Effects of Outdoor Advertising Displays on Driver Safety

Requested by
Suzy Namba, Caltrans Division of Design

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The Caltrans Division of Research and Innovation (DRI) receives and evaluates numerous research problem statements for funding every year. DRI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field.

Executive Summary

Background

Digital and other outdoor advertising displays are becoming more common along California's highways, and Caltrans is considering generating income with advertisements on changeable message signs and outdoor advertising displays on state-owned rights of way outside of the operational highway. Local agencies, commercial businesses and private landowners are also looking at digital displays as a way to generate income.

However, the technology for digital displays is relatively new, and there has been little account taken of their effects on driver safety. Further, there are no regulations regarding their font size or complexity. Caltrans needed more data to determine whether digital displays and other forms of outdoor advertising constitute a safety hazard to drivers.

To conduct this investigation, CTC carried out a literature search to:

- Identify existing or in-progress research about the driver safety impacts of static signs, digital billboards and other displays, including the effects of brightness/illumination, font size and visual complexity of the signs.
- Review research on both on-premise and off-premise signage as well as the broader aspects of how guide signs (as given in the California Manual on Uniform Traffic Control Devices) affect safety.
- Investigate how other states are regulating the use of digital displays.

Summary of Findings

We gathered information in three topic areas:

- Federal Guidance on Digital Displays
- Related Research
    - The Wachtel Report and Pre-2009 Literature on Outdoor Advertising Safety
    - Literature on Outdoor Advertising Safety Since the 2009 Wachtel Report
    - Luminance Criteria and Other Human Factors for Sign Design
- State Regulations

Following is a summary of findings by topic area.

Federal Guidance on Digital Displays

A 2007 Federal Highway Administration (FHWA) memo makes recommendations for changeable message sign message duration (8 seconds), transition time (1 to 4 seconds), brightness, spacing and locations.

Related Research

The most thorough review of the literature to date on digital display safety is the 2009 report Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs by Jerry Wachtel. Wachtel has been the president of The Veridian Group, a California human factors research consulting firm, for 22 years and has published numerous studies on outdoor advertising safety.

We give a summary of this report and include a selection of the references cited for studies in or before 2009. (We found no relevant studies for this period not included in Wachtel's report, which covers both digital and nondigital outdoor advertising.) In a separate section, we discuss literature on outdoor advertising safety that has been published since Wachtel's report.

The Wachtel Report and Pre-2009 Literature on Outdoor Advertising Safety

Based on the literature review, Wachtel concludes that:

- Studies regularly demonstrate that roadside advertising, including digital billboards, contributes to driver distraction at levels that adversely affect safe driving performance.
- There are consistent research recommendations regarding brightness, message duration and change interval, and other factors.

Wachtel also gives a thorough survey of national and international guidelines and regulations for digital billboards, and based on these (along with the literature review) makes recommendations for digital billboard guidelines, including:

- *Message duration:* A minimum display duration of sight distance to the digital billboard (feet)/speed limit (feet/second).
- *Message interval:* An interval between successive displays that is close to instantaneous as possible.
- *Display brightness:* Brightness, luminance and illuminance limits based on the ambient lighting conditions of digital billboards.
- *Digital billboard spacing:* Spacing between digital billboards that does not face a driver with two or more displays within his field of view at the same time.
- *Other:* The prohibition of visual effects, message sequencing, and the placement of digital billboards near traffic control devices and driver decision and action points.

Wachtel concludes that there is growing evidence that digital billboards distract drivers because these signs increase driver glance duration and the driver's gaze is reflexively drawn to objects of different luminance in the visual field.

Findings from the literature support the argument that while there is no definitive research showing increased crashes due to the presence of billboards or digital billboards, there is an increased crash risk based on research on the effects of billboards on driver attention and the effects of driver distraction on safety:

- Billboards can have a significant effect on driver speed, lateral control, mental workload, ability to follow road signs, and eye movements and fixations, with older drivers particularly affected. (*The Effects of Visual Clutter on Driving Performance* and *Driven to Distraction*, *An Evaluation of the Influence of Roadside Advertising on Road Safety*, and *Review of Roadside Advertising Signs*). And visual clutter generally can distract drivers (*Driver Distraction by Advertising*).
- Digital billboards attract more attention than regular billboards, with larger number of glances and longer glances (*Driving Performance and Digital Billboards* and *Observed Driver Glance*

Behavior at Roadside Advertising Signs). Wachtel notes that the implication is that the shorter the message duration, the longer the driver's glance in anticipation of the next message.

- Drivers engaging in visually demanding tasks have a crash risk three times higher than attentive drivers; while brief glances do not increase risk, glances of more than two seconds at least double crash risk (*The Impact of Driver Inattention on Near-Crash/Crash Risk*).
- While studies have not been able to establish a statistical relationship between the presence of billboards and traffic safety, these studies have been flawed in design, and the use of accident data in evaluating the impacts of billboard is ill-advised (*The Impact of Roadside Advertising on Driver Distraction, A Study of the Relationship between Digital Billboards and Traffic Safety in Cuyahoga County, Ohio*, *Driving Performance and Digital Billboards*, and *Driving Performance in the Presence and Absence of Billboards*, *Effects of Roadside Advertisements on Road Safety*).
- More research is needed. A 2009 FHWA study on the effects of commercial electronic variable message signs on driver attention and safety (of which Wachtel is a co-author) proposes a three-stage program of research: an on-road instrumented vehicle study, a naturalistic driving study and an unobtrusive observation study (*The Effects of Commercial Electronic Variable Message Signs (CEVMS) on Driver Attention and Distraction*).

<u>Literature on Outdoor Advertising Safety Since the 2009 Wachtel Report</u>

We found a number of studies on outdoor advertising safety that have been published since the Wachtel report; but only three on digital billboard safety specifically. These studies reaffirm the negative effects of billboards on driver attention, despite the fact that no correlation can be found between the presence of billboards and increased crash rates:

- Advertising billboards affect driver's ability to detect changes in road scenes, especially when the roadway background is more cluttered (*Advertising Billboards Impair Change Detection in Road Scenes*). In general they affect lateral control and mental workload (*Conflicts of Interest*), and change drivers' pattern of visual attention, increasing the amount of time needed for drivers to respond to road signs and increasing driving errors (*Effects of Advertising Billboards during Simulated Driving*). A 2010 study concludes that among distractions external to vehicles, roadside advertisements have the strongest correlation to collision frequency (*Quantifying External Vehicle Distractions and Their Impacts at Signalized Intersections*).
- A 2011 FHWA study scans outdoor advertising control practices in Australia, Europe and Japan (*Outdoor Advertising Control Practices in Australia, Europe, and Japan*).
- A 2010 Transport Research Laboratory study concludes that video billboards draw longer and more frequent glances from drivers than static advertisements, with drivers showing greater variation in lateral lane position, driving more slowly and braking harder (*Investigating Driver Distraction*). A 2011 study shows that video billboards also lead to more rear-end collisions when there is a hard-braking lead vehicle (*External Distractions: The Effects of Video Billboards and Windfarms on Driving Performance*).
- A 2010 study showed no impact on driver performance after the installation of a digital billboard (*The Impact of Sacramento State's Electronic Billboard on Traffic and Safety*), and a 2009 study shows no correlation between hazardous intersection and the presence of digital billboards in Los Angeles (*Digital Billboard Safety amongst Motorists in Los Angeles*).
- Preventing distraction by digital billboards requires controlling lighting at nighttime, lengthening message duration time, simplifying message information and prohibiting message sequencing (*Digital Billboards, Distracted Drivers*).

<u>Luminance Criteria and Other Human Factors for Sign Design</u>

We also include a number of studies on human factors for the design of signs in general (including guide signs). Topics include congruent visual information, legibility, message design for variable message signs and luminance criteria for digital billboards. A 2010 study by Arizona State University (*Digital LED Billboard Luminance Recommendations*) suggests that:

… drivers should be subjected to brightness levels of no greater than 10 to 40 times the brightness level to which their eyes are adapted for the critical driving task. As roadway lighting and automobile headlights provide lighting levels of about one nit, this implies signage should appear no brighter than about 40 nits.

State Regulations

- An undated chart from the Outdoor Advertising Association of America summarizes state regulations on changeable message advertising signs. Generally minimum message duration is between 4 and 10 seconds, with 6 and 8 seconds most common; the maximum interval between messages is 1 to 4 seconds; and spacing is most commonly 500 feet. A review of state practices is also included in Appendices B and C of the 2001 FHWA study, Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction in **Related Research**.
- We survey the digital advertising display regulations of 12 states. Of note are Massachusetts and Tennessee, which are currently updating regulations to specifically address digital billboards.

Gaps in Findings

- While there is a significant amount of research on the effects of outdoor advertising on driver distraction, there is little research definitively showing that outdoor advertising affects crash rates, and there are a limited number of studies on digital billboards specifically.
- We found little research justifying common regulations and design recommendations for digital billboards, including brightness/illumination, font size and visual complexity. Recommendations are typically based on common state practices.
- We found little research on the safety effects of signage in general, including guide signs.
- We did not find research in progress for any areas of inquiry.

Next Steps

- Caltrans may be able to gather additional information about current practice and regulations by surveying the other state DOTs.
- Caltrans could consider launching a multi-year research study, either by itself or with other states, aimed at measuring changes in crash rates after installation of digital displays.
- Caltrans could follow up with the Outdoor Advertising Association of America to determine the sources and dates of the data presented in their State Changeable Message Chart; OAAA may also have other unpublished research of interest.

Federal Guidance on Digital Displays

Guidance on Off-Premise Changeable Message Signs, Federal Highway Administration, September 2007.
http://www.fhwa.dot.gov/realestate/offprmsgsnguid.htm
Guidance from this memorandum is as follows:

- Duration of message: Between 4 and 10 seconds; 8 seconds is recommended.
- Transition time between messages: 1 to 4 seconds.
- Brightness: Adjust brightness in response to changes in light levels so that signs are not unreasonably bright for the safety of the motoring public.
- Spacing: Not less than minimum spacing requirements for signs under the federal/state agreement (FSA), or greater if determined appropriate to ensure the safety of the motoring public.
- Locations: As where allowed by the FSA except where such locations are determined to be unsafe.

Related Resources:

Outdoor Advertising Control, Federal Highway Administration, January 3, 2012.
http://www.fhwa.dot.gov/realestate/out_ad.htm
This web page provides a series of links to related topics, including a history and overview of the federal outdoor advertising control program, the possible effects of commercial electronic variable message signs on driving safety, and research about the potential safety effects of electronic billboards on driver attention and distraction.

Related Research

Studies below that are industry sponsored are preceded by an asterisk and include an indication of the sponsor.

The Wachtel Report and Pre-2009 Literature on Outdoor Advertising Safety

Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs, Jerry Wachtel, NCHRP Project 20-7 (256), Final Report, April 2009.
http://www.azmag.gov/Documents/pdf/cms.resource/NCHRP_Digital_Billboard_Report70216.pdf

Sections 2 and 3 of this report include the most thorough review to date of the literature on the use of digital displays for outdoor advertising signs. Summaries of a selection of the studies referenced in the report are provided on the following pages, along with Wachtel's comments on these studies, where relevant. (In the citations for this section, all references to "Wachtel" are to the 2009 report.)

Summaries of the following sections of the report are also provided:

- Conclusions from the literature.
- Section 4: Human Factors Issues.
- Section 5: Current and Proposed Guidelines and Regulations.
- Section 6: Recommendations for Guidelines.
- Section 7: Digital Billboards On-Premise and on the Right-Of-Way.
- Section 8: New Technology, New Applications, New Challenges.
- Section 9: Summary and Conclusions.

Conclusions from the Literature

This report gives an exhaustive review of the literature (Sections 2 and 3) and concludes broadly (pages 5 and 6 of the report) that:

- Studies regularly demonstrate that the presence of roadside advertising signs such as digital billboards contributes to driver distraction at levels that adversely affect safe driving performance.
- There is consistency in research recommendations regarding brightness, message duration and change interval, and billboard location with regard to official traffic control devices, roadway geometry and vehicle maneuver requirements at interchanges, lane drops, merges and diverges, as well as regarding constraints that should be placed on such signs' placement and operation.

Section 4: Human Factor Issues:

Beginning on page 115 of the report, Wachtel summarizes human factors issues related to digital billboards as follows:

- *Conspicuity:* Billboards with high levels of illumination and frequent changes can reduce the visibility of traffic control devices and other visual signs required for safety (vehicle brake lights, reflectors, etc.).
- *Distraction and inattention:* Inattention involves the failure of a driver to concentrate on the driving task for any reason, or for no known reason at all. It is distinguished from distraction in that it may have no known cause and possibly no remediation.
- *Information processing:* Billboards are often placed in ways that do not adhere to good human factors practice restricting the amount of information conveyed by signs.
- *The Zeigarnik Effect:* Discomfort related to task interruption may lead drivers to continue looking at changing messages on digital billboards to learn what comes next.
- *Brightness and glare:* The majority of public complaints about digital billboards concern their excessive brightness, particularly at night, to the extent that they become the most conspicuous item in the visual field and draw the eye away from other objects that need to be seen.
- *Legibility and readability:* Billboards may not adhere to Manual on Uniform Traffic Control Devices (MUTCD) guidelines on legibility, including font, letter size and color. Often they take more time to read than guidelines prescribe, taking multiple glances to communicate the intended message.
- *Novelty:* Novel stimuli make a greater demand on driver attention, and where drivers get used to static billboards, digital billboards have the ability to present new images to drivers every time the sign is approached.
- *Sign design, coding, redundancy:* Digital billboards lack the consistent design of traffic control devices, which is intended to assist recognition and decrease reaction time.
- *Visual attention:* Digital billboards, more than any previous technology used for roadside advertising, are capable of commanding drivers' attention by employing extremely high luminance levels; bright, rich colors; and a pattern of message display that may appear to flash.
- *Positive Guidance:* Drivers can be given sufficient information about road hazards when and where they need it, and in a form that enables them to avoid error that might result in a crash.
- *The Moth Effect:* Drivers may have the tendency to inadvertently steer in the direction of bright lights, leading to lane departures and crashes.

Section 5: Current and Proposed Guidelines and Regulations

This section reviews national and international guidelines and regulations for digital billboards.

Queensland, Australia

Queensland had the most comprehensive regulations, including flowcharts and tables that enable an inspector to determine exactly what types and operational characteristics of advertising signs are permissible under different road and speed conditions. Page 121 of the report describes different levels of restriction for different road categories:

For advertising devices beyond the right-of-way but visible from "motorways, freeways, or roads of similar standard," only non-illuminated signs or non-rotating static illuminated signs are permitted (p. 6-4). Where an advertising device is permitted on State-controlled roads, the same restrictions apply. Further, "variable message signs and trivision signs are not permitted on State-controlled roads" (p. 6-5). For those advertising devices that are permitted, a clear chart is provided (labeled Figure C6) that provides graphic depictions of the "device restriction area" (p. C-12).

Guidelines also establish maximum average sign luminance for zones with differing ambient street lighting. To limit the distracting potential of electronic billboards, Australia requires that digital billboards outside the boundaries of but visible from state-controlled roads (except motorways) (Category 1) be installed only where:

- There is adequate advanced visibility to read the sign.
- The environment is free from driver distraction points and there is no competition with official signs.
- The speed limit is 80km/h or less.
- The device is not a moving sign (defined elsewhere in the document).

For Category 1 digital billboards that display predominantly graphics:

- Long duration display periods are preferred in order to minimize driver distraction and reduce the amount of perceived movement. Each screen should have a minimum display period of 8 seconds.
- The time taken for consecutive displays to change should be within 0.1 seconds.
- The complete screen display should change instantly.
- Sequential message sets are not permitted.
- The time limits will be reviewed periodically.

For Category 1 digital billboards that display predominantly text:

- The number of sequential messages … may range from one to a maximum of three; in locations with high traffic volume or a high demand on driver concentration, the number of sequential messages should be limited to two.
- Where a display is part of a sequential message set, the display duration should be between 2.5 to 3.5 seconds for a corresponding message length of three to six familiar words.
- The number and complexity of words used … should be consistent with the display duration.
- The time taken for consecutive displays to change should be within 0.1 seconds.
- The complete screen display should change instantaneously.
- In a text-only display, the background color should be uniform and nonconspicuous.

Australia's regulations do not allow changeable message signs, flashing signs or digital billboards of any type if such devices would be visible by motorists traveling on motorways (Category 2). Where advertising devices are permitted within the boundaries of state-controlled roads (Category 3), such signs must be nonrotating static illuminated and nonrotating, nonilluminated signs. Neither variable message signs nor trivision signs are permitted on state-controlled roads.

South Africa

On page 126 of the report, Wachtel describes South Africa's regulations, which require that no advertisement may:

- Be so placed as to distract, or contain an element that distracts, the attention of drivers of vehicles in a manner likely to lead to unsafe driving conditions.
- Be illuminated to the extent that it causes discomfort to or inhibits the vision of approaching pedestrians or drivers of vehicles.

- Be attached to traffic signs, combined with traffic signs, … obscure traffic signs, create confusion with traffic signs, interfere with the functioning of traffic signs, or create road safety hazards.
- Obscure the view of pedestrians or drivers, or obscure road or rail vehicles and road, railway or sidewalk features such as junctions, bends, and changes in width.
- Be erected in the vicinity of signalized intersections which display the colours red, yellow or green if such colours will constitute a road safety hazard.
- Have light sources that are visible to vehicles traveling in either direction (p. 12).

Regulations provide guidance on advertisement size, colors, number of advertisements in the area, speed limit, quantity of information in the advertisement (measured in bits), illumination level and other factors.

Victoria, Australia
Regulations define the conditions under which an advertisement is a road safety hazard, including position and potential for distraction because of color or illumination. From page 130 of the report, signs must:

- Not display animated or moving images, or flashing or intermittent lights.
- Not be brighter than 0.25 candela per square metre.
- Remain unchanged for a minimum of 30 seconds.
- Not be visible from a freeway.
- Satisfy the ten point checklist.

New South Wales, Australia
Guidelines include recommendations for variable message signs on conventional roads, including message on- and off-time, changeover time, maximum distance to traffic signal, and minimum distances to other advertising devices or to official traffic devices. It also restricts the maximum luminance levels of advertising devices based on levels of ambient off-street lighting.

The Netherlands
The Netherlands has guidelines for visual distracters (including but not limited to billboards) that contain nondriving related information. Recommendations include (from page 132 of the report):

- There should be no information that actively attracts attention; this includes no moving objects, no LCD or LED screens, and no moving or changing pictures or images.
- Non-driving related information should not appear within the driver's central field-of-view (less than 10 deg from straight ahead).
- Signs should contain a maximum of five "items" (letters, numbers, symbols, etc.).
- No distractions should be permitted at merges, exits and entrances, close to road signs or in curves (specific constraints will follow).
- No telephone numbers will be permitted.
- No fluorescent colors are permitted.
- No ambiguity is permitted.
- No controversial information is permitted; examples include sex, violence, religion, nudity.
- No mixture of real and fake words is permitted.
- Commercial signs must be 90 deg to the road to minimize head turning.
- No signs will be permitted that mimic road signs in color or layout.

Brazil
A 1998 study proposes the following regulations (from page 134 of the report):

- Advertising signs should be located at a tangent to approaching drivers.
- Advertising signs should be no closer than 1000 m from one another on the same side of the road, and no closer than 500 m from the nearest advertising sign on the opposite side of the road.
- The display time of each image on a variable message sign should be long enough to appear static to 95% of drivers approaching it at highway speeds.

- The message change interval should not exceed 2 s.
- The displayed image should remain static from the moment it first appears until the moment it is changed.
- No animation, flashing or moving lights should be allowed.
- No message or image that could be mistaken for a traffic control signal should be displayed.
- Messages should be simple and concise.

United States

New York State

Regulations proposed in 2008 include:

- Minimum message duration of 62 seconds, so that no motorist would be able to see more than one message change as he or she approached any particular changeable electronic variable message sign.
- Message transition time should be instantaneous to minimize distraction.
- Minimum spacing between changeable electronic variable message sign is 5,000 feet.
- Maximum changeable electronic variable message sign brightness of 5,000 cd/m^2 in daylight and 280 cd/m^2 at night.
- Prohibited locations:
    - On interstate and controlled access highways: Within 1,100 feet of an interchange, at-grade intersection, toll plaza, signed curve or lane merge/weave area; within 5,000 feet of another changeable electronic variable message sign or official traffic device that has changeable messages.
    - On primary highways: Within 1,100 feet of an entrance or exit from a controlled access highway, a signed curve or a lane/merge area; within 5,000 feet of another changeable electronic variable message sign or official traffic control device with changeable messages.

Revised criteria made these requirements less restrictive, reducing message duration from 62 to 6 seconds and changing spacing requirements and prohibited locations. The requirements for instantaneous message transition and maximum brightness did not change.

San Antonio, TX

Regulations for a trial evaluation of 15 off-premise digital signs included a message duration time of 10 seconds; change intervals of one second or less; brightness less than or equal to 7,000 nits during the day and 2,500 nits at night; and various other regulations. (One nit = one candela per square meter.)

Flowery Branch, GA

Regulations in this community begin on page 138 of the report and include:

- Minimum message duration: to the amount of time that would result in one message per mile at the highest speed limit posted within the 5000 feet approaching the sign for the road from which the sign is to be viewed.
- Transition time: less than one-tenth of a second, with no animated transitions.
- Illumination and brightness: not greater than 12 foot-candles from the nearest point of the road.
- Freezing of the display on malfunction.
- Prohibition of message sequencing.

Oakdale, MN

Brightness is limited to 2,500 nits during the day and 500 nits at night, with adjustments for ambient light conditions and a minimum display duration of 60 seconds.

St. Croix County, WI

From page 140 of the report, signs with "external and uncolored" illumination are permitted. In addition to typical prohibitions against flashing, moving, traveling, or animated signs or sign elements, the following prohibitions apply to all signs with internal illumination:

- No illuminated off-premises sign which changes in color or intensity of artificial light at any time while the sign is illuminated shall be permitted.
- No illuminated on-premise sign which changes in color or intensity of artificial light at any time when the sign is illuminated shall be permitted, except one for which the changes are necessary for the purpose of correcting hour-and-minute, date or temperature information.
- A sign that regularly or automatically ceases illumination for the purpose of causing the color or intensity to have changed when illumination resumes (are prohibited).
- The scope of the ordinance's prohibitions include, but are not limited to, any sign face that includes a video display, LED lights that change in color or intensity, "digital ink," and any other method or technology that causes the sign face to present a series of two or more images or displays.

Outdoor Advertising Industry

The Outdoor Advertising Association of America (OAAA) publication Regulating Digital Billboards suggests that digital billboards:

- Display a message that appears for no less than four seconds.
- Have message transitions of at least one second.
- Have spacing consistent with state requirements.
- Do not include animated, flashing, scrolling, intermittent or video elements.
- Appropriately adjust display brightness as ambient light levels change.

Section 6: Recommendations for Guidelines

Wachtel makes recommendations for guidelines based on the review of literature and international, national, state and local regulations (despite the fact that "there are not yet comprehensive research-based answers to fully inform such guidance and regulation"):

- Minimum message display duration: The FHWA recommends 6 seconds, the OAAA recommends 4 seconds, and the OAAA reports that 41 states have set display minimums ranging from 4 seconds to 10 seconds. Wachtel is not aware of any research on this issue to support such guidelines, and notes that "good human factors practice would suggest that minimum display duration should differ with sight distance, prevailing speeds, and other factors." The author recommends the following formula to minimize the chance that a motorist will see more than two successive messages:

  Sight distance to the digital billboards (ft) / Speed limit (ft/sec) = Minimum display duration (sec)

- Interval between successive displays: This interval should be as close to instantaneous as possible so that a driver cannot perceive any blanking of the display screen.
- Visual effects between successive displays: Visual effects should be prohibited.
- Message sequencing: Sequencing should be prohibited.
- Amount of information displayed: To the author's knowledge, no U.S. jurisdiction places restrictions on the amount of information that may be presented on billboards, including digital billboards (although some agencies outside the United States do). There is not enough research to make recommendations, although a good starting point are guidelines for South Africa and the Netherlands (which limit information based on how much a driver can read at a given speed and while the sign is visible).
- Information presentation: Considerable guidance is available to advertisers and digital billboard owners from sources inside the outdoor advertising industry as well as human factors and traffic

safety experts, and the MUTCD itself. Digital billboards should facilitate rapid, error-free reading of roadside advertisements with lower levels of driver attentional demand and distraction. Typeface, font, color and contrast of figure and background, character size, etc., all play a role in the legibility and readability of a display.

- Digital billboard size: Recommendations for size limitations are beyond the scope of the report. The most common size for billboards of any kind is 14 feet high by 48 feet wide.
- Brightness, luminance and illuminance: Since perceived brightness can change depending on ambient light conditions, it is necessary to establish objective, measurable limits on the amount of light that such billboards actually emit, and set different upper bounds for different environmental and ambient conditions.
- Display luminance in the event of failure: Roadway authorities should incorporate into their guidelines verifiable requirements that, in the event of any failure or combination of failures that affect DBB luminance, the display will default to an output level no higher than that which has been independently determined to be the acceptable maximum under normal operation.
- Longitudinal spacing between billboards: An approaching driver should not be faced with two or more digital billboard displays within his field of view at the same time.
- Digital billboard placement with relation to traffic control devices and driver decision and action points: Prohibitions against the placement of distracting irrelevant stimuli in roadway settings where drivers must make decisions and take actions should be imposed. The guidance for Queensland, Australia, might serve as a model.
- Annual operating permits: Government agencies and roadway operating authorities might consider the practice adopted in Oakdale, MN, where owners of digital billboards are granted a permit to operate a sign for a year and must renew the permit annually.

<u>Section 7: Digital Billboards On-Premise and on the Right-Of-Way</u>

On-Premise Signs
From page 161 of the report:

> … On-premise sign regulation is typically accomplished through local zoning codes, and may, in general, be far more variable and likely less stringent with regard to the means of the display, display characteristics, or the size of the sign than comparable controls on billboards. Many such codes have changed little in recent years, despite the growth of digital technology for on-premise displays.
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> From the traffic safety perspective, it is possible that the risk of driver inattention and distraction is higher for some on-premise signs than for some [digital billboards], because on-premise signs may be larger and closer to the road, mounted at elevations closer to the approaching driver's eye level, and placed at angles that may require excessive head movements, In addition, many such signs may display animation, full motion video, sound, and other stimuli.
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> … Agencies might want to consider restrictions for on-premise sign operations at least as rigorous as those for billboards, as well as restrictions on size, height, proximity to the right-of-way, and angular placement with regard to the oncoming driver's line of sight. Of all of the guidelines proposed in this report for [digital billboards], there may well be an equal or greater need to consider similar controls for on-premise signs. In addition, consideration must also be given to such signs' capacity for animation, flashing lights or other special effects, and full motion video.

Digital Billboards within the Right-of-Way
The FHWA opposes advertising of any kind within the right of way (despite proposals for public-private partnerships in California and Nevada).

Wachtel concludes that permitting California to study its proposed exceptions to the requirements of the MUTCD and existing federal law would bring about several adverse consequences, including undermining decades of human factors research, setting a dangerous precedent and opening to challenge the entire basis of the MUTCD.

Section 8: New Technology, New Applications, New Challenges
The potential for driver distraction displaying billboards (electronic and otherwise) on moving vehicles is high, as it is for personalized and interactive billboards.

Section 9: Summary and Conclusions
From page 179 of the report:

> In short, the issue of the role of [digital billboards (DBBs)] in traffic safety is extremely complex, and there is no single research study approach that can provide answers to all of the many questions that must be raised in looking at this issue. … A small number of important research studies, all published (or to be published) within the past several years, may have opened the door to a solution to the long-standing question of whether unsafe levels of driver distraction can occur from roadside billboards. … [One study found] that a driver's eyes-off-road time due to external-to-the-vehicle distraction or inattention was estimated to cause more than 23% of all crashes and near crashes that occurred. … [Another study shows] significantly longer average glance durations to roadside digital signs than to "baseline" sites and to traditional (fixed) billboards, and the researchers suggest, *all* measures of visual glances indicative of driver distraction would prove to be significantly worse in the presence of digital signs if a full study was to be conducted at night. … [T]here is growing evidence that billboards can attract and hold a driver's attention for the extended periods of time that we now know to be unsafe.
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> … [A]n on-road study (Lee, et al., 2007) using an instrumented vehicle found many more such long glances made to DBBs and similar "comparison sites" consisting of (among other things) on-premise digital signs, than there were to sites containing traditional, static billboards, or sites with no obvious visual elements. … From the same study, we have evidence expressed by the researchers that if we were to conduct our research at night we would find that *all* measures of eye glance behavior would demonstrate significantly greater amounts of distraction to digital advertisements than to fixed billboards or to the natural roadside environment, and that driver vehicle control behaviors such as lane-keeping and speed maintenance would also suffer in the presence of these digital signs.
>
> … When we add the results of these recent, applied research studies, to the earlier theoretical work by Theeuwes and his colleagues (1998, 1999), in which they demonstrated that our attention and our eye gaze is reflexively drawn to an object of different luminance in the visual field, that this occurs even when we are engaged in a primary task, and regardless of whether we have any interest in this irrelevant stimulus, and that we may have no recollection of having been attracted to it, we have a growing, and consistent picture of the adverse impact of irrelevant, outside-the-vehicle distracters such as DBBs on driver performance.

Note: In the citations that follow, all references to "Wachtel" are from the 2009 report citation given on page 4 of this report.

The Effects of Commercial Electronic Variable Message Signs (CEVMS) on Driver Attention and Distraction: An Update, Federal Highway Administration, Report No. FHWA-HRT-09-018, February 2009.
http://www.fhwa.dot.gov/realestate/cevms.pdf
From the abstract: The present report reviews research concerning the possible effects of Commercial Electronic Variable Message Signs (CEVMS) used for outdoor advertising on driver safety. Such CEVMS displays are alternatively known as Electronic Billboards (EBB) and Digital Billboards (DBB). The report consists of an update of earlier published work, a review of applicable research methods and techniques, recommendations for future research, and an extensive bibliography. The literature review update covers recent post-hoc crash studies, field investigations, laboratory investigations, previous literature reviews, and reviews of practice. The present report also examines the key factors or independent variables that might affect a driver's response to CEVMS, as well as the key measures or dependent variables which may serve as indicators of driver safety, especially those that might reflect attention or distraction. These key factors and measures were selected, combined, and integrated into a set of alternative research strategies. Based on these strategies, as well as on the review of the literature, a proposed three stage program of research has been developed to address the problem. The present report also addresses CEVMS programmatic and research study approaches. In terms of an initial research study, three candidate methodologies are discussed and compared. These are: (1) an on-road instrumented vehicle study, (2) a naturalistic driving study, and (3) an unobtrusive observation study. An analysis of the relative advantages and disadvantages of each study approach indicated that the on-road instrumented vehicle approach was the best choice for answering the research question at the first stage.

Wachtel notes:

> It should be noted that this project was performed essentially in parallel with the present study. Although both looked at the recent literature that addressed driver behavior and performance in the presence of DBBs, the two studies had different goals and took different approaches. The study by Molino and his colleagues was intended to identify gaps in our current knowledge and design a research strategy to begin to fill those gaps, with the ultimate goal of providing the FHWA Office of Real Estate Services with a sufficient empirical basis from which to develop or revise, if appropriate, guidance and/or regulation for the use of DBBs along the Federal Aid Highway System. These goals differed considerably from the present study, whose purpose was to review, not only the recent research literature, but also existing guidelines and/or regulations that have been developed in the U.S. and abroad to address DBBs. Finally, the ultimate goal of the present study was to take what is known from the research, combine this knowledge with what has worked for regulatory authorities, and recommend new guidelines and/or regulations that could be enacted by State and local governments, and private and toll road authorities, without the need or the ability to wait for the completion of additional research. The FHWA study had no such objective.

The Effects of Visual Clutter on Driving Performance, Jessica Edquist, Accident Research Centre, Monash University, February 24, 2009.
http://www.tml.org/legal_pdf/Billboard-study-article.pdf
From the abstract: Driving a motor vehicle is a complex activity, and errors in performing the driving task can result in crashes which cause property damage, injuries, and sometimes death. It is important that the road environment supports drivers in safe performance of the driving task. At present, increasing amounts of visual information from sources such as roadside advertising create visual clutter in the road environment. There has been little research on the effect of this visual clutter on driving performance, particularly for vulnerable groups such as novice and older drivers. The present work aims to fill this gap. Literature from a variety of relevant disciplines was surveyed and integrated, and a model of the mechanisms by which visual clutter could affect performance of the driving task was developed. To determine potential sources of clutter, focus groups with drivers were held and two studies involving subjective ratings of visual clutter in photographs and video clips of road environments were carried out. This resulted in a taxonomy of visual clutter in the road environment: "situational clutter", including

vehicles and other road users with whom drivers interact; "designed clutter", including road signs, signals, and markings used by traffic authorities to communicate with users; and "built clutter", including roadside development and any signage not originating from a road authority. The taxonomy of visual clutter was tested using the change detection paradigm. Drivers were slower to detect changes in photographs of road scenes with high levels of visual clutter than with low levels, and slower for road scenes including advertising billboards than road scenes without billboards. Finally, the effects of billboard presence and lead vehicles on vehicle control, eye movements and responses to traffic signs and signals were tested using a driving simulator. The number of vehicles included appeared to be insufficient to create situational clutter. However billboards had significant effects on driver speed (slower), ability to follow directions on road signs (slower with more errors), and eye movements (increased amount of time fixating on roadsides at the expense of scanning the road ahead). Older drivers were particularly affected by visual clutter in both the change detection and simulated driving tasks. Results are discussed in terms of implications for future research and for road safety practitioners. Visual clutter can affect driver workload as well as purely visual aspects of the driving task (such as hazard perception and search for road signs). When driver workload is increased past a certain point other driving tasks will also be performed less well (such as speed maintenance). Advertising billboards in particular cause visual distraction, and should be considered at a similar level of potential danger as visual distraction from in-vehicle devices. The consequences of roadside visual clutter are more severe for the growing demographic of older drivers. Currently, road environments do not support drivers (particularly older drivers) as well as they could. Based on the results, guidance is given for road authorities to improve this status when designing and location road signage and approving roadside advertising.

The Impact of Roadside Advertising on Driver Distraction: Final Report, WSP Development and Transportation, June 2008.
http://www.highways.gov.uk/knowledge_compendium/assets/documents/Portfolio/The%20impact%20of%20roadside%20advertising%20on%20the%20travelling%20public%20-%20Report%20-%201103.pdf
This report argues against the use of accident data in evaluating the impacts of billboards. Wachtel summarizes these arguments as follows:

- There could be other unknown variables that could have led to the reported accidents.
- There are many opportunities for error or omission in data entry in police accident reporting forms.
- In minor accidents, the involved vehicles may move away from the point of rest (POR) to clear traffic lanes, thus further degrading the potential accuracy of identifying the true location. The POR of the involved vehicle(s) (which is what is commonly identified in police reports) may have little relationship to the point of distraction that was the proximal cause of the crash.
- Accidents, particularly minor accidents, are underreported.
- Accident data considers only those incidents that result in an actual collision. But there are likely many more incidences of distraction that result in driver error (such as late braking, lane exceedances) without consequence, and others that result in "near misses" that might have resulted in a crash but for the evasive actions of another driver. "As no data on 'near misses' is available, it is not possible to quantify the full effect of distraction" (p. 35).

Wachtel also summarizes the reports broad conclusions as follows:

- Although it is accepted that drivers are responsible for attending to the driving task, "visual clutter is liable to overload or distract drivers" (p. 63).
- The stakeholders could not provide statistical evidence to demonstrate the presence or absence of a correlation between roadside advertising and accidents.
- There is no desire for an outright ban on roadside advertising, but there is general agreement about the need for more guidance or regulation to control the type, location and content of such advertising.
- There is a need for additional governmental powers to remove unauthorized advertising, and there is a need to make enforcement a greater priority.

***A Study of the Relationship between Digital Billboards and Traffic Safety in Cuyahoga County, Ohio**, Tantala Associates, sponsored by the OAAA, July 2007.
Citation at http://trid.trb.org/view/2007/M/1154756
This study sponsored by the Outdoor Advertising Association of America uses police reports to examine the statistical relationship between certain digital billboards and traffic safety for seven locations in Cuyahoga County. Results show no statistical relationship between the presence of digital billboards and accidents.

Wachtel notes:

> The authors performed a post-hoc accident analysis study in which they reviewed statistical summaries of traffic collision reports, the originals of which had been prepared by investigating police officers. There are serious, inherent weaknesses in the use of this technique; such weaknesses have been understood and well documented for many years (see, for example, Wachtel and Netherton, 1980; Klauer, et al., 2006b; Speirs, et al., 2008). The use of this approach to relate crashes to driver distraction from DBBs, however, raises additional concerns.

Wachtel goes on to give an extensive critique of this study (pages 89 to 101), reprising his criticisms in the following review:

> **A Critical, Comprehensive Review of Two Studies Recently Released by the Outdoor Advertising Association of America**, Jerry Wachtel, The Veridian Group, October 18, 2007.
> http://www.scenic.org/storage/documents/Wachtel_Maryland_review.pdf
> *From the report:* In July 2007, the Outdoor Advertising Association of America (OAAA) announced on its website the issuance of two "ground-breaking studies" that addressed the human factors and driver performance issues associated with real-world digital (or electronic) billboards (EBBs), and the impact of such billboards on traffic accidents (Outdoor Advertising Association of America, 2007). … As a result of the issuance of these two studies and the claims made for them, and because of the need to address this technology by Government agencies nationwide, the Maryland State Highway Administration (MDSHA) asked this reviewer to perform an independent peer review of each of the two studies. This report represents the results of that review. … Having completed this peer review, it is our opinion that acceptance of these reports as valid is inappropriate and unsupported by scientific data, and that ordinance or code changes based on their findings is ill advised.

***Driving Performance and Digital Billboards**, Suzanne E. Lee, Melinda J. McElheny, Ronald Gibbons, Center for Automotive Safety Research, Virginia Tech Transportation Institute, sponsored by the OAAA, March 22, 2007.
http://www.oaaa.org/UserFiles/File/Legislative/Digital/6.3.9b%20Driver%20Behavior%20Research.pdf
From the abstract: Thirty-six drivers drove an instrumented vehicle on a 50-mile loop route in the daytime along some of the interstates and surface streets in Cleveland [OH]. … The overall conclusion, supported by both the eyeglance results and the questionnaire results, is that the digital billboards seem to attract more attention than the conventional billboards and baseline sites. Because of the lack of crash causation data, no conclusions can be drawn regarding the ultimate safety of digital billboards. Although there are measurable changes in driver performance in the presence of digital billboards, in many cases these differences are on a par with those associated with everyday driving, such as the on-premises signs located at businesses.

Driven to Distraction: Determining the Effects of Roadside Advertising on Driver Attention, Mark S. Young, Janina M. Mahfoud, Brunel University, 2007.
http://bura.brunel.ac.uk/bitstream/2438/2229/1/Roadside%20distractions%20final%20report%20%28Brunel%29.pdf
From the abstract: There is growing concern that roadside advertising presents a real risk to driving safety, with conservative estimates putting external distractors responsible for up to 10% of all accidents. In this report, we present a simulator study quantifying the effects of billboards on driver attention, mental workload and performance in Urban, Motorway and Rural environments. The results demonstrate that roadside advertising has a clear detrimental effect on lateral control, increases mental workload and eye fixations, and on some roads can draw attention away from more relevant road signage. Detailed analysis of the data suggests that the effects of billboards may in fact be more consequential in scenarios which are monotonous or of lower workload. Nevertheless, the overriding conclusion is that prudence should be exercised when authorising or placing roadside advertising. The findings are discussed with respect to governmental policy and guidelines.

Wachtel gives an extensive critique of the methodology for this industry-sponsored study (pages 101 to 114).

The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data, S.G. Klauer, T.A. Dingus, V.L. Neale, J.D. Sudweeks, D.J. Ramsey, Virginia Tech Transportation Institute, April 2006.
http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2006/DriverInattention.pdf
From the abstract: The purpose of this report was to conduct in-depth analyses of driver inattention using the driving data collected in the 100-Car Naturalistic Driving Study. An additional database of baseline epochs was reduced from the raw data and used in conjunction with the crash and near-crash data identified as part of the original 100-Car Study to account for exposure and establish near-crash/crash risk. The analyses presented in this report are able to establish direct relationships between driving behavior and crash and near-crash involvement. Risk was calculated (odds ratios) using both crash and near-crash data as well as normal baseline driving data for various sources of inattention. The corresponding population attributable risk percentages were also calculated to estimate the percentage of crashes and near-crashes occurring in the population resulting from inattention. Additional analyses involved: driver willingness to engage in distracting tasks or driving while drowsy; analyses with survey and test battery responses; and the impact of driver's eyes being off of the forward roadway. The results indicated that driving while drowsy results in a four- to six-times higher near-crash/crash risk relative to alert drivers. Drivers engaging in visually and/or manually complex tasks have a three-times higher near-crash/crash risk than drivers who are attentive. There are specific environmental conditions in which engaging in secondary tasks or driving while drowsy is more dangerous, including intersections, wet roadways, and areas of high traffic density. Short, brief glances away from the forward roadway for the purpose of scanning the driving environment are safe and actually decrease near-crash/crash risk. Even in the cases of secondary task engagement, if the task is simple and requires a single short glance, the risk is elevated only slightly, if at all. However, glances totaling more than 2 seconds for any purpose increase near-crash/crash risk by at least two times that of normal, baseline driving.

Driving Performance in the Presence and Absence of Billboards, Suzanne E. Lee, Erik C.B. Olsen, Maryanne C. DeHart, Virginia Polytechnic Institute and State University, February 29, 2004.
Citation at http://trid.trb.org/view/2004/M/811075
From the abstract: The current project was undertaken to determine whether there is any change in driving behavior in the presence or absence of billboards. Several measures of eyeglance location were used as primary measures of driver visual performance. Additional measures were included to provide further insight into driving performance—these included speed variation and lane deviation. The overall conclusion from this study is that there is no measurable evidence that billboards cause changes in driver

behavior, in terms of visual behavior, speed maintenance, and lane keeping. A rigorous examination of individual billboards that could be considered to be the most visually attention-getting demonstrated no measurable relationship between glance location and billboard location. Driving performance measures in the presence of these specific billboards generally showed less speed variation and lane deviation. Thus, even in the presence of the most visually attention-getting billboards, neither visual performance nor driving performance changes measurably. Participants in this study drove a vehicle equipped with cameras in order to capture the forward view and two views of the driver's face and eyes. The vehicle was also equipped with a data collection system that would capture vehicle information such as speed, lane deviation, GPS location, and other measures of driving performance. Thirty-six drivers participated in the study, driving a 35-mile loop route in Charlotte, North Carolina. A total of 30 billboard sites along the route were selected, along with six comparison sites and six baseline sites. Several measures were used to examine driving performance during the 7-seconds preceding the billboard or other type of site. These included measures of driver visual performance (forward, left, and right glances) and measures of driving performance (lane deviation and speed variation). With 36 participants and 42 sites, there were 1,512 events available for analysis. A small amount of data was lost due to sensor outages, sun angle, and lane changes, leaving 1,481 events for eyeglance analysis and 1,394 events for speed and lane position analysis. Altogether, 103,670 video frames were analyzed and 10,895 glances were identified. There were 97,580 data points in the speed and lane position data set. The visual performance results indicate that billboards do not differ measurably from comparison sites such as logo boards, on-premises advertisements, and other roadside items. No measurable differences were found for visual behavior in terms of side of road, age, or familiarity, while there was one difference for gender. Not surprisingly, there were significant differences for road type, with surface streets showing a more active glance pattern than interstates. There were also no measurable differences in speed variability or lane deviation in the presence of billboards as compared to baseline or comparison sites. An analysis of specific, high attention-getting billboards showed that some sites show a more active glance pattern than other sites, but the glance locations did not necessarily correspond to the side of the road where the billboards were situated. The active glance patterns are probably due more to the road type than to the billboard itself. One major finding was that significantly more time was spent with the eyes looking forward (eyes on road) for billboard and comparison sites as compared to baseline sites, providing a clue that billboards may actually improve driver visual behavior. Taken as a whole, these analyses support the overall conclusion that driving performance does not change measurably in the presence or absence of billboards.

Effects of Roadside Advertisements on Road Safety, Finnish Road Administration, 2004.
http://alk.tiehallinto.fi/julkaisut/pdf/4000423e-veffectsofroadside.pdf
From the abstract: The effects of roadside advertisements on road safety have been studied using various methods. The topic was studied in Finland especially in the 1970s and 1980s. The results of those studies can be summarised thusly:

- In general, the number of accidents occurring near roadside advertisements has not been observed to be higher than at reference sites.
- The negative effects of advertisements are, however, visible in accident statistics if they are focused on limited conditions (junctions).
- The effects of advertisements are apparent in driver behaviour, but the effects measured in normal traffic are small.
- Advertisements along main roads distract the detection of traffic signs and possibly also other objects relevant to the driver's task.

"Observed Driver Glance Behavior at Roadside Advertising Signs," *Transportation Research Record 1899*, 2004: 96-103.
Citation at http://trid.trb.org/view/2004/C/749677
From the abstract: This study focused on the glance behavior of 25 drivers at various advertising signs along an expressway in Toronto, Ontario, Canada. The average duration of the glances for the subjects was 0.57 s [standard deviation (SD) = 0.41], and in total there was an average of 35.6 glances per subject (SD = 26.4). Active signs that contained movable displays or components made up 51% of the signs and received significantly more glances (69% of all glances and 78% of long glances). The number of glances was significantly lower for passive signs (0.64 glances per subject per sign) than for active signs (greater than 1.31 glances per subject per sign). The number of long glances was also greater for active signs than for passive signs. Sign placement in the visual field may be critical to a sign being noticed or not. Empirical information is provided to assist regulatory agencies in setting policy on commercial signing.

Wachtel notes:

> The implication for digital signs is that the shorter the period of time for which a given message is presented, and thus the more likely it is that a given approaching driver will see one or more message changes, the more likely it is that a driver will glance at such a sign for a longer period in anticipation of the next message to be displayed. Further, digital billboards display some characteristics of both fixed, traditional billboards and the types of active signs examined here. For example, a digital billboard may display a fixed image to any particular approaching driver, but depending upon its message cycle time, a driver may see one or more different displays. In this way, it is not unlike the roller signs discussed in this study, and, depending upon the display duration and change interval, digital signs may attract the same kind of attention expressed by some of the respondents in this study. Finally, a digital billboard is likely to possess image brightness, color, contrast, and image fidelity far higher than that achieved by any of the four sign types examined by the authors in this study. While the implications of these technological advances suggest that digital billboards would be more effective at capturing attention, this remains an empirical question.

"Driver Distraction by Advertising: Genuine Risk or Urban Myth?" Brendan Wallace, *Proceedings of the Institution of Civil Engineers*, *Municipal Engineer*, Vol. 156, Issue 3, September 2003: 185-190.
Citation at http://trid.trb.org/view/2003/C/688088
From the 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 overcomplex 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.

Wachtel summarizes the major conclusions as follows:

- The adverse effect of billboards is real, but situation specific.
- Too much visual clutter at or near intersections can interfere with drivers' visual search and lead to accidents.
- It is "probable" that isolated, illuminated billboards in an otherwise boring section of highway can create distraction through phototaxis.

Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction, Federal Highway Administration, September 11, 2001.
http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf
This report reviews the literature on electronic billboards (with a focus on implications for safety) from 1980 to 2001. Based on the literature review, it identifies knowledge gaps and potential research questions categorized by roadway characteristics such as curves, interchanges and work zones; electronic billboard characteristics such as exposure time, motion and legibility; and driver characteristics such as familiarity and age. Related research findings on the legibility of changeable message signs are also included.

Wachtel gives the following overview of the report's conclusions:

> A number of the conclusions reached, while highly relevant, might be seen even more strongly in light of the observations made by other researchers. For example, the authors appropriately suggest that there may be lessons from studies into the legibility and conspicuity of official changeable message signs that could be applied to [digital billboards (DBBs)]. They further discuss the fact that low levels of illumination on official signs could lead to reduced conspicuity and, hence, reduced legibility. This difficulty might be exacerbated because DBBs typically have very high luminance levels, often leading to complaints by the traveling public as well as regulators. These high luminance levels may increase the conspicuity of the DBBs at the expense of official signs. Similarly, the authors discuss differences in response to signs by familiar vs. unfamiliar drivers, since it is understood that motorists who pass the same signs regularly become acclimated to their presence and may ignore them. Of course, one of the defining characteristics of DBBs is their ability to display a new message every few seconds, thus, in effect, presenting displays that are always new and therefore unfamiliar to all drivers.

The report also gives an overview of state regulations and practices as of 2001 (pages 5-9 and Appendices B and C) of 42 states:

- Thirty-six states had prohibitions on signs with red, flashing, intermittent or moving lights.
- Twenty-nine states prohibited signs that were so illuminated as to obscure or interfere with traffic control devices.
- Twenty-nine states prohibited signs located on Interstate or primary highway outside of the zoning authority of incorporated cities within 500 feet of an interchange or intersection at grade or safety roadside area.

"An Evaluation of the Influence of Roadside Advertising on Road Safety in the Greater Montreal Region," J. Bergeron, *Proceedings of the 1997 Conference of the Northeast Association of State Transportation Officials*, 1997: 527.
Citation at http://trid.trb.org/view/1997/C/539081
Wachtel summarizes this report's conclusions as follows:

- Attentional resources needed for the driving task are diverted by the irrelevant information presented on advertising signs. This is an impact attributable to the "nature of the information" that is conveyed on such signs. This distraction leads to degradation in oculomotor performance that adversely affects reaction time and vehicle control capability.
- When the driving task imposes substantial attentional demands such as might occur on a heavily traveled, high speed urban freeway, billboards can create an attentional overload that can have an impact on micro- and macro-performance requirements of the driving task. In other words, the impact of the distraction varies according to the complexity of the driving task. The greater the driving task demands, the more obvious are the adverse effects of the distraction on driving performance.
- The difficulty of the driving task can vary in several ways. Those that relate to the physical environment (e.g., weather, roadway geometry, road conditions) are unavoidable, and drivers must adjust to them (unless they take an alternate route or wait for better conditions). Necessary

sensory information adds to the workload of the driving task, but is, of course, needed to perform safely. In addition, road signs and signals that communicate complex but necessary information contribute to the overall workload of driving. In this case, however, years of study have been directed toward making this information as clear and as easily accessible as possible.

- To some extent, the level of mental workload that impacts driving occurs at a pre-processing level. Bergeron cites, as an example, a complex or cluttered visual environment. In this case, the attentional effort that drivers expend in searching for target objects (e.g., signs and signals) will be more laborious, demand more resources, and lead to declines in performance levels.
- The presence of a billboard increases the confusion of the visual (back)ground and may lead to conflict with road signs and signals.
- Situational factors that are likely to create a heavy mental workload include: complex geometry, heavy traffic, high speeds, areas of merging and diverging traffic, areas with road signs where drivers must make decisions, roadways in poor repair, areas of reduced visibility, and adverse weather conditions.
- The very characteristics of billboards that their designers employ to enable them to draw attention are those that have the greatest impact on what Bergeron calls attentional diversion.
- Drivers must constantly carry out the work of recognizing stimuli that may not be immediately meaningful to them. This task requires time and mental resources, both of which are in limited supply.
- Attention directs perception, and vice versa. In other words, when we are looking for something, our sensory system places itself at the service of our attention. But it is also possible for a sensation to attract the attention of drivers because it may represent something that is of potential importance. For example, authorities put flashing lights on emergency vehicles because they want drivers to attend to them.

Review of Roadside Advertising Signs, Transportation Environment Consultants, Roads and Traffic Authority, August 1989.
Citation at http://trid.trb.org/view.aspx?id=350317
From the abstract: Some of the main findings are: 1) The review study did not identify any factor or experience which would substantiate, on safety grounds, the long standing policy of prohibiting the erection of advertising signs within the road reserves of declared roads, including freeways. In fact, the literature survey, embracing over 40 publications including a comprehensive safety survey as recently as 1985, did not identify any evidence to say that, in general, advertising signs are causing traffic accidents. 2) Human factors research confirms the principle of the limited processor capacity of the driver. Management of stimuli to the driver, both inherent to the driving task and from external (distractions) sources, requires scrutiny as driving performance deteriorates when high levels of attention and decision making are involved. 3) Motorists information needs systems comprise a 'navigational' and a 'services information' component. There is a strong correlation between these needs and the adequacy of display of such information by traditional forms of advertising. 4) Changing values of aesthetics and amenity have resulted from community concerns with the disorder and clutter of traditional roadside advertising; 5) Subject to specified control conditions, advertising signs may be permitted within the road reserve of declared roads, including freeways. Desirably such signs should provide directional, tourist, services and locational information.

Wachtel summarizes the report's conclusions as follows:

- Research confirms the limited processor capacity of a driver.
- It is important that management of stimuli to the driver, both inherent to the primary task of driving and external to it (distraction) must clearly aim not to exceed the optimum rate for safe and efficient driver performance.
- When these external stimuli fall significantly below optimum, driver performance may decrease (boredom), and additional external stimuli could benefit driver response.

- Additional attentional loading by advertising signs may impair driving performance when high levels of attention and decision making are required.
- Advertisements not associated with navigational and services information needs can, subject to relevant safety controls, be permitted at roadside locations where the driving task does not heavily load the attentional capacity of the driver.

Interestingly, they reported from their interview with a Dr. S. Jenkins of the ARRB, his recommendation that "changeable message signs could be used in roadside advertisements providing each message is 'static for about 5 minutes' (i.e., the message on-time) and the changeover period between messages 'does not exceed about 2 seconds'" (p. 39).

In a later chapter of the report, the authors provide a series of "definitions and technology" (p. 49) to describe the different types of advertising signs that might be considered, and how they might be used. In a section on "internally illuminated signs" the authors provide a table showing what they consider to be the maximum luminance levels of advertising signs of different sizes which may be located in different driving environments. These data are based on recommendations from the Public Lighting Engineers in the U.K. With regard to "electronic variable-message signs" the authors devote several pages to defining terminology and identifying "factors" that should be taken into account when considering their impact (pp. 56-60). This discussion is taken directly from the Wachtel and Netherton (1980) report (pp. 68-74), and need not be repeated here.

Literature on Outdoor Advertising Safety Since the 2009 Wachtel Report

"Advertising Billboards Impair Change Detection in Road Scenes," J. Edquist, T. Horberry, S. Hosking, I. Johnston, *Proceedings of the Australasian Road Safety Research, Policing and Education Conference*, November 6-9, 2011.
http://casr.adelaide.edu.au/rsr/RSR2011/4CPaper%20166%20Edquist.pdf
From the abstract: The present experiment used the 'change detection' paradigm to examine how billboards affect visual search and situation awareness in road scenes. In a controlled experiment, inexperienced, older, and comparison drivers searched for changes to road signs and vehicle locations in static photographs of road scenes. On average, participants took longer to detect changes in road scenes that contained advertising billboards. This finding was especially true when the roadway background was more cluttered, when the change was to a road sign, and for older drivers. The results are consistent with the small yet growing body of evidence suggesting that roadside advertising billboards impair aspects of driving performance such as visual search and the detection of hazards, and therefore should be more precisely regulated in order to ensure a safe road system.

"Are Roadside Electronic Static Displays a Threat to Safety?" Rena Friswell, Elia Vecellio, Raphael Grzebieta, Julie Hatfield, Lori Mooren, Murray Cleaver, Michael De Roos, *Proceedings of the Australasian Road Safety Research, Policing and Education Conference*, November 6-9, 2011.
http://casr.adelaide.edu.au/rsr/RSR2011/4CPaper%20172%20Friswell.pdf
This study reviews the literature from 2001 to 2010 on the effects of electronic static displays (ESDs) on driver distraction, driving performance and safety, and discusses the implications of the findings for research and policy. Researchers found only 11 studies that bear directly on ESDs, and created two tables summarizing them (pages 5-8). Over half of the studies were conducted by Tantala and Tantala and were commissioned by the U.S. Outdoor Advertising Association of America, and most examined crash data before and after installation of ESDs. Five of the eight crash data studies reported no adverse effect of ESD installation on crashes, but both of the studies that compared post-installation crashes with the rates predicted by the trend in pre-installation crashes found statistically significant evidence of increased crashes following installation. Studies using measures other than crashes reported mixed findings. Gaze was directed toward the sign stimuli in the simulator and on-road studies, dual task reaction time was slowed in the presence of the sign stimuli in the laboratory experiment, and lane keeping was impaired in

the simulator study but reductions in lane keeping only approached significance on-road and there was no evidence of speed disruption on-road. Researchers conclude that while the research designs for these studies are weak, there does seem to be evidence that ESDs can have a negative impact on attention, driving performance and safety.

Outdoor Advertising Control Practices in Australia, Europe, and Japan, Federal Highway Administration, May 2011.
http://ntl.bts.gov/lib/42000/42200/42240/FHWA-PL-11-023.pdf
This study scanned practices in Australia, Sweden, the Netherlands and the United Kingdom to learn how they regulate outdoor advertising both inside and outside the roadway right of way, and also includes a desk scan of outdoor advertising practices in Japan.

General similarities between practices in the countries visited and those of the United States include (pages 1-2):

- Inconsistent enforcement and mixed success in developing more objective criteria for decision makers.
- Interest in growing commercial advertising in transportation corridors.
- Interest in generating revenue inside the right of way and removing some of the restrictions to commercial use of the right of way.
- Common interest in regulating new technologies to minimize driver distraction, such as use of and rules to govern commercial electronic variable message signs (CEVMS). The major focus is reducing crashes and fatalities.
- Prohibitions of signs that resemble official signs.
- Interest in reliable research on the safety impacts of outdoor advertising and CEVMS.

Differences (from pages 2-3 of the report) include:

- Where outdoor advertising is allowed in the countries visited, state and federal responsibility is limited to high-level and national routes.
- For permitting purposes, on-premise and off-premise signs are regulated.
- The national/federal government has a lesser role in the state's administration and program compliance.
- Sign businesses, site owners, and sign owners can incur penalties for noncompliance.
- Agencies in the countries visited rely more on safety factors and the relationship between the sign and the road environment for permitting decisions than agencies in the United States.
- Agencies have some control over message formatting, such as specifying font size and prohibiting phone numbers and e-mail addresses, to reduce driver distraction and reading time.
- Local planning authorities had more regulatory involvement in and control of sign permits in all countries visited because all areas were under some control, designation, or zoning. There were few unzoned areas because of more rigorous, comprehensive local planning and land use management.
- Use of the right- of- way for commercial billboards is limited, but more prevalent in locally controlled urban jurisdictions. One Australian state generated AU$15 million with advertising inside the right- of- way, but most countries visited are waiting until more conclusive research is done on driver distraction. Sweden is beginning a pilot.
- Signs may be removed after permitted if safety is a concern.
- In all of the countries visited, traffic and public safety play a more critical role in the permitting process than in the United States.
- All of the countries have developed criteria to identify unacceptable signs, such as those that resemble traffic control devices, could direct traffic, or could distract or confuse drivers.
- The safety evaluation process is more comprehensive, both in the documentation and burden of proof applicants must provide that a sign will not create a safety hazard and the review process after an application is submitted.

Based on this scan, researchers suggest the following steps to enhance safety (from page 4 of the report):

- Develop criteria to evaluate permit applications to identify signs that are unacceptable from a safety perspective because they resemble traffic control devices or could distract or confuse drivers.
- Update the assessment criteria used to review permit applications to reflect design, planning, environmental, and public and traffic safety criteria used by several countries visited.
- Update permitting requirements to include an analysis of the technical feasibility, benefits, safety impacts, and other effects of a proposed outdoor advertising installation.
- Conduct research on the safety impacts of outdoor advertising, and possibly require applicants to conduct a safety analysis to demonstrate the design and safety feasibility of proposed installations. Assess whether existing traffic data from intelligent transportation systems or traffic control centers could be used to track traffic patterns and establish the potential impacts of commercial electronic variable message signs on traffic flow.
- Study the effects of full-motion video on driver attention.

"Effects of Advertising Billboards During Simulated Driving," Jessica Edquist, Tim Horberry, Simon Hosking, Ian Johnston *Applied Ergonomics*, Vol. 42, Issue 4, May 2011: 619-626.
Citation at http://trid.trb.org/view/2011/C/1100574
From the abstract: The driving simulator experiment presented here examines the effects of billboards on drivers, including older and inexperienced drivers who may be more vulnerable to distractions. The presence of billboards changed drivers' patterns of visual attention, increased the amount of time needed for drivers to respond to road signs, and increased the number of errors in this driving task.

"Digital Billboards, Distracted Drivers," Jerry Wachtel, *Planning*, Vol. 77, Issue 3, March 2011: 25-27.
Citation at http://trid.trb.org/view/2011/C/1106533
From the abstract: This article discusses the negative consequences of billboards, especially those that employ digital technology. … An industry study has shown that drivers take their eyes off the road for two seconds or longer twice as often when they are looking at digital advertising signs than when they are looking at traditional billboards. … The author has identified four factors that could reduce the distraction caused by digital billboards: control the lighting at nighttime; lengthen the dwell time of messages; simplify the message by limiting the number and types of words and symbols; and prohibit message sequencing (i.e., the digital equivalent of Burma Shave-type signs).

"External Distractions: The Effects of Video Billboards and Windfarms on Driving Performance," *Handbook of Driving Simulation for Engineering, Medicine and Psychology*, CRC Press, 2011: 16-1 – 16-14.
Citation at http://trid.trb.org/view/2011/C/1114742
This study used a driving simulator to study driver reactions to the braking of a lead vehicle in the presence of wind turbines and digital video billboard. While perception response time was not affected by the presence of wind turbines, significantly more rear-end collisions occurred to the hard lead-vehicle braking event in the presence of video billboards than conventional billboard and control conditions.

***"An Examination of the Relationship between Digital Billboards and Traffic Safety in Reading, Pennsylvania, Using Empirical Bayes Analyses,"** *Moving Toward Zero: 2011 ITE Technical Conference and Exhibit*, sponsored by the Institute of Transportation Engineers, 2011.
Citation at http://trid.trb.org/view/2011/C/1103869
From the abstract: This paper examines the statistical relationship between advertising digital billboards and traffic safety using Empirical Bayes Method analyses. Specifically, this paper analyzes traffic and accident data near 26 existing, non-accessory, advertising digital billboards along routes with periods of comparison as long as 8 years in the greater Reading area, Berks County, Pennsylvania. These studied digital billboards are one type of commercial electronic variable message signs (CEVMS) which display

static messages, include no animation, flashing lights, scrolling, or full-motion video, and have duration times of 6, 8, or 10 seconds. Temporal (when and how frequently) and spatial (where and how far) statistics are summarized within multiple vicinity ranges as large as one mile near billboards. The study uses the Empirical Bayes (EB) method to predict the "expected" range of accidents at locations assuming that no digital billboard technology was introduced. The method analyzes data near 26 billboard locations, incorporates data using 51 non-digital comparison sites, and establishes a multivariate Crash Estimation Model (CEM) with a negative binomial distribution to estimate expected numbers of crashes near locations. Predictive methods in the AASHTO Highway Safety Manual are used with the Pennsylvania Department of Transportation (PennDOT) highway, geometric, and crash data.

Investigating Driver Distraction: The Effects of Video and Static Advertising, TRL Published Project Report, Transport Research Laboratory, 2010.
Citation at http://trid.trb.org/view/2010/M/919620
From the abstract: Roadside advertising is a common sight on urban roads. Previous research suggests the presence of advertising increases mental workload and changes the profile of eye fixations, drawing attention away from the driving task. This study was conducted using a driving simulator and integrated eye-tracking system to compare driving behaviour across a number of experimental advertising conditions. Forty eight participants took part in this trial, with three factors examined; Advert type, position of adverts and exposure duration to adverts. The results indicated that when passing advert positions, drivers: spent longer looking at video adverts; glanced at video adverts more frequently; tended to show greater variation in lateral lane position with video adverts; braked harder on approach to video adverts; drove more slowly past video adverts. The findings indicate that video adverts caused significantly greater impairment to driving performance when compared to static adverts. Questionnaire results support the findings of the data recorded in the driving simulator, with participants being aware their driving was more impaired by the presence of video adverts. Through analysis of the experimental data, this study has provided the most detailed insight yet into the effects of roadside billboard advertising on driver behaviour.

***"Quantifying External Vehicle Distractions and Their Impacts at Signalized Intersections,"**
Raheem Dilgir, Cory Wilson, *ITE 2010 Annual Meeting and Exhibit*, sponsored by the Institute of Transportation Engineers, 2010.
http://www.ite.org/annualmeeting/compendium10/pdf/AB10H3702.pdf
This study investigated the safety impacts of visual distractions for vehicles at 28 signalized intersections in greater Vancouver, British Columbia, and Calgary, Alberta. Site visits were conducted to assess each intersection, and three years of collision data and traffic volumes were provided by road agencies. The results indicated a positive relationship between distraction score and collision rate as well as between distraction score and collision frequency. Analysis of individual distraction criteria revealed that the strongest correlation exists between roadside advertising and safety. No other specific element was significantly more influential than another regarding safety performance, suggesting that the combined effect of various distraction features is correlated to safety performance.

The Impact of Sacramento State's Electronic Billboard on Traffic and Safety, Mahesh Pandey, California State University, Sacramento, Summer 2010.
http://csus-dspace.calstate.edu/bitstream/handle/10211.9/282/Project%20Report10a.pdf?sequence=1
This student project evaluated the traffic and safety impact of a new electronic billboard near Sacramento State adjacent to Highway 50 by analyzing traffic flow parameters on upstream portions of electronic billboards on both directions of the highway before and after the installation. Data came from the California Freeway Performance Measurement System (PeMS) database for changes in common traffic flow parameters (speed, flow rate and lane occupancy) over a two-month period before and after the installation of the electronic billboard. This project also analyzed crash and collision data from PeMS for changes in noninjury, injury and fatal crashes over a one-year period before and a one-year period after the installation of the electronic billboard.

Results showed that the presence of the electronic billboard near Sacramento State does not appear to have a significant negative impact in traffic performance (flow, speed and lane occupancy) or incidents in the study section of the freeway. Because many of the road users at this segment are probably commuters, they may be familiar with the electronic billboard, and it does not appear to affect their driving. Even though electronic billboards are capable of displaying multiple messages/commercials at different times, the advertisements do not appear to be a major distraction to drivers at this location. No changes in measurable impact on road safety after the installation of the electronic billboard were observed. At the same time, a public opinion survey indicated that more than two-thirds of self-identified drivers through the study area who were surveyed believed that this electronic billboard does not pose a safety risk to traffic.

"Conflicts of Interest: The Implications of Roadside Advertising for Driver Attention," *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 12, Issue 5, September 2009: 381-388.
Citation at http://trid.trb.org/view/2009/C/902985
From the abstract: There is growing concern that roadside advertising presents a real risk to driving safety, with conservative estimates putting external distractors responsible for up to 10% of all road traffic accidents. In this report, we present a simulator study quantifying the effects of billboards on driver attention, mental workload and performance in urban, motorway and rural environments. The results demonstrate that roadside advertising has clear adverse effects on lateral control and driver attention, in terms of mental workload. Whilst the methodological limitations of the study are acknowledged, the overriding conclusion is that prudence should be exercised when authorizing or placing roadside advertising. The findings are discussed with respect to governmental policy and guidelines.

Digital Billboard Safety Amongst Motorists in Los Angeles, Steven Clark Henson, California State University Northridge, Spring 2009.
http://www.csun.edu/~sch60990/Geog_490_PAPER.pdf
The paper discusses the impact of digital billboards and driver safety in Los Angeles via a review of literature, driver behavior surveys and a spatial analysis of high traffic collision intersections and digital billboard locations. Of 76 intersections with digital billboards, only three (4 percent) were hazardous intersections (as defined by The 2008 California 5 Percent Report and driver surveys). However, 80 percent of drivers surveyed said they were more likely to glance at a digital billboard as opposed to a standard billboard, 42.8 percent said that digital billboards inhibited the ability of motorists to concentrate on the road, and all but two respondents said their glances are longer than two seconds.

Luminance Criteria and Other Human Factors for Sign Design

In the following studies, "luminance" refers to luminous intensity per unity area, measured in candela per square meter (cd/m^2, or "nit"). Luminance differs from brightness, which measures the subjective perception caused by an object's luminance, and can differ in various contexts for an object of the same luminance.

"Congruent Visual Information Improves Traffic Signage," *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 15, Issue 4, 2012: 438-444.
Abstract at: http://trid.trb.org/view/2012/C/1141270
From the abstract: This study investigated the interference effect produced by the position of the sign elements in traffic signage on response accuracy and reaction time. Sixteen drivers performed a flanker interference reaction time task. Incongruent graphical/space solutions, actually used for the airport stack-type sign, [led] to increased reaction time and a reduction in the proportion of correct answers. These results suggest that incongruent visual information should be avoided, as this might impair drivers' performance. These findings provide important information for the specification of future signage design guidelines and for improving road safety.

"A Study on Guide Sign Validity in Driving Simulator," Wei Zhonghua, Gong Ming, Guo Ruili, Rong Jian, *Transportation Research Board 91st Annual Meeting Compendium of Papers DVD*, Paper #12-1983, sponsored by Transportation Research Board, 2012.
Citation at http://trid.trb.org/view/2012/C/1129560
This project used a driving simulator to study guide sign legibility distance. Results indicated that legibility distance was inversely related to speed and positively related to the text height of the guide sign. When the speed is 20km/h, 30km/h or 40km/h, the magnifying power of text height is 4.3, 4.1 or 3.8, respectively.

"Luminance Criteria and Measurement Considerations for Light-Emitting Diode Billboards," John Bullough, Nicholas Skinner, *Transportation Research Board 90th Annual Meeting Compendium of Papers DVD*, Paper #11-0659, sponsored by Transportation Research Board, 2011.
ftp://ftp.hsrc.unc.edu/pub/TRB2011/data/papers/11-0659.pdf
From the abstract: The present paper summarizes luminance measurements and calculations for advertising billboard signs located adjacent to highways. The primary purpose of the present information is to provide preliminary estimates of conventional externally-illuminated billboard panel luminances in the driving environment. These estimates could form a partial basis for maximum luminance requirements for electronic billboards adjacent to highways using self-luminous light sources such as light-emitting diodes. Also discussed are considerations when making luminance measurements of billboard signs in the field.

Table 1 on page 3 has a summary of luminance measurements:

TABLE 1 Summary of Billboard Sign Characteristics and Luminance Measurements

Sign location, type and color	Direction of travel facing sign	Distance of sign from roadway edge (ft)	Measurement location (and distance)	Daytime luminance (cd/m²)	Nighttime luminance (cd/m²)
I-787 conventional (white)	northbound	125 (from southbound side)	I-787 southbound (n/a)	23,100	not measured
I-787 conventional	southbound	280	Erie Boulevard (340 ft away)	1230	4
I-90 conventional (beige)	westbound	70	Erie Boulevard (70 ft away)	2880	160
I-90 conventional (purple)	westbound	25 (from eastbound side)	Erie Boulevard (70 ft away)	540	8
I-90 conventional (white)	westbound	60	Anderson Drive (310 ft away)	3300	180
I-90 conventional (white)	eastbound	180	Watervliet Avenue (80 ft away)	13,100	240
I-90 conventional (yellow)	eastbound	75	Westgate Plaza (150 ft away)	3950	150
I-90 LED (yellow)	westbound	75	Anderson Drive (290 ft away)	3810	200
			I-90 westbound (n/a)	not measured	160
I-90 LED (light green)	eastbound	75 (from westbound side)	Anderson Drive (300 ft away)	4170	320
			I-90 eastbound (n/a)	not measured	220

Digital LED Billboard Luminance Recommendations: How Bright is Bright Enough? Christian B. Luginbuhl, Howard Israel, Paul Scowen, Jennifer and Tom Polakis, Arizona State University, November 9, 2010.
http://www.illinoislighting.org/resources/DigitalBillboardLuminanceRecommendation_ver7.pdf
From the abstract: Careful and sensible control of the nighttime brightness of digital LED signage is critical. Unlike previous technologies, these signs are designed to produce brightness levels that are visible during the daytime; should too large a fraction of this brightness be used at night serious consequences for driver visibility and safety are possible. A review of the lighting professional literature indicates that drivers should be subjected to brightness levels of no greater than 10 to 40 times the

brightness level to which their eyes are adapted for the critical driving task. As roadway lighting and automobile headlights provide lighting levels of about one nit, this implies signage should appear no brighter than about 40 nits. Standard industry practice with previous technologies for floodlit billboards averages less than 60 nits, and rarely exceeds 100 nits. It is recommended that the new technologies should not exceed 100 nits.

"Effect of Luminance and Text Size on Information Acquisition Time from Traffic Signs (With Discussion and Closure)," *Transportation Research Record 2122*, 2009: 52-62.
Citation at http://trid.trb.org/view/2009/C/881884
From the abstract: This study investigated the effect of (legend) luminance and letter size on the information acquisition time and transfer accuracy from simulated traffic signs. Luminances ranged from 3.2 cd/m² to 80 cd/m² on positive-contrast textual traffic sign stimuli with contrast ratios of 6:1 and 10:1, positioned at 33 ft/in. and 40 ft/in. legibility indices, and viewed under conditions simulating a nighttime driving environment. The findings suggest that increasing the sign luminance significantly reduces the time to acquire information. Similarly, increasing the sign size (or reducing the legibility index) also reduces the information acquisition time. These findings suggest that larger and brighter signs are more efficient in transferring their message to the driver by reducing information acquisition time, or alternatively, by increasing the transfer accuracy. In return, reduced sign viewing durations and increased reading accuracy are likely to improve roadway safety.

Note: the "legibility index" is:

> ... a numerical value representing the distance in feet at which a sign may be read for every inch of capital letter height. For example, a sign with a Legibility Index of 30 means that it should be legible at 30 feet with one inch capital letters, or legible at 300 feet with ten inch capital letters. (See http://www.usscfoundation.org/USSCSignLegiRulesThumb.pdf)

Driver Comprehension of Diagrammatic Freeway Guide Signs, Susan T. Chrysler, Alicia A. Williams, Dillon S. Funkhouser, Andrew J. Holick, Marcus A. Brewer, Texas Transportation Institute, February 2007.
http://tti.tamu.edu/documents/0-5147-1.pdf
From the abstract: This report contains the results of a three-phase human factors study which tested driver comprehension of diagrammatic freeway guide signs and their text alternatives. Four different interchange types were tested: left optional exit, left lane drop, freeway to freeway split with optional center lane, and two lane right exits with optional lanes. Three phases of the project tested comprehension by using digitally edited photographs of advance guide signs in freeway scenes. Participants viewed a computer slideshow in which slides were shown for only three seconds to simulate a single driver eye glance at a sign. All signs were mounted overhead in the photographs. Participants were provided a route number and city name as a destination that could be reached either by the through route or the exit route. They indicated which lane or lanes they would choose to reach the given destination. The fourth phase of the study used a fixed-base driving simulator which presented full sign sequences consisting of two advance guides and one exit direction sign. Performance measures were distance from the gore at which required lane changes were made and number of unnecessary lane changes made. Results showed that for the left exits the standard text-only signs performed equal to or better than the diagrammatic signs. This performance was true for left lane drops also. For the right exit with optional lane, the standard text signs did well, as did the diagrammatic signs. For freeway-to-freeway splits, standard text signs with two arrows over the optional lane performed better than either style of diagrammatic sign. This report also contains an extensive literature review of previous work in the area, a discussion of testing methodology, and suggestions for future research.

Enhancing Driving Safety through Proper Message Design on Variable Message Signs, Jyh-Hone Wang, Charles E. Collyer, Chun-Ming Yang, University of Rhode Island, Kingston, September 2005. Citation at http://trid.trb.org/view/2005/M/793262

From the abstract: This report presents a study that assessed drivers' responses to and comprehension of variable message sign (VMS) messages displayed in different ways with the intent to help enhance message display on VMSs. Firstly, a review of literatures and current practices regarding the design and display of VMS messages is presented. Secondly, the study incorporates three approaches in the assessment. Questionnaire surveys were designed to investigate the preferences of highway drivers in regards to six message display settings, they were: number of message frames, flashing effect, color, color combinations, wording, and use of abbreviations. Lab experiments were developed to assess drivers' responses to a variety of VMS messages in a simulated driving environment. Two groups of factors, within-subject and between-subject factors, were considered in the design of experiment. Within-subject factors included message flashing and color combination. Between-subject factors were age and gender. To help validate results found from lab experiments, field studies were set up to study drivers' response to VMS in real driving environment. Thirty-six subjects, from three age populations (20-40, 40-60, above 60 years old) with balanced genders, were recruited to participate in both questionnaire surveys and lab experiments while eighteen of them participated in field studies on a voluntarily basis. The study findings suggest a specific set of VMS features that might help traffic engineers and highway management design VMS signs that could be noticed, understood and responded to in a more timely fashion. Safer and more proactive driving experiences could be achieved by adopting these suggested VMS features.

State Regulations

State and Local Regulation Summaries

State Changeable Message Chart, Outdoor Advertising Association of America, undated. http://www.superliciousdesign.com/ledmedia/State_Changeable_Message.pdf (or see Appendix A). This chart summarizes changeable message advertising sign regulations for 46 states:

- Three states (New Hampshire, North Dakota and Wyoming) do not allow these signs.
- Five states (Maryland, Massachusetts, Oregon, Texas and Washington) allow tri-action signs only.
- Thirty-eight states allow changeable message signs. Of these, 19 states (California, Colorado, Connecticut, Delaware, Florida, Georgia, Indiana, Kansas, Michigan, Minnesota, Missouri, New Jersey, New York, Ohio, Oklahoma, Tennessee, Utah, Virginia and Wisconsin) have statutes; 10 states (Arkansas, Idaho, Illinois, Iowa, Louisiana, Nebraska, Nevada, North Carolina, South Carolina and West Virginia) have regulations; seven states (Alaska, Arizona, Kentucky, Montana, New Mexico, Rhode Island and South Dakota) have interpretations of the federal/state agreement; and two states (Mississippi and Pennsylvania) have policy memoranda.

The document categorizes each of these states by regulations for minimum message duration ("dwell time"—generally from 4 to 10 seconds, with 6 or 8 seconds most common); maximum interval between messages (typically from 1 to 4 seconds), and spacing (500 feet is most common). It is unclear how up-to-date these regulations are; we were unable to determine the date for this chart or obtain the latest information from the OAAA, which requires paid registration for access.

The Regulation of Signage: Guidelines for Local Regulation of Digital On-Premise Signs, Menelaos Triantafillou, Alan C. Weinstein, National Signage Research and Education Conference, 2010. http://www.thesignagefoundation.org/LinkClick.aspx?fileticket=3inv%2fFyrpFk%3d&tabid=59&mid=468
From the report: Based on a recent survey of numerous jurisdictions by one of the authors, the most common regulatory provisions applicable to digital on-premise signs appear below:

- Require that the sign display remain static for a minimum of 5-8 seconds and require "instantaneous" change of the display; i.e., no "fading" in/out of the message.
- Prohibit scrolling and animation outside of unique—and mostly pedestrian-oriented—locations.
- Limit brightness to 5,000 nits during daylight and 500 nits at night.
- Require automatic brightness control keyed to ambient light levels.
- Require display to go dark if there is a malfunction.
- Specify distancing requirements from areas zoned for residential use and/or prohibit orientation of s sign face towards an area zoned for residential use.

See also Appendices B and C in Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction in **Related Research** for an overview of state regulations and practices as of 2001.

Survey of Current State Regulations

We found digital display regulations for 12 states. These regulations are summarized in the following table and then detailed by state.

State	Duration ≥	Inter-val ≤	Brightness/ Illumination	Font Size	Visual Effects	Sequencing	Spacing	Locations	Billboard Size
DE	10s	1s	Must appropriately adjust display brightness as ambient light levels change.	Size not specified. A sign that attempts or appears to attempt to direct the movement of traffic or which contains wording, color, shapes, or likenesses of official traffic control devices is prohibited.	May not contain or display any lights, effects, or messages that flash, move, appear to be animated or to move, scroll, or change in intensity during the fixed display period	Prohibited.	>2,500ft from another VMS >500ft from a static sign	Permitted within 660ft of the edge of the right-of-way of any interstate or federal-aid primary highway. > 1,000ft from an interchange, interstate junction of merging or diverging traffic, or an at-grade intersection. May not be placed along designated Delaware byways.	Not specified.
FL	6s	2s	Lighting which causes glare or impairs the vision of the driver of any motor vehicle, or which otherwise interferes with any driver's operation of a motor vehicle is prohibited. A sign may not be illuminated so that it interferes with the effectiveness of, or obscures, an official traffic sign, signal or device. Lighting may not be added to or increased on a nonconforming sign.	Not specified.	Flashing, intermittent, rotating, or moving lights are prohibited. Instantaneous transition for entire sign face required.	Not specified.	Not specified.	Not specified.	Not specified.

State	Duration ≥	Inter-val ≤	Brightness/ Illumination	Font Size	Visual Effects	Sequencing	Spacing	Locations	Billboard Size
GA	10s	3s	Must be effectively shielded so as to prevent beams or rays of light from being directed at any portion of the traveled way, which beams or rays are of such intensity or brilliance as to cause glare or to impair the vision of the driver of any motor vehicle or which otherwise interfere with the operation of a motor vehicle. Must not obscure or interfere with the effectiveness of an official traffic sign, device, or signal.	Not specified.	May not contain flashing, intermittent, or moving light or lights except those giving public service information such as time, date, temperature, weather.	Not specified.	>5,000ft from another multiple message sign.	Not specified.	Not specified.
IA	8s	1s	The intensity of the illumination may not cause glare or impair the vision of the driver of any motor vehicle or otherwise interferes with any driver's operation of a motor vehicle.	Not specified.	No traveling messages (e.g., moving messages, animated messages, full-motion video, or scrolling text messages) or segmented messages are allowed.	No segmented messages allowed.	>500ft from another LED display facing the same way in cities. >1000ft in rural areas.	Not specified.	Not specified.
KS	8s	2s	Must be effectively shielded so as to prevent beams or rays of light from being directed at any portion	Not specified.	Cannot contain or display flashing, intermittent or moving lights, including	Not specified.	>1000ft from another CMS.	Not specified.	Not specified.

State	Duration ≥	Inter-val ≤	Brightness/ Illumination	Font Size	Visual Effects	Sequencing	Spacing	Locations	Billboard Size
			of the traveled way of any interstate or primary highway and are of such intensity or brilliance as to cause glare or to impair the vision of the driver of any motor vehicle or to otherwise interfere with any driver's operation of a motor vehicle. Must not be so illuminated that they obscure any official traffic sign, device or signal, or imitate or may be confused with any official traffic sign, device or signal.		animated or scrolling advertising.				
MA	10s	0s	Must automatically adjust the intensity of its display according to natural ambient light conditions. May not cause beams or rays of light from being directed at any portion of the traveled way, which beams or rays are of such intensity or brilliance as to cause glare or to impair the vision of the driver of any motor vehicle or otherwise interfere with the operation of a motor	Not specified.	May not contain flashing, intermittent, or moving lights; or display animated, moving video, scrolling advertising; or consist of a static image projected upon a stationary object. May not display illumination that moves, appears to move or changes in intensity during	Not specified.	>500ft from any sign. >2000ft from another off premise electronic sign on the same side of the highway. >1000ft from another off premise electronic sign on the opposite side of the	Not specified.	Not specified.

State	Duration ≥	Inter-val ≤	Brightness/ Illumination	Font Size	Visual Effects	Sequencing	Spacing	Locations	Billboard Size
			vehicle. May not obscure or interfere with the effectiveness of an official traffic sign, device or signal, or cause an undue distraction to the traveling public		the static display period. This does not include changes to a display for time, date and temperature.		highway.		
NY	6s	3s	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.
OH	8s	3s	Not specified.	Not specified.	A multiple message or variable message advertising device shall not be illuminated by flashing, intermittent, or moving lights. No multiple message or variable message advertising device may include any illumination which is flashing, intermittent, or moving when the sign face is in a fixed position.	Not specified.	>1000ft from another MMS.	Not specified.	Not specified.
OR	8s	2s	Must operate at an intensity level of not more than 0.3 foot-candles over ambient light as measured by the distance to the sign	Not specified.	No flashing or varying intensity light; cannot create the appearance of movement.	Not specified.	Not specified.	Not specified.	Not specified.

State	Duration ≥	Inter-val ≤	Brightness/ Illumination	Font Size	Visual Effects	Sequencing	Spacing	Locations	Billboard Size
			depending upon its size (150 feet if the display surface of the sign is 12 feet by 25 feet, 200 feet if the display surface is 10.5 by 36 feet, and 250 feet if the display surface is 14 by 48 feet).						
TN	8s	2s	Not specified.	Not specified.	Video, animation, and continuous scrolling messages are prohibited.	Not specified.	>2000ft from another CMS.	Not specified.	Not specified.
WS	A single message or a message segment must have a static display time of at least two seconds after moving onto the signboard, with all segments of the total message to be displayed within ten seconds.	4s	No electronic sign lamp may be illuminated to a degree of brightness that is greater than necessary for adequate visibility. In no case may the brightness exceed 8,000 nits or equivalent candelas during daylight hours, or 1,000 nits or equivalent candelas between dusk and dawn. Signs found to be too bright shall be adjusted as directed by the department.	Not specified.	Displays may travel horizontally or scroll vertically onto electronic signboards, but must hold in a static position for two seconds after completing the travel or scroll. Displays shall not appear to flash, undulate, or pulse, or portray explosions, fireworks, flashes of light, or blinking or chasing lights. Displays shall not appear to move toward or away from the viewer,	Not specified.	Not specified.	Not specified.	Not specified.

State	Duration ≥	Inter-val ≤	Brightness/ Illumination	Font Size	Visual Effects	Sequencing	Spacing	Locations	Billboard Size
	A one-segment message may remain static on the signboard with no duration limit.				expand or contract, bounce, rotate, spin, twist, or otherwise portray graphics or animation as it moves onto, is displayed on, or leaves the signboard.				
WI	6s	1s	No variable message sign lamp may be illuminated to a degree of brightness that is greater than necessary for adequate visibility.	Not specified.	No flashing, intermittent or moving light. Traveling messages prohibited.	Not specified.	Not specified.	Not specified.	Not specified.

Delaware

§ 1110. Delaware Byways Program, Chapter 11: Regulation of Outdoor Advertising, Title 17: Highways, Delaware Code, State of Delaware, 2012.
http://delcode.delaware.gov/title17/c011/sc01/index.shtml#1110
From the code:

(3) Lighting. -- Signs may be illuminated, subject to the following restrictions.

a. Signs which contain, include, or are illuminated by any flashing, intermittent, or moving light or lights are prohibited, except those giving public service information such as time, date, temperature, weather, or traffic conditions, or as defined in paragraph (3)e. of this section.

e. Notwithstanding the provisions of paragraphs (b)(3)a. through d. of this section, signs commonly known as variable message signs may be changed at intervals by electronic or mechanical process or remote control, and are permitted within 660 feet of the edge of the right-of-way of any interstate or federal-aid primary highway so designated as of June 1, 1991, and of the National Highway System. These variable message signs are permitted, except as prohibited by local ordinance or zoning regulation or by the Delaware federal-state outdoor advertising agreement of May 1, 1968, and are not considered to be in violation of flashing, intermittent, or moving lights criteria provided that:

1. Each message remains fixed for a minimum of at least 10 seconds.

2. When the message is changed, it must be accomplished in 1 second or less, with all moving parts or illumination changing simultaneously and in unison.

3. A variable message sign along the same roadway and facing in the same direction of travel may not be placed, as measured along the centerline of the roadway, within 2,500 feet of another variable message sign, or within 500 feet of a static billboard sign regulated by this section, or within 1,000 feet of an interchange, interstate junction of merging or diverging traffic, or an at-grade intersection.

4. A variable message sign must contain a default design that will freeze the sign in 1 position if a malfunction occurs or, in the alternative, that will shut down.

5. A variable message sign may not contain or display any lights, effects, or messages that flash, move, appear to be animated or to move, scroll, or change in intensity during the fixed display period. A variable message sign must appropriately adjust display brightness as ambient light levels change.

6. A sign that attempts or appears to attempt to direct the movement of traffic or which contains wording, color, shapes, or likenesses of official traffic control devices is prohibited.

7. A sign may not be placed along designated Delaware byways.

Florida

Outdoor Advertising Sign Regulation and Highway Beautification Program, Florida Administrative Weekly & Florida Administrative Code, Florida Department of Transportation, October 3, 2010.
https://www.flrules.org/gateway/chapterhome.asp?chapter=14-10
From the code:

14-10.004 Permit.

(3) Changeable messages – A permit shall be granted for an automatic changeable facing provided:
(a) The static display time for each message is at least six seconds;

(b) The time to completely change from one message to the next is a maximum of two seconds;
(c) The change of message occurs simultaneously for the entire sign face; and
(d) The application meets all other permitting requirements.
(e) All signs with changeable messages shall contain a default design that will ensure no flashing, intermittent message, or any other apparent movement is displayed should a malfunction occur.

Guide to Outdoor Advertising, Florida Department of Transportation, 2012.
http://www.dot.state.fl.us/rightofway/documents/GuidetoODA.pdf
From page 15 of the guide:

Multiple messages: Your sign may display multiple messages, provided you do not have more than two sign faces for each direction the sign is facing. Mechanically changeable and digital display panels are allowed on conforming signs, provided the static display time is at least 6 seconds, and the time to change from one message to another is no great than 2 seconds. Scrolling or animated images are prohibited.

1. Flashing, intermittent, rotating, or moving lights are prohibited.
2. Lighting which causes glare or impairs the vision of the driver of any motor vehicle, or which otherwise interferes with any driver's operation of a motor vehicle is prohibited.
3. A sign may not be illuminated so that it interferes with the effectiveness of, or obscures, an official traffic sign, signal or device.
4. Lighting may not be added to or increased on a nonconforming sign.

Georgia

Article 3. Control of Signs and Signals, Chapter 6: Regulation of Maintenance and Use of Public Roads Generally, Title 32: Highways, Bridges, and Ferries, *Georgia Code*, State of Georgia, 2008.
http://oaag.net/guidelines/documents/32-6OutdoorAdvertisingStateLaw.pdf
From page 7 of the report:

32-6-75. Restrictions on outdoor advertising authorized by Code Sections 32-6-72 and 32-6-73; multiple message signs on interstate system, primary highways, and other highways.

(a) No sign authorized by paragraphs (4) through (6) of Code Section 32-6-72 and paragraph (4) of Code Section 32-6-73 shall be erected or maintained which:

(8) If illuminated, contains, includes, or is illuminated by any flashing, intermittent, or moving light or lights except those giving public service information such as time, date, temperature, weather, or other similar information except as expressly permitted under subsection (c) of this Code section. The illumination of mechanical multiple message signs is not illumination by flashing, intermittent, or moving light or lights, except that no multiple message sign may include any illumination which is flashing, intermittent, or moving when the sign is in a fixed position;

(9) If illuminated, is not effectively shielded so as to prevent beams or rays of light from being directed at any portion of the traveled way, which beams or rays are of such intensity or brilliance as to cause glare or to impair the vision of the driver of any motor vehicle or which otherwise interfere with the operation of a motor vehicle;

(10) If illuminated, is illuminated so that it obscures or interferes with the effectiveness of an official traffic sign, device, or signal;

(c) (1) Multiple message signs shall be permitted on the interstate system, primary highways, and other highways under the following conditions:

(A) Each multiple message sign shall remain fixed for at least ten seconds;

(B) When a message is changed mechanically, it shall be accomplished in three seconds or less;

(C) No such multiple message sign shall be placed within 5,000 feet of another mechanical multiple message sign on the same side of the highway;

(D) Any such sign shall contain a default design that will freeze the sign in one position if a malfunction occurs;

(E) Any maximum size limitations shall apply independently to each side of a multiple message sign; and

(F) Nonmechanical electronic multiple message signs that are otherwise in compliance with this subsection and are illuminated entirely by the use of light emitting diodes, back lighting, or any other light source shall be permitted under the following circumstances: (i) Each transitional change occurs within two seconds; (ii) If the department finds an electronic sign or any display or effect thereon to cause glare or to impair the vision of the driver of any motor vehicle or to otherwise interfere with the safe operation of a motor vehicle, then, upon the department's request, the owner of the sign shall promptly and within not more than 48 hours reduce the intensity of the sign to a level acceptable to the department; and (iii) The owner of any existing or nonconforming electronic sign shall have until October 31, 2006, to bring the electronic sign in compliance with this subparagraph and to request a permit from the department.

Iowa

Guide to Iowa Outdoor Advertising Regulations for Interstate Highways, Iowa Department of Transportation, April 2009.
http://www.iowadot.gov/iowaroadsigns/Guide_to_Outdoor_Advertising_for_Interstates.pdf
From page 7 of the guide:
Light emitting diode (LED) displays
LED displays are permitted under the following conditions:

- Adding this type of technology for an existing billboard constitutes a billboard "modification" under Iowa law. Therefore, a new permit application is required.
- Each change of message must be accomplished in one second or less.
- Each message must remain in a fixed position for at least eight seconds.
- No traveling messages (e.g., moving messages, animated messages, full-motion video, or scrolling text messages) or segmented messages are presented.
- The intensity of the illumination does not cause glare or impair the vision of the driver of any motor vehicle or otherwise interferes with any driver's operation of a motor vehicle.
- LED displays must be located a minimum of 500 feet from any other LED display facing the same direction within cities. LED displays must be located a minimum of 1000 feet from any other LED display facing the same direction in rural areas.

Kansas

Section 68-2234. Highway Advertising Control; Sign Standards; Zoning Requirements, Article 22, Highway Beautification Highway Advertising Control Act of 1972 – Revised 2006, Kansas Department of Transportation, 2006.
http://www.ksdot.org/burrow/beaut/KHACARev6.pdf
From page 5 of the report:

(d) Lighting.

(1) Signs shall not be erected which contain, include or are illuminated by any flashing, intermittent, revolving or moving light, except those giving public service information such as, but not limited to, time, date, temperature, weather or news; steadily burning lights in configuration of letters or pictures are not prohibited;

(2) signs shall not be erected or maintained which are not effectively shielded so as to prevent beams or rays of light from being directed at any portion of the traveled way of any interstate or primary highway and are of such intensity or brilliance as to cause glare or to impair the vision of the driver of any motor vehicle or to otherwise interfere with any driver's operation of a motor vehicle; and

(3) signs shall not be erected or maintained which are so illuminated that they obscure any official traffic sign, device or signal, or imitate or may be confused with any official traffic sign, device or signal.

(e) Automatic changeable facing signs.

(1) Automatic changeable facing signs shall be permitted within adjacent or controlled areas under the following conditions:

(A) The sign does not contain or display flashing, intermittent or moving lights, including animated or scrolling advertising;

(B) the changeable facing remains in a fixed position for at least eight seconds;

(C) if a message is changed electronically, it must be accomplished within an interval of two seconds or less;

(D) the sign is not placed within 1,000 feet of another automatic changeable facing sign on the same side of the highway, with the distance being measured along the nearest edge of the pavement and between points directly opposite the signs along each side of the highway;

(E) if the sign is a legal conforming structure it may be modified to an automatic changeable facing sign upon compliance with these standards and approval by the department. A nonconforming structure shall not be modified to create an automatic changeable facing sign;

(F) if the sign contains a default design that will freeze the sign in one position if a malfunction occurs; and

(G) if the sign application meets all other permitting requirements.

(2) The outdoor advertising license shall be revoked for failure to comply with any provision in this subsection.

Massachusetts

Outdoor Advertising, Office of Outdoor Advertising, Highway Division, Massachusetts Department of Transportation, 2012.
http://www.massdot.state.ma.us/highway/Departments/OutdoorAdvertising.aspx
On June 5, 2012, the Massachusetts Department of Transportation conducted a public hearing for proposed regulation changes that include provisions for electronic billboards.

3.17: Requirements for Electronic Sign Permits

(1) Permits for Electronic Signs require the prior approval of the municipality wherein the proposed sign will be located unless otherwise exempted by State law.

(2) Except as otherwise prohibited by Federal or Massachusetts law and regulations, or local ordinances or zoning regulations, permits for Electronic Signs may be issued provided such sign complies with all of the following:

(a) Has a static display lasting at least 10 seconds.
(b) Achieves an instant message change.
(c) Does not display illumination that moves, appears to move or changes in intensity during the static display period. This does not include changes to a display for time, date and temperature.
(d) Automatically adjusts the intensity of its display according to natural ambient light conditions.

(3) A permit issued pursuant to this section shall indicate that it is for an Electronic Sign. Any such permit is determined to not be prohibited by any agreement between the Department and the Secretary of Transportation of the United States. All regulations provided by 700 CMR 3.00 et. seq. are applicable to Electronic Signs. In the event a provision of this section conflicts with another section of 700 CMR, this section controls.

(4) A legally conforming sign or site may be modified to an Electronic Sign if a new permit for the Electronic Sign is obtained by the Department.

(5) Electronic Signs shall not:

(a) Emit or utilize in any manner any sound capable of being detected on a main traveled way by a person with normal hearing;
(b) Cause beams or rays of light from being directed at any portion of the traveled way, which beams or rays are of such intensity or brilliance as to cause glare or to impair the vision of the driver of any motor vehicle or otherwise interfere with the operation of a motor vehicle;
(c) Obscure or interfere with the effectiveness of an official traffic sign, device or signal, or cause an undue distraction to the traveling public;
(d) Contain more than one face visible from the same direction on the traveled way;
(e) Be located so as to obscure or otherwise interfere with a motor vehicle operator's view of approaching, merging or intersecting traffic;
(f) Be within 500 feet of any type of permitted sign;
(g) Be within 2000 feet of another off premise permitted Electronic Sign on the same side of the traveled way;
(h) Be within 1000 feet of another off premise permitted Electronic Sign on the opposite side of the traveled way;
(i) Face more than one direction of travel;
(j) Contain flashing, intermittent, or moving lights; or display animated, moving video, scrolling advertising; or consist of a static image projected upon a stationary object.

(6) Any such sign shall contain a default design that will freeze the sign in one position if a malfunction occurs.

(7) If the Department finds an Electronic Sign or any display or effect thereon to cause glare or to impair the vision of the driver of any motor vehicle or to otherwise interfere with the safe operation of a motor vehicle, upon request, the permit holder shall promptly and within not more than 24 hours reduce the intensity of the sign to a level acceptable to the Department.

(8) In addition to any municipal requirement the Department may impose any restriction as to the hours of operation for each Electronic Sign.

(9) The permit holder of an Electronic Sign shall coordinate with governmental authorities, through the Department's Division of Highways, to display, when appropriate, emergency information important to the traveling public, such as Amber Alerts or alerts concerning terrorist attacks, or natural disasters. Emergency information messages shall remain in the advertising rotation according to the protocols of the agency that issues the information, or protocols established by the Department's Division of Highways.

(10) The permit holder shall provide the Director with contact information for a person who is available 24 hours a day, 7 days a week to turn off the Electronic Sign promptly if a malfunction occurs. The sign shall contain a default mechanism that freezes the sign in one display in the event of a sign malfunction.

(11) The permit holder shall designate a minimum of 25 hours per month of total advertisement time per permit to the Department for Public Service Announcement (PSA) purposes. Said time shall be equally distributed throughout the hours of operation of the Electronic Sign. The permit holder shall submit a detailed proof of play report each month to the Director to verify that PSA's are being displayed. The Director shall determine the total number of PSA's to be aired each month and will coordinate with the permit holder for their sign. Detailed Proof of Play (POP) Reports are due by the 5th day of each month for the prior month of play. Failure to submit a POP report or failure to adhere to the minimum PSA requirement may result in a fine or revocation of permit/s.

Criticism
These regulations have been criticized for not being strong enough:

New Rules Would Mean More Billboard Blight for Massachusetts, Scenic America, 2012.
http://www.scenic.org/blog/144-new-rules-would-mean-more-billboard-blight-for-massachusetts
From the web site: A proposed set of new regulations on outdoor advertising would see Massachusetts go from having some of the strongest billboard controls in the country to some of the weakest, and result in a proliferation of signs all over the state.

Massachusetts: Coming Billboard Regulations = Complete Deregulation, Daily Kos Network, May 30, 2012.
http://www.dailykos.com/story/2012/05/30/1096048/-Massachusetts-Coming-Billboard-Regulations-Complete-Deregulation
From the web site: The strong Massachusetts billboard regulation legacy will come to a swift end if proposed new regulations by the Massachusetts Department of Transportation's Office of Outdoor Advertising (the "OOA", not to be confused with the OAAA, the Outdoor Advertising Association of America, the billboard industry lobby) are enacted.

New York

N.Y. HAY. LAW § 88: NY Code - Section 88: Control of Outdoor Advertising, FindLaw, 2012.
http://codes.lp.findlaw.com/nycode/HAY/4/88
From the web site:

> Provided that, nothing in this section shall be construed to prohibit the erection or maintenance of outdoor advertising signs, displays and devices which include the steady illumination of sign faces, panels or slats that rotate or change to different messages in a fixed position, commonly known and referred to as changeable or multiple message signs, provided the change of one sign face to another is not more frequent than once every six seconds and the actual change process is accomplished in three seconds or less, when such signs, displays and devices are permitted or authorized pursuant to this section and by the agreement ratified and approved by this section.

Ohio

"Chapter 5501:2-2 – Ohio Administrative Code (OAC)," Ohio Revised Code and Administrative Code for Advertising Device Control, Ohio Department of Transportation, November 2011.
http://www.dot.state.oh.us/Divisions/ContractAdmin/Contracts/ADC/ADC_RegBook.pdf
From the report:

> **5501:2-2-02 General provisions for the erection and control of outdoor advertising.**
> (A) (4) (b) A multiple message or variable message advertising device shall not be illuminated by flashing, intermittent, or moving lights. No multiple message or variable message advertising device may include any illumination which is flashing, intermittent, or moving when the sign face is in a fixed position.
>
> (B) Multiple message and variable message advertising devices: such advertising devices may be permitted on the interstate system or the primary system under the following conditions: (1) Each message or copy shall remain fixed for at least eight seconds; (2) When a message or copy changes by remote control or electronic process, it shall be accomplished in three seconds or less; (3) No such advertising device shall be placed within one thousand feet of another multiple message or variable message advertising device on the same side of the highway visible in the same direction of travel;(4) Such advertising devices shall contain a default design that will freeze the device in one position if a malfunction occurs; (5) Any maximum size limitations shall apply independently to each face of a multiple message or variable message advertising device; and (6) Only one multiple message advertising device shall be permitted at a single location facing the same direction.

Oregon

Chapter 377—Highway Beautification; Motorist Information Signs, Oregon Revised Statutes, 2011 edition.
http://www.leg.state.or.us/ors/377.html
From the web site:

> **377.753 Permits for outdoor advertising signs; rules.** (1) Notwithstanding the provisions of ORS 377.715, 377.725 and 377.770, the Department of Transportation may issue permits for outdoor advertising signs placed on benches or shelters erected or maintained for use by customers of a mass transit district, a transportation district or other public transportation agency.
>
> (2) The department shall determine by rule the fees and criteria for the number, size, and location of such signs but the department may not issue a permit for a sign that is visible from an interstate highway. [2007 c.199 §3]

Division 60: Signs, Department of Transportation, Highway Division, Oregon Administrative Rules, July 13, 2012.
http://arcweb.sos.state.or.us/pages/rules/oars_700/oar_734/734_060.html
From the web site:

Digital Billboard Procedures

(1) This rule describes the process for applying for a permit for a digital billboard.

(2) Definitions for the purposes of this rule:

(a) "Sign" means the sign structure, the display surfaces of the sign, and all other component parts of the sign.

(b) "Retire" means to use a relocation credit such that it no longer exists or to remove an existing sign.

(c) "Bulletin" means an outdoor advertising sign with a display surface that is 14 feet by 48 feet.

(d) "Poster" means an outdoor advertising sign with a display surface that is 12 feet by 25 feet.

(e) "Digital Billboard" means an outdoor advertising sign that is static and changes messages by any electronic process or remote control, provided that the change from one message to another message is no more frequent than once every eight seconds and the actual change process is accomplished in two seconds or less.

(3) Qualifications for receiving a digital billboard state sign permit:

(a) The proposed site and digital billboard must meet all requirements of the OMIA including, but not limited to, the following:

(A) the digital billboard is not illuminated by a flashing or varying intensity light.

(B) the display surface of the digital billboard does not create the appearance of movement.

(C) the digital billboard must operate at an intensity level of not more than 0.3 foot-candles over ambient light as measured by the distance to the sign depending upon its size.

(D) The distance measurement for ambient light is: 150 feet if the display surface of the sign is 12 feet by 25 feet, 200 feet if the display surface is 10.5 by 36 feet, and 250 feet if the display surface is 14 by 48 feet.

(b) Applicant must submit a completed application for a digital billboard state sign permit using the approved form that may be obtained by one of the following methods:

(A) Requesting from Sign Program Staff by phone at 503-986-3656;

(B) Email: OutdoorAdvertising@odot.state.or.us;

(C) Website http://www.oregon.gov/ODOT/HWY/SIGNPROGRAM/contact_us.shtml

(c) The Department shall confirm that any existing permitted Outdoor Advertising Sign or relocation credit being retired for the purpose of receiving a new digital billboard state sign permit has been removed within the 180 days allowed to construct the new permitted sign. The Department will not charge a Banking Permit Fee for the cancellation of state sign permits retired for the purpose of receiving a new digital billboard permit.

(4) This section sets forth the criteria for determining the required relocation credits or existing permitted signs that an applicant shall retire to receive one new digital billboard state sign permit:

(a) Applicants who own 10% or less of all active relocation credits at the time the application is submitted shall either remove one existing state permitted outdoor advertising sign with a display area of at least 250 square feet or provide one active relocation credit of at least 250 square feet and retire that permit. Applicants meeting these criteria are not limited to either "Bulletin" or "Poster" billboards.

(b) Applicants who own more than 10% of all active relocations credits shall apply for a new digital billboard state sign permit as follows:

(A) For a digital billboard that is intended to be a bulletin, the applicant has three options:

(i) Remove two existing bulletins, retire the permits for those signs, and retire three relocation credits; or

(ii) Remove one existing bulletin and two existing posters, retire those permits and retire three active relocation credits; or

(iii) Remove four existing posters, retire the permits for those signs, and retire three relocation credits.

(B) For a digital billboard that is intended to be a poster, the applicant has two options:

(i) Remove two existing posters, retire the permits for those signs, and retire three relocation credits;

(ii) Remove one existing bulletin, retire the permit for that sign, and retire three relocation credits.

(c) For an active relocation credit to be eligible it must be at least 250 square feet. All permits and relocation credits submitted under these procedures will be permanently cancelled and are not eligible for renewal.

(d) Any state sign permits submitted for retirement must include the written statement notifying the Department that the "lease has been lost or cancelled."

(5) The Department will determine the percentage of relocation credits owned by an applicant by dividing the total number of unused relocation credits by the total number of unused relocation credits owned by the applicant on the day the application is received.

(6) Two digital billboard state sign permits are required for any back to back or V-type digital sign. A separate application is required for each digital sign face.

(7) The first time a digital billboard is permitted it is not subject to the 100-mile rule in ORS 377.767(4). The site of the newly permitted billboard will become the established location for future reference.

(8) Relocation of permitted digital billboards. The Department will issue one digital relocation credit for each permitted digital sign that is removed. The digital relocation credit issued will be for the same square footage as the permitted digital sign that was removed. A digital relocation credit can only be used to relocate a digital billboard. A permitted digital sign can only be reconstructed as a digital billboard.

(9) Use of renewable energy resource. The applicant must provide a statement with the application that clarifies what, if any, renewable energy resources are available at the site and are being utilized. If none, then a notarized statement to that effect must be included with the application.

(10) All permitted digital billboards must have the capacity to either freeze in a static position or display a black screen in the event of a malfunction.

(a) The applicant must provide emergency contact information that has the ability and authority to make modifications to the display and lighting levels in the event of emergencies or a malfunction.

(b) The Department will notify the sign owner of a malfunction that has been confirmed by ODOT in the following instances:

(A) The light impairs the vision of a driver of any motor vehicle; or

(B) The message is in violation of ORS 377.710(6) or 377.720(3)(d).

(11) All digital billboard signs must comply with the light intensity and sensor requirements of ORS 377.720(3)(d).

(a) The Department will take measurements of the permitted digital billboard when notified that the sign has been constructed and the permit plate has been installed.

(b) The Department will use an approved luminance meter designed for use in measuring the amount of light emitted from digital billboards using the industry standard for size and distance as follows:

(A) 150 feet for 12'x 25.'

(B) 200 feet for 10.5'x 36'.
(C) 250 feet for 14'x 48'.

Tennessee

Control of Outdoor Advertising, Chapter 1680-2-3, Rules of Tennessee Department of Transportation Maintenance Division, Tennessee Department of Transportation, February 2003.

Current regulations do not include electronic billboards:
http://www.tdot.state.tn.us/environment/beautification/pdf/1680-02-03.pdf.

However, proposed revisions are under review that include guidance on digital displays:
http://www.tdot.state.tn.us/environment/beautification/docs/Revised-ODA-Rules-Redline.pdf.
From the web site:

1680-10-01-.03 CRITERIA FOR THE CONTROL OF OUTDOOR ADVERTISING DEVICES.

4. Spacing

(i) (IV) The minimum spacing for changeable message signs with a digital display is two thousand (2,000) feet, except as follows:

I. An outdoor advertising device that uses a digital display which does not exceed one hundred (100) square feet in total area to give public information such as time, date, temperature, or weather, or to provide the price of a product, the amount of a lottery prize or similar numerical information supplementing the content of a message otherwise displayed on the sign face shall not be subject to the two thousand (2,000) feet minimum spacing requirement in this item (IV).

5. Changeable Message Signs

Changeable message signs are permissible, subject to the following restrictions: (i) The message display time shall remain static for a minimum of eight (8) seconds with a maximum change time of two (2) seconds. (ii) Video, animation, and continuous scrolling messages are prohibited. (iii) Non-conforming devices shall not be converted to a changeable message sign. (iv) The changeable message sign shall contain a default design that will freeze the sign face to one position if a malfunction occurs. (v) The structure for a changeable message sign may contain sign faces that are in a double-faced, back-to-back, or V-type configuration. (vi) The minimum spacing for changeable message signs with a digital display is as provided in Rule 1680-10-.03(1)(a)4.(i)(IV).

Washington

Highway Advertising Control, M22-95, Washington State Department of Transportation, March 2011.
http://www.wsdot.wa.gov/publications/manuals/fulltext/M22-95/HighwayAdvertisingControl.pdf
From the report:

468-66-050 Sign classifications and specific provisions

(3) Type 3 – On-premise signs.

(b) Type 3(b) – Business complex on-premise sign. A Type 3(b) business complex on-premise sign may display the name of a shopping center, mall, or business combination.

(i) Where a business complex erects a Type 3(b) on-premise sign, the sign structure may display additional individual business signs identifying each of the businesses conducted on the premises. A Type 3(b) on-premise sign structure may also have attached a display area, such as a manually changeable copy panel, reader board, or electronically changeable message center, for advertising on-premise activities and/or presenting public service information.

(g) Electronic signs may be used only as Type 3 on-premise signs and/or to present public service information, as follows:

(i) Advertising messages on electronic signboards may contain words, phrases, sentences, symbols, trademarks, and logos. A single message or a message segment must have a static display time of at least two seconds after moving onto the signboard, with all segments of the total message to be displayed within ten seconds. A one-segment message may remain static on the signboard with no duration limit.

(ii) Displays may travel horizontally or scroll vertically onto electronic signboards, but must hold in a static position for two seconds after completing the travel or scroll.

(iii) Displays shall not appear to flash, undulate, or pulse, or portray explosions, fireworks, flashes of light, or blinking or chasing lights. Displays shall not appear to move toward or away from the viewer, expand or contract, bounce, rotate, spin, twist, or otherwise portray graphics or animation as it moves onto, is displayed on, or leaves the signboard.

(iv) Electronic signs requiring more than four seconds to change from one single message display to another shall be turned off during the change interval.

(v) No electronic sign lamp may be illuminated to a degree of brightness that is greater than necessary for adequate visibility. In no case may the brightness exceed 8,000 nits or equivalent candelas during daylight hours, or 1,000 nits or equivalent candelas between dusk and dawn. Signs found to be too bright shall be adjusted as directed by the department.

(h) The act does not regulate Type 3(a), 3(b), 3(c), and 3(d) on-premise signs located along primary system highways inside an incorporated city or town or a commercial or industrial area.

Wisconsin

Control of Outdoor Advertising Along and Visible from Highways on the Interstate and Federal-Aid Primary Systems, Chapter Trans 201, Wisconsin Administrative Code, February 2005.
http://docs.legis.wisconsin.gov/code/admin_code/trans/201.pdf
From the web site:

Trans 201.15 – Electronic signs

(3) Variable Message Signs.

(c) No message may be displayed for less than one-half second.

(d) No message may be repeated at intervals of less than 2 seconds.

(e) No segmented message may last longer than 10 seconds.

(f) No traveling message may travel at a rate slower than 16 light columns per second or faster than 32 columns per second.

(g) No variable message sign lamp may be illuminated to a degree of brightness that is greater than necessary for adequate visibility.

(4) Multiple Message Signs.

(a) The louver rotation time to change a message shall be one second or less.

(b) The time a message remains in a fixed position shall be 6 seconds or more.

84.30 Regulation of Outdoor Advertising, Wisconsin Legislative Documents, 2012.
http://docs.legis.wisconsin.gov/statutes/statutes/84/30
From the web site:

(3)(c)(1) Signs that contain, include or are illuminated by any flashing, intermittent or moving light or lights are prohibited, except electronic signs permitted by rule of the department.

(4)(bm) Signs may contain multiple or variable messages, including messages on louvers that are rotated and messages formed solely by use of lights or other electronic or digital displays, that may be changed by any electronic process, subject to all of the following restrictions:

1. Each change of message shall be accomplished in one second or less.
2. Each message shall remain in a fixed position for at least 6 seconds.
3. The use of traveling messages or segmented messages is prohibited.
4. The department, by rule, may prohibit or establish restrictions on the illumination of messages to a degree of brightness that is greater than necessary for adequate visibility.

APPENDIX A

State Changeable Message Chart
(Source: OAAA State Statute Matrix)

No changeable message signs allowed:	**Tri- action Only**	**Changeable Message /Digital Technology**
(3 STATES) ND, NH, WY	(5 STATES) MD, MA, OR, TX, WA,	(38 STATES) AL, AR, AZ, CA, CO, CT DE, FL, GA, ID, IL, IA, IN, KS, KY, LA, MI, MN, MO, MS, MT, NE, NV, NJ, NM, NY, NC, OH, OK, PA, RI, SC, SD, TN, UT, VA, WV, WI

State-by-state breakdown of the 38 states allowing Changeable Message/Digital technology

- States which have statutes (19):

CA, CO, CT, DE, FL
GA, IN, KS, MI, MO
MN, NJ, NY, OH
OK, UT, TN, VA, WI

- Regulations (10):

AR, ID, IL, IA*, LA, NE,
NV, NC, SC, WV

- States with interpretations of the federal/state agreement (7):

AL, AZ, KY, MT,
NM, RI, SD

- Policy memoranda (2):

MS approved a policy DOT memorandum
PA approved the technology through an internal PENNDOT memorandum (2002)
IA* regulations are undergoing a comment period

OAAA Changeable Message Criteria
Dwell Time Sequence – By State

Dwell Time (Static Message)	State
4 seconds	**CA, CO, IA, VA**
5 seconds	**NM, PA**
6 seconds	**AL, AZ, CT, FL, GA, IA, MI, MN, NV, NY, SD, WI, RI (average)**
8 seconds	**AR, ID, IN, KS, LA, MO, MS, NJ, NC, OH, OK, OR, SC, TN, UT, WV, WA**
10 seconds	**DE, IL, NE, MD, TX**
Other/State-Company Discretion	**KY, MA, MT**

Dwell and Twirl Times for message changes and spacing criteria

States Allowing Changeable Message/Digital Technology

State	Dwell time	Twirl time	Spacing *traditional 500 ft
AL	6 seconds		
AR	8 seconds or more	2 seconds or less	1500 feet
AZ	6 seconds	1 second	*
CA	4 seconds	4 seconds	1000 feet
CO	4 seconds	1 second	1000 feet
CT	6 seconds	3 seconds	*
DE	10 seconds	1 second	2500 feet
FL	6 seconds	2 seconds	1000 to 1500 feet
GA	10 seconds	2 seconds	5000 feet

Dwell and Twirl Times for message changes and spacing criteria (cont'd)

States Allowing Changeable Message Including Electronics

State	Dwell time	Twirl time	Spacing
ID	8 seconds	2 seconds	*
IL	10 seconds	3 seconds	*
IN	8 seconds	2 seconds	*
IA	6 seconds	1 second	*
KS	8 seconds	2 seconds	1000 feet
KY At discretion of state DOT			
LA	8 seconds	4 seconds	*
MI	6 seconds	1 second	*
MN	6 seconds	none	*
MS	8 seconds	instantaneous	*
MO	8 seconds	2 seconds	1400 feet
MT At discretion of state DOT			
NE	10 seconds	2 seconds	5000 feet
NV	6 seconds	3 seconds	*
***NJ** (regulatory change pending	8 seconds	1 second	3000 feet
NM Company discretion	5 seconds	1-2 seconds	*
NY	6 seconds	3 seconds	*
NC	8 seconds	2 seconds	1000 feet
OH	8 seconds	3 seconds	1000 feet
OK	8 seconds	4 seconds	*

Dwell and Twirl Times for message changes and spacing criteria (cont'd)

States Allowing Changeable Message Including Electronics

State	Dwell time	Twirl time	Spacing
PA	5 seconds	1 second	*
RI Company discretion	5-7 seconds	2-3 seconds	*
SD	6 seconds	none	*
SC	8 seconds	2-3 seconds	*
TN	8 seconds	2 seconds	2000 feet
UT	8 seconds	3 seconds	*
VA	4 seconds	none	*
WV	8 seconds	2 seconds	1500 feet
WI	6 seconds	1 second	*

States Allowing Changeable Message Including Electronics

Tri-action Only

State	Dwell time	Twirl time	Spacing
MD	10 seconds	4 seconds	*
MA	none	none	*
OR	8 seconds	4 seconds	1000 feet
TX Rural Roads Only	10 seconds	2 seconds	*
WA	8 seconds	4 seconds	*