words and sentences, not letters!

Signs use words, sentences, phrases, and images, not merely strings of letters. Word legibility introduces cognitive factors quantitatively and qualitatively different from those posed by letters (Zwahlen, et al. 1995). Static guide sign research shows that familiar word recognition is based more on global features, such as the overall shape or "footprint" of a word (Garvey, et al., 1998) rather than individual letter characteristics. As a result, sign legibility distances are longer than would be predicted by visual acuity alone (Kuhn, et al., 1998). This is known as the word superiority effect (for a review see Zineddin, 2001). Sentence reading takes this a step further as mentioned by Legge, et al. (1997) who stated that reading speed for words in sentences could be faster than for single words because of the "predictability of the words in sentences." Fine, et al. (1997) suggested that this was due in part to the additional information provided by syntactic and semantic sentence content. Because of these cognitive components, sign message recognition does not require the ability to discriminate all content elements (e.g., every stroke of a letter or even all the letters in a word, or words in a sentence or phrase) for correct message identification to occur (Proffitt, et al., 1998).

What about color?

Garvey and Mace (1996) studied CMS with red, white, and yellow elements and found no significant difference in legibility. These researchers found that color produced no difference in legibility distance that could not be accounted for by luminance, luminous contrast, or contrast orientation between signs using the following color combinations: white/green, black/white, black/orange, black/yellow, and black/red. This is consistent with the findings of research on computer displays (Pastoor, 1990). Pastoor's research findings indicate that if appropriate luminance contrast, color contrast, and luminance levels are maintained, the choice of specific colors for background and text does not affect legibility distance.

What about font?

Garvey, et al. (1997, 1998, 2001) and Garvey, Zineddin, and Pietrucha (2001) have demonstrated that font can have a dramatic affect on standard highway sign legibility and on large format letter legibility. They demonstrated that specific fonts could have superior recognition and legibility indices when compared to other fonts using letters of the same height. Yager, et al. (1998) concluded that font can have an effect on reading speed when the letter heights and luminance contrast are close to threshold; they went on to state, "Until systematic comprehensive studies are done, choices of font characteristics … will depend on uninformed biases and, perhaps, aesthetic considerations rather than optimization of performance."

What about letter, word, and line spacing?

Garvey and Mace (1996) tested inter-letter and inter-word spacing in computer simulated matrix (e.g., 5x7) CMS words and found that inter-letter spacing equal to 1/7 capital letter height produced the poorest results. They recommended a minimum spacing of 3/7th letter height. Dudek (1991), in summarizing European CMS standards, wrote that the desirable inter-character spacing is 2/7th letter height and line spacing is 4/7th letter height. Mace, et al. (1996) found an inter-line spacing of 75 percent of capital letter height to be best for three-line static standard highway signs. Woodson (1993) reported that inter-letter static sign spacing should be between

25 and 50 percent of capital letter height and inter-word spacing should be from 75 to 100 percent of letter height (in Wourms, et al., 2001).

Is lowercase more legible than uppercase?

Research by Garvey, et al. (1997, 1998) demonstrated that for static highway signs words composed of lowercase letters with a lead capital letter (i.e., mixed case) are more visible (by 12 to 15 percent) than words composed of only uppercase letters in terms of recognition of the word. They also found that all uppercase and mixed case words perform equally well for word legibility, where some individual letter reading may be required. The publication, "Passenger Information Services: A Guidebook for Transit Systems" stated that for CMS uppercase letters should be used for destinations and other short messages, and mixed case should be used for "long legends and instructions." The Public Service Vehicle Accessibility Regulations (2000) state, "Destination information shall not be written in capital letters only" and that "the use of both upper and lowercase text helps ensure that words that are not completely clear and legible to people with a degree of vision impairment or learning disability are still identifiable through shape recognition of the word." (in Wourms, et al., 2001).

Forbes, et al. (1950) conducted perhaps the definitive study on the difference in static traffic sign legibility between text depicted in all uppercase letters and that shown in mixed case. Forbes, et al. (1950) found a significant improvement in legibility distance with mixed case words versus all uppercase. Garvey, et al. (1997) replicated this result with new sign materials, a different font, and older observers. As mentioned above, Garvey and his colleagues found a 12 to 15 percent increase in legibility distance with mixed-case text under daytime and nighttime conditions. It must be understood, however, that these results were obtained with a recognition task. That is, the observers knew what words they were looking for. In instances where observers do not know the text they are looking for, improvements with mixed case are not evident (Forbes, et al., 1950; Mace, et al., 1994; and Garvey, et al., 1997).

Does contrast orientation (or polarity) have an effect?

Positive contrast signs have light copy on dark backgrounds and negative contrast signs have dark copy on light backgrounds. Garvey and Mace (1996) reported a 29 percent improvement in nighttime CMS legibility distance with positive versus negative contrast messages. Iannuzziello (2001) also recommended positive contrast for general transit signage.

The research on this issue is clear; with the possible exception of tight intercharacter spacing on static highway signs (Case, et al., 1952), positive-contrast provides greater legibility distances than negative-contrast. As far back as 1955, laboratory research by Allen and Straub found that white-on-black static highway signs provided longer legibility distances than black-on white signs. Allen, et al. (1967) replicated these results in the field. Garvey and Mace (1996) extended these results in their CMS research with the addition of orange, yellow, and green signs where positive-contrast signs resulted in improvements in legibility of about 30 percent over negative-contrast signs.

Are symbols better than text?

In a study of static traffic sign comprehension speed, Ellis and Dewar (1979) found symbolic signs to outperform those with text messages. These researchers also discovered that symbolic signs were less susceptible to glare than text signs. In a 1975 visibility study, Jacobs and his colleagues assessed the legibility distance of almost 50 highway sign symbols and their text counterparts. These researchers found that in the majority of cases, the legibility distances for the symbols were twice that of the text signs. Kline and his colleagues' (1990 and 1993) replicated this finding for a smaller set of symbols using young, middle-aged, and older observers. Kline's research also described a technique to optimize symbol legibility called recursive blurring (Figure 1). The technique results in symbols designed to "maximize contour size and contour separation." In other words, optimized symbols or logos will have elements that are large enough to be seen from a distance and spaces between the elements wide enough to reduce blurring between elements.

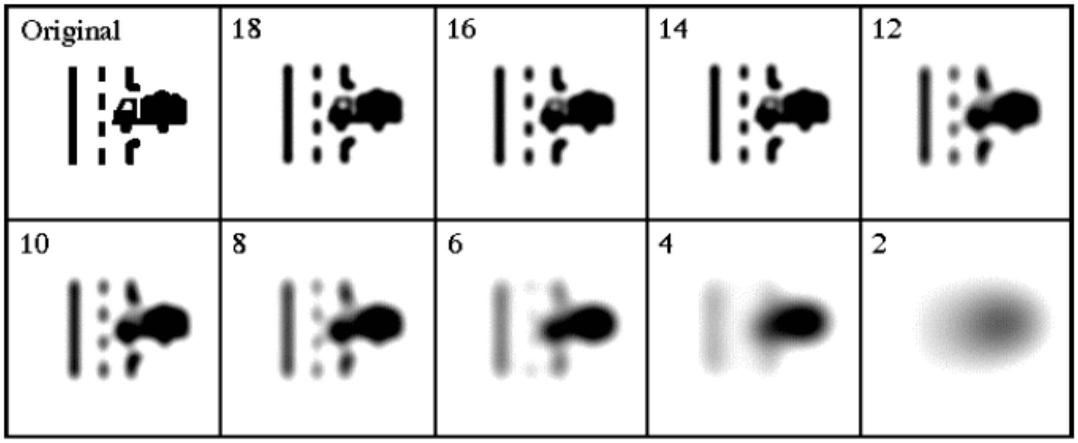

Figure 1. Example of recursive blurring to evaluate symbol visibility (Shieber, 1998).

The literature clearly indicates that, from a visibility standpoint, symbols are superior to text. Symbols, however, require a different kind of comprehension than words. Symbol meaning is either understood intuitively or learned. Although traffic sign experts and traffic engineers agree that understandability is the most important factor in symbol design (Dewar, 1988), other research has shown that what is intuitive to designers is not always intuitive to drivers, and that teaching observers the meaning of more abstract symbols is frequently unsuccessful.

Do abbreviations work?

Proffitt, et al. (1998) wrote that abbreviations take about four times as long to read as words spelled out completely. If abbreviations are absolutely necessary due to sign size constraints, they recommend two techniques:

- Truncation – where the end of the word is removed,
- Contraction – where, except for the first letter and first vowel, the vowels and the letters h, w, and y are removed.

Hutchingson and Dudek (1983) discussed three abbreviation strategies for use on CMS:

- Key Consonants – similar to Proffitt's contraction method,
- First Syllable – similar to Proffitt's truncation method,
- First Letter – only to be used in special cases such as N, S, E, and W for the cardinal directions.

Hutchingson and Dudek recommended using the Key Consonant technique on words with five to seven letters (for example, *Frwy* for *Freeway*) and the First Syllable method for words with nine or more letters (for example, *Cond* for *Condition*); however, this technique should not be used if the first syllable is in itself a new word. Proffitt, et al. (1998) reported that readers preferred contraction to truncation. Both groups of researchers state that abbreviations are to be used only as a last resort if limitations in sign size demand it, as abbreviations increase the possibility of incorrect sign interpretation. Further complicating the issue, Durkop and Dudek (2001) found that the comprehension of abbreviations can be influenced by driver age, geographic location, and education level. Alternate suggestions to deal with the limitations inherent in using abbreviations include selecting a shorter synonym for the abbreviated word, reducing letter size, reducing message length, and increasing sign size.

What is the impact of sign brightness?

In the MUTCD, the FHWA states, “Portable Changeable Message signs shall automatically adjust their brightness under varying light conditions, to maintain legibility” (USDOT, 2003). Some manufacturers recommend a 50 percent voltage reduction from daytime to nighttime conditions, while others suggest that at night signs should be dimmed to 20 percent of daytime brightness. In a study of CMS legibility for the FHWA, Garvey and Mace (1996) made more specific photometric recommendations based on human factors research with older and younger drivers. These researchers recommended a nighttime luminance of 30 candelas per square meter (cd/m^2), and 1000 cd/m^2 for bright daytime viewing. They found, however, that as subjects’ visual acuity worsened, more light was needed to achieve equivalent performance. Dudek's (1991) nighttime luminance recommendation was from 30 to 230 cd/m^2. The European highway community has been attempting to derive standard optical test methods for CMS for decades, but they have been slowed down by, among other factors, rapidly changing technology (Grahame Cheek, European Standards body (CEN), March 8, 2002: personal communication). Currently, there are no photometric standards to specify what aspect of the sign should be measured (for a discussion on the issues, see Garvey and Mace, 1996; or Lewis, 2000).

How about contrast?

Combining the results of six research efforts on static traffic sign legibility, Sivak and Olson (1985) derived a recommended contrast ratio of 12:1 for positive contrast signs (where sign copy is 12 times brighter than sign background). Staplin, et al. (1997) expanded this to between 4:1 and 50:1. Colomb and Hubert (1991) found improvements in daytime legibility of CMS to level off between 8 and 20 percent contrast (defined as the difference between the luminance of the letters and the background, divided by the luminance of the background). Legge, et al. (1997) found a reduction in reading speeds at contrast levels below 10 percent. Stainforth and Kniveton (1996) reported that a generally accepted luminance contrast ratio for CMS is 10:1. Dudek (1991) stated that for CMS, a contrast ratio between 8:1 and 12:1 should be used for light emitting technologies (e.g., LEDs) and 40 percent daytime and 50 percent nighttime contrast for light reflecting technologies. The "Passenger Information Services: A Guidebook for Transit Systems" recommends 70 percent contrast for all signs (Wourms, et al., 2001).

How should long sign messages be displayed? (Paging and Streaming)

EMCs are capable of presenting more information than will fit on a single static screen or display. For CMS, the MUTCD states "Techniques of message display such as fading, exploding, dissolving, or moving messages shall not be used" (USDOT, 2003), but commercial EMCs are not subject to these regulations. While there is no research on fully dynamic video display on signs, there is information in the literature on dynamically displayed text that might apply to some EMC applications.

If more than a single screen of information is required, the messages must be displayed in some dynamic format, either by paging or by some form of scrolling or streaming. Paging means that the information is static, but a number of pages of information are shown sequentially to convey the entire message. Scrolling typically denotes that the text is moving down the sign from the top to the bottom. Streaming refers to text that moves across the sign from the right to the left. Streaming is the method used most frequently with single line message boards. Highway CMS nearly exclusively use paging because, "The text of the messages shall not scroll or travel horizontally or vertically across the face of the sign" (USDOT, 2003).

In evaluating LED "next-stop" CMS on buses, Bentzen and Easton (1996) found that, "static messages were clearly superior to streaming messages." However, these researchers reported that when the message was too large to fit on a single static page, streaming messages outperformed paging messages. On the other hand, Kang and Muter (1989) reported earlier research (Sekey and Tietz, 1982) that found reading speed to be slower for constant scrolling (also known as "Times Square" presentation) than either irregular scrolling ("saccadic") or page mode. However, their own research supports that of Bentzen and Easton (1996), and Kang and Muter concluded that constant scrolling works at least as well as static techniques and is preferred by readers.

A study sponsored by the Transportation Management Center Pooled-Fund Study (http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new_search.cfm?new=0) titled *Impacts of Dynamically Displaying Messages on Changeable Message Signs* is underway to address some of these issues. The objective of the research is to "Conduct human factors studies to determine the effects of dynamically displaying messages on CMSs including at a minimum: a) flashing an entire one-frame message; b) flashing one line/word of a one-frame message; and c) alternating text on one line of a two-or-more-line CMS while keeping the other line(s) of text constant on the second frame of the message." The final report is scheduled for release in July of 2005.

How fast should sign information move?

How long a static message should be displayed and how fast a dynamic message should stream across the sign is mainly a function of the target audience's reading rate. As mentioned earlier, Proffitt, et al. (1998) found the average adult reading rate to be about 250 words per minute. Kang and Muter (1989) put the rate at 280 wpm for college students. There are numerous and varied recommendations regarding both EMC message duration and speed. It has been recommended that, "a line of text should be displayed for at least ten seconds, preferably a little longer." (ECMT, 1999), and there is Dudek's 1991 recommended of a minimum exposure time for CMS of "one second per short word… or two seconds per unit of information" for use with unfamiliar observers as discussed earlier. Harris and Whitney (1993) wrote that if scrolling is used, information should be left on the screen for at least twice the normal reading time. Barham, et al. (1994) found a fixed time of about 10 seconds was needed to avoid confusion when a scrolled message is used. In light of this finding, they recommended that the duration of message displays should be from 10 to 20 seconds (in Wourms, et al., 2001). Joffee (1995) recommended a display time of 1.6 seconds when a single line CMS must display multiple pages of information. Finally, Bentzen and Easton (1996) evaluated the effect of streaming rates, defined as the length of time any given pixel is in view from when it appears on the right of the sign to the time it disappears on the left side. These researchers found 2.75 and 2.56 second streaming rates to be optimal for single word CMS messages. They reported that a streaming rate of 3.5 seconds was so slow as to appear to flicker and a streaming rate of 1.5 seconds was too fast for subjects to consistently read the message.

WHAT ARE THE SAFETY IMPLICATIONS OF EMCs?

For any sign to be useful it must be conspicuous; that is, it must have a high probability of being detected by its target audience. All highway signs, including EMCs, are therefore designed to attract driver attention. Although there is little scientific evidence to support claims that EMCs and outdoor advertising signs in general have a negative impact on road safety, it is often stated that these signs compete with basic driving demands for driver attention, thereby distracting drivers from the safe operation of their vehicles.

Distinctions, however, must be drawn between the terms, “attraction,” “distraction,” and “dangerous distraction.” The term distraction can be defined as attracting attention away from some primary task. Simply put, the primary driving task is to safely maneuver the vehicle from point a to point b. Anything that distracts a vehicle operator to a degree that results in hazardous driving behavior is a dangerous distraction (e.g., cellular phones). When used to describe commercial signs, the term distraction is seen as synonymous with the creation of a traffic hazard. The fact that drivers pay attention to commercial signs is not in dispute, the issue is whether this attention has a negative impact on driving performance.

Eye Movement Research

Four driver eye movement studies were recently conducted to evaluate driver behavior in the presence of commercial signs; two of these included off-premise EMCs. Young (2004) reported the results of a 1999 eye movement study where 50 subjects ranging in age from 18 to 70 were driven over a 30-mile course with 28 static billboards. The subjects were seated in the vehicle’s passenger seat. Young stated that 74 percent of the billboards were seen and 48 percent were read.

Lee, et al. (2003) evaluated the eye movements and driving behavior of 36 younger and older drivers as they drove a 35-mile loop in Charlotte, NC, USA. The test route included sections with billboards (static only), others with just traffic signs, and others with neither. Thirty billboard passes were evaluated. There was no change in speed variability or lateral position within the lane (measures of driver inattentiveness) associated with outdoor advertising. The researchers concluded, “The presence of billboards does not cause a measurable change in driver behavior, in terms of visual behavior, speed maintenance, or lane keeping.”

Beijer (2004) conducted a study to evaluate the “possible distracting effect on driver [eye] scanning behavior of roadside advertisements.” The study employed 25 subjects between 25 and 50 years of age who drove four miles of a Toronto, Canada expressway and were exposed to 37 commercial signs. A head mounted infrared eye tracking device was used (EL-MAR Vision 2000). Five on- and off-premise EMCs displaying moving text and images were included in the study. The EMCs and other active signs (roller bar and scrolling text) elicited significantly more and longer glances than did the static billboards. The EMCs had the greatest number of “long glance durations” (greater than 0.75 seconds) and five times as many long glances as static billboards.

As previous studies using only static billboards did not find significant distraction (e.g., Lee, et al., 2003), Beijer concluded that “active advertising signs may result in greater distraction than past studies of the effect of commercial signing might indicate.” However, Beijer admitted that sign placement was not controlled in the study and that the more expensive EMCs and other active signs were generally located closer to the center of the driver’s visual field increasing the likelihood of detection and longer glance duration as these researchers reported that “An average of 79.5 percent of glances were within ten degrees of center and 97.6 percent were within 25 degrees.”

Smiley, et al. (2004) evaluated the effect of outdoor advertising on eye movements using the same apparatus as Beijer. This study was specifically aimed at addressing the effects of on- and off-premise EMCs. Sixteen subjects, age 25 to 50, drove through four downtown intersections (three with EMCs) and a section of urban expressway in Toronto, Canada along which a single EMC was mounted. In summarizing the eye movement behavior, the authors stated, “Glances at advertising, static billboards or video signs [EMCs], constituted only 1.5 percent of total glances. Mean glance durations were short – generally between 1/5 and 3/5 of a second.” Overall, 45 percent of the subjects looked at the four EMCs evaluated in this research. At the intersections, 48 percent of subjects looked at the EMCs, while on the expressway this fell to 36 percent. Twenty-five percent of EMC glances were longer than 0.75 seconds in duration, and 73 percent were within 20 degrees of the subjects’ line of sight. The researchers wrote, “In some cases glances at [EMCs] were made unsafely, that is, at short headways, for long durations and at large angles off the line of sight." Overall however, these researchers concluded that, "No evidence was found that glances at video signs [EMCs] reduced the proportion of glances at traffic signs or signals" and there was no evidence that the EMCs reduced subject detection of cyclists or pedestrians.

Driver attention in the presence of static commercial signs

Three studies conducted in the 1970s evaluated the possible effect of commercial signs on driver attention. As the studies were conducted before EMC signs were available, the research focused on static signs. In their research on distraction by irrelevant information, Johnston and Cole (1976) presented observers with 240 "likely to distract" commercial signs. These researchers concluded, "These experiments have demonstrated that the human operator has the capacity to shed irrelevant information." They went further to state that "the general effect of distraction ... does not represent a physiological phenomenon against which the operator has no defense." Two field studies (Tindall, 1977; and Sanderson, 1974; in Andreassen, 1985) support the conclusions from Johnston and Cole's laboratory research. Tindall found that drivers are more likely to ignore signs that are not relevant to the driving task and more likely to attend to signs that have a direct effect on driving performance. Sanderson reported that when a commercial sign was placed among traffic signs, drivers have significantly greater recall of the traffic signs than of the commercial signs.

Although they did not evaluate EMCs specifically, in a recent study of driver distraction conducted for the AAA Foundation for Traffic Safety (Stutts, et al., 2003), researchers evaluated national (U.S.) and state (North Carolina) crash data and concluded that while "driver inattention is a major contributor to highway crashes…the search appears to suggest that some items – such as CB radios, billboards, and temperature controls – are not significant distractions." Specifically, out of two years of national narrative data from 1997 and 1998, only eight of 332 and nine of 412 crashes respectively involving driver distraction were attributed to "other distractions" that included "looking outside vehicle (in rear view mirror, at traffic, at road signs, in store window, for gas station, for parking space, for business, etc)." North Carolina narrative data were evaluated for 1998, and no crashes were associated with drivers being distracted by billboards. However the study (Stutts, et al., 2003) did mention that "those ages 65 and older were more likely to have been distracted by objects and events outside the vehicle (other vehicles, signs, animals, etc.) and by other (unspecified) distractions."

In an evaluation of literature on driver distraction by items external to the vehicle, Wallace (2003a) looked at the possible impact of static billboards. He concluded,

> "It is still not proven whether billboards attract attention from driving or not. Certainly there is a large amount of scientific evidence suggesting they might under certain circumstances, and a few suggestive correlation and laboratory studies suggesting they do. However all the studies are flawed: either because they are correlation studies, because they are too small scale to draw conclusions from, or because of issues of ecological validity."

Wallace went on to state, "Nevertheless the case for arguing that visual 'clutter' at junctions (associated with billboards and signs) can lead to unsafe driving is very strong. However more research is needed on specific cases to demonstrate the extent of the effect."

Driver attention in the presence of EMCs

The goal of a recent publication by the FHWA (FHWA, 2001) was to "review the literature on the safety implications of electronic billboards [EMCs], and to identify knowledge gaps in the findings." Major findings of this research include:

- A 1994 Wisconsin DOT Report found increases in rear end and sideswipe crash rates (from 21 to 36 percent depending on the direction of traffic) with the introduction of a variable message advertising sign that changed images at a rate of 12 per minute. Six years of crash data were evaluated, three before the 1984 sign installation and three after.
- Nevada, Utah, Texas, New York, New Hampshire, and Massachusetts "reported no evidence of increased traffic safety problems after the installation of electronic information displays in their city centers and along their highways."
- "In most instances, researchers were not able to verify that an [EMC] was a major factor in causing a crash."
- "At this point, it appears that there is no effective technique or method appropriate for evaluating the safety effects of [EMCs] on driver attention or distraction."

Crashes in the presence of static commercial signs

Several older studies attempted to evaluate the relationship between traffic accidents and static commercial signs. All of these studies have the difficult task of attempting to associate accident causation with a single factor. Johnston and Cole (1976) called accidents "multi-factorial" and stated, "Just as it is difficult to conclude that roadside advertising contributes significantly to an increase in accident rates, it is equally difficult to assert with confidence that it makes no contribution whatsoever."

In one of the earliest research efforts exploring the relationship between collisions and static commercial signs, Rykken (1951) reported that a preliminary study of approximately 170 miles of Minnesota roadway found no relationship between the presence of commercial signs and accident occurrence. This researcher went further and implied that long roadway sections with no advertising might actually result in driver fatigue and excessive speed. Rykken qualified his results, however, by stating that an accident analysis is only as good as the accident reports, and that these reports "...may not be sufficiently accurate nor adequate to completely fix the cause of many accidents."

Rusch (1951) published an accident analysis study aimed at determining the safety impact of static roadside advertisements. The author concluded that "inattention" and "misdirected attention" were the main causes of an increased number of accidents in high-advertising and roadside business areas and attributed this inattention to advertising signs. However, in a 1985 synthesis of the literature on traffic accidents and advertising signs, Andreassen questioned the results of Rusch's correlational study, stating that the study "does not prove anything about the effect of advertising signs on accident occurrence." Andreassen wrote that any number of other factors might have contributed to the accident increase. In addition to the Rusch report, Andreassen (1985) evaluated the results of five other studies that examined the relationship between advertising signs and accidents. He reported that two of the studies found a positive correlation and three found no relationship. He stated that the studies reporting positive results were "discredited by subsequent analysis." Andreassen's final conclusion was that "There is no current evidence to say that advertising signs, in general, are causing traffic accidents." In a recent review of the topic Coetzee (2003) similarly concluded that although there is some reason to believe that billboards might result in higher accident rates, "limited empirical proof of advertisements resulting in more accidents exist."

Tantala and Tantala (2005) recently conducted a correlational analysis that evaluated the relationship between crashes occurring on a section of the New Jersey Turnpike and placement of advertising signs. Data on 22,971 crashes from 1998 to 2001 were used in the evaluation. There were 123 static on-premise and off-premise advertising signs on the test section of the turnpike used in this research. The analyses revealed "extremely weak" (from 0.1 to 0.2) correlations between sign density and crashes, and a near zero to slightly negative correlation between crashes and sign proximity (that is, crashes were not more likely to occur near signs). Given the extremely low correlations, the researchers concluded that neither the proximity nor the density of commercial signs were statistically associated with increases in the number of roadway crashes.

Crashes in the presence of EMCs

As part of the research project discussed above, Tantala and Tantala (2005) conducted a second accident analysis that evaluated the "before-after" effect installing a single EMC. The on-premise EMC was mounted at an intersection in Bucks County, PA on U.S. Business Route 1. A portion of the sign included "varied aspects of simulated movement including scrolling, wipe-on, wipe-off, blending, and rapid copy variations involving different messages in a constantly changing mode of operation." Crash data were collected for one year before and one year after the January 2002 sign installation. A total of 68 accidents took place in 2001 and 60 accidents occurred in 2002. As the traffic volume increased by 5.3 percent during this time period, this represents a decrease in crash rate of 16 percent. The researchers concluded that in the specific instance evaluated in their study, the EMC did not affect traffic crash rate: "The results of this study conclude that advertising signs have no statistical influence on the occurrence of accidents. These analyses also suggest that no causal relationship between signs and accidents exists." However, they also suggest that more sign locations and more crash data over a greater period of time should be evaluated in future research.

The data from Smiley, et al.'s 2004 research discussed previously were reanalyzed to look specifically at the potential roadway safety effects of EMCs (Smiley, et al., 2005). In addition to the driver eye movement behavior reported in Smiley, et al. 2004, the 2005 report looked at crashes before and after EMC sign installation, contained an evaluation of driver behavior in the presence and absence of EMCs, and included a survey of road user perception of the potential safety impact of these signs.

Inappropriate braking, lateral lane position, and "the time it took for the 5th vehicle in a queue to cross the stop line after the commencement of green" (a measure of driver attention while waiting at a red signal) were recorded at three intersections where EMCs were located. The EMCs were visible from two of the four approaches to each intersection. At one intersection there was an increase in inappropriate braking on the EMC approaches compared to the non-EMC approaches, but no change in lateral position or time to cross the stop line. No effect of EMCs was found on any of the three variables tested at the other two intersections.

Vehicle speed and spacing between vehicles were recorded before and after sign installation on a section of expressway from which an EMC was visible. The results of this analysis were inconclusive. Also, before and after sign installation crash data were evaluated at each of the three intersection sites and the expressway location. Three to four years of before crash data and one to two years of after data were included in the analyses. Given the small number of collisions at the intersection sites, no significant change in crashes was found to be associated with the installation of the EMCs. The expressway evaluation also resulted in non-significant changes in crashes associated with the installation of an EMC.

Despite these findings, a public survey of 152 roadway users conducted by Smiley, et al. (2005) had the following results:

- 65 percent said EMCs have a negative effect on driver attention,
- 59 percent said, as a driver, their attention is drawn to EMCs in downtown locations, and 49 percent of that group indicated a negative effect on driving safety,
- 59 percent said, as a driver, their attention is drawn to these signs on expressways, and 44 percent of that group indicated a negative effect on driving safety,
- 86 percent of subjects said there should be restrictions on EMCs in the interest of traffic safety, and 73 percent of that group said that video signs should not be placed at intersections and 62 percent of the group favoring restrictions said that video signs should not be placed on highways,
- 6 percent reported experiencing near collisions as a result of an EMC,
- 1.3 percent had experienced rear-end collisions that they associated with video advertising signs, and
- On a scale of 1 to 7 (1 = not at all distracting, 7 = very distracting to drivers) "video advertising signs were rated at 3.7, higher than billboards (2.1), but close to the same as road construction (4.0), and lower than in-car cell phone use (5.6) in terms of distraction."

In the conclusion of their report, Smiley and her colleagues (2005) stated, "based on the 4 studies reported on in this paper, and the amalgamation with the results of an earlier study of eye movements for a video sign on the Gardiner Expressway it cannot be concluded at this time that video advertising signs are either safe or unsafe." They suggested that the potential impact on traffic safety is highly sign- and location-dependant and that some signs mounted in some locations may very well negatively impact traffic safety, while others will not. They recommended that more research be conducted with larger crash data sets to evaluate the potential impact on safety, and more eye movement studies should be conducted to "determine design and placement factors which keep driver distraction to a minimum."

EMC ZONING REGULATIONS

The BPS Outdoor Advertising website reports that 24 percent of U.S. states prohibit moving or animated signs and that 29 percent have "timing limits" on EMCs (BPS Outdoor, 2004). Through interviews with state DOTs, review of DOT websites, and a meeting with members of the National Alliance of Highway Beautification Agencies' (NAHBA), information from 44 states were evaluated (FHWA, 2001). The conclusion was that "common billboard guidelines governing [EMCs]…do not exist." A consistent feature among the guidelines, however, is the prohibition of signs that have flashing, intermittent, or moving lights.

Wisconsin is very specific in delineating the acceptable use of EMCs and its requirements are representative of other states that have strict EMC codes (CTC & Associates, 2003):

- No message may be displayed for less than one-half second;
- No message may be repeated at intervals of less than two seconds;
- No segmented message may last longer than 10 seconds;
- No traveling message may travel at a rate slower than 16 light columns per second or faster than 32 columns per second; and
- No variable message sign lamp may be illuminated to a degree of brightness that is greater than necessary for adequate visibility.

WHAT ARE THE PRESSING EMC RESEARCH NEEDS?

Given that EMCs are used for so many purposes, and the application of EMCs is so varied, there appears to be a pressing need to develop a set of guidelines that would provide EMC designers, manufacturers, and users with some needed direction in how to use these signs most effectively.

Many of the design elements for EMCs are listed in Table 2. While this list is not exhaustive, it does represent most of the issues that must be considered before designing, fabricating, and placing an EMC.

Table 2. EMC Design Elements.

• Target Audience
o Drivers
o Passengers
o Non-occupants
• Content
o Message
▪ Text
▪ Symbols
▪ Moving Image
o Use of Color
• Placement
o Location
o Number of Signs
o Orientation
o Mounting Height
o Roadway Offset
• Conspicuity
• Legibility
o Luminance/Contrast
o Letter Height
o Font
o Kerning
o Negative Space
o Words per Line
o Lines per Page
o Pages per Message
o Message Motion (e.g., scrolling, streaming, dissolves)
o Message Duration (minima and maxima)
o Negative Duration (minima and maxima)
• Size
o Maximum Dimensions
o Minimum Dimensions
• Understanding/Comprehension
• Retention
• Regulations
o Federal
o State
o Local
• Safety
o Distraction
o Accident Analysis
o Public Acceptance
o Regulator Acceptance

EMC designers must first consider what the sign is to be used for. Once the purpose of the sign has been established, the target audience can be identified. As the target audience becomes known, the message content should begin to evolve. Will the sign be used to direct drivers to a driveway entrance? Is the sign promoting a special event taking place at a later date that is of interest to the general public? Or is it merely a general advertisement of a product or service? After identifying a target audience and formulating the message content, placement issues such as location, the number of signs, the orientation of the signs, the mounting height, and lateral offset can be addressed. After the placement has been established, conspicuity and visibility issues should come into play. Are the sign viewers fixed or moving relative to the sign? How fast are they moving? Answers to these questions will begin to detail elements such as contrast values, letter heights, lines of text, numbers of panels, and sign size. To assess the effectiveness of the sign, an evaluation of whether the message is legible and understood and retained by the target audience should be conducted. All through the design process the EMC should be evaluated in terms of compliance with all applicable regulations. Lastly, there should be some assurance that the EMC will not compromise the safety of the general public.

One should also keep in mind that EMCs represent a very special case of sign viewing in that the people seeing the sign can be moving and the images on the sign can be moving. This case is somewhat unprecedented in visual and cognitive research. Therefore, by examining the nature of the design elements, along with what is known (and not known) about user performance, while keeping in mind the special nature of the tasks associated with viewing EMCs, the following general recommendations regarding research can be made.

Viewing a dynamic sign from a moving vehicle

It would seem that the single most pressing need for EMC designers is to have more information about how drivers view a dynamic sign from a moving vehicle. As mentioned above, there is no directly relevant research in this area related to commercial signs. Therefore, it would be valuable to have more information about nearly every design element related to sign visibility in the context of a moving viewer looking at a sign with a dynamic image. (For purposes of discussion, the term “changing” will be used to denote an image that is static on a single panel, but the panel changes on or off as part of a multiple panel message, the term “moving” denotes that the image is moving on the individual panel.)

Letter Height – What is the appropriate letter size (i.e., height) for a driver to view a changing message? This information could be derived using analytical methods that simulate a vehicle approaching an EMC sign at a certain speed given the number of panels in the message. What is the appropriate letter size for a driver to view a moving message?

Font – What effect would the selection of a specific font have on the selection of letter height? In a static viewing condition, this is known somewhat. In a dynamic viewing condition, this is unknown.

Kerning – There are guidelines for spacing the letters, within a specified font, used to form the words in a static message; however, whether these kerning values are still valid under dynamic conditions is not known.

Negative Space – Although the MUTCD does address the issue in the form of a requirement for copy placement and spacing on highway guide signs, information on this topic for dynamic sign messages is non-existent.

Words per Line – There is limited information on the maximum numbers of words that can be read and understood for a single line of text on a static sign. As with many of the other design elements, there is no information about this for dynamic signs.

Lines per Page – While three lines of text seem to be optimal on static signs, there is no corresponding information regarding this design element for dynamic signs. For a moving message, issues such as order and speed of presentation and presentation duration of each line would have to be considered.

Pages per Message – The number of pages are limited by the legibility thresholds and the duration of the presentation. The time the driver has to read a message is dependent on how far from the sign reading can begin, and how long the sign is visible given how fast the vehicle, in which the driver is traveling, is moving. This is similar to the issues with letter height discussed above in that an analytical approach could be used to provide design guidance, but this would only apply to changing and not moving messages.

Message Motion – How the message "comes on to" and "leaves" the EMC will influence a driver's ability to read and understand the message. Scrolling, streaming, and screen dissolves will increase the time needed by the driver to perform this task; however, very little is known about how great this increase in time actually is.

Message Duration/Negative Duration – The length of time that the message is presented, whether it be as part of a changing message or a moving message is very important relative to the driver reading and understanding a particular message. Further, the amount of negative duration (i.e., blank screen time) is also important for successful completion of this task. There is very little known about these issues.

Combination of Visual Design Elements – Each of the issues discussed above is further complicated when considered in conjunction with other design elements. For example, letter height is influenced by font selection. Message duration and negative duration will depend on font and/or letter height. Lines per page and pages per message could be affected by message motion and duration.

Regulations and Safety

EMC designers, manufacturers, and operators should be aware of relevant regulations and public sector official's and private citizen's safety concerns. As cited earlier in the report, Wisconsin has very specific requirements regarding the design of EMCs (CTC & Associates, 2003). It is likely that there are other relevant national, state, and local regulations governing EMC design and use. The EMC community would benefit from knowing what types of controls have already been established in this area. Further, a delineation of specific quantitative data regarding regulations (maximums and minimums) for certain design elements would be useful to EMC designers.

This report has also demonstrated, in discussions in prior sections, that while collision data are important, safety goes beyond accident studies. Perceptions by government regulators and private citizens can influence the regulatory climate discussed above. The FHWA memorandum stating that, "[CMS] can convey only a limited amount of information and may not be the safest or most effective method in many cases" or the study by Smiley and her colleagues (2005) finding that 86 percent of a group of 152 road users said that there should be restrictions on EMCs in the interest of traffic safety, and 73 percent of that group said that video signs should not be placed at intersections and 62 percent of the group who favored restrictions said that video signs should not be placed on highways, demonstrates that safety in not just a matter of numbers but also one of individual perceptions.

As with the visual design elements, it would be useful to have more information in some of these areas too.

Regulations – Given that the limited number of regulations uncovered in the literature review show some very specific detail related to the operation of EMCs (e.g., minimum message display times, maximum display times for multiple panel messages), there is a need for further research into issues such as: What level of government should/does control EMCs? When specific values are used what are they based on? And if regulations are necessary, what would be a good model set of regulations (i.e., design guidelines)?

Qualitative Safety – The perceived safety of anything is usually a matter of perceived risk and perceived consequences. This paradigm works well unless there is a serious mismatch between the perceived risks and consequences and the actual risks and consequences. Before embarking on a research program dealing with quantitative safety measures, it is paramount to have some understanding of what the perceptions of government regulators and the general public are regarding of EMCs. The limited data reported on in this paper shows a fairly negative perception regarding the safety of EMCs. Is this perception widely held? By what sectors of the population? Answers to these types of questions should provide a blueprint regarding how to proceed with any quantitative safety studies.

Quantitative Safety – Regarding EMCs, safety translates into two major areas, driver distraction and collisions. For EMCs to be proven as safe or unsafe, there need to be objective studies that demonstrate that after EMCs are installed, there is no increase in the number accidents that are directly attributable to the presence of the EMC. This type of study would be very difficult to conduct as most collisions are not based on any one factor. However, studies that show that EMCs create no more driver distraction than other types of on or off road information sources or distracters would act as a surrogate measure of roadway safety.

Recommended Research

The following is a list of potential research projects that could be used to begin to address the pressing research needs detailed above.

Title: *Perception of EMC Safety*

Method: This would include a detailed survey and critical evaluation of international, national, state, and local EMC regulations and the rationale for their development. Extensive surveys of government regulators' and the public's perception of EMC safety would also be conducted. Model regulations could be drafted.

Title: ***EMC Comprehension***

Method: Understanding of messages displayed on EMCs would be evaluated in a laboratory setting using computer generated EMC messages and measuring performance by evaluating message comprehension and retention including the time it takes to absorb the message. Messages displayed in static and dynamic formats would be evaluated.

Title: ***EMC Legibility – Laboratory Study***

Method: The legibility of EMCs would be evaluated in a laboratory setting using computer generated EMC messages and measuring performance by recording eye movements and determining the minimum content size (or maximum distance). The eye movement recordings will also provide information about how people obtain information from EMCs (e.g., what do they look at first, how long do they dwell on images, etc). Messages would be displayed in static and dynamic formats of varying complexity.

Title: ***EMC Conspicuity and Legibility – Field Study***

Method: The conspicuity and legibility of EMCs from a dynamic viewer perspective would be evaluated in a field setting using a variety of EMCs (dynamic and static). Performance would be measured using an eye movement device. The distances and viewing angles at which the signs are first detected and when they are read will be recorded. The effects of sign type, message characteristics, environmental, and viewer variables will be evaluated.

Title: ***EMC Safety***

Method: The safety of EMCs would be evaluated by selecting a large number of locations where EMC have been placed and determining the before-after crash rate and by comparing the crash rates to similar locations that do not have EMCs installed.

Title: ***Model EMC Guidelines***

Method: Model EMC guidelines would be developed that take the design and use of EMCs through a process that includes consideration of what the sign's purpose is, the target audience, message content, placement, and conspicuity and visibility.

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Appendix A
Annotated Bibliography

Battelle. (2004). Amber, emergency, and travel time messaging guidance for transportation agencies. Battelle Memorial Institute, Final Report. 22 pgs.

Abstract:
This study was undertaken to provide guidance to transportation officials in planning, designing, and providing various types of traveler information messages using changeable message signs (CMSs). Three primary issues related to messaging are addressed by these guidelines: (1) The basis for the message, i.e., what condition is occurring, what segment is impacted, and what outcome or driver response is desired; (2) How the content is determined, i.e., how is the message structured to maximize driver comprehension, is the message aimed at commuters, unfamiliar drivers, or other groups, is the content automated or put together by a TMC operator, and how is the message coordinated with other information dissemination techniques, e.g., 511; and (3) What policies govern the display of messages, i.e., whose authority is needed to initiate a message, what are the arrangements for posting, updating, and terminating a message, what is the process for interagency coordination (especially with non-transportation agencies), how are messages prioritized during periods when multiple messages are desired, and how are 24/7 operations ensured. The study was divided into three tasks: (1) a literature/background review; (2) a "scan" of the practice; and (3) best practices/lessons learned.

Beijer, D. (2004). Observed driver glance behavior at roadside advertising. Presented at Transportation Research Board Annual Meeting, Washington, D.C., 14 pgs.

Abstract:
Express routes in North America are becoming more crowded, both in traffic density and in visual clutter, resulting in a higher demand for driver attention, a possible concern for regulators. Advertising signs add to this demand on visual attention. This study focused on glance behaviour of 25 drivers at various advertising signs along a Toronto expressway. Subjects averaged glances of 0.57 seconds in duration (sd = 0.41), and 35.6 glances per subject in total (sd = 26.4). Active signs, containing moveable displays or components, comprised 51% of signs, and received significantly more glances (69% of all glances and 78% of long glances). Number of glances was significantly lower for passive signs (0.64 glances per subject per sign) when compared to active signs (greater than 1.31 glances per subject per sign). Number of long glances was also greater for active signs compared to the passive signs. Sign placement in the visual field may be critical. This study provides empirical information to assist regulatory agencies in setting policy on commercial signing.

Bergeron, J. (1997). An evaluation of the influence of roadside advertising on road safety in the greater Montréal region. Proceedings of the 1997 Conference of the Northeast Association of State Transportation Officials Quebec, Canada, pg. 527.

Abstract:
In Quebec, the Loi sur la publicite le long des routes [Act goerning roadside advertising] adopted in 1988 prohibits the installation of billboards within 100 meters of a highway right-of-way. However, the Act does not apply to Urban Community, City and Township territories. This legal loophole has allowed many billboards to be constructed alongside highways in metropolitan areas including Montreal. It has been shown that such billboards are accident-promoting factors.

In an urban setting, analysis of the relation between posted advertising - either conventional or variable message type - and increased driver information-processing mental loading defines this problem clearly. In light of its responsibilities in road safety matters, the ministere des transports has therefore proposed amending the Code de la securite routiere to prohibit the installation of such billboards in certain areas deemed particularly at risk.

Brill, L.M. (2002). LED Billboards: Outdoor advertising in the video age. SignIndustry.com. Available at: http://www.signindustry.com/led/articles/2002-07-30-LBledBillboards.php3

Abstract:
LED video display billboards have emerged on a grand scale that converges into a unique display format that is one part print, one part television advertising and one 'digital hieroglyphics.' LED video billboards, like their print counterparts, can be seen hanging out on the sides of freeways silently shouting brand identity, product placements and message of 'buy now for the best deal of a lifetime.'

Cao, Y. and Wang, J.H. (2003). Evaluation of design and display factors of changeable message signs. Institute of Transportation Engineers 2003 Annual Meeting and Exhibit. 24 pgs.

Abstract:
A two-phase study on the design and display factors of changeable message signs (CMSs) was conducted through a series of blocked-factorial experiments. Subjects sit in the driver's seat of a 1998 Ford Taurus sedan. Computers generated CMS images, merged with a driver's view driving video, and were projected onto a screen in front of the vehicle. Subjects were required to make proper responses signaling their comprehension of the CMS stimuli. Eighteen subjects balanced by age and gender participated the experiments. Phase I investigated the effects of discrete displayed CMSs' font size, font color, subjects' age, gender, and their interactions. It found that font color, drivers' age, and gender significantly affected response time. Green and 5 x 7 matrix were the best font color and font size, respectively. Older drivers responded the fastest among the three age groups but with the lowest accuracy. No significant correlations were found between response time and accuracy. Response times of different subjects were significantly different, but the effects of font color and size were consistent. Phase II studied the influences of display format, number of message lines, lighting, driving lane, and their interactions. It found that discrete displayed messages took less response time than sequential displayed ones. Single-line messages were better than multiple-line ones. Motorists could better view CMSs in sunny days, and better view CMSs when driving in the outer lane. Older drivers exhibited slower response and less accuracy than younger drivers; females exhibited slower response but higher accuracy than males

Chatterjee, K., Hounsell, N.B., Firmin, P.E., and Bonsall, P.W. (2002). Driver response to variable message sign information in London. Transportation Research. Part C: Emerging Technologies 10(2), pgs 149-169.

Abstract:
This paper presents the results of a study of driver response to information on variable message

signs (VMS) that have been installed in London to notify motorists of planned events and current network problems. Questionnaires were employed to investigate the effect of different messages on route choice. Stated intention data from the questionnaire was used to calibrate logistic regression models relating the probability of route diversion to driver, journey and message characteristics. The resultant models indicate that the location of the incident and the message content are important factors influencing the probability of diversion. A survey of drivers' actual responses during the activation of an immediate warning message showed that only one-third of drivers saw the information presented to them and few of these drivers diverted, although many found the information useful. The rate of diversion was only one-fifth of the number predicted from the results of the stated intention questionnaire. The low response rate achieved for the stated intention survey is thought to have exaggerated drivers' responsiveness to VMS messages. Survey data for another UK city with a newly installed VMS system showed that the number of drivers diverting due to VMS information was very similar to that expected from the results of the stated intention questionnaire. The results of the current study suggest that the low proportion of drivers noticing VMS information has implications for the future placement of VMS so that the best opportunities for drivers to see the information are exploited. Results also suggest that the current usage to display advance warnings may be detracting from its effectiveness as a means of disseminating immediate warning information in incident-management situations.

Coetzee, J.L. (2003). The evaluation of content on outdoor advertisements. South African National Roads Agency Final Report, 13 pgs. Available at: http://www.itse.co.za/

Abstract:

Using the number of bits on advertisement content as the only quantitative criteria was identified as a problem. Accident statistics were evaluated to determine the relationship between advertisements and increased accident rates and it was found that in general, advertisements result in higher accident rates. No accident data related to the content of advertisements was however found. This study investigates an analytical approach to evaluate the contents on advertisements, based on the characteristics of the driver. These characteristics include vision, reaction time, reading time, legibility factors, spare capacity to process information and selective attention. A parallel is drawn between a drivers reading of road signs and the reading of outdoor advertisements. A concept of the critical zone – the 500m in front of an advertisement - is developed and the control of content in this zone is quantified. Rules are proposed to evaluate the content for advertisements that will hopefully provide a more practical, defendable approach to evaluate the content of outdoor advertisements.

Colomb, M. and Hubert, R. (1991). Legibility and contrast requirements of variable-message signs. Transportation Research Record, No.1318, pgs. 137-141.

Abstract:

New technologies such as optic fibers and light-emitting diodes are now used for information matrix signs. A field study was carried out to evaluate the best conditions for the legibility of these signs during the day and at night. For legibility criteria, the contrast between the letters and the sign background is chosen for daylight conditions and the luminance of the letters for night conditions. The performance of some commercially available signs is compared with the study results.

Colomb, M., Hubert, R., Carta, V., and Bry, M. (1991). Variable-message signs: legibility and recognition of symbols. Proceedings of the Conference, Strategic Highway Research Program and Traffic Safety on Two Continents, Gothenburg, Sweden, pgs. 46-62.

Abstract:
A laboratory study of the understanding of six types of signs was conducted using transparencies produced by the EDGAR graphic software developed for the purpose. The signs were presented to observers for a limited time. The influences of the number of points in the matrix and of the shape of the symbol were investigated. This study raises the problem of specifying matrix symbols. It should be continued in an attempt to arrive at simple recommendations for the main symbols. It would be best to discuss this question at the international, or at the European level, since the symbols on road signs should be the same in all countries.

CTC & Associates, LLC (2003). Electronic billboards and highway safety. Bureau of Highway Operations, Wisconsin Department of Transportation, 8 pgs. Available at: http://www.dot.wisconsin.gov/library/research/docs/tsrs/tsrelectronicbillboards.pdf

Abstract:
We located two FHWA resources that are especially helpful for getting familiar with the issues: the Office of Real Estate Services (ORES) Web site and the study entitled *Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction.* The study affords an in-depth look at how states are regulating electronic outdoor advertising, from lenient control at one end to the prohibition of outdoor advertising at the other. Wisconsin addresses the issue with rules for the content, timing and brightness of EBBs and tri-vision signs. However, standard billboard guidelines governing EBBs and tri-vision signs do not exist: few states, in fact, define the term "electronic billboard." Research on the issue of electronic ads causing driver distraction would suggest that the jury is still out. While some studies conclude that extra-vehicular distractions cause crashes, it has proven difficult to identify and measure the role of electronic advertising in driver distraction. However, promising methodologies have been proposed for focused study of the issue, and for trimming the risk of driver distraction from electronic advertising.

Dadic, I., Kos, G., and Brlek, P. (2003). Application of changeable message signs in traffic. Promet Traffic-Traffico, 15(5). Pgs. 307-314.

Abstract:
In the Republic of Croatia, changeable message signs are being introduced on high serviceable roads in order to improve the flow management in the network and increase the traffic safety level. The equipment installed in the past was not set according to the unique criteria, thus resulting in the installation of relatively incompatible equipment set in a disorganized manner. This work presents the basic guidelines in applying changeable message signs, primarily on the Croatian motorways. The types and levels of influence on the traffic are described, and the traffic and weather criteria for the application of changeable message signs are defined. The paper also analyzes the principles of installing the changeable message signs on roads and road facilities, recommending priorities in presenting the changeable signs.

Davis, P., Sunkari, S., Dudek, C., and Balke, K. (2002). Requirements specification for DMS message optimization software tool (MOST) Texas Department of Transportation Final Report No. FHWA/TX-03/4023-2, 110 pgs.

Abstract:
Composing a message for a dynamic message sign (DMS) requires managers and supervisors at the Texas Department of Transportation (TxDOT) Traffic Management Centers to consider numerous factors. For example, they must consider the content and length of the message as well as memory load for motorists. Following documented guidelines about formatting and phrasing of messages, the requirements for a software system called the DMS Message Optimization Software Tool, or MOST, are discussed. The system is designed to accept input data through a graphical user interface, to allow selection of terms, and to produce a message suitable for display in a DMS. The application automatically applies principles of good message design and allows users to customize their messages. The design of the system follows work done previously in TxDOT Project 0-4023.

Dudek, C.L. (1991). Guidelines on the use of changeable message signs. Final Report - DTFH61-89-R-00053. 269p. U.S. DOT Federal Highway Administration, Washington, D.C.

Abstract:
The 1986 FHWA publication "Manual on Real-Time Motorist Information Displays" provides practical guidelines for the development, design, and operation of real-time displays, both visual and auditory. The emphasis in the Manual is on the recommended content of messages to be displayed in various traffic situations; the manner in which messages are to be displayed--format, coding, style, length, load redundancy, and number of repetitions; and where the messages should be placed with respect to the situations they are explaining. This report is intended to provide guidance on 1) selection of the appropriate type of Changeable Message Sign (CMS) display, 2) the design and maintenance of CMSs to improve target value and motorist reception of messages, and 3) pitfalls to be avoided, and it updates information contained in the Manual. The guidelines and updated information are based on research results and on practices being employed by highway agencies in the United States, Canada and Western Europe. CMS technology developments since 1984 are emphasized. Since the use of matrix-type CMSs, particularly light-emitting technologies, has increased in recent years. Matrix CMSs have received additional attention in this report. The report concentrates on design issues relative to CMSs with special emphasis on visual aspects, but does not establish specific criteria to determine whether to implement displays. The intent is to address display design issues for diverse systems ranging from highly versatile signing systems integrated with elaborate freeway corridor surveillance and control operations to low cost, less sophisticated surveillance and signing systems intended to alleviate a single specific problem.

Dudek, C.L. (1997). Changeable message signs. NCHRP Synthesis of Highway Practice. 237, 63 pgs.

Abstract:

This synthesis will be of interest to traffic engineers in federal, state, provincial, and local transportation agencies that are responsible for the design and operation of safe and efficient highway systems. It will also be useful to consulting traffic engineers, sign manufacturers, and vendors in the private sector who assist governmental clients in the application of changeable message sign (CMS) and other intelligent transportation systems (ITS) technology. It is an update of NCHRP Synthesis No. 61 (1979). It describes the various types of permanently mounted CMSs in use in the United States and Canada. This technology, also referred to as "variable message signs" or "motorist information displays", is in widespread use in North America. This report of the Transportation Research Board provides information on the various CMS types in use, their typical characteristics, including the technology types, the character (letters and numbers) types and size, and conspicuity. The synthesis presents a discussion on the types of messages used when there are no incidents. Other aspects, such as procurement, maintainability, and warranties are also discussed.

Dudek, C; Trout, N; Booth, S; Ullman, G. (2000). Improved dynamic message sign messages and operations. Texas Department of Transportation Final Report No. FHWA/TX-01/1882-2, 188 pgs.

Abstract:
This report provides the results of an extensive laboratory investigation of a total of 15 specific issues related to dynamic message sign (DMS) operations statewide. These issues were identified and approved by the Texas Department of Transportation project advisors responsible for DMS operations in their respective districts. Laptop computers were used to simulate DMS message displays. After each message display, participating subject drivers responded to questions designed to determine the level of recall and comprehension of the information contained in the message. Response times as well as message format/sign operating preferences were also collected from the subject drivers. The report contains specific recommendations concerning DMS issues in the following four categories: (1) communicating time and day for future roadwork to motorists; (2) motorist interpretations of specific words or phrases used on DMSs; (3) DMS operating practices; and (4) using DMSs with lane control signals

Dudek, C.L. and Ullman, G.L. (2002). Flashing messages, flashing lines, and alternating one line on changeable message signs. Transportation Research Record No. 1803, pgs. 94-101.

Abstract:
Results of human factors laboratory studies conducted in Texas pertaining to the display of messages using the following dynamic characteristics of changeable message signs (CMSs) are presented: (a) the effect of flashing an entire one-frame message, (b) the effect of flashing one line of a one-frame message; and (c) the effect of alternating text on one line of a three-line CMS while keeping the other two lines of text the same. Two hundred sixty Texas drivers were recruited in Dallas, El Paso, Fort Worth, Houston, and San Antonio to participate in the laboratory studies designed to simulate these CMS characteristics on laptop computers. The drivers responded to questions designed to determine the level of recall and comprehension of the information contained in the message. Response times, message format, and sign operating preferences were also collected. The results showed that in the laboratory setting, flashing a one-frame message did not adversely affect driver recall or comprehension to a significant degree

compared with when the message was not flashed. However, average reading times were significantly higher when the message was flashed. Flashing one line of a three-line message appeared to adversely affect recall of parts of the message. In addition, average reading times were significantly higher for the flashing line message. Alternating one line of text and keeping the other two lines constant did not adversely affect message recall. However, average reading times increased significantly.

Durkop, B.R. and Dudek, C.L. (2001). Texas driver understanding of abbreviations for changeable message signs. Transportation Research Record No.1748, pgs 87-95.

Abstract:

Research was conducted as part of an ongoing project for the Texas Department of Transportation to evaluate the use of changeable message signs (CMSs) in Texas. The objective was to determine motorist understanding of abbreviations for use on CMSs. A human factors study was conducted in six locations in Texas. Participants were given a list of abbreviations and were asked to interpret the full words or phrases. The results identified 24 abbreviations that were understood at an acceptable level for use on CMSs in Texas; acceptability was based on a criterion of 85% or more of the participants' correctly interpreting the word or phrase. Differences in study location comprehension levels were also examined. Twelve abbreviations were recommended for use only at particular locations on the basis of the varying comprehension levels among the six study locations. Abbreviations that were understood by less than 85% of the participants were not recommended for use in Texas.

FHWA. (1996). Uniform traffic control and warning messages for portable changeable message signs. FHWA-RD-95-173, Summary Report, 2 pgs.

Abstract:

The purpose of this study was to develop and test word and symbol traffic control and hazard warning messages for use on portable changeable message signs (PCMSs). The literature was reviewed, State highway engineers were interviewed, PCMS manufacturers were surveyed, and motorists were questioned to develop an extensive list of candidate PCMS messages for subsequent evaluation during the laboratory and field-testing. More than 800 messages were identified for 30 situations. The laboratory studies were conducted to identify those key words or phrases that the motorist felt were most effective. Field tests, both daytime and nighttime, were conducted for candidate messages that lacked a clear winner during the laboratory studies. Also six symbol messages were shown during the field tests to evaluate motorist comprehension of these messages. This summary report presents some of the research results. The full report, which has the same title as this summary report, is FHWA-RD-95-171 (TRIS 00720253).

FHWA. (2001). Research review of potential safety effects of electronic billboards on driver attention and distraction. Federal Highway Administration Final Report. Report No. FHWA-RD-01-071. Available at:
http://www.fhwa.dot.gov/realestate/elecbbrd/index.htm#contents.

Abstract:

Advances in outdoor display technology, and decreases in cost, support an interest in expanding deployment of high resolution and dynamic imaging in outdoor advertising. This raises questions on the effects that electronic billboards (EBBs) and other dynamic signs such as tri-vision signs may have on driver distraction. The purpose of this report is to present a review of the literature on the safety implications of electronic billboards, to identify knowledge gaps in the findings of the review, and to develop a research plan to address the knowledge gaps. The general approach in this review was to identify information about potential safety implications of EBBs. Factual data regarding billboard safety were sought through a review of existing research literature and information obtained from government staff. Because driver distraction is of interest in other areas of research, such as cellular telephone use and in-vehicle visual information equipment, the present report examines these areas for possible cross-fertilization results. The report concludes with a set of research questions and research findings that are directed to the safe design of dynamic billboards.

FHWA. (2003). Portable changeable message sign handbook: PCMS. FHWA-RD-03-066. McLean, VA 22101. 10 pgs.

Abstract:
A portable changeable message sign (PCMS) is a traffic control device that is capable of displaying a variety of messages to inform motorists of unusual driving conditions. This capability is achieved through elements on the face of the sign that can be activated to form letters or symbols. The message is limited by the size of the sign (usually three lines with eight characters per line). A PCMS is housed on a trailer or on a truck bed and can be deployed quickly for meeting the temporary requirements frequently found in work zones or accident areas. The purpose of this handbook is to present basic guidelines for the use of PCMSs. This handbook presents information on the PCMS and is intended to illustrate the principles of proper PCMS use.

Finley, M.D., Wooldridge, M.D., Mace, D, and Denholm, J. (2001). Photometric requirements for portable changeable message signs. Texas Department of Transportation, TX-02/4940-2, Research Report 4940-2, TTI: 7-4940. 40 pgs.

Abstract:
Portable changeable message signs (PCMSs) are traffic control devices that advise motorists of unexpected traffic and routing situations. In contrast to static signing, PCMSs convey dynamic information in a variety of applications, such as work zones, incident management, traffic management, and warning of adverse conditions. Although PCMSs have been used in traffic control applications for many years, there are no established photometric standards for the device that can be used as the basis for a procurement specification. The only provision related to the visibility of PCMSs is a requirement in the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways--Part VI" which indicates that PCMSs be visible from at least a half mile (under ideal day and night conditions) and the sign message is legible at a minimum of 650 ft. However, the manual does not provide a means for determining whether PCMSs meet these criteria. This project reviewed the performance of PCMSs and developed photometric standards to establish performance requirements. In addition, researchers developed photometric test methods and recommended them for use in evaluating the performance of PCMSs. This report

includes a review of the literature and provides documentation for the standards and procedures recommended.

Flad, H.K. (1997). Country clutter: visual pollution and the rural roadscape. The Annals, 553, pgs. 117-129.

Abstract:
The landscape of rural America has been profoundly influenced by social, cultural, and economic changes. The rural roadscape is a visible text of these changes, and the transportation palimpsest a cultural text of the American ideal of mobility. This article briefly examines the growth of the presence of the automobile and the automobile's role in changing the face of rural America, with an emphasis on the aesthetics of the roadscape. In the late twentieth century, a concern for the visual environment has become an important part of environmental assessment, and selected aspects of roadside visual pollution, particularly signs, are examined, especially as they relate to federal and state legislation concerning billboards. Lastly, public and private sector efforts to preserve and enhance cultural and historical rural landscapes, through such measures as the designation of scenic roads, is presented as an example of more holistic transportation planning

Fontaine, M.D. (2003). Guidelines for application of portable work zone intelligent transportation systems. Transportation Research Record No1824, pgs. 15-22.

Abstract:
Work zone intelligent transportation systems (WZITSs) are promoted as a way to improve safety and reduce congestion at work zone locations where traditional traffic management centers do not exist. These systems usually integrate portable changeable message signs and speed sensors with a central control system that automatically determines appropriate messages that are based on current traffic conditions. Manufacturers of these systems claim that WZITSs can warn drivers of downstream congestion, alert drivers to slower speeds ahead, and suggest alternate routes on the basis of prevailing conditions. Transportation agencies are often asked to make decisions on the installation of a WZITS without the benefit of objective information on its expected performance. Relatively few operational tests of these systems have been performed, and the results are not always well documented or conclusive. Agencies need guidance to help them determine whether a WZITS system would improve safety and operations at a specific site. Applications of WZITSs are reviewed, and a series of guidelines for their deployment, based on lessons learned from past tests, is presented.

Garvey, P.M. and Mace, D.J. (1996). Changeable message sign visibility. Federal Highway Administration Report No: FHWA-RD-94-077, Final Report, 137 pgs.

Abstract:
The object of this contract was to identify problems with the visibility of changeable message signs (CMSs), particularly for older drivers, and to develop design guidelines and operational recommendations to ensure adequate conspicuity and legibility of in-service CMSs. This project was divided into three main sections: a field survey of in-use CMSs, a series of laboratory

experiments and static field studies, and a partially controlled dynamic field study. The research was designed to optimize CMS components, including the character variables (font, width-to-height ratio, color, and contrast orientation) and the message variables (inter-letter, inter-word, and inter-line spacing).

Guerrier, J. and Wachtel, J. (2001). A simulator study of driver response to changeable message signs of differing message length and format (abstract only). Driving Assessment 2001: The First International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design. Aspen, Colorado, pgs. 164-165.

Abstract:
Highway congestion nationwide continues to increase, and three Florida urban areas rank among the top ten. Florida has been studying and implementing intelligent transportation system technologies to address its congestion problems, with a focus on its special populations such as the elderly and multi-cultural groups for which English is not the primary language. One of these technologies most widely deployed is the changeable message sign (CMS). Fifty-two CMSs are operational in Florida, with 39 more scheduled for deployment soon. Although CMSs have the potential to facilitate travel, certain issues must be considered to ensure that they do not exacerbate the congestion problem. One key CMS operational issue is the number of phases required to present a complete message. "On-time" for two-phase messages varies from 2.5 to 5 seconds per phase across the State. Of course, the appropriateness of this on-time depends not only on the characteristics of the CMS itself, but on the road, traffic and weather conditions, and driver characteristics. This study, funded by the National Institute on Aging, investigated issues related to the number of CMS phases and their on-time. The authors used a low-cost, interactive driving simulator supplemented with a video monitor above the main display. While simulator screens presented interactive road and traffic conditions, the supplemental monitor displayed the CMS. Young and old drivers drove the simulator under different workload conditions and responded to road closure/detour information on the CMS. All CMS displays were developed in accordance with accepted guidelines and were reviewed for content by independent experts. Results showed consistent and significant age effects across all tested conditions. In addition, the authors found significantly poorer response for all drivers under the two-phase CMS, despite the fact that the message "on-time" was nearly 2 seconds longer than that used in two major Florida jurisdictions. The findings have implications for CMS design and operation in Florida and in other jurisdictions with similar populations.

Harder, K.A., Bloomfield, J., and Chihak, B.J. (2003). The effectiveness and safety of traffic and non-traffic related messages presented on changeable message signs (CMS). Minnesota Department of Transportation MN/RC-2004-27 Final Report. 61 pgs.

Abstract:
The objectives of this study investigating Changeable Message Signs (CMS) were to determine whether or not CMS messages really work, whether or not they cause traffic slow downs, and whether or not they have an impact on traffic flow. The participants were 120 licensed drivers from three age groups--18-24, 32-47, and 55-65 years old. Two experiments were conducted in a fully-interactive, PC-based STISIM driving simulator. Experiment One investigated the effectiveness of the following message, "CRASH/AT WYOMING AVE/USE THOMPSON

EXIT." In Experiment Two, the final CMS message was: "AMBER ALERT/RED FORD TRUCK/MN LIC# SLM 509." Results were as follows: In Experiment Two, only 8.3% of the participants had Excellent AMBER Recall Scores, while 51.7% has Good scores. Gender significantly affected the AMBER Recall Scores--there were more females than males in the Excellent Category. A greater proportion of those who knew what AMBER Alert meant were in the Excellent and Good Categories. 21.7% of the participants slowed down by at least 2 mph. Whether or not traffic delays will result from drivers slowing to read AMBER Alerts in real life will depend on the extent of the slow downs and on current traffic density. In Experiment One, 55.8% of the participants took the Thompson Exit after seeing the Thompson Exit Message. Of the 53 participants who did not take the exit (1) 35.9% ignored the CMS message because they did not think that it applied to them; (2) 35.9% did not understand the CMS message; and (3) 22.5% did not notice the message. (It is not known why 5.7% of the 53 did not take the exit.) Changes to the wording of the messages are recommended.

Hitchins, D (2001). Lowercase font set development for variable message signs (VMS). 8th World Congress on Intelligent Transport Systems, 10 pgs.

Abstract:
Current Transit New Zealand (road controlling authority in New Zealand) policy dictates that within the most heavily congested sections of the Auckland motorway system, Variable Message Signs (VMS) are used only to display traffic related messages. When not doing so they remain blank. For some, this policy has been of concern, since when a VMS is blank drivers cannot tell whether it is working or not, and therefore whether traffic conditions are normal. The counter-argument to this is that VMS illuminated with unimportant information may cause unnecessary distraction to motorists. Also, if signs are displaying a message of some sort all of the time; drivers might not read the messages at all in time, on the basis that they are rarely important. One method of overcoming this problem is to display familiar safety messages on selected VMS using lower case font. This will enable drivers to perhaps distinguish general safety messages from important road related information, which is normally displayed using upper case font. The benefits, costs and risks associated with current Transit practice has yet to be quantified. Empirical studies to gain a better understanding of driver behavior and response to this practice is currently underway and will aim to investigate and identify a range of options available for extended display on VMS, along with their likely impacts.

Holick, A.J. (2000). Development of portable variable message sign user guidelines for common applications. Compendium: papers on advanced surface transportation systems, pgs. 89-120.

Abstract:
This report focuses on the development of guidelines for the use of portable variable message signs (PVMS). The guidelines are designed to assist users in properly placing the PVMS and message displays. Information was collected on researched guidelines and state DOT operators' manuals and the results were compared. A draft set of user guidelines based on these comparisons was then produced. The guidelines covered the following areas: process, audience, purpose format, logical order, visual inspection, and terminating and updating messages.

Huchingson, R.D. and Dudek, C.L. (1983). How to abbreviate on highway signs Transportation Research Record, No. 904**,** pgs. 1-4.

Abstract:
This study investigated abbreviations for 80 traffic-related words by having a sample of drivers compose abbreviations and then having a different sample identify the word after being given the most popular abbreviation. Abbreviations were classified by percentage of subjects who correctly identified the words when presented alone and, again, when presented in the context of another word. The study identified strategies employed in abbreviating words, explored the relation between highly stereotyped abbreviations and success in understanding them, and recommended a set of abbreviations that likely could be used successfully on changeable-message signs.

Jones, S.L. Jr., and Thompson, M.W. (2002). State of the practice for displaying non-traffic related messages on dynamic message signs. Today's Transportation Challenge: Meeting Our Customer's Expectations. Institute of Transportation Engineers. 22 pgs.

Abstract:
Dynamic message signs (DMS), also referred to as changeable message signs (CMS) and variable message signs (VMS), have been used for over 30 years to provide traffic information to motorists and have become a prominent component of intelligent transportation systems (ITS). They have become an important component of many advanced traveler information and traffic management systems. DMS allow for the dissemination of real-time traffic information to motorists and are generally deployed in urban areas to inform motorists of traffic conditions (e.g., expected delays, estimated travel times, diversion routes, lane closures). DMS have become an important source of motorist information during incidents, special events, and work zone traffic control. The value of DMS, or any traffic information source, is dependent on two items: (1) The accuracy and usefulness of the information disseminated; (2) Motorists' willingness and ability to understand and utilize the information. The latter point involves the public perception of traffic information technologies. The quality of traffic-related messages as well as the overall presence of DMS affects the public perception. Traffic management agencies must understand that DMS affect public perception even when they are not actively conveying traffic-related information. Motorists may perceive blank signs as inoperable or may question the allocation of resources to technologies that seem to be (from their perspective) underutilized. On the other hand, displaying information not germane to real-time traffic conditions may erode the credibility of DMS and reduce their effectiveness as a traffic management tool. The purpose of the research presented herein was to assess the professional opinion regarding DMS usage during normal traffic conditions.

Kang, T.J. and Muter P. (1989). Reading dynamically displayed text. Behavior & Information Technology, 8(1), pgs. 33-42.

Abstract:
Two experiments were carried out to find an optimal electronic text display method given limited display space. The display formats tested fell into two categories: Times Square, in which text is scrolled from right to left; and rapid, serial, visual presentation (RSVP), in which text is

presented one or several words at a time to a fixed location in the display. Previous studies have indicated that Times Square format is not as efficient as page format display or, by extrapolation, as RSVP. These studies, unlike the present experiments, did not include a smooth-scrolling (pixel-by-pixel) condition. In Experiment 1, a comparison was made between multiple-word RSVP and three versions of Times Square format, differing only in the size of the steps by which the display was scrolled. Except for the largest step-size, comprehension was as high in the Times Square condition as in the RSVP condition. The subjects expressed a significant preference for smooth scrolling Times Square over any other condition. Experiment 2 showed that comprehension for smooth scrolling Times Square was at least as high as that for RSVP at presentation rates ranging from 100 to 300 words per minute. Times Square reading is discussed in terms of optokinetic nystagmus (OKN).

Lee, K. (2004). Electronic billboard: its influence on public space. Master's Thesis Presented to The Faculty of the Department of Television, Radio, Film and Theatre San Jose State University.

Abstract:
As an outdoor advertising medium, the electronic billboard, which is a combination of a billboard and television, has been emerging. However, little research has been done concerning the medium. Using multiple methodological approaches, this thesis investigates the influence of the electronic billboard on public space. Initially, it explores the space-altering characteristic of the electronic billboard by examining billboards and television respectively in terms of their relationships with environments. Secondly, it conducted observational research in Times Square, New York, and Shibuya, Tokyo, and recorded the phenomenon of electronic billboards. The information and data gathered from this research are discussed ethnographically and analyzed using typology. Research on this subject reveals that the electronic billboard makes its location placeless by delivering messages, which are not relevant to its geographical origin. In the larger context of urbanization, the electronic billboard represents a birth of antigeographical place.

Lee, S.E., Olsen, E.C.B., and DeHart, M.C. (2003). Driving performance in the presence and absence of billboards. Executive Summary. Foundation for Outdoor Advertising Research and Education, Washington, DC. 5 pgs.

Abstract:
The goal of this project was to ascertain whether or not driving behavior changes in the presence or absence of billboards. Drivers' visual behavior was measured by eyeglance location. In addition, lane deviation and speed changes were noted. The conclusion of the study was that billboards to not cause a change in driving behavior when driving behavior is evaluated in terms of maintenance of speed, visual behavior, or keeping in one's lane.

Lewis, D.J. (2000). Photometric requirements for arrow panels and portable changeable message signs. AASHTO Conference Proceedings Juneau, Alaska, pgs. 215-221

Abstract:
Arrow panels and portable changeable message signs are often used in work zones to inform drivers of the need for a lane change or caution. The "Manual on Uniform Traffic Control

Devices" (MUTCD) requires that Type C arrow panels have a minimum legibility distance of 1.6 km (1 mi). However, the MUTCD does not provide a subjective means for determining whether an arrow panel meets this criterion. Nor are there industry photometric standards for message panels. The purpose of this project is to develop a reliable and repeatable objective method for measuring the photometrics of arrow and message panels to ensure adequate performance. The research project tasks include a review of the state of the art, reviews of existing pertinent specifications, development of initial test methods, evaluations of arrow and message panel visibility and the effectiveness of the test methods, revisions and modifications of the test methods, and documentation of research activities and findings. The research findings will be described in a research report and a project summary report. The recommended test methods will be included in both documents.

Lopez, E. and Abedon, D. (2001). Operational standards for dynamic message signs. 8th World Congress on Intelligent Transport Systems. Sydney, Australia. 9 pgs.

Abstract:
The term dynamic message sign is an umbrella classification for numerous intelligent transportation systems (ITS) en-route information sign technologies. Included under this umbrella are: changeable message signs, variable message signs, blank out signs, and lane control signs. This research effort looks at permanent variable and changeable message sign technologies only and will refer to them as "variable message signs (VMS)." With the proliferation of dynamic message signs throughout the United States, are variable message signs being operated and maintained uniformly at a national level, if not, is the overall effectiveness and benefits to the motoring public being compromised? Past experience with static signs has shown that by unifying how signs are installed, operated and maintained the same "look and feel" is created so that all motorists respond to the sign in the same manner regardless of where they are in the nation. With no clear guidance on this issue, state and local agencies are struggling with, and at times developing their own standards on VMS operations. This challenge has led many practitioners to haphazardly install variable message signs around the nation without being accountable of any consequences.

Lucas, A. and Montoro, L. (2004). Some critical remarks on a new traffic system: VMS part II. In: the human factors of transport signs. CRC Press LLC, pgs 199-212.

Abstract:
Information technologies are aiding the growth of new and more rational road transport systems. At the core of Intelligent Transport Systems (ITS), traffic management and control critically depend on technical devices and road information well suited for road users because, in the end, the information in front of road users (e.g. VMS) is the basic tool for improving road traffic. In addition to a necessary technological optimism, a critical view is necessary for lessening or avoiding pitfalls. New presentation systems may distort the road sign system and worsen communication to road users. Official and unofficial road signs are currently undergoing promising research and professional and policy inquiries, hopefully to aid mobility and road safety. It is clear, though, that ITS may promote a heterogeneous, uncontrolled extension of the road sign system, thus making interpretation on the part of road users more difficult. In addition to changing road information elements (e.g., pictograms, abbreviations, and verbal labels), new

VMS device structures force the use of different message formats, making road sign harmonization and coherence all the more difficult.

Metaxatos, P. and Soot, S. (2001). Evaluation of the driver's ability to recall the message content of portable changeable message signs in highway work zones. Journal of the Transportation Research Forum, 40(1), pgs. 129-141.

Abstract:
This paper examines factors that affect the ability of drivers to recall Portable Changeable Message Sign (PCMS) messages in highway work zones. A Chi square analysis has found that the time of day, driver's age, type of vehicle, and familiarity with the site are relevant factors, and that drivers were more likely to recall messages that contain action rather than problem statements. A regression analysis revealed that drivers recalled the PCMS message components that they desired to see almost twice as often, and that drivers familiar with the construction site were almost twice as likely to observe an action statement.

Nsour, S.A. (1997). IVHS and the elderly driving. Traffic Congestion and Traffic Safety in the 21st Century: Challenges, Innovations, and Opportunities. Chicago, Illinois, pgs. 333-339.

Abstract:
This study was conducted on two groups, 385 elderly people and 126 young people with the age of 65 as the dividing line. The purpose is to examine the driving tasks that elderly see as difficult and then explore the possibilities of using Intelligent Vehicle Highway Systems (IVHS) to solve some of the driving problems faced by the elderly. The study showed that the tasks of driving at night, driving on two-lane highways at night, driving in rainy weather at night, and reading changeable message signs are the top most difficult tasks for elderly as compared with young drivers. About 25% of the elderly surveyed view reading changeable message signs as either difficult or very difficult. The most frequent suggestions by the elderly on improvements to the highway were those related to making signs more visible/readable, increasing sign-exit distance, and increasing sign illumination and reflection. About 52% of suggestions by the elderly on vehicle instrumentation centered on making the instrumentation more visible. The percentage of elderly in favor of electronic navigation maps is roughly 62% compared to 85% of the young.

Parentela, E. and Eskander, N. (2001). Effectiveness of changeable message signs (CMS) on Los Angeles freeways. Improving Transportation Systems Safety and Performance. 2001 Spring Conference and Exhibit, Institute of Transportation Engineers. Monterey, California. 6 pgs.

Abstract:
A survey was conducted to evaluate the effectiveness of changeable message signs (CMS) along Southern California freeways in terms of driver's response to displayed messages. The survey participants are regular commuters who spend an average of less than one to three hours daily on the freeway and are familiar with the operation of CMS. The usefulness of CMS and its ability to convey clear, accurate and reliable messages are some of the questions included in the survey. The paper also addresses the drivers' perception on trip safety and travel time. The results indicate a general agreement that CMS are helpful and reliable. Yet, while most motorists pay

attention to the displayed messages and follow the diversion messages such as a detour, 28 percent consider them to be a distraction and 17 percent do not want to see additional CMS.

Proffitt, D.R., Wade, M.M., and Lynn, C. (1998). Creating effective variable message signs: human factors issues. Virginia Department of Transportation, VTRC 98-CR31, Final Contract Report; Project No. 9816-040-940, 25 pgs.

Abstract:
This report addresses the human factors issues related to the reading and comprehension of variable message sign (VMS) messages. A review of the literature was conducted on factors that affect how people read VMSs. Several topics were reviewed. The first topic was literacy. Since reading literacy is not a requirement for obtaining a driver's license, VMS composition should reflect the varied reading competence levels of motorists. It was found that about 25% of Virginians over the age of 16 are weak readers and will likely encounter problems reading VMSs. The second topic addressed how people read. Reading is an interactive process that derives much of its speed and accuracy from implicit knowledge acquired through familiarity. This implies that VMS messages should present familiar, standardized content whenever possible. A review of the literature on warning signs was the third topic. This review found that effective warning signs should have several properties: short, concise messages are both easier to read and more likely to be read; and signal words, such as CAUTION, are not effective. Finally, areas for further research were identified. Symbolic messages and abbreviations are worthy of further investigation as they have the potential for easy recognition, provided they are familiar to motorists and can be accommodated by the VMS. In addition, although the Manual on Uniform Traffic Control Devices (MUTCD) advises angling the VMS away from the roadway to reduce headlight glare, angling the VMS toward the roadway could be desirable for increasing readability. In both these areas, theoretical and practical work is needed. The report recommends that these human factors characteristics and limitations be taken into consideration in the deployment of VMSs and in the composition of their messages.

Smiley, A., Persaud, B., Bahar, G., Mollett, C., Lyon, C., and Smahel, T., (2005). Traffic safety evaluation of video advertising signs. Presented at the Transportation Research Board’s Annual Meeting, Washington, D.C., 18 pgs.

Abstract
Road authorities are under increasing pressure from advertisers to allow video advertising in the right of way, but are understandably concerned about whether or not video signs constitute a driving hazard. At the City of Toronto’s request, a comprehensive assessment of traffic safety impacts related to such signs was carried out in a series of studies involving three downtown intersections and an urban expressway site. An on-road eye fixation study was carried out to determine if drivers look at video advertising signs. Conflict studies were conducted to determine if there were more conflicts on video-visible than video-not-visible intersection approaches. A before-and-after sign installation study of headways and speeds on the urban expressway was carried out. Crashes, before and after sign installation, at the expressway and three intersection sites, were compared. Finally, a public survey was conducted to determine if video advertising was perceived to impact traffic safety. Based on the eye fixation study and the public survey data, it is

apparent that video advertising can distract drivers inappropriately, leading to individual crashes. However, the evidence from other studies was not consistent, suggesting that for the particular signs studied, overall impacts on traffic safety are likely to be small. Further studies, especially prospective ones with larger crash data sets are required to be certain.

A comparison between this study and an earlier one suggests there are large differences in driver distraction dependent on the placement and environment in which the sign is seen. Further studies are required to determine factors, which minimize driver distraction.

Smiley, A., Smahel, T., and Eizenman, M. (2004). The impact of video advertising on driver fixation patterns. Presented at the Transportation Research Board’s Annual Meeting, Washington, D.C., 18 pgs.

Abstract:
In order to assess driver distraction due to video advertising signs, eye fixation data were collected from subjects who passed 4 video advertising signs, 3 at downtown intersections and 1 on an urban expressway. On average drivers looked at the signs 45% of the time they were present. When drivers looked, they made 1.9 glances on average, with an average duration of 0.48 seconds. The distribution of eye fixations on intersection approaches where video signs were visible was compared to that on approaches on which video signs were not visible. There were no significant differences in the number of glances made at traffic signals or street signs. On the video approach there was a trend towards a greater proportion of glances at the speedometer and rear-view mirrors. Glances were made at short headways (1 second) and in unsafe circumstances (while crossing an intersection). In the downtown area, glances at static commercial signs were made at larger angles and at shorter headways than was the case for video signs.

A comparison of our results with other studies showed that video signs were less likely to be looked at than traffic signs (about half the time versus virtually every time), that individual average glance durations and total durations were similar to those found for traffic signs. However, another on-road study indicates that some video signs can be very distracting. A video sign on a curve that was directly in the line of sight and visible for an extensive period attracted 5.1 glances per exposed subject.

Soot, S. and Metaxatos, P. (1999). Policies for use of changeable message signs in highway work zones Illinois Transportation Research Center Final Report, Report No. ITRC FR 97-1, 207 pgs.

Abstract:
Portable Changeable Message Sign (PCMS) systems used in work zones are programmable supplementary traffic control devices that display messages composed of letters, symbols or both and provide information and instructions to the traveling public approaching work zone activities. The study seeks to develop warrants and criteria for PCMS deployment in Illinois highway work zones. It is recommended that PCMS systems be used during long- and intermediate-term stationary work, for traffic control through incident areas, and in projects where advance-time notification is needed. The discussion focuses on spacing criteria, number of signs required, sign visibility and message legibility, text alignment, distance criteria, message length, duration and type, project-level operational guidelines, message storage and dissemination, repair, maintenance and utility costs, as well as control and coordination issues.

The study concludes that additional research is needed in order to: develop a comprehensive standardized statewide database of messages and message abbreviations; develop a comprehensive repository with information about the technology of the various components of the PCMS units; coordinate PCMS units used in highway work zones with a corridor or regional ATMS system; and maintain information about the use of a PCMS unit in a work zone project and possibly integrate it with other relevant information in a management system.

Tantala, M.W. and P.J. Tantala. (2005). An examination of the relationship between advertising signs and traffic safety. Presented at the Transportation Research Board's Annual Meeting, Washington, D.C., 25 pgs.

Abstract
The purpose of this study is to examine the relationship between advertising signs and traffic safety. The first part of this study establishes statistical correlation coefficients between advertising signs and accidents along the New Jersey Turnpike (for more than four years of data and about 23,000 accidents). This study considers various situations, with and without bias from turnpike interchanges. The results are analyzed for a variety of commonly accepted scenarios relating accident density to sign-density (the number of signs), to Viewer Reaction Distance (how far from a sign the driver is potentially within the "influence" of a sign), and to sign proximity (how far the accident is from the nearest sign). The second part of this study examines the incidence of traffic accidents at a specific, recently installed sign and for a period of time both before and after the installation of the sign. After the installation of a specific, advertising sign at a Pennsylvania intersection, the traffic volume increased, the APV (accident rate) decreased, the maximum number of accidents in any given day or week decreased. The results of this study conclude that advertising signs have no significant statistical influence on the occurrence of accidents. These analyses also suggest that no causal relationship between advertising signs and accidents exists. Geospatial and geostatistical methods are used rigorously.

Ullman, G.L., Ullman, B.R., Dudek, C.L., and Trout, N.D. (2004). Legibility distances of smaller character light-emitting diode (LED) dynamic message signs for arterial roadways. City of Dallas Transportation Management Systems Final Report, 41pgs.

Abstract:
This report documents the results of a legibility study of 9-in. and 10.6-in. characters on dynamic message signs (DMSs) for use on arterial roadways. The study, conducted at Dallas, Texas, consisted of 60 Dallas residents (demographically balanced with respect to age and education) who drove a test vehicle as they approached DMSs with one of the above two character heights. Study administrators recorded the distance from the sign at which the participant could correctly read a three-character word. Data were recorded for three trials on each of the two character heights for each participant. Data were collected during daylight (sun overhead) and nighttime conditions. The 85th percentile legibility distances for each character height were used to estimate available viewing times under various approach speeds. These available viewing times dictate the units of information that can then be presented on a DMS of a particular character size. Based on the results of the analysis, researchers recommend that the City of Dallas continue to utilize 12-in. characters for DMSs on their arterial roadways. Even then, the amount of information that is presented on the DMS should be limited to 3 units of information or less

under nighttime viewing conditions. Agencies should consult other references, as documented within this report, regarding proper message design principles, appropriate abbreviations to use, etc., prior to designing and implementing an arterial street DMS system.

USDOT (2003). Manual on Uniform Traffic Control Devices. U.S. DOT, Federal Highway Administration. Available at: http://mutcd.fhwa.dot.gov/

Abstract:
The Manual on Uniform Traffic Control Devices (MUTCD) defines the standards used by road managers nationwide to install and maintain traffic control devices on all streets and highways. The MUTCD is incorporated by reference in 23 Code of Federal Regulations (CFR), Part 655, Subpart F. Although the MUTCD is routinely updated to include amendments that clarify new standards and incorporate technical advances, it has been more than 20 years since the manual was entirely rewritten, and the most recent edition was published in 1988. The new MUTCD is published in 3-ring binders for easy updating, on CD-ROM, and on the Internet. Redesigned text format will help users identify STANDARDS -- "shall" conditions; GUIDANCE -- "should" conditions; OPTIONS -- "may" conditions; and SUPPORT -- descriptive and/or general information for designing, placing, and applying traffic control devices. Measurements are presented in both metric and English units.

USSC. (2003). United States Sign Council best practices standards for on-premise signs. Available at: http://www.ussc.org/publications.html

Abstract:
A research-based approach to sign size, legibility, and height. Amply illustrated with tables, charts, and mathematical formulae designed to facilitate the calculation of sign letter height and copy area, negative space, overall sign size, and sign height as functions of the speed of travel utilizing the application of such factors as message size, message scan time, viewer reaction time and distance, and copy area; all presented in easy to understand language and simple tables or formulas.

Van Houten, R. and Malenfant, J.E.L. (2002). Evaluation of changeable message signs (CMS) on I-4 at exits 30a and 30b to assign ramp traffic and at Princeton St. to sign for cultural events. Florida Department of Transportation Final Report. 34 pgs.

Abstract:
Florida Department of Transportation performed an experimental analysis of a series of changeable message signs functioning as freeway guide signs to assign traffic to Universal Theme Park via one of two eastbound exits based on traffic congestion at the first of the two exits. An examination of crashes along the entire route indicated a statistically significant increase in crashes at the first eastbound exit following the actuation of the system. Behavioral analysis scored from videotapes of driver behavior at the first eastbound exit, revealed that the reassignment of the theme park exit was associated with an increase in the percentage of motor vehicle conflicts such as the percentage of vehicles cutting across the exit gore and the percentage of motorists making unsafe lane changes in the immediate vicinity of the exit. A

human factors analysis revealed that the method used for switching the designated or active theme park exit on the series of changeable message signs led to the presentation of conflicting messages to some motorists. The second experiment evaluated the use of a phased method of switching the designated theme park exit to eliminate the delivery of conflicting messages. The new method for switching the designated theme park exit was not associated with an increase in motorists cutting across the exit gore or unsafe lane changes. Based on the results obtained in the second experiment, it is recommended that the system used to assign the active exit based on traffic congestion be added to the Manual on Uniform Traffic Control Devices (MUTCD). A third experiment evaluated the use of changeable message signs to provide information on cultural events in the Orlando area at a single exit (eastbound and westbound). These signs were not associated with an increase in crashes. It is also recommended that this use for changeable message signs be added to the MUTCD

Wachtel, J. (1981). Electronic advertising along highways--concern for traffic safety. Public Roads, 45(1), pgs. 1-5.

Abstract:
Developments in electronics, computers, and communications are being applied to traffic signs. One of the most advanced developments is the lamp matrix system, which is one form of a commercial electronic variable message sign (CEVMS). Although a 1978 amendment to the Highway Beautification Act legitimized commercial signage using the latest technology, earlier federal laws still in force prohibited signs illuminated by flashing, intermittent, or moving light or signs that move or have animated or moving parts. The Federal Highway Administration through research and field observations demonstrated that CEVMS's have the potential for animation and for flashing, moving, and intermittent message presentation, and some operating signs already display these characteristics. In addition a correlation was established between roadside advertising and traffic accidents.

Wachtel, J., and Netherton, R. (1980). Safety and environmental design consideration in the use of commercial electronic variable-message signage. Federal Highway Administration Final Report: FHWA-RD-80-051, 101pgs.

Abstract:
This study reviews existing reported research and experience regarding use of commercial electronic variable-message signs (CEVMS), and evaluates research findings and methods in terms of implications for highway safety and environmental design. Aspects of CEVMS design and use that are capable of adversely affecting highway safety and/or environmental quality are identified and discussed in terms of the adequacy of existing research and experience to permit formulation of quantified standards for safe and environmentally compatible use. This report notes, with illustrations, the principal forms of variable-message signage developed for official traffic control and informational use, and the major forms of variable-message signage utilizing electronic processes or remote control for display of commercial advertising and public service information in roadside sites. Studies of highway safety aspects of outdoor advertising, which are based on analysis of accident data, are evaluated and reasons for apparent conflicts of their findings are discussed. Studies of highway safety aspects of outdoor advertising generally and CEVMS specifically based on human factors research and dealing with distraction and

attentional demands of driving tasks are discussed in relation to issues involved in the development of standards.

Wallace, B. (2003a). Driver distraction by advertising: genuine risk or urban myth? Proceedings of the Institution of Civil Engineers, Municipal Engineer 156, Issue ME3
Pgs. 185 – 190. Available at: http://cogprints.org/3307/01/driverdistractionarticle.pdf

Abstract:
Drivers operate in an increasingly complex visual environment, and yet there has been little recent research on the effects this might have on driving ability and accident rates. This paper is based on research carried out for the Scottish Executive's Central Research Unit on the subject of external-to-vehicle driver distraction. A literature review/meta-analysis was carried out with a view to answering the following questions: is there a serious risk to safe driving caused by features in the external environment, and if there is, what can be done about it? Review of the existing literature suggests that, although the subject is under-researched, there is evidence that in some cases over complex visual fields can distract drivers and that it is unlikely that existing guidelines and legislation adequately regulate this. Theoretical explanations for the phenomenon are offered and areas for future research highlighted.

Wallace, B. (2003b). External-to-vehicle driver distraction. Scottish Executive Central Research Unit Report. Available at: http://www.scotland.gov.uk/library5/finance/evdd-00.asp

Abstract:
This report presents the findings of a literature review of all available literature published in English since 1945 on the subject of external-to-vehicle driver distraction. The report as carried out by Human Factors Analysts Ltd. (HFAL) on behalf of the Scottish Executive between December 2002 and March 2003. The research consisted of three main elements. First, a general review of the literature pertaining to driver distraction. Second, a review of literature specifically concentrating on external-to-vehicle distraction. And finally, a review of literature pertaining to billboards and signs as an external distracter, in an attempt to discover whether there is evidence that billboards and signs are a contributory factor to road accidents.

Walton, J.R., Barrett, M.L., and Crabtree, J.D. (2001). Management and effective use of changeable message signs. Kentucky Transportation Cabinet, KTC-01-14/SPR233-00-1F, Final Report. 51 pgs.

Abstract:
Changeable message signs (CMSs) are used to communicate accurate, timely, and pertinent information to travelers on Kentucky's roadways. This information helps travelers avoid hazards or delays and respond properly to changing roadway conditions. In an ideal environment, the Kentucky Transportation Cabinet (KYTC) would be able to allocate CMSs to various areas of the state based upon changing needs. The location of each sign would be monitored, and the message could be controlled and checked remotely. Currently these capabilities do not exist. KYTC has four different types of portable CMSs in use throughout the state. Each type has different internal and external interfaces, and each requires different replacement parts. Also,

there is no policy or guidelines in place for the use of these signs. The decision on how and when the CMSs are used is made at the district level on a case-by-case basis. This research effort includes an evaluation of Kentucky's current inventory and usage of CMSs, identification of key issues associated with the signs, and identification of state and regional policies on the management and use of CMSs. Recommended guidelines for the management and use of CMSs are included in this report.

Yager, D., Aquilante, K., and Plass, R. (1998). High and low luminance letters, acuity reserve, and font effects on reading speed. Vision Research, 38, pgs. 2527-2531.

Abstract:
Compared reading speed in 46 normally sighted high school and optometry students with two fonts, Dutch (serif) and Swiss (sans serif). Text was displayed on a computer monitor, white letters on black, with the RSVP method. Luminance of the letters was either 146.0 or 0.146 cd/m^2. Lower-case x-height of the fonts was approximately 5.5 times as large as letter acuity. At the high luminance, there was no difference between reading rates. There was a significant advantage for the Swiss font at the low luminance. The acuity reserve for Swiss was higher than for Dutch at the low luminance, which may account for the difference in reading speeds.

Young, S. (2004). Visibility achieved by outdoor advertising. Perception Research Services Summary Report. Available at:
http://www.prsresearch.com/articles/visibility_achieved_by_outdoor_ad.htm

Abstract:
Perception Research Services of Fort Lee, NJ, implemented a pilot study of attention to outdoor advertising, as documented via the use of PRS ShopperVision eyeglasses, i.e., the recording of passengers' seeing experience while traveling in an automobile on a high speed interstate highway. Fifty licensed drivers were interviewed (25 men and 25 women). All were between the ages of 18 and 70, with one-third 18 to 34, one-third 35 to 49, and one-third 50 to 70. Each participant was in an automobile (wearing PRS ShopperVision eye glasses) for a 30-minute highway drive. The drive took place in northern New Jersey along Interstates 95 and 80. Twenty-eight (28) boards were posted along these highways. 74 percent of boards in the rider's field of view were noted and 48 percent of the boards in the rider's field of view were read.

Zwahlen, H.T., Sunkara, M., and Schnell, T. (1995). Review of legibility relationships within the context of textual information presentation. Transportation Research Record,
No. 1485, pgs. 61-70.

Abstract:
An extended review of the relevant legibility literature was conducted to provide normalized legibility performance data for a comparison and consolidation of past legibility research. The data were normalized by expressing the legibility performance in terms of visual angle subtended by the character height. The data revealed large variations in visibility performance among the reviewed studies, despite similar or even identical experimental treatments. The normalized data were grouped into sets, relating the visual angle to the width-to-height ratio W/H, the

intercharacter spacing-to-height ratio S/H, and the stroke width-to-height ratio SW/H, for both negative and positive contrast. Second-order polynomial least-squares functions were established to obtain a proposed and tentative functional relationship between the visual angle and W/H, S/H, and SW/H. As expected the data indicated that positive-contrast characters generally require smaller stroke widths than negative-contrast characters and that more widely spaced characters show an increased legibility over closely spaced characters. The present investigation provides display designers with proposed and analytical functional relationships between legibility performance (visual angle) and typographical properties.