Daniel Luna <daniel.luna@lacity.org>

Public Comments Not Uploaded Agenda Item 10 TCN CF 22-0392 -Exhibit to CIS - too large to submit by City Council File

1 message

claramsolis@earthlink.net <claramsolis@earthlink.net> Tue, Nov 7, 2023 at 1:19 PM
Reply-To: clerk.plumcommittee@lacity.org
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Dear Ms. Rosales,

We submitted a CIS but were unable to load the Exhibits because the file was too large. I am attaching it here. Our president, Angela Torres-Gonzalez will be at the hearing today to speak to the CIS.

I am attaching the exhibit here.

Clara Solis

Historic Highland Park NC

HISTORIC HIGHLAND PARK NEIGHBORHOOD COUNCIL
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Certified as NC #33 May 28, 2002

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CITY OF LOS ANGELES
CALIFORNIA

HISTORIC HIGHLAND PARK NEIGHBORHOOD COUNCIL

October 6, 2023

Los Angeles City Council
City Hall
200 N. Spring Street
Los Angeles, CA 90012

COMMUNITY IMPACT STATEMENT

In Opposition to Building of Transportation Communication Network- TCN

RE: Council File 22-0392: In Opposition to Digital Off-Site Signs/Outdoor Advertising/ Transportation Communication Network Program Structures/LACMTA

The Historic Highland Park Neighborhood Council (HHPNC) represents over 60,000 Los Angeles stakeholders who reside, own property or conduct business in the neighborhoods of Highland Park and Garvanza. The HHPNC Board voted at its Board and Stakeholder meeting held October 5, 2023 to submit this Community Impact Statement regarding Council File 22-0392: In Opposition to Digital Off-Site Signs/Outdoor Advertising/ Transportation Communication Network Program Structures/LACMTA.

The purpose of the proposed project is to "provide a network of TCN Structures that would incorporate intelligent technology components to promote roadway efficiency, improve public safety, increase communication, and provide for outdoor advertising that would be used to fund new and expanded transportation programs. The TCN Program also includes the removal of existing static signage throughout the City. Implementation of the Project would include the installation of up to 34 Freeway-Facing (FF) TCN Structures and 22 Non-Freeway Facing (NFF) TCN Structures, all on Metro owned property."

The HHPNC concludes that there is not sufficient evidence that this project is needed or that it will benefit residents of Los Angeles. Further, we are concerned that to the contrary, this project could present a danger to motorists and pedestrians, have a negative impact on our historical resources, and negatively impact the well-being of our residents and wildlife.

We are also concerned that there will be significant impacts including safety impacts to pedestrians and motorists from the building of this project. The Draft Environmental Impact Report was biased in favor of the project and inadequately addressed the significant impacts from it. For example, Appendix K, the Transportation and Traffic Safety Review cherry picks three studies to conclude that drivers overwhelmingly pay attention to the road ahead, regardless of the presence of CEVMS or billboards. Two of the studies included are industry sponsored. Additionally, for no clearly explained reasons, the preparer excludes studies done outside of the United States. In doing this, the preparer seems to disregard the widely used literature reviews prepared by Jerry Wachtel, CPE of the Veridian Group. Wachtel's work is cited extensively by local and state government researchers.

Further, for the reasons stated within this letter we believe this project will endanger the safety of Los Angeles residents.

I. SAFETY

The HHPNC is concerned for the safety of motorists and residents in the City of Los Angeles from the effects of TCN. We share the concerns indicated below in Wachtel's Literature Review.

A. Wachtel's 2018 Updated Literature Review (See Attached) concludes:
   1. Broadly summarized, the more recent studies have tended to find that outdoor advertising signs, particularly Commercial Electronic Variable Message Signs (CEVMS) Commercial Electronic Variable Message Signs, attract drivers' attention, and that more dramatic and salient signs attract longer and more frequent glances.
   2. Several of the reported studies suggested that the distraction caused by outdoor advertising signs could be tolerated by experienced drivers and when attentional or cognitive demands of the driving task were low, but that the risk increased when such signs competed for the driver's visual attention with more demanding road, traffic, and weather conditions, when travel speeds were higher, or when an unanticipated event or action (such as a sudden lane change or hard braking by a lead vehicle) occurred to which the driver had to respond quickly and correctly.
   3. In addition, the more recent research continues to show that the drivers most susceptible to unsafe levels of distraction from roadside billboards are

the young (who are more prone to distraction and less adept at emergency vehicle response) and the elderly (who have more difficulty with rapidly shifting attention, poorer night vision and glare susceptibility, and slower mental processing time). As will be seen in this Compendium, these concerns are heightened today, with our elderly driver population growing quickly, traffic increasingly dense, more roads under maintenance or repair (construction and work zones create added risks), and larger, brighter digital and video roadside advertising signs competing for the driver's attention.

4. Finally, the most recent epidemiological studies (dating from 2014 and 2015) have begun to demonstrate what has long been suspected but not proven - that roadside billboards are associated with increases in crash rates where such billboards are located.

B. Appendix K, Transportation and Safety Review as previously indicated cherry picked two industry prepared studies in Ohio from 2007 and one 2012 Federal Highway Administration Study. These studies each have limitations and in our opinion are far from conclusive in determining that CEVMS are safe.
   1. The 2012 study was conducted in two cities, one in Richmond, Virginia and the other in Reading, Ohio. In both cities, there was a small sample size, in Reading 31 participants and in Richmond 24 participants. The author acknowledges that there were issues with the interpretation of the specific contributions made by billboards and the environment to the driver's behavior. The author also found that, "The drivers were generally more likely to gaze at CEVMS than at standard billboards," even though he concluded that drivers spent most of their time gazing at the task at hand. Additionally, the billboard refresh rate was 8-10 seconds. The Metro billboard refresh rate would be 8 seconds less than in the study. Shorter refresh rates could be more distracting.
   2. One of the 2007 studies, looked at driver fixation time with CEVMS and found it to be longer than for regular billboards it was less than 1 second, which they concluded was less than the 2.0 second fixation duration threshold that is considered dangerous by the NHTSA
   3. The other 2007 study looked at traffic accidents. A 2009 FHA study, indicates the limitations of such studies, "crashes are rare multicausal events which are difficult to measure."

C. We are concerned that the studies conducted do not look at cities like Los Angeles and that the safety of our residents are at risk.
   1. None of the studies cited have studied a large city such as Los Angeles where our traffic is legendary.
   2. Additionally, we have a large population whose primary language is not English. None of the studies referenced have looked at multilingual populations whose primary language is other than English.

D. There is a failure to consider the totality of the circumstances that drivers today face including increasingly complex cars and cell phones or how that one second distraction along with other distractions impact drivers. See The LA Times article from July 2022: https://www.latimes.com/business/story/2022-07-06/we-are-killing-people-how-technology-has-made-your-car-a-candy-store-of-distraction

II. TRAFFIC

Our stakeholders have raised the question of what impact these signs will have on traffic. Residents have noticed that where these signs are located on a freeway such as the I-5 in Commerce near the Citadel, traffic slows.Additionally, while the authors may find that a one second fixation is not significant, in a city of millions and tens of thousands of drivers passing these signs, those seconds add up. We do not believe this issue was sufficiently addressed in the study.

III. IMPACTS ON WILDLIFE

The HHPNC is concerned about the impacts this proposed project will have on humans and wildlife.

A. A recent article in the LA Times cites the impacts from light pollution on residents and wildlife In the article, the journalist(s) reflect that animals cannot avoid light pollution. (See attached): https://www.latimes.com/science/story/2022-09-20/how-an-effort-to-reduce-fossil-fuel-use-led-to-another-environmental-problem-light-pollution)
   1. UCLA Urban Ecologist, Travis Longcore, PhD states, “There are many, many species who don’t go out and forage during the full moon because it’s too bright and they know they’re going to be vulnerable to predators,”
   2. The article states, “According to the National Audubon Society, 80% of North American migratory bird species fly at night, and they’re confounded by city lights.”
   3. Further, there are impacts on humans as well, for example, “Humans, too, are vulnerable to light pollution. Artificial light blocks the production of melatonin, a hormone that regulates sleep cycles, and disrupted sleep cycles have been linked to an array of health problems. The American Medical Assn. warned in 2016 that high-intensity, blue-rich LED lights were “associated with reduced sleep times, dissatisfaction with sleep quality, excessive sleepiness, impaired daytime functioning, and obesity.”

B. Our community is concerned that there are cumulative impacts from this project which have not been fully addressed including light pollution which will impact the poorest residents and our communities of color who often live closest to transportation corridors. There will also be cumulative impacts to wildlife including migratory wildlife. This project will add to light pollution as will the recently approved bus station LED’s.

C. The Biological report that was prepared was inadequate in addressing the impacts to wildlife. It suggests there could be impacts near the Los Angeles River but fails to even visit the site to see what is there. Additionally, it appears there could be impacts to migratory wildlife that use these bodies of water on their migrations. It does not study the impact to Hollenbeck Park in Boyle Heights which appears to be near FF-10 and FF-11. At this park, egrets and other waterfowl use the park as a stopping ground. FF-06 and FF-07 is located in a particularly sensitive area, between Elysian park, Egret Park, an area of the Los Angeles River that indeed has vegetation near the Los Angeles River Greenway Trail, Confluence Park, below Los Angeles River Center and Gardens. Sites FF13 and FF14 should be excluded for impacts to federally listed Least Bell's Vireo. We are concerned that impacts and mitigation to wildlife in these areas and throughout the city were not fully addressed including impacts to birds and bats.

IV. CORRUPTION

The HHPNC is concerned because our city has seen a great deal of corruption in recent years. We are concerned that this proposed project will undoubtedly create more opportunities for corruption.

A. The City of Los Angeles has faced corruption amongst politicians and staff. Billboard companies and commercial digital billboards have also been a problem. We are concerned that this project presents more opportunity for corruption within our city. (See the attached articles for more information on this.)
B. According to the indictment of Huizar, the approvals of the sign district for The Reef (Council File 16-1058-S2) and of the redevelopment of the billboard-fronted Luxe Hotel (Council File 17-1009-S2) were allegedly tainted by illegal developer-funded kickbacks to Huizar as chair of the PLUM Committee. The alleged bribery took the form of free trips, concert tickets, nepotism, and campaign contributions.

V. IMPACTS TO HISTORICAL RESOURCES

A. Visual Impacts to Fourth Street Bridge. We are concerned about the visual impacts to this historic bridge. A look at the location of the sign NFF-21 reveals no urgent need for signage except to obtain advertising dollars. This sign is not needed for safety. It is not replacing anything. It should be removed from consideration.
B. NFF-13 and NFF-16 are likewise not replacing anything but will have visual impacts to historical resources, Little Tokyo Historic Village and Japanese Village Plaza. The 30 feet structures would have a significant impact on the communities and the large senior populations. They could also impact senior housing nearby.
C. NFF-2 will have significant visual impacts to the Spring Street bridge. Again, there is no need for signage at this location as none exists now. This is just another opportunity for revenue at the cost of a beautiful historic view that will be greatly diminished by a 30 foot sign.

VI. DISPROPORTIONATE IMPACTS TO COMMUNITIES OF COLOR AND LOW INCOME COMMUNITIES

We are concerned that this project will have disproportionate impacts to lower income communities and communities of color. Metro properties, freeways and public transportation are more often in these communities. Therefore, these communities will have more of the proposed unsightly signs with light pollution and traffic safety impacts. Additionally, there is housing located near some of the proposed signs. The residents living nearby will have their health impacted by increased pollution from traffic stalls to view the signs, the light pollution and increased traffic safety risks.

For the foregoing reasons, the HHPNC urges the denial of the TCN project.

Thank you for the opportunity to comment.

Angela Gonzales-Torres
President, Historic Highland Park Neighborhood Council

Compendium of Recent Research Studies on Distraction from Commercial Electronic Variable Message Signs (CEVMS)

Prepared by
Jerry Wachtel, CPE
President, The Veridian Group, Inc.
Berkeley, California

February 2018

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Background

This is the second in a series of brief updates based upon this author's 2009 report for AASHTO through NCHRP Project 20-7/256,[1] which was a comprehensive and critical review of research that had been undertaken, and guidelines that had been developed up to that time that addressed the potential consequences for driver distraction from Commercial Electronic Variable Message Signs (CEVMS) along the roadside.

We critically reviewed all of the research papers (more than 40) that had been published or presented within the prior 30 years. These papers represented the work of academic, industry, and government researchers in many countries (including, but not limited to: Sweden, Denmark, Israel, Canada, US, England, and Australia), and which followed many different research protocols. Whereas earlier studies (primarily those from the 1990s and prior) often suffered from limitations in equipment, methodology, or statistical rigor, leaving their conclusions open to question and controversy, those performed in the more recent past were generally more robust, and tended to reach similar conclusions to each other.

The previous update was done in June, 2013 and presented at a joint meeting of AASHTO's traffic engineering and highway safety subcommittees. The new material in this update includes nine studies in five countries.

Broadly summarized, the more recent studies have tended to find that outdoor advertising signs, particularly CEVMS, attract drivers' attention, and that more dramatic and salient signs attract longer and more frequent glances. This attention is often captured through a "bottom up" physiological process, in which the driver attends to the sign unintentionally and unconsciously, with the eyes captured involuntarily by the sign's changing imagery, brightness, conspicuity, and/or movement.

Several of the reported studies suggested that the distraction caused by outdoor advertising signs could be tolerated by experienced drivers and when attentional or cognitive demands of the driving task were low, but that the risk increased when such signs competed for the driver's visual attention with more demanding road, traffic, and weather conditions, when travel speeds were higher, or when an unanticipated event or action (such as a sudden lane change or hard braking by a lead vehicle) occurred to which the driver had to respond quickly and correctly.

In addition, the more recent research continues to show that the drivers most susceptible to unsafe levels of distraction from roadside billboards are the young (who are more prone to distraction and less adept at emergency vehicle response) and the elderly (who have more difficulty with rapidly shifting attention, poorer night vision and glare susceptibility, and slower mental processing time). As will be seen in this Compendium, these concerns are heightened today, with our elderly driver population growing quickly, traffic

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[1] Wachtel, J. (2009). "Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs: Final Report. NCHRP Report 20-7/256. Available at: http://rightofway.transportation.org/Documents/NCHRP%20Reports/20-7(256)%20digital%20outdoor%20advertising_aashto.pdf

increasingly dense, more roads under maintenance or repair (construction and work zones create added risks), and larger, brighter digital and video roadside advertising signs competing for the driver's attention.

Finally, the most recent epidemiological studies (dating from 2014 and 2015) have begun to demonstrate what has long been suspected but not proven – that roadside billboards are associated with increases in crash rates where such billboards are located.

The research and guidelines reviewed in our 2009 report set the stage for the 21 research articles and guidelines that are reviewed and summarized in this compendium.

While employing a broad array of approaches and methodologies, the common theme clearly indicates that the more that commercial digital signs succeed in attracting the attention of motorists that render them a worthwhile investment for owners and advertisers, the more they represent a threat to safety along our busiest streets and highways, where these signs tend to be located.

The long awaited study by the Federal Highway Administration (FHWA), announced on the agency's website on December 30, 2014, is an outlier in this group of recent studies (except for those sponsored by the outdoor advertising industry[2]), in that it found no relationship

[2] In 2007, two studies sponsored by the outdoor advertising industry (the Outdoor Advertising Association of America [OAAA] and its research arm, the Foundation for Outdoor Advertising Research and Education [FOARE]) were submitted through the peer review process to the Transportation Research Board of The National Academies. Both reports, one a human factors study by the Virginia Tech Transportation Institute (VTTI), and the other an epidemiological study by Tantala and Tantala, received overall negative reviews from peer reviewers, and were therefore rejected by TRB both for presentation and publication. Although Virginia Tech has not performed subsequent work in this field, Tantala and Tantala have continued to perform research under the sponsorship of OAAA/FOARE. However, for whatever reasons, FOARE and OAAA have not made the subsequent studies available to the public, so they could not be addressed in this Compendium of research.

The Tantala and Tantala 2007 study was an epidemiological analyses of crash rates, but the authors established data collection parameters that led them to exclude from examination the very driver cohorts (older drivers) and road locations (interchange areas) known to be at greatest risk for distraction. Subsequent comments from the senior author of these studies, to the effect that their subsequent studies follow the same basic methodology as the one performed in 2007 (with the exception of a more robust statistical technique to analyze the data), remains a cause for concern because of these methodological biases. The other industry study released by FOARE in 2007, the human factors analysis performed by VTTI, actually found that digital signs were associated with more long-duration glances away from the forward roadway than other types of signs, and further found that the problem was considerably worse at night. However, the authors edited their final report to make it seem as if these adverse consequences did not exist, and their industry sponsors terminated the nighttime research after the pilot data had been collected and reviewed. At that time, many experts considered an "eyes-off-road" duration of two seconds or longer to be the threshold for a substantially higher level of crash risk, and the Virginia Tech team actually found a number of instances in which digital signs caused participating drivers to take their eyes off the road for two and three seconds or longer, whereas the other test conditions (areas with traditional billboards and roadway sections devoid of billboards) did not produce this result to the same extent.

between digital billboards and adverse driver scanning behavior. The FHWA study, however, has been severely criticized for faulty methods and analyses in a peer-reviewed critique by the present author[3]. The FHWA study remains available on the agency's website, but has never been formally published.

It has been shown that road environments cluttered with driving-irrelevant material (often called visual complexity) make it difficult to extract critical information necessary for safe driving in a timely manner, a particular problem for older drivers. In addition, with the growing proliferation of CEVMS, ever-newer technology that renders them more compelling, the expansion of on-premise signs using this technology, and several States considering the use of such signs within the right-of-way, it was deemed appropriate to provide an up-to-date review of the most recent research and guidelines.

The next section of this report provides a brief summary of each of the studies. The following section, the Compendium itself, provides further details about each study, including its sponsorship, research protocol, strengths and weaknesses, and source identification. This document concludes with a complete list of references as cited.

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[3] Wachtel, Jerry (2015). "A Peer-Reviewed Critique of the Federal Highway Administration (FHWA) Report Titled: "Driver Visual Behavior in the Presence of Commercial Electronic Variable Message Signs (CEVMS)." Available at: http://nebula.wsimg.com/722c5bb9d76d4b10b6d7add54d962329?AccessKeyId=388DC3CA49BF0BEF098B&disposition=0&alloworigin=1

Summary of Findings

This section summarizes the major findings of each of the 22 studies discussed in the Compendium. Key conclusions are highlighted in **bold**. The subsequent section of this report, the Compendium itself, provides additional detail about each study, and information about how to access the study, where available.

The studies are cited here, and in the Compendium, in generally chronological order.

Chan, et al., 2008 – USA, Amherst, MA

The researchers compared susceptibility to distraction from sources inside the vehicle (e.g. phone dialing, map reading) to those outside the vehicle (e.g. billboards) for both young novice drivers and experienced drivers. As predicted, for the in-vehicle distractors, the young drivers looked away from the roadway for extended periods (2 seconds or longer) more than twice as often as the experienced drivers. Surprisingly, however, results showed that: (a) external distractors were even more distracting, and (b) the experienced drivers were just as distracted as the newly-licensed drivers on this critical measure of distraction when they performed the outside-the-vehicle tasks. The authors had assumed that experienced drivers would exercise the same degree of caution with the external distractors as they did with the internal ones. Instead, "the experienced drivers showed little concern for the effect that diverting their attention to the side of the roadway might have had on their ability to perceive potential risks immediately in front." In some 81% of the external tasks, older drivers glanced for longer than 2s away from the forward roadway. The authors concluded by saying**:** **"...we think that our drivers engaged in the external search task were truly distracted with potentially serious consequences."**

Young, et al., 2009 - England

In this driving simulator study, participants drove rural, urban, and highway routes in the presence and absence of roadside billboards, while their driving performance was measured. Billboards had a detrimental effect on lateral control, and appeared to increase crash risk. Longitudinal control was not affected. The most striking effects were found for driver attention. Driver mental workload (using the NASA developed TLX scale) significantly increased in the presence of billboards. On rural roads and motorways, results showed that billboards were consciously attended to at the cost of more relevant road signs. The authors reached a **"persuasive overall conclusion that advertising has adverse effects on driving performance and driver attention**. Whilst there are sometimes conflicts of interest at Local Authority level when authorizing billboards (since Councils often take a share of the profit from roadside advertising), these data could and should be used to redress the balance in favour of road safety."

Backer-Grøndahl, & Sagberg, 2009 - Norway

The authors asked drivers who had actually been involved in a crash to identify, from a list, what they believed were the causes of distraction for that crash. (Cell phone use was excluded). The most frequently reported sources of distraction were: (1)

conversations with passengers, and (2) attending to children in the back seat. However, **when the researchers applied the statistical method known as quasi-induced exposure, they found that distractions with the "highest relative risk" were: (1) billboards outside the vehicle, and, (2) searching for addresses. The authors note that both of the highest risk distractors were *visual* distractions, rather than physical, auditory, or cognitive ones.**

Chattington, et al., 2009 - England

The researchers found "significant effects on both drivers' visual behavior and driving performance" in the presence of both static and video billboards. As expected, the video signs were seen as more potent distractors than similarly placed static signs. The authors state that their results "support and extend (the findings of) other studies of driver distraction by advertising," citing studies by Crundall, et al, and of Young and Mahfoud (both of which were extensively reviewed in the Wachtel 2009 report for AASHTO). The study showed that **several aspects of driving performance were adversely affected by both video and static billboards, with the video signs generally more harmful to such performance than the static signs. The authors list these effects as: speed control, braking, and lane position maintenance.**

Horberry, et al., 2009 - Australia

Road authorities may be justified in using the best research information available, even if incomplete, coupled with engineering judgment, for the development of billboard guidelines**. The authors recommend that their client (Queensland, Australia) adopt advertising restrictions at known areas of high driver workload, including "locations with high accident rates, lane merges, curves/bends, hills and road/works/abnormal traffic flows."** (They state that) "this is broadly in line with Wachtel who recommended a restriction of advertisements at times when driver decision, action points and cognitive demand are greatest – such as at freeway exits/entrances, lane reductions, merges and curves. Although useful for all road users, such restrictions would be of specific benefit to older drivers."

Gitelman, et al., 2010 - Israel

The authors studied crashes at two highway locations along the same heavily traveled freeway – a "treatment" section in which previously visible billboards were covered as part of a trial period, and a "control" section in which the billboards remained visible. At the control sites, crashes remained essentially the same throughout the 3-year study period; at the treatment sites, crashes declined dramatically after the billboards were covered. The results were similar for injury and fatal crashes. After adjusting for traffic volume**, crashes were reduced at the treatment sites (where billboards had been covered) by the following percentages: all crashes by 60%; injury/fatal crashes by 39%; property damage crashes by 72%.**

Bendak & Al-Saleh, 2010 - Saudi Arabia

The authors used a driving simulator in which test subjects drove on two similar roads, one with advertising signs and one without. Twelve male volunteers, ages 23-28, participated in the study. Driver opinions about billboards were also sought using a simple questionnaire distributed to male drivers at random in the city of Riyadh, Saudi Arabia. 160 questionnaires were returned. Results of the simulator study showed that **the driving speed of participants was not affected by the presence of advertising signs. However, two of the five indicators were statistically significant. Both "drifting unnecessarily from (the) lane" and "recklessly crossing dangerous intersections" were significantly more prevalent in the presence of billboards**. Although not reaching statistical significance, each of the other three measures, tailgating, speeding, and failure to signal, were all worse in the presence of billboards. Half of the respondents to the questionnaire indicated that they had been distracted by a billboard, and 22% indicated that they had been put in a dangerous situation due to distraction from billboards.

Milloy & Caird, 2011 - Canada

This was a driving simulator study that looked at distraction effects of a video billboard and a wind turbine. **The results demonstrated a *causal* (italics original) relationship between the presence of a video billboard and collisions with, and delays in responding to, the lead vehicle.**

Edquist, et al., 2011 - Australia

"The finding that the presence of billboards increases time to detect changes is an important one." Billboards can automatically attract attention when drivers are engaged in other tasks, delaying their responses to other aspects in the environment. The effect of billboards was particularly strong in scenes where response times are already lengthened by high levels of visual clutter. This is of particular concern because roads with high levels of clutter are the very kind of busy, commercial, high traffic environments where billboards are most often erected."

The results are consistent with growing evidence suggesting that billboards impair aspects of driving performance such as visual search and the detection of hazards, and therefore should be more precisely regulated.

Dukic, et al., 2012 - Sweden

In this on-road, instrumented vehicle study**, drivers had a significantly longer dwell time (time looking at the billboards), a greater number of fixations, and a longer maximum fixation duration when driving past digital billboards compared to other signs along the same road sections.**

Perez, et al., 2012 – USA, Washington, DC

The authors of this Federal Highway Administration (FHWA) sponsored study used an instrumented vehicle that recorded volunteer drivers' eye glances as they drove along pre-determined routes in Reading, Pennsylvania and Richmond, Virginia. The routes included digital as well as static billboards, undefined on-premise signs, and areas free of commercial signage. The routes were driven during daylight and at night, and the report found that **digital billboards "were not associated with 'unacceptably long glances away from the road'." As noted above, however, the draft report of this**

study was strongly criticized by the agency's selected peer reviewers, particularly with regard to the efficacy of the obtained eye glance data. Indeed, the participants in the study did gaze more often to digital billboards than to other signs, in some cases more than twice as much. (For example 71% vs. 29% at night in Richmond). As a result of the critical peer reviews, the authors took 33 months to revise the study, which, although dated September 2012, was released on the agency's website on December 30, 2013. This revised report, in turn, was reviewed by the present author, whose critical report was reviewed and agreed-to by 14 independent expert peer reviewers. To our knowledge, the revised FHWA report was not subjected to peer review by the agency prior to its issuance on the agency website, and it has never been given an official agency report number, putting it in a state of uncertainty with regard to its publication.

Divekar, et al., 2013 – USA, Amherst, MA

Experienced drivers are far less likely to be distracted by inside-the-vehicle tasks (e.g. cell phone, map display, entertainment system) than novice drivers. However, the researchers were surprised to find that **experienced and novice drivers are at an equal and elevated risk of getting into a crash when they are performing a secondary task outside the vehicle such as looking at billboards**

Roberts, et al., 2013 - Australia

The appearance of movement or changes in luminance can involuntarily capture attention, and engaging information can capture attention to the detriment of driving performance, particularly in inexperienced drivers. Where this happens in a driving situation that is also cognitively demanding, the consequences for driving performance are likely to be significant. Further, if this results in a situation where a driver's eyes are off the forward roadway for 2 seconds or longer, this will further reduce safety. Additionally, road environments cluttered with driving-irrelevant material may make it difficult to extract information that is necessary for safe driving, particularly for older drivers. The studies that have been conducted show convincingly that roadside advertising is distracting and that it may lead to poorer vehicle control.

Herrstedt, et al., 2013 - Denmark

The authors studied drivers using an instrumented car equipped with an eye-tracking system, a GPS system for registering the vehicle's speed, and a laser scanner for measurement of following distances to other road users. The overall findings of the studies demonstrate that **"advertising signs do affect driver attention to the extent that road safety is compromised."** In 69% of all drives past advertising signs, the driver glanced at least once at the sign; in almost half of all drives, the driver glanced twice or more at the same sign. For 22% of all drives, the total glance duration of successive glances was two (2) seconds or longer. In 18% of all drives, glance durations of one (1) second or longer was recorded. In approximately 25% of all glances, the safety buffer to the vehicle ahead was less than two (2) seconds, and in 20% of the glances, the safety buffer was less than 1.5 seconds. This study has been praised in independent peer review by Dr. Richard Pain, Transportation Research Board Senior Program Officer, retired. Dr. Pain considered this study to be the best designed and conducted on-road study in this field, the conclusions of which, he believes, were far more valid and robust than those of the FHWA study (discussed above).

Hawkins, et al., 2014 – USA, College Station, TX

This study, sponsored by the on-premise signage industry, was a statistical (epidemiological) analysis of crash rates in the vicinity of on-premise digital signs that had been first installed in 2006-07. On premise signs differ from billboards in several ways. Per the common meaning of the term, on-premise signs must advertise only a business or service that is available on the property on which the sign is located. Because of that, on-premise signs typically function to identify the business and, as such, they may have little text or imagery other than that required for such identification. On the other hand, they are often closer to the road than billboards are permitted to be, and it is often possible for them to be larger than billboards and to feature motion or the appearance of motion. This study employed an analysis methodology known as *empirical Bayes* (or EB) to look at before-and-after crash data in four states. A total of 135 sign locations and 1,301 control sites were used, and the researchers found **"no evidence the installation of on-premise signs at these locations led to an automatic increase in the number of crashes."**

Schieber, et al., 2014 – USA, Vermillion, SD

In this simulator study the authors varied message length (4, 8, or 12 words) on digital billboards that participants drove past at either 25 or 50 MPH. Although there was no decrement in lane keeping or billboard reading performance at the lower speed on straight roads**, "clear evidence of impaired performance became apparent at the higher (50 MPH) driving speed." The analysis revealed that, rather than weaving in and out of lane while reading the billboards with longer messages, participants tended to slowly drift away from the lane center and then execute a large amplitude corrective steering input about eight (8) seconds *after* passing the billboard.** Eye gaze analysis showed that information processing overload began to emerge with a message length of eight (8) words, and was clearly present with twelve (12) word messages under the 50 MPH condition.

Gitelman, et al., 2014 - Israel

In 2014, these authors had the opportunity to add an additional data set to that in their 2010 study (discussed above), and to reanalyze the data from the original study. This was because the road authorities issued a decision to reauthorize the display of billboards that they had previously had ordered covered. In other words, the authors had the opportunity to study traffic crashes on a single roadway when billboards were: (a) visible, then (b) covered, then (c) visible again. The 2010 study examined conditions (a) and (b), and the 2014 supplement added condition (c) and a reanalysis of (a) and (b). They found that**: "The results support and strengthen the previous findings." Removal/covering of the billboards from the highway (condition [b]) was associated with a 30-40% reduction in injury crashes from condition (a) according to two different databases, whereas the reintroduction/uncovering of the billboards (condition [c]) was associated with a 40-50% or 18-45% increase in such crashes, depending on the database cited. The trends were similar and**

consistent across damage-only, injury, and total accidents as well as nighttime vs. daytime injury accidents.

Sisiopiku, et al., 2015 – USA, AL, FL

The authors analyzed crashes from eight (8) digital billboard locations in Alabama and ten (10) in Florida. All sites were on high speed, limited access highways. A total of 377 crashes in Florida and 77 in Alabama were used in the analysis. Actual traffic collision reports were used since the authors discovered numerous errors in coding in the summary crash databases that they initially examined. Although the data set was too small to employ statistical analyses, the authors found that **"the presence of digital billboards increased the overall crash rates in areas of billboard influence compared to control areas downstream of the digital billboard locations. The increase was 25% in Florida and 29% in Alabama."** The predominant crash types that were overrepresented at billboard locations were rear-end and sideswipe collisions, both typical of driver distraction.

Rempel, et al., 2015 - Canada

These authors, working on behalf of the Transport Association of Canada, developed a set of guidelines for the control of digital and projected advertising signs. The resultant guidelines are based on a comprehensive literature review, a survey of Canadian governmental jurisdictions, a review of existing sign regulations, interviews with international Governmental agencies, discussions with sign industry representatives, and the application of human factors and traffic engineering principles. **The key principle documented in the Guidelines is that they "provide recommendations designed to control (digital billboards) *such that they emulate static advertising signs* (italics added), and therefore result in a similar distracting and road safety effect as static advertisements."**

Samsa & Phillips, 2015 - Australia

These authors, working on behalf of the Outdoor Media Association of Australia, studied 29 participants, ages 25-54 in an instrumented vehicle. The participants were fitted with "eye tracking glasses" and their eye fixations and driving performance was assessed as they drove a 14.6 km route in Brisbane, Queensland**. The route took them past a "number" of advertising signs, including static, digital, and on-premise signs. The results showed that fixation durations "were well below" 0.75 seconds, and that there were no significant differences in vehicle headways between the three types of signage. One statistically significant finding was that lateral deviation was poorer when billboards were present.** (Note that, at present, only an Abstract of this industry-sponsored study is available).

Belyusar, et al., 2016 – USA, Cambridge, MA

In this on-road study, data was collected from 123 subjects, nearly equally divided between males (63) and females (60) and between young (age 20-29, N = 63) and older (age 60-69, N = 60). These volunteers drove an instrumented vehicle under normal driving conditions (with no specific tasks to perform) past a digital billboard on a posted 65 MPH roadway with four travel lanes in each direction. Data was collected during late morning and early afternoon to avoid commuter traffic. The authors state: **"In contrast to the recent FHWA report (Perez, et al., 2012), the findings revealed statistically significant changes in total number of glances and, depending upon the direction of travel, moderate-to-long duration glances in the direction of the billboard." Older drivers were thought to be particularly affected. The authors also found that: "Drivers glanced more at the time of a switch to a new advertisement display than during a comparable section of roadway when the billboard was simply visible and stable."** Given typical billboard dwell (cycle) times of six (6) or eight (8) seconds, these findings add to the argument the dwell times for such signs should be considerably longer.

Mollu, 2018 - Belgium

Per a 2015 European Commission report, distraction accounts for 10-30% of all European road accidents. Although there is no consistent definition of distraction, most definitions describe a *diversion* of attention away from the driving task, and *toward a competing activity* inside or outside the vehicle. This diversion of attention may be visual and/or cognitive. The author and his colleagues sought to study whether the glance behavior of road users was influenced by advertising signs, whether such signs lead to changes in driving behavior and whether there were notable effects on road safety as a result. Thirty-five test subjects (age range 20-69; 54% male) completed the protocol and drove a simulator past LED billboards with 3, 6, and 15-second dwell times, and at 41 and 65-meter distances from pedestrian crossings. The signs were placed in a road segment with a retail zone and in one transitioning to a built-up area. All other characteristics of the sign (size, placement, illumination, etc., were held constant. At the shortest display times and the closest distance to the pedestrian crossing the study showed significantly higher mental demands and lower performance. The longer the message display time, the fewer glances were made to the sign. The signs also contributed to higher approach speeds to pedestrian crossings and delayed slowing upon approach to the crossing. There was also an indication, although not statistically significant, of increased swerving behavior (change in lateral position) in the presence of the billboards.

Key to Codes Used in Tables:

*Type of Study:

N = on-road, naturalistic
Q = on-road, quasi-naturalistic
C = on-road, controlled
S = lab, simulator
L = lab, other
E = epidemiological, crash data
R = review of other work
CR = critical review of other work
D = discussion /consultation with experts
G = guidelines or regulations development
QI = questionnaires, interviews, surveys, focus groups, etc.

**Type of Signs Studied:

O = On-premise
C = Conventional billboard
D = Digital billboard
V = Sign contains video or animation
H = Official highway sign
U = Unknown

Date 1st published/presented	2008
Location	U.S. (Massachusetts)
Author(s) Title Affiliation	Chan, E., Pradhan, AK, Knodler, MA, Jr., Pollatsek, A. & Fisher, DL Empirical Evaluation on a Driving Simulator of the Effect of Distractions Inside and Outside the Vehicle on Drivers' Eye Behaviors
Forum	TRB – presentation and CD ROM
Peer Reviewed?	Yes
Sponsor/funding source	National Science Foundation; National Highway Traffic Safety Administration (NHTSA)
Type of Study*	S
Type of Signs Studied**	C (simulated)
Brief Description of Method	Young, novice drivers (age 16-17) are at greatly elevated risk of crashing, and it is believed that distraction plays a large role in such crashes. More experienced, older teen drivers (age 18-19) have also been shown to look away from the forward roadway for extended periods of time. This simulator study compared such extended, off-roadway glance durations of newly licensed drivers to those of older, experienced drivers, using eye movement recordings as participants drove along a simulated roadway and engaged in distracting tasks both inside and outside the vehicle.
Summary of Findings	The researchers compared the average maximum duration of an *episode*, (the maximum time that drivers spent continuously looking away from the forward roadway). For the in-vehicle distractors, the average was 1.63s for the experienced drivers, and 2.76s for the younger drivers. Another measure, the percentage of scenarios in which the maximum duration of an episode was greater than 2s, yielded similar findings. The results were statistically significant between the two groups. As predicted for in-vehicle distractors, the young drivers looked away from the roadway for extended periods (2s or longer) more than twice as often as the experienced drivers while engaged in inside-the-vehicle distractors (such as phone dialing, map reading, and CD searching). Surprisingly, however, results showed that: (a) external distractors were even more distracting, and (b) there was no difference between newly-licensed and experienced drivers on this critical measure of distraction when the drivers performed outside-the-vehicle tasks, specifically, searching for a target letter in a 5x5 grid representative of a billboard. The authors had assumed that experienced drivers would exercise the same degree of caution with the external distractors as they did with the internal ones. Instead, "the experienced drivers showed little concern for the effect that diverting their attention to the side of the roadway might have had on their ability to perceive potential risks immediately in front. In fact, in 81% of the external tasks, older drivers glanced for longer than 2s away from the forward roadway. The authors conclude: "…we think that our drivers engaged in the external search task were truly distracted with potential serous consequences."
Strengths	The study is the first to directly compare the susceptibility to distraction from internal and external tasks between newly licensed and experienced drivers.
Weaknesses/Limitations	Older drivers were not included in this study. The representativeness of the outside-the vehicle task is questionable.
Availability/Accessibility	TRB 2008 Annual Meeting CD-ROM

Date 1st published/presented	2009
Location	UK (England, London)
Author(s) Title Affiliation	Young, MS, Mahfoud, JM, Stanton, N. Salmon, PM, Jenkins, DP & Walker, GH. "Conflicts of Interest: The implications of roadside advertising for driver attention." Brunel University, West London, England
Forum	Transportation Research Part F: Traffic Psychology and Behaviour, Vol. 12(5), September 2009, 381-388.
Peer Reviewed?	Yes
Sponsor/funding source	Insurance company – The Rees Jeffreys Road Fund
Type of Study*	S
Type of Signs Studied**	C, H
Brief Description of Method	The study was conducted in the University's driving simulator. 48 drivers drove urban, rural, and motorway routes in the presence and absence of billboards. Dependent variables included measures of speed and lateral control, and driver attention (mental workload, eye movements, and recall of signs and billboards).
Summary of Findings	The presence of billboards had a detrimental effect on lateral control, and appeared to increase crash risk. Longitudinal control was not affected. More striking effects were found for driver attention. Driver mental workload significantly increased in the presence of billboards. On rural roads and motorways, results showed that billboards were consciously attended to at the cost of more relevant road signs. "We must once again emphasize the persuasive overall conclusion that advertising has adverse effects on driving performance and driver attention. Whilst there are sometimes conflicts of interest at Local Authority level when authorizing billboards (since Councils often take a share of the profit from roadside advertising), these data could and should be used to redress the balance in favour of road safety."
Strengths	A fully interactive high fidelity simulator was used. The use of the NASA-TLX instrument for measuring subjective mental workload was a useful tool that is used too infrequently in studies of driver performance. All participants experienced identical road and sign condition the only manipulation being the presence or absence of billboards.
Weaknesses/Limitations	The sample of participants did not include either older or younger drivers – the age groups thought to be at greatest risk for adverse consequences of billboard distraction. Measures of lateral and longitudinal variability were constrained by the study design and were not fully representative of the measures of these variables used most commonly in the US.
Availability/Accessibility	Journal is available online.

Date 1st published/presented	2009
Location	Norway
Author(s) Title; Affiliation	Backer-Grøndahl, A., & Sagberg, F. "Relative crash involvement risk associated with different sources of driver distraction." Institute of Transport Economics, Norway
Forum	First International Conference on Driver Distraction and Inattention
Peer Reviewed?	Yes
Sponsor/funding source	Unknown
Type of Study*	E, QI
Type of Signs Studied**	C
Brief description of method	Used web- and paper-based questionnaire to ask 4300+ drivers who had been in a crash to identify from a list of possible choices the cause of their crash. Separated those at fault from those not at fault. Relative crash risk of each factor was estimated using the quasi-induced exposure method.
Summary of Findings	The most *frequent* sources of distraction were: (1) conversations with passengers, and (2) attending to children in the back seat. When the statistical method was applied to the data, it was found that distractions with the "*highest relative risk*" were: (1) billboards outside the vehicle, and, (2) searching for addresses. The authors note that both of the highest risk distractors were *visual* distractions, vs. physical, auditory, or cognitive.
Strengths	Authors controlled for possible confounding variables (such as age, gender, driving experience [years] and annual mileage driven) using logistical regression with culpability as the dependent variable.
Weaknesses/Limitations	Some researchers question the viability of the quasi-induced exposure method; cell phone use was (intentionally) excluded from the questionnaire. (It likely would have proven to be the highest risk factor). Confidence intervals were quite large.
Availability/Accessibility	Presented at large international conference; published in conference proceedings.

Date 1st published/presented	2009
Location	UK - England
Author(s) Title Affiliation	Chattington, M., Reed, N., Basacik, D., Flint, A., & Parkes, A. "Investigating Driver Distraction: The Effects of Video and Static Advertising: Transport Research Laboratory
Forum	Report
Peer Reviewed?	Yes
Sponsor/funding source	Transport for London
Type of Study*	S
Type of Signs Studied**	C, V
Brief Description of Method	Used the high fidelity TRL driving simulator, with a specifically designed urban/suburban database typical of the area around London. 48 participants drove 4 different routes, each of which required about 15 minutes. Participants did not know the purpose of the study. Their eye movements were unobtrusively recorded. Roadside advertising was designed to vary by: location (placement within the scene); type (static or video); and exposure duration (at 30 MPH, drivers could see at least 50% of the advertisement for either 2, 4, or 6+ seconds. Video ads ran in a 6-second loop.
Summary of Findings	"The report has found significant effects on both drivers' visual behavior and driving performance when static and video adverts are present and that the video adverts seem more potent distractors than similarly placed static adverts. The results support and extend (the findings of) other studies of driver distraction by advertising." (Here, the authors cite the work of Crundall, et al, and of Young and Mahfoud, both of which were extensively reviewed in the Wachtel 2009 report for AASHTO). The study showed that several different aspects of driving performance were adversely affected both video and static billboards, with the video signs generally more harmful to such performance than the static signs. The authors describe these effects as being "fundamental to the safe control of the vehicle." The effects include: speed control, braking, and the variability of each of these measures, as well as drivers showing that they are "less able to maintain a consistent lane position"
Strengths	A very comprehensive and sophisticated simulation study. The researchers went so far as to pre-screen the content of the simulated advertisements to ensure that they were of equivalent interest to the different age groups in their participant population.
Weaknesses/Limitations	It is important to note that this study compared digital video billboards to traditional static billboards (i.e. it did not examine digital billboards with intermittent displays (i.e. those that change their message every 6-8 seconds) that are typical in the U.S. Although the authors state that their participants represented a "wide range of ages," it is not known how well young and old drivers were represented in the study. This is of concern because these two age groups at the ends of the driving population distribution are known to have the greatest degree of difficulty with attention and distraction.
Availability/Accessibility	TRL Report Number RPN256.

Date 1st published/presented	2009
Location	Australia, Queensland
Author(s) Title Affiliation	Horberry, T., Regan, MA, & Edquist, J. Driver Distraction from Roadside Advertising: The clash of road safety evidence, highway authority guidelines, and commercial advertising pressure. University of Queensland (Australia), INRETS (France), Monash University (Australia).
Forum	Unknown
Peer Reviewed?	Yes
Sponsor/funding source	Swedish National Road and Transport Institute, VTI
Type of Study*	CR, D, G
Type of Signs Studied**	C, D
Brief Description of Method	Critical review of the research, worldwide, as well as existing guidelines and regulations.
Summary of Findings	"Road authorities around the world may … be justified in using the best research information available (albeit incomplete) coupled with engineering judgment for the development of 3rd party advertising guidelines." The authors recommend that Main Roads Queensland adopt advertising restrictions at known areas of high driver workload including "locations with high accident rates, non-junction related lane merges, curves/bends, hills and road/works/abnormal traffic flows. This is broadly in line with Wachtel who recommended a restriction of advertisements at times when driver decision, action points and cognitive demand are greatest – such as at freeway exits/entrances, lane reductions, merges and curves. Although useful for all road users, such restrictions would be of specific benefit to older drivers." The authors correctly point out the flaw in arguments that suggest that guidance or regulatory controls are premature because there is a lack of data showing a causal relationship between billboards and accidents
Strengths	The study examined in detail the existing (2002) guidelines that seek to "minimize the possibility for 3rd party roadside advertisements to distract drivers…" with an intent toward developing upgraded guidelines.
Weaknesses/Limitations	The review of current guidelines, worldwide, is somewhat superficial.
Availability/Accessibility	https://document.chalmers.se/download?docid=653291678

Date 1st published/presented	2010
Location	Israel (Tel Aviv)
Author(s) Title Affiliation	Gitelman, V., Zaidel, D., & Doveh, E. "Influence of Billboards on Driving Behavior and Road Safety,"
Forum	Presented at: Fifth International Conference on Traffic and Transportation Psychology (2012); and at Annual Meeting of Transportation Research Board of the National Academies (2013)
Peer Reviewed?	Yes
Sponsor/funding source	Israel National Roads Authority
Type of Study*	E
Study Design	Quasi-experimental: Before and after crash date with controls – Crash data with DBBs present (2006-7) and absent (2008), with and without signs that were covered. Dependent measure – crashes and injuries. Control variable – traffic volume. Study sites – 8 treatment and 6 control.
Type of Signs Studied**	C
Brief Description of Method	Because of complaints, Israel's Supreme Court ruled that a series of billboards on an urban freeway near Tel Aviv had to be removed for 1 year while an evaluation took place. At control sites, the billboards remained visible throughout the study period. At treatment sites, billboards were visible in the "before" period (2006-7), and were covered during the "after" period (2008). Crashes were recorded and categorized (property damage only, injury or fatality) under four conditions: (a) at treatment sites while signs were visible; (b) at treatment sites after signs were covered; (c) at control sites where signs were visible; and (d) at the same control sites while signs were still visible but signs were covered at the treatment sites.
Summary of Findings	At control sites, crashes remained essentially the same throughout the 3-year study period; at the treatment sites, crashes declined dramatically after the billboards were covered. The results were the same for injury and fatal crashes. After adjusting for traffic volume, crashes were reduced at the treatment sites (where billboards were visible in the "before" period but covered during the "after" period) by the following percentages: all crashes by 60%; injury/fatal crashes by 39%; property damage crashes by 72%.
Strengths	For a field study, this used a well-controlled research design. Before-and-after measures were obtained both for sites where the billboards were covered during the study, and for the sites where the billboards remained visible during this same time period. Road sections were in close proximity, on the same highway, ensuring that traffic speeds and volumes, as well as weather conditions, law enforcement activity, etc. were comparable.
Weaknesses/Limitations	There might have been differences in certain roadway characteristics between the treatment and control sites (e.g. curves, merges, etc.) that were not identified.
Availability/Accessibility	Findings available as PowerPoint from either conference; original study is in Hebrew only; English translation not yet available.

Date 1st published/presented	2010
Location	Saudi Arabia
Author(s) Title Affiliation	Bendak, S., & Al-Saleh, K. “The Role of Roadside Advertising Signs in Distracting Drivers.” King Saud University
Forum	*International Journal of Industrial Ergonomics, 40,* 233-236.
Peer Reviewed?	Yes
Sponsor/funding source	Research Centre of the College of Engineering, King Saud University
Type of Study*	S, QI
Study Design	
Type of Signs Studied**	O, C, D, V
Brief Description of Method	Twelve male drivers, age 23-28, drove a simulator consisting of two urban roadways, each 9.3-km long, and matched for physical, environmental and traffic characteristics. One road contained advertising signs; the other was devoid of advertisements.
Summary of Findings	The average driving duration was 12.83 minutes for each route showing that the presence of advertising signs did not materially affect driving speed. There were no accidents. Lane placement and position maintenance suffered significantly in the presence of advertising signs. According to the authors: “swinging and drifting from lane in the presence of advertising signs is a strong indication of how such signs distract drivers and affect their performance.” A second finding was that “recklessly crossing dangerous intersections” was also significantly and adversely affected by the presence of advertising signs. This finding, according to the authors “indicates the loss of this fine coordination between paying attention and driving. … This can reasonably attributed… to the longer reaction time needed in the presence of hazards due to being distracted.” All three of the other measures: tailgating, “overspeeding,” and failure to signal, were poorer in the presence of advertising signs, but these were not statistically significant. In response to the questionnaire, 50% of the 160 respondents said they had been distracted by advertising signs, and 22% reported having been in a dangerous situation at least once due to being distracted by advertising signs.
Strengths	The two simulated routes driven were matched for key characteristics; the differences between them were essentially only in the presence or absence of advertising signs.
Weaknesses/Limitations	No females and no drivers older than 28 were included. “Advertising” signs of many different types were comingled, so it was impossible to identify the effects of any one category of signs, such as billboards. No definition is provided of the behavior identified as “recklessly crossing dangerous intersections.” The authors attribute poorer performance in this measure to longer reaction time in the presence of the advertising signs, but there is no indication that they measured this response. The questionnaire completed by 160 respondents was not included in the paper.
Availability/Accessibility	www.elsevier.com/locate.ergon

Date 1st published/presented	2011
Location	Canada (Calgary, Alberta)
Author(s) Title Affiliation	Milloy, SL; and Caird, JK. "External Driver Distractions: The Effects of Video Billboards and Wind Farms on Driver Performance." University of Calgary
Forum	Book chapter
Peer Reviewed?	Yes
Sponsor/funding source	Unspecified
Type of Study*	S
Type of Signs Studied**	V (simulated)
Brief Description of Method	The contribution to driver distraction from in-vehicle technologies such as cell phones, I-Pods, and navigation systems have been studied extensively. But it is external distractions that compose the single largest category of distraction-related crashes. The least is known about such crashes, possibly because the variety of people, objects and events that make up external distractions are very difficult to study in a controlled empirical fashion. In theory, drivers often have spare cognitive capacity that they can allocate toward distractors such as billboards. The question asked here was: what happens when an unlikely but totally plausible emergency event takes place – can the driver "reallocate" his or her attention so as to respond to the event in a timely manner. In this "event-based" scenario, either the driver responds adequately or not. In this simulator study, drivers on a freeway moving at 80 km/h (50 mph) in an industrial environment passed a video billboard at the same time that a lead vehicle suddenly braked hard.
Summary of Findings	The results found a *causal* (italics original) relationship between the presence of the video billboard and collisions with, and delays in responding to, the lead vehicle. The authors note that the billboards in this study were less able to capture the drivers' attention than video billboards in the real world because the simulated billboards were not as bright as actual billboards, and because the study was not conducted at night, where the distracting effects were believed to be greater. The implication is that real world safety problems may be more significant than those indicated by the study.
Strengths	A high fidelity, interactive driving simulator with a 150-degree forward field of view was used. All 21 subjects made three drives, and viewed two static and two video billboards in each. The images on the billboards were different in each presentation. A lead vehicle appeared intermittently, and, twice during each presentation, braked suddenly so that the subject had to respond quickly to avoid a collision
Weaknesses/Limitations	Younger and older drivers, those believed to be most susceptible to such distractions, were not included in the study. Learning may have occurred from earlier drives, and subjects may have come to use the appearance of billboards as a visual cue to prepare to brake for the lead vehicle.
Availability/Accessibility	Published in: "Handbook of Driving Simulation for Engineering, Medicine and Psychology." Edited by: D.L. Fisher, M. Rizzo, J.K. Caird, & J.D. Lee. Boca Raton: CRC Press.

Date 1st published/presented	2011
Location	Australia, Perth
Author(s) Title Affiliation	Edquist, J., Horberry, T., Hosking, S. & Johnston, I "Advertising billboards impair change detection in road scenes" Monash University Accident Research Centre
Forum	2011 Australasian Road Safety Research, Education & Policing Conference
Peer Reviewed?	Yes
Sponsor/funding source	Unknown
Type of Study*	L
Type of Signs Studied**	C, H
Brief Description of Method	The authors used a "change detection" paradigm to study how billboards affect visual search and situation awareness in road scenes. Change detection time has been shown to correlate with at-fault errors in a simulated driving task. In a controlled experiment, inexperienced (mean age 19.3), older (73.0), and comparison (34.8) drivers searched for changes to road signs and vehicle locations in static photographs of road scenes. The road scenes ranged from suburban main streets to multilane highways to provide varying levels of background clutter. The actual experimental protocol is too complex to include in this summary, but may be found in the original article.
Summary of Findings	"The finding that the presence of billboards increases time to detect changes is an important one. This result lends support to the idea that billboards can automatically attract attention when drivers are engaged in other tasks, delaying their responses to other aspects in the environment The effect of billboards was particularly strong in scenes where response times are already lengthened by high levels of built or designed clutter. This is particularly concerning, as road scenes with high levels of built and/or designed clutter are just the sort of busy, commercial, high traffic environments where billboards are most often erected." 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 an official road sign, and for older drivers. The results are consistent with the small but growing body of evidence suggesting that roadside 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.
Strengths	The change detection task has been shown to be relevant to safe driving performance, but has been underutilized in research. The inclusion of three diverse age cohorts addresses limitations in many other studies.
Weaknesses/Limitations	The study did not include an actual, or simulated driving task; rather a surrogate measure for visual subtasks required during driving. (However, the results are consistent with mounting evidence showing that roadside billboards impair key aspects of driving performance). Horberry, et al., (2009) argue that: "rather than waiting until it can be proven beyond doubt that roadside advertising is responsible for a particular collision, road authorities should regulate billboards to minimize the probability of interference with driving."
Availability/Accessibility	http://casr.adelaide.edu.au/rsr/RSR2011/4CPaper%20166%20Edquist.pdf

Date 1st published/presented	2012
Location	Sweden (Stockholm)
Author(s) Title Affiliation	Dukic, T., Ahlstrom, C., Patten, C., Kettwich, C., & Kircher, K. "Effects of Electronic Billboards on Driver Distraction." Swedish National Road and Transport Research Institute, and Karlsruhe Institute of Technology
Forum	Journal of Traffic Injury Prevention
Peer Reviewed?	Y
Sponsor/funding source	Swedish Transport Administration
Type of Study*	Q
Type of Signs Studied**	D
Brief Description of Method	The Swedish government allowed 12 digital billboards to be erected along highways near Stockholm for a trial period during which this, and related research was conducted. 41 volunteers drove an instrumented vehicle past 4 of the billboards in both day (N = 20) and night (N = 21) conditions. Eye movements (and other measures) were recorded. "A driver (was) considered to be visually distracted when looking at a billboard continuously for more than two seconds with a single long glance, or if the driver looked away from the road for a 'high percentage of time'." (This is defined in the study based on prior research, but is too complex for inclusion in this brief summary). Dependent measures were eye tracking and driving performance measures.
Summary of Findings	Drivers had a significantly longer dwell time (time looking at the billboards), a greater number of fixations, and a longer maximum fixation duration when driving past a DBB compared to other signs along the same road sections. No differences were found for day-night, or for specific driver performance variables.
Strengths	Excellent review of the relevant literature and explanation of the psycho-physiological processes involved
Weaknesses/Limitations	It is known from other research that younger drivers (e.g. those under age 25) and older drivers (e.g. those over age 65) are more likely to be distracted by roadside stimuli that are irrelevant to the driving task; this study was limited to drivers between the ages of 35 and 55.
Availability/Accessibility	http://www.tandfonline.com/doi/abs/10.1080/15389588.2012.731546

Date 1st published/presented	2012
Location	USA
Author(s) Title Affiliation	Perez, WA, Bertola, MA, Kennedy, JF, & Molino, JA "Driver Visual Behavior in the Presence of Commercial Electronic Variable Message Signs (CEVMS)." SAIC (now Leidos)
Forum	Unnumbered FHWA Report
Peer Reviewed?	N[4]
Sponsor/funding source	Federal Highway Administration
Type of Study*	C
Type of Signs Studied**	O, C, D, H
Brief Description of Method	FHWA contractor used instrumented vehicle with on-board eye glance data recording as participant drivers drove along predetermined routes in Reading, PA and Richmond, VA. Each route took the participants past a series of on-premise and off-premise (billboard) signs, apparently both conventional and digital, during daytime and at night.
Summary of Findings	Gazes to the road ahead were high across all test conditions; however, in three of the four test conditions digital and conventional billboards resulted in a lower probability of gazes to the road ahead as compared to the control conditions in which billboards were not present (although on-premise signs, including, potentially, electronic signs, might have been present). In Richmond, drivers gazed more at the digital than standard billboards at night, but this difference was not found in Reading.
Strengths	The study used state-of-the-art eye glance recording equipment. The study route had drivers pass signs on rural and urban routes, and surroundings that differed in visual complexity.
Weaknesses/Limitations	Numerous critical discrepancies between draft and final reports; errors in identifying billboard locations including size, distance from road edge, side of road; both far and near distances at which eye glances to billboards were recorded were artificially truncated; two experimenters sat in the vehicle with the participant driver; data overload required experimental vehicle to pull off road for resets; inappropriate recordation of billboard luminance levels; confounding of billboards with on-premise signs.
Availability/Accessibility	Report is available on the FHWA website at http://www.fhwa.dot.gov/real_estate/oac/visual_behavior_report/final/cevmsfinal.pdf

[4]In March 2011, FHWA released a draft version of the report to three pre-selected peer reviewers. The reviewers were not identified and the draft report was not made available to the public. The comments of two of the three reviewers (the third did not provide meaningful or comprehensive comments) were so critical of the draft report (stating, in essence, that the report's findings about eye glance durations to billboards were not credible) that FHWA spent the next 33 months revising and rewriting the report. A final report, which was *not* peer reviewed, was released on the agency's website on December 30, 2013, although the report was dated September 2012. Although the unreleased draft report was given the official agency report number FHWA-HEP-11-014, the final report remains unnumbered and unpublished.

Date 1st published/presented	2013
Location	U.S. (Massachusetts, Amherst)
Author(s) Title Affiliation	Divekar, G., Pradhan, AK, Pollatsek, A., & Fisher, DL; "Effects of External Distractions" University of Massachusetts, Amherst
Forum	Journal
Peer Reviewed?	Yes
Sponsor/funding source	National Institutes of Health, National Science Foundation, Arbella Insurance Group Charitable Foundation
Type of Study*	S
Type of Signs Studied**	D (simulated)
Brief Description of Method	Following previous research in the same lab, the authors sought to understand: (a) why experienced drivers were taking such long glances at external distractions (simulated billboards) when they were unwilling to do so for distractors inside the vehicle, and (b) if these experienced drivers were sacrificing some of their ability to monitor visible hazards in the roadway ahead of their vehicle, are they sacrificing even more of their ability to anticipate unseen hazards. Novice and experienced drivers performed an external search task (reading a simulated billboard) while driving in a simulator. Eye movements were recorded, as were vehicle performance.
Summary of Findings	Distractions are a major contributor to crashes, and almost one-third of such distractions are caused by sources external to the vehicle. Of these, digital billboards stand out because of their brightness and changing imagery. Recent research indicates that such billboards may attract attention away from the forward roadway for extended periods of time, and converging evidence shows that looking away from the forward roadway for such extended periods is associated with elevated crash risk. The external tasks in this study were designed to be similar to scanning a sign dense with information in the real world, such as a digital billboard that changed message every few seconds. "This study provides clear evidence that external tasks are distracting not only for novice drivers, but also for more experienced drivers." For both groups, external distractions significantly affect the drivers' anticipation of hazards. Overall the study showed that experienced as well as novice drivers are at an elevated risk of getting into a crash when they are performing a secondary task such as looking at a billboard.
Strengths	Sophisticated driving simulator with realistic hazard scenarios.
Weaknesses/Limitations	The simulated billboards, although requiring an external, visual distraction task, were not very representative of roadside billboards. There was no effort to study the effects of such external distractions on older drivers, a group known to be at high risk for such distraction
Availability/Accessibility	Transportation Research Record, Journal of the Transportation Research Board No. 2321.

Date 1st published/presented	2013
Location	Australia
Author(s) Title Affiliation	Roberts, P., Boddington, K., & Rodwell, L. "Impact of Roadside Advertising on Road Safety" ARRB Group (formerly Australian Road Research Board)
Forum	Austroads Road Research Report: Publication No. AP-R420-13
Peer Reviewed?	Unknown
Sponsor/funding source	Austroads (The Association of Australian and New Zealand Road Transport and Traffic Authorities)
Type of Study*	CR, G
Type of Signs Studied**	O, C, D, V
Brief Description of Method	(a) A critical review of existing literature to study the risk of distraction from roadside advertising, and to communicate these findings; (b) document and review existing guidelines across different highway agencies to identify gaps and inconsistencies; (c) develop guiding principles and make guidance recommendations that could be used to create guidelines and to harmonize guidelines across diverse agencies.
Summary of Findings	Most drivers, under most conditions, most of the time, probably possess sufficient spare cognitive capacity that they can tolerate driving-irrelevant information. The problem comes in some driving situations where it becomes likely that (the appearance of) movement or changes in luminance will involuntarily capture attention and that particularly salient emotional or engaging information will capture attention to the detriment of driving performance, particularly in inexperienced drivers. Where this happens in a driving situation that is also cognitively demanding, the consequences for driving performance are likely to be significant. Further, if this attentional capture also results in a situation where a driver's eyes are off the forward roadway for a significant amount of time (i.e. 2 seconds or longer) this will further reduce safety. Additionally, road environments cluttered with driving-irrelevant material may make it difficult to extract information that is necessary for safe driving, particularly for older drivers. The studies that have been conducted show convincingly that roadside advertising is distracting and that it may lead to poorer vehicle control. Results from the Klauer, et al (2006) studies show that looking at an external object increased the crash risk by nearly four times, nonetheless the number of crashes resulting from such distraction is probably quite small. This suggests that the contribution of roadside advertising to crashes is likely to be relatively minor. Nonetheless, from the Safe System perspective it would be difficult to justify adding any infrastructure to the road environment that could result in increased distraction for drivers. The exception to this may be in the case long drives on monotonous roads where drivers are likely to suffer the effects of passive fatigue.
Strengths	A comprehensive review, not only of existing research, but also of relevant human factors principles, advertising sign technology, and best practices.
Weaknesses/Limitations	Although the authors extensively review and comment on existing regulations and guidelines, only brief mention is made of guidelines in the U.S.
Availability/Accessibility	Available on the Austroads website

Date 1st published/presented	2013
Location	Denmark
Author(s) Title Affiliation	Herrstedt, L., Greibe, P., & Andersson, P. "Roadside Advertising Affects Driver Attention and Road Safety." Trafitec, Denmark
Forum	International Conference
Peer Reviewed?	Yes
Sponsor/funding source	Unknown
Type of Study*	Q
Type of Signs Studied**	C, D
Brief Description of Method	32 drivers, both men and women between the ages of 23 and 70, drove an instrumented vehicle on one of several comparable routes. Drivers had to have a current license and not require eyeglasses while driving. Drivers were not informed in advance of the purpose of the drive. The car's instruments recorded eye movements, vehicle speed and position, and proximity to vehicles ahead of the test vehicle. A "safety buffer" was calculated which reflected the time available for the driver to respond to a sudden critical situation requiring immediate action to avoid an accident.
Summary of Findings	A total of 109 drives past advertising signs were completed, and a total of 233 glances to the 16 roadside advertising signs were recorded. Results showed that, in 69% of all drives, the driver glanced at the advertisement at least once. In nearly half of all drives, the driver glanced two or more times to the same billboard. 18% of all glances lasted for 1 second or longer, and the total duration of successive glances on a single drive was 1.5 seconds or longer in 29% of trials, 2.0 seconds or longer in 22% of trials, and 3.0 seconds or longer in 10% of trials. In 65 of the 233 glances (28%), a vehicle ahead was present within a time gap of less than 3.0 seconds. In 59 cases (25%) the safety buffer was less than 2.0 seconds, and in 20% of all cases, the safety buffer was as low as 1.5 seconds. The authors conclude that, in 25% of all cases, driving safety was reduced because the safety buffer was less than 2 seconds to the lead vehicle. Further, in 16% of all drives (17 out of 109), the sum of cumulative glances to the same billboard resulted in visual distraction using the method developed by VTTI (2.0 seconds or more within a 6.0 second window). In other words, the authors state: "In more than every sixth drive past, visual distraction occurs as a result of the advertising sign." Their overall conclusion was that "the investigated advertising signs do capture drivers' attention to the extent that it impacts road safety."
Strengths	This is one of only two known on-road studies to combine measures of driver glance behavior (number and duration of glances to billboards) with the simultaneous measure of following distance to a vehicle ahead, and the only one to (apparently) calculate such following distances via laser scanner for accuracy. Older drivers were included in the participant group.
Weaknesses/Limitations	More details about the specific billboards studied would have been helpful.
Availability/Accessibility	*Proceedings of the 3rd International Conference on Driver Distraction and Inattention.*

Date 1st published/presented	2014
Location	US
Author(s) Title Affiliation	Hawkins, HG, Jr., Kuo, P-F, & Lord, D. "Statistical Analysis of the Traffic Safety Impacts of On-Premise Digital Signs" Texas A&M University
Forum	93rd Annual Meeting of the Transportation Research Board
Peer Reviewed?	Yes
Sponsor/funding source	On-premise sign industry (Signage Foundation, Inc.)
Type of Study*	E
Type of Signs Studied**	O
Brief Description of Method	135 sites in four states, where on premise signs had been installed in 2006-07, were compared to 1,301 control sites using the Empirical Bayes (EB) statistical methodology.
Summary of Findings	There were no statistically significant changes in crash frequency associated with the installation of the on-premise digital signs studied. A calculated safety effectiveness index was equal to 1.00, with the 95 percent confidence interval between 0.93 and 1.07. The findings were similar for each of the four investigated States. The researchers concluded that "there is no evidence (that) the installation of on-premise signs at the locations (studied) led to an automatic increase in the number of crashes." The authors point out in their conclusions that it might be of interest to examine whether or not the index varies as a function of sign design and operation or characteristics of the crashes themselves.
Strengths	The study employed a large database and a robust statistical analysis procedure.
Weaknesses/Limitations	The on-premise signs to be studied were chosen by the sponsor and individual sign companies rather than by the authors or at random. It is possible that the selection criteria included a bias toward the least potentially distracting signs (in terms of size, color, contrast, animation, video, etc.).
Availability/Accessibility	Paper No.: 14-2772 of the 93rd Annual Meeting of the Transportation Research Board.

Date 1st published/presented	2014
Location	USA
Author(s) Title Affiliation	Schieber, F., Limrick, K., McCall, R., & Beck, A. "Evaluation of the Visual Demands of Digital Billboards Using a Hybrid Driving Simulator" University of South Dakota
Forum	Journal
Peer Reviewed?	Yes
Sponsor/funding source	Unknown
Type of Study*	S
Type of Signs Studied**	D (Simulated)
Brief Description of Method	The authors used a purpose-built hybrid driving simulator designed "for investigating the limits of sign reading performance while driving." The driving task and the view of the road ahead used a validated, commercial simulator; but the digital billboard stimulus was implemented on a separate 20:1 scaled LCD display mounted on a linear actuator rail that could move the simulated sign toward the observer at angular velocities simulating speeds up to 55 mph. 18 university undergraduates participated. Gaze direction (road ahead vs. billboard) was captured by a video recording of each participant's face as they drove– this technique was previously demonstrated by the senior author. Participants drove once at 25 and again at 50 mph. Digital billboard stimuli were presented at predetermined random intervals, and contained either 4, 8, or 12 frequently used English words, also displayed at random.
Summary of Findings	The authors state: "Although little or no decrement in lane keeping or reading performance was observed at slow speed (25 MPH) on straight roads, clear evidence of impaired performance became apparent at the higher driving speed (50 MPH). Lane keeping performance was significantly degraded when participants were required to read digital billboards with 8 or more words at the higher speed. This decrement became greater when the sign contained 12 words. Surprisingly, the decrements in lane keeping performance emerged *after* the participants had finished reading the sign. The participants tended to slowly drift away from the center of the lane, and then executed a large amplitude corrective steering input during the 8-second interval after encountering the digital billboard. Eye gaze statistics and reading performance showed that information processing overload began to emerge at a message length of 8 words and was clearly present when 12 words were displayed.
Strengths	Sophisticated, hybrid driving simulator with a custom built zoomed image sign projector designed to overcome traditional simulator constraints on sign legibility at realistic distances. Simulated digital billboards contained different, common words of 4-5 letters each, and each was presented in the same size and location on the billboard.
Weaknesses/Limitations	No older drivers were studied. There is no discussion of the validity of the hybrid driving simulator for this specific application. The simulated billboards were only 10 ft. in width, only about one-fifth the width of typical highway billboards.
Availability/Accessibility	*Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting,* 2214-2218.

Date 1st published/presented	2014
Location	Israel (Tel Aviv)
Author(s) Title Affiliation	Gitelman, V., Zaidel, D., Doveh, E., & Silberstein, R. "Accidents on Ayalon Highway - Three Periods Comparison: Billboards Present, Removed, and Returned"
Forum	
Peer Reviewed?	Yes
Sponsor/funding source	Israel National Roads Authority
Type of Study*	E
Study Design	Quasi-experimental: Billboards present (2006-07), absent (2008), present again (2009-12) with controls. Dependent measure – property damage and injury crashes. Control variable – traffic volume. Study sites – 8 treatment and 6 control.
Type of Signs Studied**	C
Brief Description of Method	Because of complaints, Israel's Supreme Court ruled that a series of billboards on an urban freeway near Tel Aviv had to be removed, i.e. covered, for one year while an evaluation took place. At the end of the experimental period, the billboards were uncovered such that they were again visible to motorists. At control sites, the billboards remained visible throughout the study period. At treatment sites, billboards were visible in the "present" period (2006-7), covered during the "removed" period (2008), and visible again in the "returned" period (2009-12). Crashes were recorded and categorized (property damage only, injury or fatality) under six conditions: (a) at treatment sites while signs were visible; (b) at treatment sites after signs were covered; (c) at treatment sites where signs were visible again after having been uncovered; (d) at control sites where signs were visible; and (e) at the same control sites while signs were still visible but signs were covered at the treatment sites; and (f) at control sites while signs were again visible at the treatment sites.
Summary of Findings	At control sites, crashes remained essentially the same throughout the 6-year study period; at the treatment sites, crashes declined dramatically after the billboards were covered, and returned just as dramatically once the billboards were uncovered and therefore again visible. The results were the same for injury and fatal crashes. After adjusting for traffic volume, crashes were reduced at the treatment sites (where billboards were visible in the "before" period but covered during the "after" period) by the following percentages: all crashes by 60%; injury/fatal crashes by 39%; property damage crashes by 72%.
Strengths	For a field study, this used a well-controlled research design. Before-and-after measures were obtained both for sites where the billboards were covered during the study, and for the sites where the billboards remained visible during this same time period. Road sections were in close proximity, on the same highway, ensuring that traffic speeds and volumes, as well as weather conditions, law enforcement activity, etc. were comparable.
Weaknesses/Limitations	There might have been differences in certain roadway characteristics between the treatment and control sites (e.g. curves, merges, etc.) that were not identified.
Availability/Accessibility	Complete study is in Hebrew only; English translation is available for the Executive Summary only.

Date 1st published/presented	2015
Location	USA
Author(s) Title Affiliation	Sisiopiku, VP, Islam, M., Haleem, K., Alluri, P. & Gan, A. "Investigation of the Potential Relationship between Crash Occurrences and the Presence of Digital Billboards in Alabama and Florida"
Forum	Conference Paper
Peer Reviewed?	Yes
Sponsor/funding source	U.S. Department of Transportation/RITA, Alabama Department of Transportation, Florida Department of Transportation
Type of Study*	E
Type of Signs Studied**	D
Brief Description of Method	The authors analyzed historical crash records from the states of Alabama and Florida. They identified locations of digital billboards along major limited-access roadways and chose 18 suitable sites for analysis, each with its own control site. Crash records were obtained for a five-year period from a centralized database in Alabama, and crash rates were determined per million vehicle miles travelled at each site. The procedure was similar in Florida, although only three years were studied. Because many crashes in the vicinity of the billboards were found to be located incorrectly, the authors retrieved the actual police traffic collision reports for 783 crashes. Of these, 406 had to be eliminated due to coding errors in the original summary reports, leaving a total of 377 crashes for the safety assessment.
Summary of Findings	The authors state: "The overall results were consistent between the two states. The presence of digital billboards increased the overall crash rates at "digital advertising billboard influence zones" by 25% in Florida and 29% in Alabama, compared to control sites. In addition, sideswipe and rear-end crashes were overrepresented at digital billboard influence zones compared to control sites.
Strengths	Included in their influence zone was a short distance (minimum 0.05 mile) downstream of each billboard. This is in keeping with the findings of Schieber, et al., discussed elsewhere in the present document. The influence zone and associated control zone for each billboard were matched for traffic and roadway conditions.
Weaknesses/Limitations	The authors provide no explanation for how the specific billboard locations were chosen out of all possibilities that they identified. Apparently, they identified "influence zones" by calculating the distances upstream of each digital billboard from which the sign could be seen, using Google Street View. There seems to have been no effort to relate sight distance in the real world to that shown in the Google Street View images. It is unclear whether their 5 years of data (AL) and 3 years (FL) correspond to periods when the billboards studied were actually in place, given that the authors seem to have selected sites from Google Street View.
Availability/Accessibility	*Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting,* 2214-2218.

Date 1st published/presented	2015
Location	Canada
Author(s) Title Affiliation	Rempel, G., Montufar, J., Forbes, G., & Dewar, R. "Digital and projected advertising Displays: Regulatory and Road Safety Assessment Guidelines." MORR Transportation Consulting, Ltd., Intus Road Safety Engineering, Inc.., Western Ergonomics, Inc.
Forum	Transportation Association of Canada Report
Peer Reviewed?	Yes
Sponsor/funding source	Transportation Association of Canada
Type of Study*	CR
Type of Signs Studied**	O, D
Brief Description of Method	The authors performed a critical literature review, met with representatives of Canadian government agencies and outdoor advertising companies, investigated practices and regulations/guidelines in other countries, and applied human factors principles toward the development of guidelines for Canada.
Summary of Findings	The resultant guidelines are specific to traffic safety issues – they do not address the aesthetic, "nuisance," or economic factors of such signs. Guidance is developed for sign density, spacing, dwell time (which they call "frame duration"), illuminance (which they authors call "brightness"), proximity to traffic control devices and driver decision points, message sequencing and text scrolling, animation, and transition time between messages. The overriding principle proposed in this report is that digital advertising signs should "emulate" traditional signs.
Strengths	A comprehensive review, not only of existing research, but also of relevant human factors principles, advertising sign technology, and best practices.
Weaknesses/Limitations	Accepted industry practices regarding DBB lighting rather than getting the views of lighting experts or undertaking their own independent evaluation.
Availability/Accessibility	Available for purchase from Transportation Association of Canada at http://tac-atc.ca/en/digital-and-projected-advertising-displays-publication-now-available

Date 1st published/presented	2015[2]
Location	Australia
Author(s) Title Affiliation	Samsa, C., & Phillips, T. "Digital Billboards 'Down Under': Are they Distracting to Drivers and can Industry and Regulators Work Together for a Successful Road Safety Outcome?" Samsa Consulting, Outdoor Media Association of Australia
Forum	*4th International Conference on Driver Distraction and Inattention*
Peer Reviewed?	Yes
Sponsor/funding source	Outdoor Media Association of Australia
Type of Study*	C
Type of Signs Studied**	C, D, O
Brief Description of Method	29 participants, ages 25-54, drove an instrumented vehicle along a 14.6 km route in Brisbane, Queensland. Drivers were fitted with "eye tracking glasses."
Summary of Findings	Average fixation durations were "well below 0.75 s". There were no significant differences in average vehicle headway between the three signage types. There was a statistically significant difference in lateral deviation when billboards were present.
Strengths	The data showing significant differences in lateral deviation in the presence of billboards is in accord with findings from other recent studies.
Weaknesses/Limitations	No older drivers were studied. There is little description of the eye tracking glasses used, but this apparatus is not known to provide the precision necessary to determine exactly where the wearer is looking. No information is provided to enable the reader to determine how vehicle headways were measured; as such it is not possible to compare this study to the one conducted in Denmark, where headway measurement was clearly described.
Availability/Accessibility	https://www.ivvy.com/event/DD2015

[2]At the present time, this paper is available only as an Abstract. Our comments might change once we are able to review the complete paper.

Date 1st published/presented	2016
Location	USA
Author(s) Title Affiliation	Belyusar, D., Reimer, B. Mehler B., & Coughlin, JF. "A Field Study on the Effects of Digital Billboards on Glance Behavior During Highway Driving." New England University Transportation Center & MIT Age Lab
Forum	Accident Analysis and Prevention, 88, 88-96
Peer Reviewed?	Yes
Sponsor/funding source	US Department of Transportation, Region 1 New England, University Transportation Center at MIT, and the Toyota Class Action Settlement Safety Research and Education Program.
Type of Study*	Q
Type of Signs Studied**	D
Brief Description of Method	This on-road study had 123 subjects, nearly equally divided between males and females and between young and old. Participants drove an instrumented vehicle under normal driving conditions, with no specific tasks to perform, past a digital billboard on a highway with a speed limit of 65 MPH.
Summary of Findings	The authors found statistically significant changes in total number of glances and, depending upon the direction of travel, moderate-to-long duration glances in the direction of the billboard as compared to sections of the roadway in which the billboard was not visible. Older drivers were particularly affected. The authors also found that: "Drivers glanced more at the time of a switch to a new advertisement display than during a comparable section of roadway when the billboard was simply visible and stable." They concluded: "Given typical billboard dwell (cycle) times of six (6) or eight (8) seconds, these findings add to the argument the dwell times for such signs should be considerably longer."
Strengths	The driving task was quasi naturalistic; both young and old drivers, and both males and females, were equally represented.
Weaknesses/Limitations	Only one billboard, with two faces, was used in the analysis. There could be characteristics of that sign, or its location, which make the results not generalizable to other billboards.
Availability/Accessibility	http://www.sciencedirect.com/science/article/pii/S0001457515301664

Date 1st published/presented	2018
Location	Belgium, Flanders
Author(s) Title Affiliation	Mollu, K. "Influence of an Illuminated Digital Billboard on Driving Behavior with a Focus on Variable Display Time and Distance from a Pedestrian Crossing." Hasselt University and Flanders Agency for Roads and Traffic
Forum	TRB Subcommittee on Digital Billboards
Peer Reviewed?	Yes
Sponsor/funding source	Flanders Agency for Roads and Traffic
Type of Study*	N
Type of Signs Studied**	D (simulated)
Brief Description of Method	Using a driving simulator, investigators compared subjective workload and responses of drivers to pedestrians crossing in crosswalks. Subjects included 35 persons, age 20-60, with 54% male. Signs varied in dwell time and location in retail zones or in transitions to built-up areas.
Summary of Findings	Study participants rated their mental demand significantly higher and their own performance lower when a digital billboard was present. The minimum speed upon approach to the pedestrian was higher and was reached closer when a DBB was present. Although not statistically significant, lateral displacement was higher in the presence of the DBB. Brake-reaction time (perception reaction time) to the pedestrian was approximately 1.5 times higher in the presence of the DBB – and there was no effect of dwell time or distance to the sign.
Strengths	High definition driving simulator; roads agency sponsored; reasonably large number of subjects. A large number of billboards and road settings were used.
Weaknesses/Limitations	None of the display times matched those in most common use; simulated digital billboards were smaller than those in common use in the U.S.
Availability/Accessibility	Author

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Citations:

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Mollu, K. (2018). "Influence of an Illuminated Digital Billboard on Driving Behavior with a Focus on Variable Display Time and Distance from a Pedestrian Crossing (Simulator Study)." Presented at the Annual Meeting of the TRB Digital Billboards Subcommittee Meeting.

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Schieber, F., Limrick, K. McCall, R, & Beck, A. (2014). Evaluation of the Visual Demands of Digital Billboards Using a Hybrid Driving Simulator. *Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting,* 2214-2218.

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"Conflicts of Interest: The implications of roadside advertising for driver attention." *Transportation Research Part F: Traffic Psychology and Behaviour, Vol. 12*(5), 381-388.

Effects of Outdoor Advertising Displays on Driver Safety

Requested by
Suzy Namba, Caltrans Division of Design

October 11, 2012

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
  - o The Wachtel Report and Pre-2009 Literature on Outdoor Advertising Safety
  - o Literature on Outdoor Advertising Safety Since the 2009 Wachtel Report
  - o 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*).

Literature on Outdoor Advertising Safety Since the 2009 Wachtel Report

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*).

Luminance Criteria and Other Human Factors for Sign Design

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.

Section 7: Digital Billboards On-Premise and on the Right-Of-Way

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.
>
> 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.
>
> … 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.
>
> … [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/m^2 to 80 cd/m^2 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.

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

No changeable message signs allowed:	**Tri- action Only**	**Changeable Message /Digital Technology**
(3 STATES)	(5 STATES)	(38 STATES)
ND, NH, WY	MD, MA, OR, TX, WA,	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	*

The Effects of Commercial Electronic Variable Message Signs (CEVMS) on Driver Attention and Distraction: An Update

PUBLICATION NO. FHWA-HRT-09-018 FEBRUARY 2009

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

FOREWORD

The Highway Beautification Act of 1965 outlined control of outdoor advertising, including removal of certain types of advertising signs, along the Interstate Highway System and the existing Federal-aid primary roadway system. Since that time, most States have evolved a body of legislation and/or regulations to control off-premise outdoor advertising (billboards), and many local governments have developed similar rules.

The advent of new electronic billboard technologies, in particular the digital Light-Emitting Diode (LED) billboard, has necessitated a reevaluation of current legislation and regulation for controlling outdoor advertising. In this case, one of the concerns is possible driver distraction. In the context of the present report, outdoor advertising signs employing this new advertising technology are referred to as Commercial Electronic Variable Message Signs (CEVMS). They are also commonly referred to as Digital Billboards (DBB) and Electronic Billboards (EBB).

The present report reviews research concerning the possible effects of CEVMS used for outdoor advertising on driver safety, including possible attention and distraction effects. The report consists of an update of earlier published work, an investigation of applicable research methods and techniques, recommendations for future research, and an extensive bibliography. The report should be of interest to highway engineers, traffic engineers, highway safety specialists, the outdoor advertising industry, environmental advocates, Federal policy makers, and State and local regulators of outdoor advertising.

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Director, Office of Safety
Research and Development

Gerald Solomon
Director, Office of Real Estate
Services

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16. 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.

17. Key Words	18. Distribution Statement
Commercial Electronic Variable Message Signs, CEVMS, Digital Billboards, DBB, Electronic Billboards, EBB, Driver Attention, Driver Distraction, Driver Safety, Outdoor Advertising	No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

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Unclassified	Unclassified	94	N/A

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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1.0 INTRODUCTION

The present report reviews research concerning the possible effects of Commercial Electronic Variable Message Signs (CEVMS) used for outdoor advertising on driving safety. The report consists of an update of earlier published work by Farbry et al., which consists of an investigation of applicable research methods and techniques, recommendations for future research, and an extensive bibliography.[1] The Federal Highway Administration (FHWA) has evaluated possible safety effects of CEVMS in two previous studies. The first study was completed in 1980 and the second in 2001.[1,2] Since then, CEVMS technology has evolved, in particular the expanded use of digital Light Emitting Diode (LED) arrays, as well as the implementation of new programmable formats and messages. The present report concentrates on identifying potential factors that may contribute to determining whether there are any significant safety concerns or distraction effects with regards to CEVMS used for outdoor advertising. Throughout the present report, the acronym CEVMS will be employed to refer to both the singular and plural case.

1.1 BASIC RESEARCH QUESTION

The basic research question being addressed in this report is whether the presence of CEVMS along the roadway is associated with a reduction in driving safety for the public. Increases in vehicle crashes along a certain portion of the roadway are generally regarded as an indication of a possible safety concern. Thus, the measurement of crash rates in the vicinity of CEVMS in comparison with crash rates at matched control locations without CEVMS is one possible way to determine possible safety impacts. But, the crashes are rare multicausal events which are difficult to measure. Therefore, measurements of driving behavior in near-crash situations are sometimes taken as a substitute for crashes. These safety surrogate measures may then be generalized to other driving behaviors that represent possible precursors of crashes—like sudden braking, sharp swerving, or traffic conflicts—even though no crash occurs. Usually, because these safety surrogate measures are more frequent and easier to measure, they are often employed instead of or in addition to crashes. Thus, determining the frequency of occurrence of certain relevant safety surrogate driving behaviors in the vicinity of CEVMS in comparison with the frequency of occurrence of such behaviors at matched control locations without CEVMS is another possible way to determine possible safety impacts. The validity of using such safety surrogate measures rests on the assumption that they are related to actual vehicle crashes, which seems intuitively reasonable but has not been conclusively demonstrated.

There is another approach to determining the possible safety impact of CEVMS. This approach is based upon the abstract psychological constructs of driver attention and distraction. A driver must devote a certain amount of attention to the driving task at hand, and sufficient distraction from that driving task could be associated with the higher risk of a crash. The measurement of driver eye glance behavior is often taken as an indirect indicator of attention. Thus, the driver's eye glances should be concentrated in the region of the roadway ahead, and any frequent or long eye glances away from this region toward other objects, including CEVMS, could be regarded as an indication of possible driver distraction. If the eye glances toward a certain object and away from the roadway ahead are sufficiently frequent or sufficiently long to exceed criteria established for safe driving, this outcome can be taken as an indication of a possible safety impact. The validity of using eye glance behavior measures in this manner rests on two assumptions: that eye glances are related to attention and/or distraction and that there are generally accepted safety criteria for excessive eye glances away from the roadway ahead. These assumptions are not universally accepted.

In summary, the basic research question is whether the presence of CEVMS along the roadway is associated with a reduction in driving safety for the public. The three fundamental methods for answering this question include if there is an increase in crash rates in the vicinity of CEVMS, if there is an increase in near-crashes or safety surrogate measures in the vicinity of CEVMS, and if there are excessive eye glances away from the roadway ahead in the vicinity of CEVMS.

1.2 SCOPE

In this report, a CEVMS will be defined as a self-luminous advertising sign which depicts any kind of light, color, or message change which ranges from static images to image sequences to full motion video. The CEVMS may also be referred to as an Electronic Billboard (EBB) or a Digital Billboard (DBB). The present report concentrates on the possible effects of CEVMS on driver attention, driver distraction, and roadway safety. The report is divided into 10 sections: Introduction, Literature Review Update, Key Factors and Measures, Research Strategies, Future Research Program, Recommended First Stage Study, Conclusions, References, Bibliography, and Appendices.

Investigating the possible safety effects of CEVMS is sufficiently complex so that no single experiment will answer all of the relevant scientific and engineering questions. The present report outlines a top-level broad program of potential future research, and it defines in greater detail three possible studies, any one of which could serve as a possible first step. After these discussions, a course of action is recommended. Although off-premise advertising signs constitute the main focus of FHWA attention, the influence of on-premise advertising signs will also be considered to create a more comprehensive and consistent research approach.

In parallel with the present project, a related study is being performed under National Cooperative Highway Research Program (NCHRP) Project 20-7 (256), titled “Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs.” Both the present project and the NCHRP study begin with the understanding that, despite years of research, there have been no definitive conclusions about the presence or strength of adverse safety impacts from CEVMS. The two projects differ in three significant ways. First, the NCHRP study is undertaking a broad, critical review of the research literature in this field. The present project is more focused on literature update oriented toward the identification of suitable independent and dependent variables for future research. Second, the NCHRP study is reviewing current regulations and guidelines for the control of roadside advertising that may exist in foreign countries to assess their applicability to U.S. highways and streets. Aside from mention in the literature review update portion, the present report does not directly address regulations and guidelines. Third, the NCHRP study will synthesize current research results and current regulations and guidance to recommend how State and local governments might enact reasonable temporary guidance for the control of CEVMS within their own jurisdictions. Such guidance may be applicable on an interim basis pending the outcome of future, more conclusive research outlined in the present project. As a result, such interim guidance may need to change as new technical information is developed. The present report does not provide guidance to States on the control of CEVMS.

2.0 LITERATURE REVIEW UPDATE

2.1 BACKGROUND

The research that addresses the possible safety and distraction effects of outdoor advertising billboards has been extensive and long standing. Dating back to the 1930s, this research reached a peak in the 1950s and 1960s. Research continued at low ebb through the 1980s, and then all but ceased. With the advent of newer billboard technologies (e.g., lamp matrix, rotating disc, tri-vision, and, most recently, LED) and with the corresponding questions raised by regulators, safety researchers, and the public, research has increased again since the turn of the century. These newer billboard technologies, especially the LED technology, ushered in the increasing use of CEVMS for on-premise and off-premise advertising. The current research focuses on information that has become available since the publication of the most recent FHWA report, but it also includes earlier relevant studies not previously identified.[1] The present review is organized into five major categories according to the research context for the study: post-hoc crash studies, field investigations, laboratory investigations, previous literature reviews, and reviews of practice. The categories that contain empirical data have a brief discussion of potential methodological problems inherent in the types of studies characteristic of that category.

2.2 POST-HOC CRASH STUDIES

Post-hoc crash studies review police traffic collision reports or statistical summaries of such reports to understand the causes of crashes that have taken place in the vicinity of some change to the roadside environment. In the present case, the change of concern is the introduction of CEVMS to the roadside or the replacement of conventional billboards with CEVMS.

A number of studies have been conducted over the years using the crash methodology. Three such studies were not reviewed in prior FHWA studies. In a study similar to that conducted in the 1970s in Massachusetts, the Freeway Operations Unit of the Wisconsin Department of Transportation (WisDOT) analyzed bidirectional crashes on I-94 near an electronic billboard with a 5.0 s message dwell time.[3,4] Crash rate data were collected for 3 years prior to and 3 years after sign operation began. For eastbound traffic, total crashes increased 36 percent over the 3 year post operational period compared to the baseline preoperational condition. In addition, side-swipe crashes increased 8 percent, and rear-end crashes increased 21 percent. For westbound traffic, total crashes increased 21 percent, sideswipe crashes increased 35 percent, and rear-end crashes increased 35 percent. The authors of the WisDOT study concluded that, "it is obvious that the variable message sign has had an effect on traffic, most notably in the increase of the side-swipe rate" (p. 3).[4]

Stutts et al. conducted an analysis of several crash data reporting systems to identify major sources of driver distraction and the relative importance of different types of distraction as contributing factors in motor vehicle crashes.[5] Distraction was described as one form of inattention, and it has been implicated as a factor in more than half of the police reported inattention crashes identified by the National Highway Transportation Safety Administration.[6] In this study, 8.3 percent of drivers involved in police-reported crashes were identified as distracted, but 35.9 percent of these crashes were coded as "unknown." For this and other reasons, it is believed that the reported percentage of distraction-related crashes substantially under-represents the true statistics.(5) Among the types of distractions coded in the database, the largest contributor (29.4 percent) was "outside person, object, or event," and the second largest (25.6 percent) was "other."

Smiley et al. studied the relationship between video advertising signs and motor vehicle crashes at downtown intersections and on the freeway.(7) Crash data were analyzed from three intersections before and after the introduction of video advertising signs. When the three intersections were evaluated individually, two demonstrated increases in both total and rear-end crashes; the third showed no significant increase in such crashes. The authors believe that the lack of statistical significance may be due to the small number of crashes identified. For the freeway environment, crash data on the video approach was compared to crash data for three non-video approaches, one of which was deemed the most comparable (control) segment. For this comparison, the authors report a negligible increase in injury collision crash frequencies on the video approach.

Following the design of their earlier study on conventional billboards, Tantala and Tantala analyzed police accident reports in the vicinity of seven digital billboards on interstate highways near Cleveland, OH.(8) Both their current and earlier studies were sponsored by the outdoor advertising industry. Reported crashes were analyzed for a period of 18 months prior to and after the conversion of these billboards from conventional to digital. They found essentially no statistically significant differences in crash rates before and after the conversion.

Unfortunately, all post-hoc crash studies are subject to certain weaknesses, most of which are difficult to overcome. For example, the vast majority—more than 80 percent in one study—of accidents are never reported to police; thus, such studies are likely to underreport crashes. Also, when crashes are caused by factors such as driver distraction or inattention, the involved driver may be unwilling or unable to report these factors to a police investigator. Another weakness is that police, under time pressure, are rarely able to investigate the true root causes of crashes unless they involve serious injury, death, or extensive property damage. Furthermore, to have confidence in the results, researchers need to collect comparable data in such studies before and after the change and in the after phase at equivalent but unaffected roadway sections. Last, since crashes are infrequent events, data collection needs to span extended periods of time, both before and after introduction of the change. Few studies are able to obtain such extensive data. For a more specific analysis of some possible design and methodological concerns with the study by Tantala and Tantala, see Wachtel.(8,9)

2.3 FIELD INVESTIGATIONS

The spectrum of field investigations related to roadway safety is broad. It includes unobtrusive observation, naturalistic driving studies, on-road instrumented vehicle investigations, test track experiments, driver interviews, surveys, and questionnaires. Klauer et al., in one of several papers to emerge from a National Highway Traffic Safety Administration (NHTSA) project known as the "100-Car Naturalistic Driving Study," provides preliminary information about the role of driver inattention in crashes and near-crashes.(10) Although the study did not specifically address CEVMS, it represents an important methodology for investigating driver distraction. Their results show that 78 percent of crashes and 65 percent of near-crashes included driver inattention and/or distraction as a contributing factor. This contribution from inattention and distraction is larger, by a factor of three, than previous research has indicated. The authors believe that the "100-Car Naturalistic Driving Study" provides the first direct link (i.e., without reliance on crash surrogate measures) showing distraction/inattention as a contributing factor to motor vehicle crashes. In another variant of the "100-Car Naturalistic Driving Study," Klauer et al. identifies four specific unsafe behaviors that contributed to crashes and near-crashes.[(11)] One of these, inattention and/or distraction, is of direct relevance to the present project. This term is operationally defined by Klauer et al. as a driver looking away from the forward roadway for greater than 2.0 s. Under these conditions, the odds of a crash or near-crash are nearly twice those than when the driver attends to the forward roadway. The study stresses the importance of including near-crashes in the database for two reasons. First, the kinematics of crashes and near-crashes are similar, meaning they involved comparable levels of driver emergency actions, such as swerving and hard braking. Second, 83 percent of the crashes in this study were not reported to the police. Thus, the study indicates that relying on crash statistics alone will substantially underreport crashes due to inattention and/or distraction.

Lee, McElheny, and Gibbons undertook an on-road instrumented vehicle study on interstate and local roads near Cleveland, OH.[(12)] The project, conducted on behalf of the outdoor advertising industry, looked at driver eye glance behavior toward digital billboards, conventional billboards, comparison sites (sites with buildings and other signs, including digital signs), and control sites (those without similar signage). Performance measures, such as speed maintenance and lane keeping, were also recorded. Although the major data collection was done in daylight, a small pilot study was conducted at night. One of the key questions that the study sought to answer was whether longer glances consisting of over 1.6 s were associated more with any of the event types.[(12)] This question is based on findings from various studies, including the "100-Car Naturalistic Driving Study," which indicates that longer glances away from the road are associated with higher crash rates.[(13)] In discussing their results, the authors state, "…the distributions of glance duration were similar across all event types, and there was no obvious pattern of longer glances being associated with any of the event types" (p. 59).[(13)] The findings from the nighttime pilot study led to, "the overall conclusion, supported by both the eye glance results and the questionnaire results, that the digital billboards seem to attract more attention than the conventional billboards and baseline sites (as shown by a greater number of spontaneous comments regarding the digital billboards and by longer glances in the direction of these billboards" (p. 10).[(13)] However, in view of the small number of participants, these data were not analyzed. The authors suggest that at least some of these findings, "would show statistical significance" if a larger study were to be conducted (p. 64).[(13)]

Beijer, Smiley, and Eizenman, working on behalf of the Government of Toronto, Canada, evaluated driver eye glances toward four different types of roadside advertising signs on roads in the Toronto, Canada area.[(14)] The study employed an on-road instrumented vehicle approach with a head-mounted eye-tracking device. Active signs—all but traditional billboards—consistently received longer glances and more total glances than fixed signs. The study found that 22 percent of all glances were defined as long or greater than 0.75 s. Since 22 of the 25 subjects made at least one long glance at an advertising sign, the authors conclude that, "distraction…was not just an isolated incidence" (p. 101).[(14)] The authors suggest that active signs may result in greater distraction than past studies of the effects of commercial signing might indicate.

After a previous study raised concerns about the number and duration of glances made to video advertising signs along an expressway in Toronto, Canada, Smiley et al. conducted another study at the request of the city government.(7,15) Five different measures were taken, including eye movements, traffic conflicts, traffic speed and headway, crash data, and public surveys. The crash data results were described earlier. The results from the other measures were mixed. All of the video signs attracted attention; the probability of a driver's looking at such a sign upon approach was nearly 50 percent. The average glance duration was 0.5 s, similar to those for official traffic signs. However, one-fifth of the video sign glances lasted longer than 0.75 s, and some lasted as long as 1.47 s, which were considered unsafe amounts of time. About 38 percent of glances at the video billboards were made when headways were 1.0 s or less, and 25 percent of the glances took place when the signs were more than 20 º off the line-of-sight. These glances were also considered to be unsafe. According to the study, glances at static billboards and bus shelter ads were made at even greater angles and shorter headways.

It is noteworthy that the earlier study that led to this research, also evaluating a video billboard on an expressway in Toronto, Canada, produced dramatically different results. This study found five times the number of glances per subject and three times the glance duration than did the later 2004 study.(15) Smiley et al. attribute these differences to the longer sight distance available for the sign in the earlier study, the uninterrupted view, and the location of this sign on a curve.(7)

Smiley et al. also employed safety surrogate measures of conditions which might be precursors of a possible crash.(7) The study measured these safety surrogate indicators by means of the unobtrusive observation method. The drivers of the vehicles were not aware that they were being observed. In this context, the study measured traffic conflicts, vehicle speed, and vehicle headway. When comparing video and non-video approaches at the same intersection, at one intersection the authors found no differences in traffic conflicts; however, at the other, they found a significant increase in drivers who applied their brakes without cause on the video approach. Given the comparability of sites, they concluded, "the only reason that could be found for increased braking…was the presence of the video sign" (p. 108).(7) The speed and headway data were inconclusive.

In addition, Smiley et al. employed a "public" survey method to determine whether video advertising might be considered to have "a negative effect on traffic safety" (p. 110).(7) Participants in the survey were approached at three intersection sites which had video advertising. Of the 152 persons surveyed at the 3 locations, 65 percent felt that video advertising signs had a negative effect on the ability of a driver to attend to pedestrians and cyclists. Furthermore, 59 percent of the people said that as drivers, their attention was drawn to such signs, while 49 percent of those felt that such signs had a negative effect on traffic safety. A surprisingly large number of people—9 out of 152—stated that they personally had experienced near-crashes, and 2 had experienced actual rear-end crashes that they associated with video advertising signs. In addition, 86 percent of the respondents suggested that restrictions should be placed on those types of signs, such as their locations and brightness.

Three of the field investigations of CEVMS effects mentioned earlier employ indirect measures of driver attention (eye glances) in the context of an on-road instrumented vehicle experimental approach. Although CEVMS stimuli are real, the experimental approach suffers from a degree of artificiality in its implementation. The research participants usually drive in an experimental vehicle along a route which is contrived for experimental purposes, and the route does not serve a useful purpose in their daily lives. The research participants sometimes drive with an experimenter present in the instrumented vehicle, and they sometimes wear a head-mounted eye-tracking device. Two of the three studies cited used a somewhat intrusive but more accurate head-mounted eye-tracking device. One study used a less obtrusive but also less accurate vehicle-mounted eye-tracking device, where cameras were mounted in the vehicle cab. Although the research participants were not told the purpose of the investigation, the participants were definitely aware that they were participating in a driving experiment of some kind, and they may not have exhibited entirely natural behaviors as a result. Furthermore, eye glance behavior is difficult to measure, and it is not easy to relate directly to attention and distraction. For a more specific analysis of some further design and methodological concerns with the Lee et al. study cited above, see Wachtel.(12,9)

The unobtrusive observation method employed in the field by Smiley et al. to collect safety surrogate measures of potential crashes (e.g., sudden braking, inadequate headway, etc.) does not create an artificial environment for the driver.(7) Usually, the sensing devices (loop detectors, remote cameras, or posted human observers) are hidden in the environment, and they are not noticed by the drivers. There is no problem of artificiality; the drivers in the study are not even aware that they are part of a study. However, the safety surrogate variables being measured are usually infrequent, often multicausal, comparatively subtle, and difficult to measure. For CEVMS, these variables can also occur over great distances, adding to the difficulty in accurately and reliably capturing data relating to these variables.

Finally, the public survey method employed by Smiley et al. collected the opinions, attitudes, and feelings of passersby at intersections with video advertising signs.(7) The results, while interesting as a measure of public sentiment, are difficult to relate to the basic research question of determining whether there are any significant distraction effects or concrete safety concerns with regards to CEVMS used for outdoor advertising.

2.4 LABORATORY INVESTIGATIONS

Laboratory investigations related to roadway safety can be classified into several categories: driving simulations, non-driving simulator laboratory testing, and focus groups.

For one such investigation, a non-driving simulator laboratory testing environment was used.(16) For this study, researchers filmed a 27 minute drive and had 200 licensed drivers view the film while their eye movements were recorded. Billboards generated greater levels of visual attention than suggested by measures of recall. Billboards were viewed by individuals whether they were in the "target" audience or not and regardless of whether the billboard was of high or low interest. In addition, billboards located close to official highway signs received more attention than those that were farther away.

In a driving simulation laboratory, Crundall et al. compared street level advertisements (SLAs), such as those on bus shelters, to raised level advertisements (RLAs), which include elevated ads on poles or streetlights.(17) The study was based on the understanding that, in undemanding situations, drivers have spare attentional capacity; however, when cognitive demands increase, spare capacity diminishes. As a result, eye movements must focus on the driving task at hand.

Based on their prior research, Crundall et al. believe that if an advertisement is within the driver's visual field during a search for hazards, it will attract visual fixations and distract attention needed to safely perform the driving task.[17] Because the most relevant information for hazard detection is distributed along a horizontal plane, the authors believe that the majority of visual fixations will fall within this plane when the driver is looking for driving-relevant information. Thus, if an advertisement is located within this window, it will receive more fixations than will advertisements located outside this window. The principal research hypotheses tested were that during conditions when drivers were looking for hazards, SLAs would receive the most attention. When spare capacity was greater, the attention given to RLAs would increase. The results supported these hypotheses. A post-drive survey showed that SLAs were judged more hazardous than RLAs.

Young and Mahfoud used a driving simulator in which subjects drove three routes in the presence and absence of billboards.[18] The presence of billboards adversely affected driving performance in terms of lateral control and crashes. Billboards also had an adverse impact on driver attention in terms of the number of glances made to them, and they were associated with a higher subjective mental workload. In addition, the recall of official road signs was adversely affected by billboards, which the authors interpreted to mean that drivers were attending to billboards instead of relevant road signs. The authors reached a "persuasive overall conclusion that advertising has adverse effects on driving performance and driver attention" (p. 18).[18]

In a recent study using a driving simulator, Chan and her colleagues compared the impacts of in-vehicle versus external-to-vehicle distractors on performance of inexperienced versus experienced drivers.[19] The authors were particularly concerned with young, novice drivers because of the elevated crash risk for this segment of the driving population. They were also concerned because the researchers believed that distraction could adversely affect the novice drivers' poorly developed hazard detection and avoidance skills. Chan et al. theorized that external distraction may be more harmful than internal distraction because when drivers are looking within the vehicle, it should be obvious to them that they are not processing relevant roadway information. However, when drivers are looking at sources outside the vehicle, it is likely that the forward roadway is still somewhere within the field of view. Thus, it may not be obvious to drivers (particularly inexperienced drivers) that this important information is not being fully processed since it is peripheral, unattended, or both.

Chan et al. were primarily interested in the longest glances away from the forward roadway since these have been implicated in prior studies (e.g., Horrey and Wickens[20]) as major contributors to crashes. Thus, they used as their dependent measure the maximum time that drivers spent continuously looking away from the forward roadway during a specific distraction task. In terms of in-vehicle distractors, as hypothesized, inexperienced drivers showed a consistent pattern of looking away from the roadway for longer periods of time than experienced drivers. However, the findings about external distractions were quite different and unexpected in two key ways. There was very little difference in the duration of distraction episodes between the experienced and inexperienced drivers, and the maximum distraction durations were significantly longer for the out-of-vehicle tasks than for the in-vehicle tasks. The two experience groups showed little differences in the percentage of distraction episodes longer than 2.0 s, 2.5 s, and 3.0 s, in all cases longer for the external than for the in-vehicle distractors. The study also demonstrated that, "drivers are more willing to make extended glances external to the vehicle than internal to the vehicle" (p. 17).[19] Chan et al. conclude that, "it is likely that our out-of-vehicle tasks (which not only engage attention but also draw the eyes and visual attention away from in front of the vehicle) would have quite significant detrimental effects on processing the roadway in front of the vehicle" (p. 22).[19]

Three of the laboratory investigations of possible distraction effects mentioned above employ indirect measures of driver attention (eye glances) in the context of a driving simulation experimental approach. The interactive driving simulator approach offers considerable experimental control over stimulus parameters, like the size, number, proximity, and change rate of CEVMS or other advertising display. The simulator is also well suited for executing parametric studies of the effects of these variables on possible driver distraction. However, the approach suffers from all of the sources of artificiality found in the on-road instrumented vehicle approach for conducting field research mentioned earlier. Also, the approach adds the important source of virtual driving as opposed to real driving. Although the vehicle cab of the driving simulator may have certain degrees of motion (pitch, roll, heave, etc.) to enhance the sense of virtual driving, the vehicle cab does not move down the roadway. The visual scene passes by while the driver and vehicle remain stationary. This degree of artificiality requires considerable adaptation on the part of the research participants, most of whom need some amount of training to become accustomed to the differences between driving in a simulator and driving on a real road. Moreover, in the case of CEVMS, present driving simulators do not have sufficient visual dynamic range, image resolution, and contrast ratio capability to produce the compelling visual effect of a bright, photo-realistic LED-based CEVMS on a natural background scene.

One laboratory investigation had research participants watch films of driving scenes containing billboards while their eye movements were being recorded.[16] This study represents an example of a non-driving simulator laboratory method. It suffers from all of the aforementioned limitations of laboratory CEVMS or billboard research. In addition, it does not measure the participants' response while engaged in a driving task.

2.5 PREVIOUS LITERATURE REVIEWS

Garvey summarizes the literature on sign visibility, legibility, and conspicuity on behalf of the advertising industry.[21] One of his recommendations bears on the issue of distraction from billboards. He suggests that signs need not be detectable at distances greater than the minimum required legibility distance. Specifically, he states, "if a sign is detected before it is legible, the driver will take numerous glances at the sign in attempts to read it" before it becomes legible, and "these momentary diversions are inefficient and potentially dangerous" (p. 1).[21]

Cairney and Gunatillake, working on behalf of the Government of Victoria, Australia, undertook a review of the literature with the goal of generating recommendations for guidelines for the control of outdoor advertising in that State.[22] They cited two prior reviews by Wachtel and Netherton in the United States and by Andreassen in Australia as the basis of their review.[2,23] Since these earlier studies, the technology used for the display of roadside advertising and the addition of in-vehicle distractors has changed. Cairney and Gunatillake conclude that the principal concern remains the effects that a sign may have on a driver's visibility of other road users, the roadway, and traffic control devices, particularly at high-demand locations, such as interchanges. They suggest several research approaches, including case studies, site investigations, and laboratory simulations to address these newer technologies. They conclude that the best of the studies conducted to date demonstrate that when all confounding variables are controlled statistically, sites with advertising signs have higher crash rates than sites without them. However, large, well-controlled studies will be required to detect significant effects because the effect size is small. They further conclude that changeable message signs may have a more direct bearing on crash rate than static signs. The findings of the study suggest that unregulated roadside advertising has the capability of creating a significant safety problem. The conclusions from their review run counter to Andreassen's conclusion that, "there is no current evidence to say that advertising signs, in general, are causing accidents" (p. 4).(23)

On behalf of the Scottish government, Wallace undertook the most extensive and critical review of the literature since the two earlier FHWA studies.(24) The study concludes that driver distraction from attention-getting sources can occur even when the driver is concentrating on the driving task. Furthermore, there is abundant evidence that billboards can function as distractors, particularly in areas of visual clutter. Billboards can distract in "low information" settings, and distraction from external factors is likely to be underreported and underrepresented in crash databases.

The Dutch National Road Safety Research Institute reviewed the recent literature for the Dutch authorities and emphasized some of the stronger, more consistent points made in other studies, such as billboards should not be placed near challenging road settings, especially at or near intersections. Also, they should not resemble official traffic signs in pattern or color.(25) Furthermore, dynamic signs that display motion or include moving parts should not be permitted. A key conclusion was that, "precisely in a dangerous situation it is important for the driver to have his attention on the road; an advertising billboard can slow the driver's reaction time, which increases the chance of a crash" (p. 2).(25)

The WisDOT sponsored a study which summarizes available information about the safety impacts of outdoor electronic billboards and tri-vision signs.(26) Similar to Crundall, et al. and Wallace, the authors of this study determined that greater visual complexity associated with a high-volume location, such as intersections, required drivers to search the environment more than at lower-volume locations.(17,26) The authors stated, "it can be conjectured that additional visual stimuli such as billboards may add additional demand to driver workload in high-volume intersections" (p. 6).(26)

Bergeron, on behalf of the Government of Quebec, Canada, re-reviewed many of the studies originally examined by Wachtel and Netherton and added reviews of several studies conducted subsequent to 1980.(2,27) His findings and conclusions, similar to those of other researchers, indicate that attentional resources needed for the driving task are diverted by the irrelevant information presented on advertising signs. This distraction leads to degradation in oculomotor performance, which adversely affects reaction time and vehicle control capability. The study concludes that when the driving task imposes substantial attentional demands that might occur on a heavily traveled, high-speed urban freeway, billboards can create an attentional overload that can have an impact on micro and macroperformance requirements of the driving task.

2.6 REVIEWS OF PRACTICE

Bergeron also performed a site review at a major elevated expressway in Montreal, Canada, which was proposed for two future billboards.[28] By reviewing the scene and considering various parameters such as traffic volumes, road geometry, and traffic control devices, Bergeron concludes that this 1.1 km section was already causing excessive cognitive demands, particularly for the many unfamiliar drivers. He concluded that the billboards would be inadvisable for several reasons. First, the location creates a substantial demand on drivers' mental workloads because of its complex geometry, heavy traffic, high traffic speeds, merging and diverging traffic, and the presence of signs and signals that require drivers to make rapid decisions. Also, at the perceptual level, the billboards would add confusion to the visual environment, thus impairing drivers' visual search, tracking, and reaction time. In addition, at an attention level, billboards could distract drivers. Last, the billboards could add to a driver's mental workload in a setting where workload is already quite high. In a road situation such as this one, Bergeron concludes that the billboard is a "useless drain on limited attentional resources" (p. 5), and it could lead to reduced performance through inattention errors by overloading the driver's information processing abilities.[28]

du Toit and Coetzee address the current regulatory process for advertising signs visible from national roads.[29] The authors report that the South African government engages in careful scrutiny of proposed advertising signs before they are approved for use. All applications receive a desktop review followed by a site visit. If a decision cannot be made at this point, the authorities evaluate crash statistics for the proposed location to determine that if it is hazardous. Key questions asked as part of the review include the following:

- Will the proposed sign obscure the view of an official road sign?
- Will the sign cause a disruption of information flow to the driver?
- Will the sign's location distract the driver's attention at merge/diverge areas, curves, and interchanges?

A clear system exists in South Africa that requires certain spacing between road signs, particularly those that are close to interchanges; proposed advertising signs must fit within the parameters. This system, as codified in the South African Road Traffic Signs Manual (SARTSM), is intended, "to allow adequate time for the driver to read, interpret and react on the information on the road sign" (p. 7).[29] The authors report that for a recent review period, 86.7 percent of all applications were rejected. Of those, 40.8 percent were rejected because the advertisement was too close to existing road signs, 20 percent were rejected because the sign disrupted the flow of information to the driver, and 7.5 percent were rejected because the sign was too close to a ramp gore.

As a result of his work cited immediately above, Coetzee reviewed literature, performed a regulatory analysis, and recommended changes to regulations for outdoor advertising control in South Africa.[30] Although superficially similar to regulations in the United States, billboard control in South Africa goes much further, regulating the design and amount of information (in bits) that can be displayed on a given sign, as well as the proximity of two or more advertising signs to one another and to road features, such as official signs and interchanges. In South Africa, message sequencing, visual clutter, and sign size are restricted for different display technologies. This document includes a description of the terms *critical event* and *critical zone*, and it demonstrates how regulations would control advertising signs in these applications. Coetzee finds support from the earlier work of Ogden and the experiments of Johnston and Cole, concluding that, whereas drivers may be able to ignore advertisements when the driving task requires attention, it is possible that an attention-getting sign can assume primary importance and interfere with not only any spare capacity that a driver might have but also the information processing capacity reserved for primary task performance.(31,32) The danger arises, according to Coetzee, when processing the information on the advertisement interferes with the driver's principal vehicle control task in situations that demand attention and rapid reactions.(30) The Coetzee report is the only work in the present review of the literature that has attempted to establish the parameters of billboard location and content based on theories of information processing and cognitive demand.

2.7 CONCLUSIONS FROM LITERATURE REVIEW

2.7.1 Basic Research Question

The basic research question being addressed in the present report is whether the presence of CEVMS used for outdoor advertising is associated with a reduction in driving safety for the public. When regarded from a scientific perspective, the present literature review does not provide an adequate answer to this question. The studies reviewed are inconclusive.

The present literature review reveals a disjointed array of isolated studies revealing sometimes contradictory and inconclusive results. Some studies show statistically significant driver safety concerns or distraction effects, but not all levels of distraction have negative safety impacts. Some studies go one step further and compare a statistically significant distraction with a criterion level of distraction claimed to represent the threshold of negative safety performance. This approach represents a substantial improvement, but it depends heavily upon the veridicality of the chosen criterion level of distraction. Other studies show no statistically significant safety or distraction effects at all, or they show mixed results. Some studies which show no statistically significant safety or distraction effects have been demonstrated to have serious flaws in their experimental and/or statistical designs. These studies are often plagued with two intrinsic methodological problems. First, they may not have sufficient measurement accuracy and precision to distinguish CEVMS distraction from noise in the data. Second, they may not have sufficient statistical power to reveal a small but important distraction effect which may really exist; i.e., they have not sampled enough events, drivers, or conditions to demonstrate an effect which may be obscured by variability due to sampling. In summary, from the perspective of strict statistical hypothesis testing, the present literature review is inconclusive with regard to demonstrating a possible relationship between driver safety and CEVMS exposure. From this perspective, the more stringent restrictions on the placement of billboards found in other countries might be regarded as a conservative precautionary measure, erring on the side of protecting public health from a possible but unproven threat and not as a response to an established driving safety hazard. That is not to say that such a conservative approach is inappropriate, but it should be acknowledged as such.

The present literature review does reveal a preponderance in the number of studies (5:1) which show some driver safety effects due to traditional billboards and CEVMS in comparison with the number of studies that show no driver safety effects at all due to these stimuli. In addition, four other studies show mixed results. Three lists were prepared below to demonstrate this outcome. These lists included only empirical research studies, regardless of the methodology employed. Studies that reviewed literature or practice were not included unless they also contained an original research component. Studies previously reviewed in the earlier FHWA projects were also not included.

The following research studies reported potential adverse safety effects for all dependent measures:

- Wisconsin Department of Transportation.[(4)]
- Young.[(16)]
- Crundall, et al.[(17)]
- Young and Mahfoud.[(18)]
- Chan, et al.[(19)]

The research study by Tantala and Tantala[(8)] reported no adverse safety effect on any dependent measure.

The following research studies reported potential adverse safety effects using some dependent measures and no effects using other dependent measures:

- Lee, McElheny, and Gibbons.[(12)]
- Beijer, Smiley, and Eizenman.[(14)]
- Beijer.[(15)]
- Smiley et al.[(7)]

Such an outcome could lead one to conclude that there is more evidence for a possibly meaningful negative safety impact than evidence against such an impact. This conclusion is not warranted for at least two reasons. First, a simple tally of the number of studies which support a given research hypothesis compared with the number of studies which do not support the hypothesis may be misleading. Such a tally neglects to weight the various studies for their intrinsic strength of experimental design, statistical power, and care of execution. One strong landmark study with a robust experimental design and a sufficiently large sample of cases or drivers can topple a host of weaker investigations with fewer credentials. Yet, credentialing and weighting studies can become a subtle and subjective matter. It is difficult to judge studies on their relative strengths because it requires experience and judgment. While it may be relatively easy to identify the champion study and give that study a strong weighting, it is more difficult to evaluate the weaker studies at the middle and bottom of the list.

Second, there is a strong propensity in scientific research to search for differences. The current Western model of reductionist scientific inquiry, coupled with its reliance on the paradigm of parametric statistics, is aligned against supporting the null hypothesis. This hypothesis states that there are no observed differences between two or more different treatments, i.e., that matters under scientific scrutiny are due to chance. This propensity to search for differences is so strong that when anticipated results are small or subtle, researchers often seek out conditions in nature that are worst case examples to find any affect at all. This causes the results to suffer from a lack of generalization when the entire population becomes the frame of reference. Thus, the present literature review acknowledges a possible natural and intrinsic bias toward including more studies that show a possible distraction effect of CEVMS exposure than studies that do not. Once these two considerations are recognized—a lack of weightings for comparing studies and a propensity to emphasize differences—the present literature review realigns to its original inconclusive outcome. In summary, present scientific techniques are not adapted to providing proof that CEVMS do not distract drivers; they only afford opportunities to demonstrate that they do distract drivers and possibly to what extent. If the demonstrated extent of distraction is minor and below the accepted criterion to interfere with safe driving, then the safety impact may be considered negligible.

2.7.2 Methodological Implications

The inconclusive literature review findings suggest the need for carefully controlled and methodologically sound investigations of the relationships between CEVMS, driver distraction, and safety. The review also suggests several factors that need to be considered in future research. One plausible model posits that drivers often have spare attentional capacity, and they can afford to divert their visual attention away from the driving task to look at objects irrelevant to the driving task, such as CEVMS. According to this model, when driving demand increases because of fixed hazards (such as dangerous roadway geometry or complex interchanges) or transient hazards (such as slowing traffic, vehicle path intrusion, or adverse weather), spare capacity is reduced or eliminated, and the driver devotes more capacity to the driving task. In this model, driver workload emerges as an important issue. By applying this model, in some countries, outdoor advertisements are not allowed in areas where known fixed hazards exist. Such locations include, but are not limited to, sharp horizontal or vertical curves and areas where high cognitive demand is imposed by the roadway, traffic, or environment, like intersections, interchanges, and locations of merging or diverging traffic. In some countries, billboards are also not allowed where they might interfere with the processing of important information from official road signs. These prohibitions do not in themselves prove that distraction is worse in high driver workload situations. However, they do point to the need to consider conditions of differing driver workload in an effective future research program on possible safety effects from CEVMS exposure.

When scanning for hazards, drivers' eye movements tend to fall within a horizontal window centered on the focus of expansion in the forward view. This focus of expansion is related to the visual flow of the moving scene where points and objects all emerge from a single point. Because an attention-getting billboard may be able to attract a driver's glance even unintentionally, a CEVMS that falls within this scanning pattern can interrupt the pattern and cause a distraction at an inopportune time. Furthermore, research suggests that the distraction from a roadside billboard may be unconscious. Consequently, drivers may not be aware that they are being distracted, and they are unable to verbalize that any distraction occurred. Although where someone's eyes look may not be the same as where his or her attention is focused, a theoretical connection may be implied. Through this connection, measurements of eye glance behavior permit the researcher to gain potential entrance into this realm of unconscious allocation of attention. This allocation of attention should play an important role in an effective program for future research.

In addition, it cannot be assumed that all CEVMS are equal, even those of the same size, height, and LED technology to display their images. The impact of a CEVMS in an undeveloped area with relatively low levels of nighttime ambient lighting may be quite different from that of a CEVMS in a more urban context among other buildings and structures in an area with high nighttime illumination levels. Furthermore, characteristics of the CEVMS displays may, in and of themselves, lead to measurable differences in distraction, such as information density, colors of figure and background, character size and font, and message content. These characteristics cannot be assumed to be equivalent for purposes of comparisons. One possible solution to this problem may be for future research studies to exercise a certain degree of experimental control over the CEVMS message itself. This may require a deeper level of cooperation with the billboard industry than has been encountered in previous studies. Such increased cooperation could be beneficial in establishing a collaborative research environment among industry, government, and university stakeholders.

Finally, a frequently changing CEVMS, which can generally be seen long before it can be read, raises a particular concern for distraction. This is because drivers may continue to glance at the CEVMS to observe changes in varying content with various sizes of lettering until the sign content can be read. The implication here is that future studies may need to embrace longer viewing distances.

3.0 KEY FACTORS AND MEASURES

The study of possible CEVMS effects on driver safety represents a complex research endeavor. There are numerous key factors affecting a driver's response to CEVMS. Many of these influential factors may be designated as independent research variables in need of specification or control within a given research design. Likewise, there are numerous inferred measures of driver safety which may serve as possible dependent variables for observation and measurement. Depending upon the specific research design, some of these independent and dependent variables may swap places.

3.1 KEY FACTORS (INDEPENDENT VARIABLES)

For classification purposes, the key factors, or major independent variables, may be categorized into various types. The list of key factors shown below gives some of the independent variables which might be considered in the study of possible safety effects of CEVMS. These key independent variables were selected from a more comprehensive analysis by means of a process to be described later. This analysis grouped all of the independent variables into five major categories according to source as follows:

- Billboard.
- Roadway.
- Vehicle.
- Driver.
- Environment.

After this initial analysis, a subsequent evaluation selected only the most important, or key, factors or variables. Each category lists the key independent variables which belong to that category. The lists below contain independent variables from four of the five above mentioned categories. The vehicle category is missing because all of the variables belonging to that category were eliminated in the selection process. For cross reference purposes, the decimal number shown in brackets to the right of each variable gives the outline number from the more detailed analysis upon which the selection was based (see table 1 in appendix A). In parentheses to the right of certain variables are given some examples and explanations which serve to clarify that particular variable.

The following are the key factors relating to the billboard:

- Location [1.1] (lat./long., GPS, mile marker, survey location, reference location).
- Sight distance [1.1.3].
- Resolution [1.2.3] (dpi, LEDs/inch, crispness).

- Luminance [1.2.4] (brightness).
- Contrast ratio [1.2.4].
- Day/night settings [1.2.4].
- Change rate [1.3.2] (image changes).
- Dwell time [1.3.2].
- Change time [1.3.2].
- Sequencing [1.3.2] (apparent motion).
- Full motion video [1.3.4].
- Engagement value [1.3.5] (ability to hold attention).
- Message [1.4].

The following are the key factors relating to the roadway:

- Category [2.1.1] (two-lane rural, collector, arterial, freeway).
- Geometry [2.2.2] (curve radius: horizontal, vertical).
- Intersection [2.2.3] (signalized, stop controlled).
- Interchange [2.2.4].
- Exit [2.2.4].
- Entrance [2.2.4].
- Merge [2.2.4].
- Gore [2.2.4].
- Traffic [2.3] (average daily traffic, peak traffic, level of service).

The following are the key factors relating to the driver:

- Age [4.1].
- Gender [4.1].
- Demographics [4.1].

- Years driving [4.2].
- Route familiarity [4.2].
- State [4.3] (alert, fatigue, alcohol, drugs).

The following are the key factors relating to the environment:

- Visual clutter [5.1.1].
- Nearby billboards [5.1.1].
- Ambient lighting [5.1.1].
- Official signs [5.2] (illuminated, luminous (VMS), retro-reflective).
- On-premise signs [5.3] (conventional, tri-vision, digital, full motion video).

The combined list of key factors given above represents a subset of the most influential independent variables in terms of importance to a future program of research. This subset of variables was selected from a more extensive list of the major independent variables which might play a role. As mentioned previously, the list of all major independent variables may be found in outline form in table 1 in appendix A. The bracketed decimal numbers in the list of key factors refer to the corresponding outline numbers in table 1. In addition, the table cites some of the advantages and disadvantages of employing that particular variable. The combined list of key factors presents the 32 variables which were judged to be the most influential variables from table 1.

The more comprehensive and detailed analysis represented in table 1 identifies considerably more possible independent variables. The approximately 60 types of variables listed in the table are further broken down into 185 specific subtypes or levels of independent variables which could play an important role in studying the possible effects of CEVMS on driver distraction and roadway safety. It is encouraged to carefully examine the many independent variables and their advantages and disadvantages, as described in table 1 in appendix A, to gain a greater appreciation of the complexity of the research problem. With such a profusion of important factors affecting the study of CEVMS effects, no single experiment could possibly answer all of the relevant scientific or engineering questions.

The key independent variables were selected from the expanded list represented in table 1 by three senior research psychologists, all coauthors of the present report and familiar with CEVMS research. The criterion for selection was the importance of that factor in conducting research on CEVMS effects. Thus, the list of key factors indicates critical independent variables which need to be considered in any proposed program of research. The brightness and crispness, or photo realism, of the CEVMS images are extremely important. Any image changes, apparent motion or video motion in the CEVMS, and location parameters are also critical factors. The next level of importance relates to environmental factors. Two distinct classes of variables must be taken into account: general visual clutter and the presence of other off-premise commercial CEVMS (nearby billboards). In particular, compelling information from CEVMS used for advertising may conflict with important roadway safety information conveyed by nearby traffic control devices (official signs). The question should also be raised concerning possible enhanced distraction caused by the urgency of Amber Alerts and other public safety messages displayed on CEVMS. Any contextual links among the messages from several sequential CEVMS, as well as any specific user interactions with the CEVMS must be taken into account. Factors to consider for drivers include their familiarity with the driving route and the expected presence or absence of CEVMS. Lastly, the complexity of the roadway geometry and the volume of traffic are likely to play significant roles.

3.2 KEY MEASURES (DEPENDENT VARIABLES)

The study of driver safety is a complex area of investigation. There are numerous objective, inferred, and subjective measures of driver behavior which might serve as dependent variables in a program of proposed research on the possible safety effects of CEVMS. As demonstrated in the discussion concerning independent variables, the key measures or dependent variables may be categorized into types. The list of key measures shown below gives 28 key measures, or dependent variables, which might be considered possible safety effects of CEVMS. As was the case for the list of key factors (independent variables), the list of key measures represents a down selection from a more extensive list of the major dependent variables of interest (see table 2 in appendix A). The dependent variables are grouped into the following four major categories:

- Vehicle behavior.
- Driver and vehicle interactions.
- Driver attention and distraction.
- Crashes.

The structure of the list of key measures for dependent variables is similar to that for the list of key factors for independent variables. In the case of dependent variables, the major variable categories of driver and vehicle interactions and crashes found in table 2 are missing from the list of key measures below because all of the variables belonging to these two categories were eliminated in the selection process.

Key measures relating to vehicle behavior are as follows:

- Speed [1.1] (continuous, exceeding speed, speed variance).
- Lane position [1.2] (continuous, lane excursions, lane variance).
- Acceleration [1.3] (longitudinal, lateral, heave).
- Other vehicle interactions [1.4].
- Headway [1.4.1] (time to collision).

- Gap acceptance [1.4.2] (merge, passing).
- Conflicts [1.4.3] (near-crashes).
- Violations [1.4.4] (red light running, failure to yield, failure to stop).
- Errors [1.4.5] (missed exit, wrong lane).
- Timing [1.4.6] (late movements, premature movements).
- Infrastructure interactions [1.5].
- Response to roadway geometry [1.5.1] (swerves, sudden braking).
- Response to traffic control devices [1.5.2] (misses, delays).
- Pedestrian interactions [1.5.3] (yields).

Key measures relating to driver attention/distraction are as follows:

- Eye glance behavior [3.1.1] (number and duration of glances, glance object).
- Distractor performance [3.1.2] (secondary task).
- Visual occlusion [3.1.3].
- Feature detection [3.1.4].
- Feature recognition [3.1.5].
- Driver workload [3.1.6] (task performance).
- Head turning [3.1.7].
- Driver errors [3.1.8].
- Reaction time [3.1.9] (perception-reaction time).
- Surprise [3.2.1] (orienting response).
- Conspicuity [3.2.2] (attention grabbing).
- Search patterns [3.2.3].
- Capacity [3.2.4] (self-regulated attention, spare capacity).
- Subjective measures [3.3].

As mentioned above, the more detailed analysis underlying the combined list of key measures shown above may be found in table 2 in appendix A. Table 2 for the dependent variables has the same general structure as table 1 for the independent variables. The approximately 65 types of dependent variables listed in table 2 are further broken down into 105 specific subtypes or levels of variables which could play an important role in measuring the possible effects of CEVMS on driver distraction. As noted before, it is encouraged to carefully examine the many dependent variables and their advantages and disadvantages, as described in table 2 in appendix A, to gain a greater appreciation of the wide variety of ways that driver safety can be measured as they relate to possible influences from CEVMS. With so many potential measurement techniques available, care must be taken in selecting appropriate dependent variables for any proposed program of research.

Only the key dependent variables are listed in the combined list of 28 key measures given above. They were selected by the same process used to select the key independent variables in the list of key factors. As indicated before, the criterion for selection was importance in conducting research on CEVMS effects. Thus, the list of key measures indicates critical measures which need to be considered in future research. Eye glance behavior can serve as a particularly important potential indicator of specific visual distractions. The concept of self-regulated attention is very important for establishing excessive levels of distraction, despite difficulties in establishing a criterion threshold. This concept refers to attention that is under the driver's conscious control, as opposed to involuntary attention, which may compel the driver to glance away from the road for an excessive amount of time. Increases in driving conflicts and errors are likewise effective measures of safety. The next level of importance relates to other observations of vehicle behaviors, including determinations of acceleration, lane position, and speed. Similarly important infrastructure interactions, such as driver responses to roadway geometry and traffic control devices, need to be considered.

4.0 RESEARCH STRATEGIES

To successfully investigate the potential safety effects of CEVMS, the key factors (independent variables) and key measures (dependent variables) described in the previous section need to be selected, combined, and integrated into an effective research strategy. There are a number of possible research strategies that could address the basic research question. The list of recommended research strategies shown below lists eight key research approaches that might be considered. This list was generated from a more comprehensive and detailed analysis of the research strategies which might be of interest. This comprehensive analysis of research strategies was divided into six major groups (see table 3 in appendix A). The first group focuses on observing or counting actual motor vehicle crashes as they might occur or have occurred in the field. This field portion includes retrospective crash data base studies. The second group entails observing motor vehicle crashes as they might occur in a driving simulator. The third group involves observing safety surrogate measures as they might actually occur in the field. The fourth group focuses on observing safety surrogate measures as they might occur in a driving simulator. The fifth and sixth groups relate to social surveys and analytical studies. In this instance, the down-selection process eliminated all research strategies concerning crashes, social surveys, and analytical studies. Within the parentheses next to each strategy are some selected advantages and disadvantages associated with using that type of strategy in conducting research.

Only the key strategies are shown in the list of recommended research strategies. They were selected by the same process used to select the key independent and dependent variables, with one important exception. This exception involves the incorporation of several assumptions which were derived from the antecedent analysis of potential independent and dependent variables. First, the brightness, sharpness, photo realism, and visual context of the CEVMS are extremely important. Since these characteristics are difficult to reproduce in a laboratory, laboratory methods tended to be judged low. In addition, certain participant-related variables, in particular eye glance behavior, are highly effective measures of distraction and workload. Any research method that supported the measurement of such variables tended to be judged high. Last, crash data involve rare events with multiple causal factors, making them difficult to measure. The CEVMS technology is too new to have an adequate crash heritage. In general, crash estimation methods tended to be judged low.

After incorporation of the above assumptions, the following final list of recommended research strategies was developed. This final list included strategies from only two of the original six groups of strategies.

The recommended research strategies for the safety surrogate field group include the following:

- Unobtrusive observation [3.1] (natural driving context/no eye glance data, expensive).
- Naturalistic driving [3.2] (natural driving context/insensitive eye glance data, expensive).
- On-road instrumented vehicle [3.3] (experimental control, sensitive eye glance data, efficient, cost effective/artificial drive purpose).

- Closed-course test track [3.4] (stimulus control, efficient, cost effective/out of context driving).

- Commentary driving [3.5] (easy/artificial response, interfere with driving).

- Non-vehicle based field testing [3.6] (easy/artificial, out of context).

The recommended research strategies for the safety surrogate laboratory group include the following:

- Driving simulator [4.1] (experimental control, sensitive eye glance data, efficient/limited stimulus, artificial).

- Non-simulator laboratory [4.2] (relatively easy/artificial, out of context).

The more detailed analysis underlying the above combined list of recommended research strategies may be found in table 3 in appendix A. In the table, the more comprehensive analysis of research strategies is further broken down into approximately 55 specific categories and 165 subtypes or levels of these categories. The reader is encouraged to carefully examine the many strategies and their advantages and disadvantages, as described in the table, to gain a greater appreciation of the wide variety of potentially relevant research methods which might be employed to study possible CEVMS effects.

Table 3 can be used to discriminate among potential candidate research strategies. Certain research strategies can be eliminated from further consideration. Analytical studies cannot fill knowledge gaps and consequently often fall prey to reliance on unfounded assumptions. Social surveys are based on memory and opinion, and they are generally administered far from the event of interest both in terms of time and space. Crash rates, whether observed in the field or in the laboratory, represent extremely rare events, which are often the result of multiple complex causes and thereby difficult to evaluate. CEVMS technology has not been deployed long enough to accumulate a sufficient number of proximal motor vehicle crashes to make reliable estimates concerning population crash statistics in the field. Driving simulators used to measure safety surrogates have the advantage of careful control over stimulus parameters and testing conditions, but they suffer the disadvantage of being unnatural and artificial. More importantly, driving simulators have difficulty reproducing the luminance contrast and bright photorealism of the new CEVMS technology. In a similar manner, the closed-course test track and non-vehicle based field testing techniques represent a comparatively artificial and out-of-context experimental environment even though they are conducted in the field. Finally, commentary driving also affords natural billboard stimuli, but the driving task becomes somewhat artificial.

The three research strategies which were judged to be the most effective were the on-road instrumented vehicle, the naturalistic driving, and the unobtrusive observation method, which were all used to measure driver distraction and safety surrogates. Thus, the outcome of the present investigation of research strategies recommends three primary candidates for consideration in any program of future research to study the possible effects of CEVMS on driver distraction and roadway safety. Each of the three study methods represented has its own unique advantages and disadvantages. All three of these top candidate research strategies should be considered in developing any future research program on CEVMS effects. They provide the basis for selecting a recommended first stage study in such a program.

This is not to say that other research strategies do not have a significant role to play in a comprehensive research program directed toward a common goal. For example, if significant negative CEVMS safety effects have already been found using one of the primary research strategies, subsequent driving simulator experiments might be employed to systematically vary certain billboard location, timing, or spacing parameters in a controlled and consistent manner to establish billboard placement guidance. In addition, combinations of research strategies can result in synergistic efficiency. For example, both the unobtrusive observation and the naturalistic driving methods naturally support the simultaneous collection of crash, near-crash, or safety surrogate data. The analysis of crash data will also be needed to relate measures of driver distraction to more direct determinants of roadway safety.

5.0 FUTURE RESEARCH PROGRAM

As stated previously, it is not possible to answer all of the critical questions concerning possible attention, distraction, and safety impacts from CEVMS in a single experiment. Instead, a carefully crafted program of research needs to be conceived and implemented to embrace a series of interrelated experiments and studies directed at answering different facets of this complex issue. This section describes the important elements of a recommended research program. This research program is broadly defined to provide a background and context for more concrete alternative first stage studies outlined in section 6.0. This section describes a long-range multistudy research program covering a number of years. Section 6.0 will outline three methods for implementing the first stage of that program.

5.1 STAGES

The proposed research program would have the following three stages:

- Stage 1—The attention and distraction effects of CEVMS would be investigated to determine whether any observed or measured distractions due to CEVMS is sufficient to interfere with attentional criteria for safe driving. This stage is directed at discovering whether or not distraction from CEVMS represents a potential driving hazard. Initial CEVMS parameters must be chosen carefully so as not to bias the result from the outset.

- Stage 2—If potential interfering distraction is observed, it would be necessary to investigate the relationship between the observed distraction and various CEVMS parameters (e.g., luminance, change rate, distance, CEVMS spacing, engagement level of sign content, and road geometry) to determine possible limitations on CEVMS deployment and operation which might reduce distraction to noninterfering levels. This stage is directed at developing empirical data to support the development of possible restrictions or regulation of CEVMS to reduce potential driving hazards.

- Stage 3—As related to CEVMS, researchers would have to investigate the relationship between distraction, defined in terms of eye glance behavior and safety surrogate measures (driving conflicts, errors, etc.), and safety, defined more directly in terms of crashes, fatalities, injuries, and property damage. This stage focuses on validating the eye glance and safety surrogate measures used to infer attention and distraction effects of CEVMS through the primary safety criterion of protecting life, health, and property.

The above stages of the proposed research program are to be pursued sequentially. The initial stage is directed at determining whether or not a potentially harmful CEVMS distraction effect exists. To demonstrate such a distraction effect, an independent and objective threshold criterion of excessive distraction must be employed. If no potentially harmful distraction is shown, at least as far as driving safety is concerned, there would be little need to pursue the second stage of developing a basis for regulating CEVMS or the third stage of relating CEVMS distraction to more direct measures of safety (crashes). If potentially harmful distraction is shown in the first stage, the second and third stages would be implemented in order. The order of the last two stages may appear to be reversed. Normally, it would seem desirable to establish a relationship between CEVMS distraction and crashes before developing a basis for regulation. However, in this instance, the LED-based digital CEVMS technology is so new that it will not be possible to reliably measure crashes for some time. Meanwhile, if possible distraction is shown, the community of practitioners engaged in outdoor advertising control will need near-term technical information on the luminance, contrast, change rates, and spacing of CEVMS to minimize that distraction. For this reason, the stages have been proposed in the order given above.

5.2 APPROACH

The literature review update in section 2.0 points to some important principles that should be incorporated into the proposed program of research to enhance the probability that the program can successfully achieve its goals. These principles can be regarded as lessons learned from the experience of previous research. First, empirical studies should employ CEVMS stimuli, as well as a variety of comparison stimuli, including standard (non-digital) billboards, built objects of casual visual interest (e.g., houses, barns), and natural background control scenery (e.g., trees, fields). This principle establishes a relevant visual context against which to contrast CEVMS stimuli. Next, empirical studies should be constructed so as to compare the effects of CEVMS and the effects of the various comparison stimuli. This principle implies that some measurable (statistically significant) effect should be demonstrated for as many of the comparison stimuli as possible, at least for the standard billboards. It is necessary to show some distraction effect for both CEVMS and standard billboards relative to a baseline to be sure that the study is not just measuring random noise in the data. In addition, for the case of distraction and safety surrogate performance measures, the measured effects of CEVMS and standard billboards need to be compared with each other and with an independently determined criterion of potentially harmful consequences. The application of this criterion needs to incorporate the concept of self-regulated attention, as indicated in section 3.0. Last, to the degree possible, direct experimental control should be exerted over the CEVMS stimuli. In the first stage of determining a meaningful distraction effect, this control can be limited to turning the CEVMS on and off for predetermined periods according to a strict experimental protocol. In the second stage of establishing possible parameter limitations, this control may need to be expanded to changing the luminance, message change rate, or some other CEVMS characteristic according to an experimental protocol.

These four principles define the basic approach for implementing the proposed research program. They provide guidance and direction to the proposed program. It should be emphasized that only a systematic multiyear broad program of research can adequately answer the important questions posed by the community interested in outdoor advertising control concerning the possible distraction effects and safety implications of CEVMS. No single experiment can provide the solution. It should also be emphasized that all stages of the research program must be sensitive to the practical needs of the outdoor advertising community, which includes highway engineers, traffic engineers, the outdoor advertising industry, environmental advocates, and outdoor advertising regulators. Even though the second stage is where most of these practical needs are addressed, at all stages of the research, investigators need to try to provide practical information on the luminance, contrast, change rate, display size, display spacing, or other parameters over which the outdoor advertising community could possibly exert some control. Administrators concerned with issuing permits for billboards need practical engineering results to assist them in there daily jobs.

5.3 STRUCTURE

As outlined above, the proposed research program consists of three stages. The first stage focuses on determining the potential existence of harmful distraction effects due to CEVMS. The second stage involves determining limitations or restrictions to CEVMS parameters which could reduce or eliminate the implied potentially harmful distracting effects. The third stage focuses on relating the reduction in implied potentially harmful distraction to actual safety benefits of decreasing crashes, fatalities, injuries, and property damage on the roadway. The sections below describe these stages in more detail.

5.3.1 Stage 1—Determination of Distraction

The first stage, to determine the potential existence of harmful CEVMS distraction, may be implemented in many different ways. According to the analysis of research strategies in section 4.0, the three most effective approaches are the on-road instrumented vehicle, the naturalistic driving, and the unobtrusive observation methods.

The on-road instrumented vehicle method is sensitive to a wide range of variables, including accurate eye glance measurements. It affords the opportunity to ensure that the test participants drive by many CEVMS and comparison sites in a structured and reproducible manner.

The naturalistic driving method is similar to the on-road instrumented vehicle technique, but it has less control since the test participants drive their own vehicles according to their own personal daily schedules. As a result, the participants may pass few, if any, billboards. Furthermore, the naturalistic driving method has difficulty supporting accurate eye glance measurements, and it requires considerably more effort and expense. However, the naturalistic driving method is less artificial and has a high degree of face validity.

Although the unobtrusive observation method also involves considerable effort and expense, the data collected are based on the observation of vehicles rather than individual drivers. The unobtrusive observation method is the least artificial of the three because with this technique, research participants are generally unaware of being observed.

This first stage of the research program would employ one or more of these study approaches as a first step. A single method could be selected, or more than one approach could be combined. For example, the on-road instrumented vehicle and the unobtrusive observation method could make an effective combination, but the cost would be high. In either case, this first stage should also be designed to answer, at least in a preliminary manner to whatever degree possible, some of the practical questions of interest to the community concerned with outdoor advertising control.

5.3.2 Stage 2—Basis for Regulation

If the results of the first stage reveal a CEVMS driver distraction effect sufficient for public concern, then the second stage of the proposed research program would be implemented to provide an initial technical basis for possible regulation. This stage would consist of a series of eye glance and safety surrogate evaluations in the field and in the laboratory designed to investigate the various parameters of CEVMS which contribute to driver distraction. Although field methods can capture the realism of the CEVMS stimulus, they do not allow the researcher to independently vary a variety of CEVMS parameters one at a time so as to isolate the effect of that variable, as some of the laboratory techniques would. For example, this second stage might begin with attempts to estimate the gross effects of certain salient CEVMS parameters in the field. Throughout this section, the brightness of the CEVMS will be used as an example, but the approach can be adapted to many other relevant CEVMS characteristics. For example, many current CEVMS displays adjust their brightness for day and night. If the outdoor advertising industry would agree to adjust the brightness of several installations both during the day and at night for the purposes of experimentation, partial estimates of the effects of brightness on eye glance behavior might be elaborated for selected luminance levels.

To obtain a more complete functional relationship between eye glance distraction and CEVMS luminance, a test track or driving simulator experiment might be devised. If it were possible to erect an experimental CEVMS installation at a test track location, the test track experiment would have realistic brightness and contrast levels, as well as controlled exposure conditions. However, it would suffer from a highly constrained and unnatural driving environment. The driving simulator experiment could easily portray a wide variety of driving environments with realistic contexts, but it would suffer from a severely restricted range of luminance and contrast ratios. Nonetheless, to overcome these disadvantages, correction factors or transformations might be applied to the test track data to account for discrepancies in level of attention and to the driving simulator data to account for photometric discrepancies. The incorporation of such correction factors or transformations to relate test track and laboratory data to driving data on real roads underscores the necessity of conducting a combination of field and laboratory testing environments in this stage of the proposed research program. Some degree of field validation needs to be a part of any laboratory component of the research during this stage.

This second stage of the research program must be designed to answer, to the degree possible, the practical questions of the community interested in outdoor advertising control. This is the stage of research which addresses functional relationships regarding the effects of CEVMS luminance (brightness), change rates, size, display spacing, and other variables on driver distraction and roadway safety. These functional relationships could subsequently be translated by outdoor advertising administrators and regulators into concrete rules which protect the safety of the driving public while at the same time allowing commercial growth and the rights of the outdoor advertising industry. To be fully successful, this stage of the research program must be pursued with active participation from all stakeholders, which include industry, environmentalists, researchers, and regulators alike.

5.3.3 Stage 3—Relationship to Crashes

The third stage of the proposed research program relates changes in potentially harmful distraction effects due to various CEVMS parameters to changes in actual roadway safety (crashes and their consequent fatalities, injuries, and property damage). This stage is directed at validating the earlier findings with regard to CEVMS distraction based on eye glance and safety surrogate measures in the context of retrospective crash data. This stage of the program would likely employ the Empirical Bayes, or Bayesian, method of analyzing crash statistics. The Bayesian approach formally incorporates prior knowledge into the process of current research, and it translates probabilistic calculations into statements of belief concerning statistical hypotheses in place of the classical confidence interval concept employed in parametric statistics. The Empirical Bayes method also incorporates the crash history of other control sites with similar traits to account for extraneous factors which may be influencing the crash data at the site of interest. In short, the Empirical Bayes method possesses distinct statistical advantages over the naïve before/after technique and even the before/after technique with a simple control. The Empirical Bayes method is well suited for the task of estimating vehicle crash rates along different stretches of roadway, including those stretches with CEVMS. The prediction of baseline crash rates, and their potential increase or decrease with the introduction of CEVMS, is essential to this final stage of the proposed research program. This final stage should also be designed to answer, to whatever degree possible based on crash statistics, some of the practical questions of interest to the community concerned with outdoor advertising control. Because of the low numbers of crashes and their susceptibility to multiple determining causes, considerable effort, time, and expense will likely have to be expended on this final stage.

6.0 RECOMMENDED FIRST STAGE STUDY

The first stage of the research program, determination of distraction, provides the context for selecting the recommended next study. The first goal of this stage of the program is to determine whether any observed or measured distraction due to CEVMS is sufficient to interfere with attentional criteria for safe driving. The second goal is to provide some preliminary practical technical information that could be of help to the community interested in outdoor advertising control. This goal could consist of furnishing initial indications of the possible distraction effects produced by one or more of the concrete variables over which the community might exert some control, such as luminance (brightness), change rate, display size, and display spacing. According to the analysis summarized in section 4.0, to provide an initial answer to these types of questions, the three most effective research strategies are the on-road instrumented vehicle, the naturalistic driving, and the unobtrusive observation methods. In the present section, one possible preliminary study is briefly described using each of these three approaches. A more detailed description of each study approach is given in appendix B. This detailed description includes more specific information on the general method, factors and measures employed, advantages and disadvantages, and budgetary cost. After project initiation, a more comprehensive work plan and more in-depth budget will need to be developed. That comprehensive work plan should receive inputs from all of the important stakeholders in CEVMS research, which include industry, environmentalists, researchers, and regulators alike. After careful and thorough deliberation, the final details of that comprehensive work plan and budget may differ considerably from what is suggested in this section or in appendix B.

6.1 SUMMARY OF STUDY APPROACHES

6.1.1 On-Road Instrumented Vehicle

The on-road instrumented vehicle method employs an instrumented vehicle which is brought to the study site. The study site is a location where there are one or more CEVMS installations along a public access roadway. Each research participant drives the instrumented vehicle along a prescribed route, which includes CEVMS installations, standard (non-digital) billboards, objects of casual visual interest (e.g., houses and barns), and natural background control scenery (e.g., trees and fields). Each participant completes several such drives. The instrumented vehicle is capable of measuring vehicle speed, vehicle lane position, longitudinal acceleration, lateral acceleration, GPS time and position, and driver eye glance direction and duration. The instrumented vehicle is also equipped with accurate vehicle-mounted or head-mounted eye-tracking equipment, video cameras (forward and cab views), and a voice recorder. The major independent variable in the study is the presence or absence of CEVMS and other comparison visual stimuli along the driving path. If possible, the CEVMS should be capable of being turned off and on or changing along some other dimension like luminance or change rate, according to a prearranged experimental design. Other important independent variables are the time of day (day/night), traffic conditions (peak, nonpeak) and driver variables (age, gender, and route familiarity). The primary dependent variables are the frequency, direction, and duration of driver eye glances. Secondary dependent measures are safety surrogate indicators associated with driver errors and other measures of driver performance, such as speed changes, headway, lane deviation, and traffic conflicts. A rough budgetary estimate for conducting such an on-road instrumented vehicle study is between $400,000 and $800,000 (see appendix B for more details).

6.1.2 Naturalistic Driving

The naturalistic driving method employs a standardized instrument package which is installed in each participant's own private vehicle or in a vehicle loaned to the participant. The participant's vehicle appears and performs as it normally would. Participants drive their vehicles as part of their daily life routines, making control of CEVMS exposure difficult. The instrument package is capable of measuring speed, lane position, acceleration, GPS time and position, driver eye glance frequency, direction, and duration. However, because of the unobtrusive nature of the experimental technique, this method cannot support the use of accurate head-mounted or vehicle-mounted eye-tracking equipment. Once the participant's vehicle has been instrumented, data are collected by means of automatic wireless downloads without participant awareness or involvement. The major independent variable is the presence or absence of CEVMS and other comparison visual stimuli (standard billboards, buildings, control settings, etc.) along the driven path. If possible, the CEVMS should be controlled according to a prearranged experimental protocol. Secondary independent variables could include the type of vehicle (sedan, pickup, or SUV) and driver characteristics (age, gender, and route familiarity). The primary measures or dependent variables are the frequency, direction, and duration of the driver's eye glances. However, as a result of the lower degree of accuracy in eye movement recording, this study method depends more heavily on secondary dependent variables. Safety surrogate measures associated with driver errors and other measures of driver performance (headway, lane deviation, conflicts, and erratic maneuvers) are of increased importance in this method. Additional dependent variables may include the time of day (day/night), traffic conditions (peak, nonpeak), in-vehicle distractions (eating, cell phone use), state of fatigue, etc. A rough budgetary estimate for conducting such a naturalistic driving study is between $2 million and $4 million (see appendix B for more details).

6.1.3 Unobtrusive Observation

The unobtrusive observation method employs an array of static cameras or other sensors mounted near the locations of the CEVMS and other comparison stimuli. The cameras are capable of recording the behavior of vehicles passing the various relevant visual stimuli as a part of the natural flow of traffic. The drivers are usually completely unaware that their vehicles are being observed. Post-hoc analysis of the video recordings from these cameras can yield data similar to some of that obtained by the on-road instrumented vehicle and naturalistic driving methods including vehicle speed, lane position, acceleration, and time. However, the data from distal video cameras are usually far less accurate and reliable than what can be collected by instruments on board the vehicle. Moreover, with present measurement technology, such video recordings cannot yield any data concerning driver eye glance movements. The major independent variable is the presence or absence of CEVMS and other comparison visual stimuli (standard billboards, buildings, etc.) along the driving path. If possible, the CEVMS should be controlled according to a prearranged experimental protocol.

Some secondary independent variables might include the time of day (day/night) and traffic conditions (peak, nonpeak). This study method depends completely on safety surrogate measures associated with driver errors and other measures of driver performance (headway, lane deviation, and erratic maneuvers), and it requires a large camera array over a long distance recording for extended periods, as well as extensive data analysis. A rough budgetary estimate for conducting such an unobtrusive observation study is between $1 million and $3 million (see appendix B for more details).

6.2 COMPARISON OF STUDY ALTERNATIVES

This section has introduced and described three different candidate approaches for the recommended next study, which include the on-road instrumented vehicle method, the naturalistic driving method, and the unobtrusive observation method. Each study method would be capable of addressing the two-part basic research question to determine whether any observed or measured distraction due to CEVMS is sufficient to interfere with attentional criteria for safe driving, and to provide some preliminary practical technical information that could be of help to the community interested in outdoor advertising control. However, each method has certain advantages and disadvantages with regard to its ability to address these two questions.

The on-road instrumented vehicle method was judged the best, having the advantage of being sensitive to a wide range of participant variables, including accurate eye glance measurements with real CEVMS stimuli in natural settings. The degree of experimental control afforded by this method makes it the most productive of the three. Driving scenarios can be selected with a number of CEVMS and standard billboard stimuli along a single drive, which can be repeated both within and across research participants. To the degree that accurate measurements of visual distraction and eye glance behavior are pivotal dependent variables, the on-road instrumented vehicle method has the clear advantage. The high degree of experimental control ensures that exposure to CEVMS and to comparing visual stimuli is uniform and consistent. The on-road instrumented vehicle approach is the most productive research method for producing quality data in the shortest amount of time for the least cost.

The naturalistic driving method was judged the second best, offering some similar advantages to the on-road instrumented vehicle method. However, it suffered from less experimental control over CEVMS exposure, less ability to capture participant-related variables, and more logistical complication and expense. Both of these methods are somewhat related from the perspective of the research participant. In both cases, the research participant is driving in an instrumented vehicle on a real road. Both allow the determination of driver eye glance behavior to some degree, but the increased level of experimental control exercised in the on-road instrumented vehicle method gives this technique a distinct advantage, both in terms of more accurate eye glance measurements and more consistent driver exposure.

Finally, unobtrusive observation of safety surrogate measures involves no direct contact with the driver, thus preserving a completely natural driving environment. However, this method is not sensitive to participant variables. In particular, it is not possible to measure eye glance behavior with this method. This method depends solely on safety surrogate measures. Furthermore, since these safety surrogate measures are relatively subtle to detect at a distance, this method can be costly and time-consuming to implement.

The on-road instrumented vehicle method has a strong advantage in productivity and efficiency. The major advantage of the other two methods is the natural and unobtrusive nature of the study procedure from the perspective of the research participants. However, some degree of artificiality may be a small price to pay to gain the cost effectiveness of the on-road instrumented vehicle method. In the final analysis, the present report recommends the on-road instrumented vehicle method as the best choice for the first stage study. This recommendation is made on the basis of scientific merit, timeliness of producing a meaningful result, and cost.

7.0 CONCLUSIONS

The present report reviews the possible safety effects of CEVMS. The report consists of an update of earlier published work, an investigation of applicable research methods and techniques, recommendations for future research, and an extensive reference list and bibliography. The literature review update covers recent post-hoc crash studies, field investigations, laboratory investigations, previous literature reviews, and reviews of practice. The conclusion of the literature review is that the current body of knowledge represents an inconclusive scientific result with regard to demonstrating detrimental driver safety effects due to CEVMS exposure. This outcome points toward the importance of conducting carefully controlled and methodologically sound future research on the issue.

The present report also analyzes the key factors or independent variables affecting a driver's response to CEVMS and the key measures or dependent variables which serve as indicators of driver safety. These key factors and measures are selected, combined, and integrated into a set of optimal research strategies. Based on these strategies, as well as on lessons learned from the literature review update, a proposed long-term program of research has been developed to address the problem. This research program consists of three stages, which include determination of distraction, basis for possible regulation, and relationship of distraction to crashes.

The present report only addresses the first stage of the proposed research program in detail. For this first stage, three candidate studies, which are an on-road instrumented vehicle study, a naturalistic driving study, and an unobtrusive observation study, have been introduced and compared. An analysis of the relative advantages and disadvantages of each study indicate that the on-road instrumented vehicle study is the best choice as the recommended first stage in answering the basic research question.

APPENDIX A—EXPANDED TABLES

A.1 KEY FACTORS (INDEPENDENT VARIABLES)

Table 1. Expanded key factors (independent variables).

Variable	Ref. #	Advantages	Disadvantages
1.0 Billboard			
1.1 Location	8, 129, 38, 15, 44, 32		
1.1.1 Lat./long.; GPS; mile marker; survey location; reference location; mobile	13, 53, 160	Important to define stimulus; Easy to measure.	Likely to require travel expenses.
1.1.2 Distance from roadway; setback			Less important.
1.1.3 Sight distance; visual occlusions; distance first detected	13, 53	Determines exposure time.	
1.1.4 Orientation; angle to road; side of road; two-sided	144		Less important.
1.2 Display	144		
1.2.1 Type: Conventional; Digital; Tri-vision	125, 48	Digital type stands out.	Tri-vision likely to disappear.
1.2.2 Size; length; height; visual angle; mounting height	129, 32	Off-premise sizes somewhat standard.	On-premise sizes variable.
1.2.3 Resolution; dpi; LEDs/in	95, 48, 53	Crispness (sharpness) of image important.	
1.2.4 Luminance; contrast ratio; day/night settings	48, 53, 144	Brightness (luminance) extremely important.	Night setting may depend upon background illumination.
1.3 Dynamics	31		

Variable	Ref. #	Advantages	Disadvantages
1.3.1 Type: static; changing	158, 129, 26	Changing images extremely important. Static serves as control.	
1.3.2 Change rate; dwell time; change time; sequencing	48, 50, 158, 94	Change pattern important. Easy to measure.	
1.3.3 Special effects: wipe, dissolve, scintillate		Adds to uniqueness and conspicuity.	More difficult to measure.
1.3.4 Full motion video	125, 126	Full motion video extremely compelling.	Difficult to specify exact content seen.
1.3.5 Engagement value: ability to hold attention		Important overall distraction variable	Difficult to measure; requires subjective rating.
1.3.6 Sound			
1.4 Message	129, 44, 144, 53		
1.4.1 Type: text; graphics; mixed; targeted	32, 31	Particular message may be secondary.	
1.4.2 Text: word count; font size; color; content; legibility; affect	32, 48		Many variations. Less important.
1.4.3 Graphics: size; complexity; color; content; affect	31, 50		Difficult to specify. Many varieties.
1.4.4 Public safety alerts		Social benefit.	May be more distracting than advertising.
1.4.5 Interactive: encourages driver response		Interactive may require more attention.	
2.0 Roadway			
2.1 Type			

Variable	Ref. #	Advantages	Disadvantages
2.1.1 Category: two-lane rural; collector; arterial; freeway	13, 15 71, 54	Important determinate of driver workload.	Many variations even in single category.
2.1.2 Lanes: number; width; markings; medians; shoulders; rumble strips			Less important.
2.1.3 Speed: posted; advisory; 85th percentile; median	50	Changes urgency of correct driving responses.	
2.1.4 Condition: dry, wet, ice, rain; oil slick		Important to driver control over vehicle.	
2.1.5 Traction: coefficient of friction			
2.2 Complexity	15		
2.2.1 Tangent: level; grade			Less important.
2.2.2 Curve: horizontal; vertical	13, 44, 118	May place sudden demand on driver attention.	
2.2.3 Intersection: signalized; stop controlled	129, 38, 48	Increased driver workload.	Wide variety of intersection complexities.
2.2.4 Interchange: exit, entrance, merge, gore	26, 44, 32, 48	Controlled access. More carefully engineered.	
2.2.5 Driveway; entrance			Less important.
2.2.6 Lane change: merge; diverge; lane drop		May place sudden demand on driver attention.	
2.2.7 Other: bicycle lane; fire house			Less important.
2.3 Traffic	158, 38, 15, 113,		

Variable	Ref. #	Advantages	Disadvantages
2.3.1 Average daily traffic; peak traffic; level of service	118	Likely to increase driver workload.	
2.3.2 Traffic mix: cars, trucks, buses, motorcycles			Less important.
2.3.3 Pedestrians			Mainly only in urban settings.
3.0 Vehicle	59		
3.1 Type: automobile; SUV; truck; motorcycle		Motorcycle has least obstructed view.	
3.2 Condition: response; vehicle dynamics			Hard to determine in field.
3.3 Windshield: size; tinting; field of view		Defines some stimulus exposure characteristics.	
4.0 Driver	10		
4.1 Characteristics: age; gender; demographics	53, 23, 12, 54		Less important.
4.2 Experience: years driving; route familiarity	15, 100	Route familiarity extremely important.	
4.3 State: alert; fatigue; alcohol; drugs			Difficult to measure.
4.4 Distractions: conversation; eating; cell phone	24, 90, 25		
5.0 Environment			
5.1 Visual—general	113		
5.1.1 Visual clutter; nearby billboards; ambient lighting	160, 15, 32, 44	Complexity of visual environment extremely important.	Difficult to specify.

Variable	Ref. #	Advantages	Disadvantages
5.1.2 Day/night viewing: dawn; dusk; sun-glare	53	Nighttime viewing of bright images important.	
5.1.3 Visual flow			Less important.
5.2 Official signs	160, 2, 26, 100		
5.2.1 Type: regulatory, advisory, navigational	94	Regulatory most important.	
5.2.2 Location: left, right, overhead	44, 15	Billboard can conflict with sign.	
5.2.3 Lighting: illuminated; luminous (VMS); retro-reflective		Luminous (VMS) signs most important.	
5.2.4 Density: number in view, type mix	15		Many variations in urban settings.
5.2.5 Dynamics: change rate; motion; video		Extremely important point of possible conflict.	Motion and video not yet allowed.
5.2.6 Message: text; graphics			Less important
5.3 On-premise signs			
5.3.1 Type: conventional; Tri-vision; digital; full motion video	144	Digital and video most important.	Tri-vision likely to disappear.
5.3.2 Location: left, right, high, low	144		
5.3.3 Lighting: illuminated; luminous; LED	144	Bright, high resolution very compelling.	Difficult to measure.
5.3.4 Density: number in view, type mix		Can add to visual clutter.	Many variations possible.
5.3.4 Dynamics: change rate; motion; video; sound	144	Extremely important variable.	

Variable	Ref. #	Advantages	Disadvantages
5.3.5 Message: text; graphics; interactive		Interactive important.	Text and graphics less important.
5.4 Geographic	15		
5.4.1 Population: urban; suburban; rural	13, 71	Can affect visual clutter.	Many variations.
5.4.2 Terrain: mountain; valley; desert; hilly; near water		Can affect driver workload.	Many variations.
5.4.3 Area: city; state; region			Less important.
5.5 Meteorological			
5.5.1 Temperature; humidity; cloud cover	53		Less important.
5.5.2 Precipitation: rain; snow; fog; ice; visibility	53	Can affect driver workload.	

A.2 KEY MEASURES (DEPENDENT VARIABLES)

Table 2. Expanded key measures (dependent variables).

Variable	Ref. #	Advantages	Disadvantages
1.0 Vehicle Behavior	48		
1.1 Speed	125, 50		
1.1.1 Continuous		More accurate profile.	Large amounts of data. Expensive.
1.1.2 Discrete locations		Less data.	Cheaper.
1.1.3 Speed exceedances: high; low		Distraction indicator.	
1.1.4 Speed variance		Distraction indicator.	Best with continuous data.
1.2 Lane position	161, 48, 54		
1.2.1 Continuous		More accurate profile.	Large amounts of data. Expensive.
1.2.2 Discrete locations		Less data.	Cheaper.
1.2.3 Lane excursions: right; left	23	Distraction indicator.	More difficult to measure.
1.2.4 Lane variance		Distraction indicator.	Best with continuous data.
1.3 Acceleration	48, 54		
1.3.1 Longitudinal: hard braking; delayed acceleration; braking without cause		Excellent surrogate for distraction.	
1.3.2 Lateral: swerves	39	Good surrogate for distraction.	
1.3.3 Heave: bumps	125, 48		Not important.
1.4 Other vehicle interactions	39		

Variable	Ref. #	Advantages	Disadvantages
1.4.1 Headway (car following); time to collision	125, 48, 118	Good surrogate for distraction.	
1.4.2 Gap acceptance: merge; passing		Good surrogate for distraction.	Difficult to measure.
1.4.3 Conflicts; near-crashes	125	Extremely important measure.	
1.4.4 Violations: red light running; failure to yield; failure to stop			Low probability events.
1.4.5 Errors: missed exit; wrong lane		Good surrogate for distraction.	
1.4.6 Timing: late movements; premature movements			Difficult to measure.
1.5 Infrastructure interactions			
1.5.1 Response to roadway geometry: swerves; sudden braking	118, 15	Surrogate for distraction.	
1.5.2 Response to traffic control devices: misses, delays	15	Surrogate for distraction.	
1.5.3 Pedestrian interactions; yields			Only in urban settings.
1.6 Signals	39		
1.6.1 Brake light	125	Indication of sudden deceleration.	
1.6.2 Turn signals			Less important.
1.6.3 Other: backup lights			Not important.

Variable	**Ref. #**	**Advantages**	**Disadvantages**
2.0 Driver/Vehicle Interactions			
2.1 Steering			
2.1.1 Gross movements: curves; turns		Surrogate for distraction.	
2.1.2 Fine movements: lane keeping	60		Difficult to measure.
2.2 Throttle			
2.2.1 Pedal press; pedal position; duration			Less important.
2.2.2 Pedal release; duration			Less important.
2.3 Brake	125		
2.3.1 Pedal press; duration; excursion		Surrogate for distraction.	
2.3.2 Pedal release			Less important.
2.4 Shift (manual only)			
2.4.1 Gear selection (speed)			Not important.
2.4.2 Gear transitions (shifts)			Not important.
2.5 Displays	154		
2.5.1 Speedometer		Secondary visual distractor.	
2.5.2 Other: gauges; radio			Less important.
2.6 Other controls	154, 25		
2.6.1 Safety: windshield wipers; instrument lights; horn; turn signals	54		Less important, except turn signals.

Variable	Ref. #	Advantages	Disadvantages
2.6.2 Entertainment: radio; CD player	48, 24, 54	Secondary distractor.	
2.6.3 Auditory/vocal: voice actuated	154		Low probability of occurrence.
3.0 Driver Attention / Distraction	79, 113, 32, 146, 145		
3.1 Objective measures	129		
3.1.1 Eye glance behavior: eye movements; number of glances; duration of glances; glance object	129, 42, 125, 53, 160, 83, 161, 78	Excellent measure of unconscious attention / distraction.	Delicate, expensive equipment. Difficult to calibrate. Expensive to analyze data.
3.1.2 Distractor performance; secondary task	83, 53	Excellent measure of distraction.	Can increase risk in field experiments. Can be artificial.
3.1.3 Visual occlusion	15	Good measure of distraction.	Can increase risk in field experiments. Unnatural driving task.
3.1.4 Feature detection	48		
3.1.5 Feature recognition	48	Good measure.	
3.1.6 Driver workload; task performance	38, 15, 113	Excellent indicator of distraction.	Complicated to measure.
3.1.7 Head turning	78	Easy to measure.	Less important.
3.1.8 Driver errors	83	Excellent measure of distraction.	Many varieties. Low probability of occurrence.
3.1.9 Reaction time; perception-reaction time	15	Good indicator of distraction.	Difficult to measure.
3.2 Inferred measures			
3.2.1 Surprise; orienting response			Difficult to measure.

Variable	Ref. #	Advantages	Disadvantages
3.2.2 Conspicuity; attention grabbing			Difficult to measure.
3.2.3 Search patterns	15	Indicative of visual hypotheses.	
3.2.4 Capacity: self-regulated attention; spare capacity	15	Extremely important concept.	Hard to establish criterion threshold.
3.3 Subjective measures	161		
3.3.1 Conversational drive		Good possible method.	Lots of extraneous data.
3.3.2 Rating scale		Inexpensive.	Imprecise.
3.3.3 Questionnaire		Inexpensive.	Imprecise.
3.3.4 Survey	125	Relatively inexpensive.	Sampling frame difficult.
3.3.5 Focus group		Small sample. Lots of data.	Confounding social variables.
4.0 Crashes	158, 125, 26, 44, 128, 161, 95, 121		
4.1 Type: head-on; sideswipe; rear-end; backing; run-off-road; pedestrian	39	Very important discriminator variable. Related to ultimate goal.	Rare events. Many contributing factors. Difficult to estimate statistically.
4.2 Severity: fatal; injury; property damage; unreported		Important to determine impact.	Rare events. Many factors. Difficult to estimate statistically.
4.3 Method of measurement			Rare events. Hard to estimate.
4.3.1 Direct observation: simulator; field camera	42	Best studied in simulator. No chance of injury.	
4.3.2 Before/after study	39, 158	Most common study type.	No control site. Regression toward mean.

Variable	Ref. #	Advantages	Disadvantages
4.3.3 Before/after with control		Control adds rigor.	Regression toward mean.
4.3.4 Before/after/before		More convincing causal effect.	Regression toward mean.
4.3.5 Regression model		Directly account for multiple factors	Large amounts of data on many variables
4.3.6 Empirical Bayes		Control for regression toward mean.	More complicated statistical model.
4.3.7 Full Bayes		More complete treatment of conditional probabilities.	Not widely used.

A.3 KEY RESEARCH STRATEGIES

Table 3. Expanded key research strategies.

Method	**Ref. #**	**Advantages**	**Disadvantages**
1.0 Crashes: Field	97, 95, 21		
1.1 Unobtrusive observation			
1.1.1 Participant: random, uncontrolled; usually unknown	49	No sampling bias.	Do not know participant sample.
1.1.2 Experimenter: usually absent; remote observation; unknown to participant	49	No artificial participant behaviors due to experimenter.	
1.1.3 Stimuli: natural, ordinary, in context; variable, uncontrolled	49	Natural stimuli.	Stimuli not uniform; e.g., weather effects.
1.1.4 Responses: crashes; antecedent vehicle behaviors; rare; few participant variables	49	Directly related to the safety goal.	Extremely rare events; insensitive to participant variables.
1.1.5 Scenario: natural route and purpose; uses own vehicle	49	Completely natural experimental context; uses own vehicle.	Long-term monitoring required.
1.2 Naturalistic driving			
1.2.1 Participant: selected, sampled	79, 78, 42	Know participant sample.	Possible sampling bias.
1.2.2 Experimenter: absent; remote observation; known to participant	79, 78, 42		Possible artificial participant behaviors.
1.2.3 Stimuli: natural, ordinary, in context; variable, uncontrolled	79, 78, 64, 42	Natural stimuli.	Stimuli not uniform; e.g., weather effects.
1.2.4 Responses: crashes; antecedent vehicle and participant behaviors; rare	79, 78, 64, 42	Directly related to ultimate goal; sensitive to some participant variables.	Extremely rare events; difficult to collect adequate sample of crashes.

Method	Ref. #	Advantages	Disadvantages
1.2.5 Scenario: natural route and trip purpose; uses own vehicle	79, 78, 64, 42	Mostly natural experimental context; uses own or borrowed vehicle.	Participant aware of test status; may be injured or killed; vehicle may be damaged or destroyed; expensive.
1.3 Retrospective database: fatal, injury, property damage	87, 49, 128, 14, 58,	Directly related to ultimate goal.	Crashes are rare events; difficult to estimate.
1.3.1 Before-after study	158, 1, 130	Most common study type.	No control site; regression toward mean.
1.3.2 Before-after study with control	120	Control adds rigor.	Regression toward mean.
1.3.3 Before-after-before study		More convincing causal effect.	Regression toward mean.
1.3.4 Regression model		Directly account for multiple factors.	Large amounts of data on many variables.
1.3.5 Empirical Bayes		Control for regression toward mean.	More complicated statistical model.
1.3.6 Full Bayes		More complete treatment of conditional probabilities.	Not widely used.
2.0 Crashes: Laboratory			
2.1 Driving simulator			
2.1.1 Participant: selected, sampled	70	Know participant sample.	Possible sampling bias.
2.1.2 Experimenter: remotely present, unobtrusive observation	70	More experimenter control.	Possible artificial participant behaviors.
2.1.3 Stimuli: simulated, artificial; consistent, controlled	70	Extremely repeatable stimulus conditions.	Artificial stimuli; hard to simulate conspicuity and legibility.

Method	Ref. #	Advantages	Disadvantages
2.1.4 Responses: programmed crashes; antecedent participant and vehicle behaviors; can be more frequent crashes	70	Some control over crashes; can program more frequent crash opportunities.	Lack of negative consequences can unnaturally alter frequency of crashes.
2.1.5 Scenario: contrived route, artificial; unnatural vehicle and environment; safe from harm	70	Control over driving scenario; participant safe from harm.	Unnatural vehicle and environment; artificial scenario; simulator sickness.
2.2 Non-simulator laboratory	87		
2.2.1 Crash scenarios: movies, pictures, acting out		Relatively easy; less resources.	Artificial, out-of-context testing environment.
2.2.2 Crash reconstructions: questionnaires, focus groups		Relatively easy; focus groups more expensive.	Artificial, out-of-context testing environment; focus group social biases.
3.0 Safety Surrogate: Field	34, 85		
3.1 Unobtrusive observation			
3.1.1 Participant: random, uncontrolled; usually unknown	15	No sampling bias.	Do not know participant sample.
3.1.2 Experimenter: usually absent; remote observation; unknown to participant	15	No artificial participant behaviors due to experimenter.	
3.1.3 Stimuli: natural, ordinary, in context; variable, uncontrolled	15	Natural stimuli.	Stimuli not uniform; e.g., weather effects.
3.1.4 Responses: crash precursors; antecedent vehicle behaviors; more frequent; few participant variables	15	More frequent events than crashes; can collect more data with less risk.	Crash precursors only indirect indicators; insensitive to participant variables.
3.1.5 Scenario: natural route and trip purpose; uses own vehicle	15	Completely natural experimental context; uses own vehicle.	
3.2 Naturalistic driving			

Method	Ref. #	Advantages	Disadvantages
3.2.1 Participant: selected, sampled	79, 78, 42	Know participant sample.	Possible sampling bias.
3.2.2 Experimenter: absent; remote observation; known to participant	79, 78, 42		Possible artificial participant behaviors.
3.2.3 Stimuli: natural, ordinary, in context; variable, uncontrolled	79, 78, 42	Natural stimuli.	Stimuli not uniform; e.g., weather effects.
3.2.4 Responses: crash precursors; antecedent vehicle and participant behaviors; more frequent events	79, 78, 42	More frequent events than crashes; can collect more data with less risk.	Crash precursors only indirect indicators.
3.2.5 Scenario: natural route and trip purpose; uses own vehicle	79, 78, 118, 42	Mostly natural experimental context; uses own or long-term borrowed vehicle.	Participant aware of test status; may be injured or killed; vehicle may be damaged or destroyed; expensive.
3.3 On-road instrumented vehicle	14		
3.3.1 Participant: selected, sampled	54, 18	Know participant sample.	Possible sampling bias.
3.3.2 Experimenter: present; direct observation and interaction	83	More experimenter control; increased experiment safety.	Possible artificial participant behaviors.
3.3.3 Stimuli: selected; natural, in context	83, 18	Natural stimuli.	Stimuli not uniform; e.g., weather effects.
3.3.4 Responses: crash precursors; antecedent vehicle and participant behaviors; more frequent	54, 18	More frequent events than crashes; can collect more data with less risk.	Crash precursors only indirect indicators.
3.3.5 Scenario: natural route, artificial trip purpose; uses experimental vehicle	54, 83, 18	Semi-natural experimental context; more safe.	Artificial trip purpose; unfamiliar vehicle.
3.4 Closed-course test track			

Method	**Ref. #**	**Advantages**	**Disadvantages**
3.4.1 Participant: selected, sampled	136	Know participant sample.	Possible sampling bias.
3.4.2 Experimenter: present; direct observation and interaction	136	More experimenter control; increased experiment safety.	Possible artificial participant behaviors.
3.4.3 Stimuli: selected; out of context	136	Semi-natural stimuli.	Stimuli not uniform; some possible control.
3.4.4 Responses: crash precursors; antecedent vehicle and participant behaviors; more frequent	136	More frequent events than crashes; can collect more data with less risk.	Crash precursors only indirect indicators.
3.4.5 Scenario: unnatural route, artificial trip purpose; uses experimental vehicle	136	Low probability of harm to participant or vehicle.	Unnatural experimental context.
3.5 Commentary driving			
3.5.1 Participant: selected, sampled	36	Know participant sample.	Possible sampling bias.
3.5.2 Experimenter: present; direct observation; extensive interaction	36	More experimenter control; increased experiment safety.	Possible artificial participant behaviors.
3.5.3 Stimuli: selected; natural, in context	36	Natural stimuli.	Stimuli not uniform; e.g., weather effects.
3.5.4 Responses: extensive driver commentary; running verbal description; crash precursors observable		Collect large amounts of data; direct observation of gross attention.	Commentary could interfere with driving task; artificial task.
3.5.5 Scenario: natural route, artificial trip purpose		Semi-natural experimental context; more safe.	Artificial trip purpose.
3.6 Non-vehicle based field testing			
3.6.1 Roadside interviews	14, 125, 85	Relatively easy; less resources.	Artificial, distal testing environment.

Method	Ref. #	Advantages	Disadvantages
3.6.2 Fuel station, nearby mall interviews		Relatively easy; less resources.	Artificial, out-of-context testing environment.
4.0 Safety Surrogate: Laboratory	36		
4.1 Driving simulator			
4.1.1 Participant: selected, sampled	161, 4, 70, 82	Know participant sample.	Possible sampling bias.
4.1.2 Experimenter: remotely present, unobtrusive observation	161, 4, 70, 82	More experimenter control.	Possible artificial participant behaviors.
4.1.3 Stimuli: simulated, artificial; consistent, controlled	161, 4, 70, 82	Extremely repeatable stimulus conditions.	Artificial stimuli; hard to simulate conspicuity and legibility.
4.1.4 Responses: programmed crash precursors; antecedent participant and vehicle behaviors; can have more frequent events	10, 82, 4	Some control over near-crashes; can program more frequent near-crash opportunities.	Lack of negative consequences can unnaturally alter frequency of near-crashes.
4.1.5 Scenario: contrived route, artificial; unnatural vehicle and environment; safe from harm	161, 4, 70, 82	Control over driving scenario; participant safe from harm.	Unnatural vehicle and environment; artificial scenario; simulator sickness.
4.2 Non-simulator laboratory	75		
4.2.1 Pre-crash scenarios: movies, pictures, acting out	160, 36	Relatively easy; less resources.	Artificial, out-of-context testing environment; weak response measure.
4.2.2 Pre-crash reconstructions: questionnaires, focus groups	36	Relatively easy; focus groups more expensive.	Artificial, out-of-context testing environment; weak response measure; focus group social biases.
5.0 Social Survey	14, 125		
5.1 Telephone survey		Less resources; personal interviewer; more flexible.	Out of context; opinions only; more labor intensive; smaller scale.

Method	Ref. #	Advantages	Disadvantages
5.2 Mail survey		Less resources; standardized; larger scale.	Out of context; opinions only.
5.3 E-mail survey		Less resources; standardized; large scale.	Out of context; opinions only; internet user bias.
6.0 Analytical Study			
6.1 Literature review	53, 38, 26, 129, 52	Benefit from previous knowledge and mistakes.	Based on old information; abstract; hard to apply.
6.2 Review of practice	15, 44	Socially oriented, practical, legal.	Based on old information; not scientific; possibly misleading.
6.3 Deductive-inductive reasoning study	26	Less resources; no need for new data.	Must often make dangerous assumptions; cannot fill in knowledge gaps.

APPENDIX B—DETAILED DESCRIPTION OF STUDIES

B.1 ON-ROAD INSTRUMENTED VEHICLE APPROACH

The most effective research strategy to emerge from the analysis undertaken in section 6.0 is the on-road instrumented vehicle method. The following describes one possible study which might be conducted using this method.

B.1.1 Method

The on-road instrumented vehicle method employs an instrumented vehicle which is brought to the study site, along with a crew of about two or three researchers. The study site is a location where there is at least one CEVMS installation along a public access roadway. Preferably, there would be several CEVMS installations at the location so that a single test driving scenario might pass a few different CEVMS in the course of about half an hour of driving. The investigation should include at least two or three study sites which already have CEVMS in place. At each study site, approximately 20 to 30 research participants would be recruited from the local area.

Each research participant would drive the instrumented vehicle along a prescribed route, which includes CEVMS installations, standard (non-digital) billboards, human-constructed objects of casual visual interest (houses, barns, etc.), and natural background control scenery (trees, fields, etc.). Each drive takes less than 1 hour (preferably about 30 minutes), and each participant would return for several drives on different days. Other aspects would vary as well, such as the time of day, traffic density, and CEVMS conditions (e.g., CEVMS turned on versus CEVMS turned off). Each participant would complete between three and six such drives. The instrumented vehicle and crew would usually remain at a given study site for about 1 to 2 months. The crew would consist of an experimenter and a safety observer, who would both be present in the instrumented vehicle. The safety observer would also serve as a research assistant or technician. The instrumented vehicle is capable of measuring vehicle speed, vehicle lane position, longitudinal acceleration, lateral acceleration, GPS time and position, and driver eye glance direction and duration. The instrumented vehicle is also equipped with accurate vehicle-mounted or head-mounted eye-tracking equipment, video cameras (forward and cab views) and a voice recorder.

B.1.2 Factors and Measures

The major factors or independent variables in the study are the presence or absence of CEVMS and other comparison visual stimuli (standard billboards, buildings, etc.) along the driving path. If possible, the CEVMS should be capable of being turned off and on or changed along some other dimension like luminance or change rate, according to a prearranged experimental design. The period of time that the CEVMS is off or changed could be kept relatively brief and carefully controlled since the study will follow a strict protocol. Other important independent variables are the time of day (day/night), traffic conditions (peak and nonpeak), and driver variables (age, gender, and route familiarity). One or more of the primary CEVMS variables of interest to the community concerned with outdoor advertising control should be represented by varying levels along the driving route (e.g., different degrees of luminance, change rate, or display spacing) as much as possible. Direct experimental control would be preferable to site selection in this regard.

The primary measure or dependent variable in this study is the frequency, direction, and duration of driver eye glances, which serves as an indication of visual attention and distraction. The fundamental hypothesis is that drivers have limited attention; they self-regulate their attention to perform demanding tasks. In the case of the driving task, a certain proportion of their attention needs to be concentrated on the roadway scene ahead. To the degree that eye glance behavior can serve as a measure of visual attention, eye glances need to be concentrated on the roadway ahead. If the frequency and duration of eye glances away from the roadway ahead exceed accepted norms or criteria for keeping a driver's eyes on the road, then driver safety may be compromised. Thus, eye glance behavior is the primary dependent variable in the study. Eye glance behavior has an intuitive connection to visual attention and is sensitive to subtle visual search strategies, including those which are below the level of conscious awareness (see section 2.7.2). Depending upon the type of eye glance measuring instrumentation selected, the act of measuring eye glance behavior may prove to be a more or less significant distraction to the driver in itself. This experimentally-induced artifact can be controlled by selecting a minimally intrusive measurement method or by ensuring adequate adaptation to the instrumentation on the part of the research participant.

This study includes another class of secondary dependent variables. These are safety surrogate measures associated with driver errors and other measures of driver performance, such as speed changes, headway, lane deviation, and traffic conflicts. These secondary variables can be measured by instrumentation in the vehicle in terms of speed, acceleration, and lane position. These secondary variables can also be directly observed and noted by the experimenter and/or safety observer in the instrumented vehicle for later analysis in terms of sudden braking, inadequate headway, swerving, and conflicts. Thus, events indicative of possible driver error or other maladaptive behavior can be flagged by human observers. Also, for these events, only objective vehicle performance data needs to be analyzed, saving considerable effort and expense by eliminating the need to analyze large amounts of continuous vehicle performance data.

B.1.3 Advantages/Disadvantages

One advantage of this method is its ability to implement accurate eye-tracking measurements which afford the opportunity to observe subtle and often unconscious eye movements. This ability to measure unconscious eye movements correlates with unconscious distraction facilitates incorporation of the notion of self-regulated attention into the experimental paradigm. When a driver is attempting to concentrate on the roadway ahead, a distractor, which unconsciously diverts attention away from the roadway against the driver's will, may have a more severe safety consequence than a distractor which can be maintained under conscious and voluntary control. Thus, in addition to being able to measure distraction which is both conscious and voluntary, accurate eye-tracking determinations have the potential to probe other phenomena, such as unconscious and involuntary distraction as they relate to CEVMS exposure.

Another advantage of this method is the ability to structure driving scenarios to have an appropriate number of CEVMS, standard billboard, and other visual stimuli all located on a controlled course, which all research participants drive in a consistent manner. The ability to choose and structure the test drive assures adequate and uniform exposure to CEVMS and other relevant visual stimuli. The ability to exert experimental control is a valuable asset to this method. It facilitates a clean and robust statistical analysis of the data because all of the participants are exposed to all of the experimental conditions the same number of times in a relatively controlled manner. Experimental control ensures a high level of CEVMS exposure, thereby contributing to the productivity and cost effectiveness of this technique.

However, examined from a different perspective, such a degree of experimental control may also be regarded as a disadvantage. A certain amount of artificiality is introduced into the driving situation thereby. Research participants are definitely aware that they are participating in a controlled experiment, driving someone else's car on a contrived route which does not serve a personal purpose related to daily life. In addition, with the experimenter riding along with the participants in the vehicle, there may be a tendency for the participants to try to please the experimenter and to drive in some unnatural way. The introduction of eye-tracking equipment adds to the artificiality of the situation. Wearing head-mounted eye-tracking gear definitely represents unnatural driving attire. However, most research participants rapidly adapt to the gear with time, and they often report that they are unaware of its presence after a short drive. Vehicle-mounted eye-tracking equipment can be far less intrusive, although the tedious calibration procedures and the presence of the cameras in the car remind participants that their head and eye movements are constantly being monitored. These are all valid experimental concerns; however, none of these interventions is likely to profoundly alter the driving behavior, much less the eye glance movements, of the research participants, as long as they are not informed of the purpose of the study. The enhanced experimental efficiency that this approach has to offer far outweighs its artificiality drawbacks.

B.1.4 Budgetary Cost

A rough budgetary estimate for conducting such an on-road instrumented vehicle study is between $400,000 and $800,000. The main cost drivers for this method are the eye glance measuring technology and the crew needed to implement the experiment at the study sites. The range in this estimate relates to the number of study sites, adequacy of the sites, length of the experimental drive, number of experimental drives, number of research participants, difficulty in obtaining research participants, ability to turn the CEVMS off and on, and numerous other factors which cannot be determined without further planning.

B.2 NATURALISTIC DRIVING APPROACH

The naturalistic driving method is similar to the on-road instrumented vehicle method. The major difference is that the participants drive their own vehicles (or loaned vehicles) for their own personal purposes. The method typically employs a large number of such vehicles. The following describes one possible study which might be conducted using this method.

B.2.1 Method

The naturalistic driving method employs a standardized instrument package which is installed in the participant's own private vehicle or in a vehicle loaned to the participant. The installation is made as unobtrusive as possible so that the participant's vehicle appears and performs as it normally would. The instrument package is capable of measuring many of the same variables as the on-road instrumented vehicle, such as speed, lane position, acceleration, GPS time and position, driver eye glance frequency, direction, and duration. The instrument package is also connected to the vehicle data bus so that additional vehicle-related measures of engine, braking, and steering performance are also recorded. However, because of the unobtrusive nature of the experimental technique, this method cannot support the use of extremely accurate head-mounted or vehicle-mounted eye-tracking equipment. In the present state of technology, these accurate eye movement instruments involve careful calibration procedures with the driver. With this method, the eye-tracking system is mounted in the dashboard in a manner which involves little or no driver interaction. Once the participant's vehicle has been instrumented, data are collected by means of automatic wireless downloads without participant awareness or involvement. The instrumentation is left in the vehicle for a period of 3 to 6 months, during which time the participant drives the vehicle for normal personal or business use.

The fact that participants drive their own vehicles for their own use reduces control and adds uncertainty to the study. It is difficult to control where the participants are going to drive and when. The study site must be selected carefully so that participants are likely to drive by at least some of the target CEVMS installations. The participants must be selected carefully so that they are likely to take the selected roadway with some reasonable frequency. As a result of this increased uncertainty, the number of study sites must be increased to 4 and 5, the number of research participants selected at each site must be increased to 50 and 75, and the duration of measurement for each participant must be increased to 3 and 6. In this study, it is even more important that there are several CEVMS installations at each study site. As was the case for the on-road instrumented vehicle study, each study site needs to include CEVMS installations, standard (non-digital) billboards, objects of casual visual interest (houses, barns, etc.), and natural background control scenery (trees, fields, etc.).

B.2.2 Factors and Measures

As with the on-road instrumented vehicle study, the major factors or independent variables are the presence or absence of CEVMS and other comparison visual stimuli (standard billboards, buildings, control settings, etc.) along the driven path. If possible, the CEVMS should be turned off and on or changed in some other way, according to a prearranged experimental design. However, in this instance, the CEVMS would have to be turned off or changed for longer periods of time because it is not certain when the instrumented test vehicles might pass. These are the primary independent variables. Secondary independent variables could include the type of vehicle (sedan, pickup, or SUV) and driver characteristics (age, gender, and route familiarity). In addition, as much as possible, one or more of the primary CEVMS variables of interest to the community concerned with outdoor advertising control should be represented by varying levels in the selection of CEVMS stimuli.

As in the on-road instrumented vehicle study, the primary measure or dependent variable is the frequency, direction, and duration of driver eye glances. The fundamental hypothesis of self-regulated attention which needs to be concentrated on the roadway scene ahead remains the same. As before, if the frequency and duration of eye glances away from the roadway ahead exceed accepted norms or criteria, then driver safety is assumed be compromised. Thus, eye glance behavior is the primary dependent variable in this study, as well. However, the particular unobtrusive and disengaged dashboard-mounted eye-tracking device may not be capable of making as accurate measurements of eye-movements as can other more delicate vehicle-mounted or head-mounted devices which require periodic participant calibration. Consequently, this study method depends more heavily on secondary dependent variables. Safety surrogate measures associated with driver errors and other measures of driver performance (headway, lane deviation, conflicts, and erratic maneuvers) become increasingly important in this method. Since the participants will be driving according to their own personal schedules, additional dependent variables may include the time of day (day/night), traffic conditions (peak and nonpeak), in-vehicle distractions (eating and/or cell phone use), and state of fatigue.

B.2.3 Advantages/Disadvantages

The naturalistic driving method possesses one major advantage over the on-road instrumented vehicle method: the driving scenario, driving task, and driving purpose are all completely natural. The research participants drive their own vehicles (or ones loaned to them) on their own personal schedules along personally selected routes to meaningful destinations. Although to a lesser degree, the naturalistic driving method shares another advantage with the on-road instrumented vehicle method: its ability to implement eye-tracking measurements. In fact, the dashboard-mounted eye-tracking device is far less intrusive to the driver than the head-mounted eye-tracking device sometimes employed in the on-road instrumented vehicle method.

Unfortunately, some dashboard-mounted eye-tracking devices may not be as sensitive and accurate as a head-mounted device. Also, they may not be able to track extensive head movements or measure subtle eye glances indicative of unconscious distraction. The useful field of view can also be an issue with certain unobtrusive vehicle-mounted eye-tracking equipment. Consequently, this experimental method may be less effective in its ability to probe the subtle phenomena of unconscious and involuntary distraction as they relate to CEVMS exposure.

Another disadvantage of this method is its inherent lack of structured driving scenarios. Since participants drive whenever and wherever they want, it is difficult to ensure adequate and uniform exposure to CEVMS and other relevant visual stimuli. This lack of experimental control and higher degree of uncertainty necessitate an increase in the number of study sites, research participants, and duration of the study, which negatively impacts the productivity and cost effectiveness of the technique. For example, this method typically requires the instrumentation of a relatively large number of vehicles at any given study site instead of the instrumentation of just one vehicle which is shared by many research participants. Another minor disadvantage is that research participants are aware that they are participating in an experiment, even if the study is minimally intrusive in terms of daily life routine.

B.2.4 Budgetary Cost

A rough budgetary estimate for conducting such a naturalistic driving study is between $2 million and $4 million. The main cost drivers for this method include increasing the number of study sites, installing instruments in a large number of vehicles at a single site, and collecting and analyzing data covering a long period of time. The range in this budgetary estimate relates to the number of study sites, adequacy of the sites, number of vehicles which need to be instrumented at one time, number of research participants, difficulty in obtaining research participants, driving patterns of the research participants, length of the study at any given site, ability to turn the CEVMS off and on, and numerous other factors which cannot be determined without further planning.

B.3 UNOBTRUSIVE OBSERVATION APPROACH

The unobtrusive observation method is different from the on-road instrumented vehicle method and the naturalistic driving method. The major distinction is that no study participants are selected, and all data are obtained from the natural flow of traffic past the CEVMS and other comparison stimuli. The following describes one possible study which might be conducted using this method.

B.3.1 Method

The unobtrusive observation method employs an array of static cameras or other sensors mounted near the locations of the CEVMS and other comparison stimuli. The other sensors may include loops, tubes, or radar to measure vehicle passes and driving parameters. The present report will focus on video recording of traffic. The cameras are capable of recording the behavior of vehicles passing the various relevant visual stimuli as a part of the natural flow of traffic. The drivers are usually completely unaware that their vehicles are being observed. Post-hoc analysis of the video recordings from these cameras can yield data similar to some of that obtained by the on-road instrumented vehicle and naturalistic driving methods, which include vehicle speed, lane position, acceleration, and time. However, the data from distal video cameras are usually far less accurate than what can be collected by instruments onboard the vehicle. Moreover, with present measurement technology, such video recordings cannot yield any data concerning driver eye glance frequency, direction, and duration. The camera arrays are usually left in place for a period of several months to 1 year at each study site. There would typically be three to four such sites in the study. At each study site, separate camera arrays would need to be installed at the locations of all selected CEVMS displays, standard (non-digital) billboards, objects of casual visual interest (houses, barns, etc.), and natural background control scenery (trees, fields, etc.).

B.3.2 Factors and Measures

As in the on-road instrumented vehicle and naturalist driving studies, the major independent variables are the presence or absence of CEVMS and other comparison visual stimuli (standard billboards, buildings, etc.) along the driving path. If possible, the CEVMS should be controlled according to a prearranged experimental protocol. However, in this instance, the CEVMS would have to be changed for longer durations because it is possible to predict when vehicles might pass. In addition, one or more of the primary CEVMS variables of interest to the community concerned with outdoor advertising control should be represented by varying levels in the selection of CEVMS stimuli. These constitute the primary independent variables. Since continuous video recording will be employed, the experimenter can decide to select different times of data collection for further analysis. This capability can provide insight into some secondary independent variables such as time of day (day/night) and traffic conditions (peak, nonpeak).

In contrast to the on-road instrumented vehicle and naturalistic driving studies, the primary dependent variable is not driver eye glance behavior. Instead, this study method depends completely on safety surrogate measures associated with driver errors and other measures of driver performance (headway, lane deviation, and erratic maneuvers). These are subtle driving behaviors to measure by means of distal cameras mounted along the roadway. Unless the cameras are mounted very high, multiple vehicle images may occlude each other. For a long stretch of roadway, such as might required for CEVMS exposure, a relatively large array of cameras may be needed. Thus, a large amount of data needs to be collected and analyzed in such a study. Automatic machine vision video analysis algorithms can help in the data analysis process, but such algorithms are not yet sufficiently sensitive and robust to reliably identify all of the subtle indicators of driver errors, conflicts, or maladaptive performance which might accompany CEVMS exposure. The use of other sensors instead of or in addition to cameras may mitigate some of these data analysis problems to a certain extent.

B.3.3 Advantages/Disadvantages

The unobtrusive observation method possesses one major advantage over the other two methods: the data are derived from the natural flow of traffic. Other than erecting camouflaged camera arrays at various locations along the roadway, the experimenter does not disturb the natural flow of human driving. As opposed to the other two methods, the vast majority of drivers are completely unaware that they are part of a study depending on how well the camera camouflage works. Other sensors used for this application can also be hidden and made extremely hard to detect. This is the major advantage of the unobtrusive observation method. Another strong advantage is the large number of vehicles which pass by the CEVMS and other comparison stimuli every day. Sample sizes can be relatively large.

Like the other techniques, the unobtrusive observation method has disadvantages as well. First, with present technology, it is not possible to implement eye-tracking measurements in such a study. The inability to measure eye glance behavior makes it difficult to investigate important constructs, like self-regulated attention and unconscious distraction as they relate to CEVMS exposure. The method is left to rely on safety surrogate measures, such as driver errors and maladaptive maneuvers. These relatively subtle pre-crash and near-crash driving behaviors are difficult to measure by means of distal video cameras. Such driving behaviors also occur very seldom and need to be observed over great distances, leading to the necessity to collect large amounts of video data from extended camera arrays over long periods of time. The collection, reduction and analysis of such large amounts of data tend to make this method time-consuming and expensive.

B.3.4 Budgetary Cost

A rough budgetary estimate for conducting such an unobtrusive observation study is between $1 million and $3 million. The main cost drivers for this method include designing camera arrays which can measure subtle vehicle maneuvers, installing camera arrays to record a large extent of roadway for all CEVMS and comparison stimuli, and collecting and analyzing data covering a long period of time. The range in this budgetary estimate relates to the number of study sites, adequacy of the sites, number and location of cameras in an array, method of recognizing safety surrogate measures, length of the study at any given site, ability to turn the CEVMS off and on, and numerous other factors which cannot be determined without further planning.

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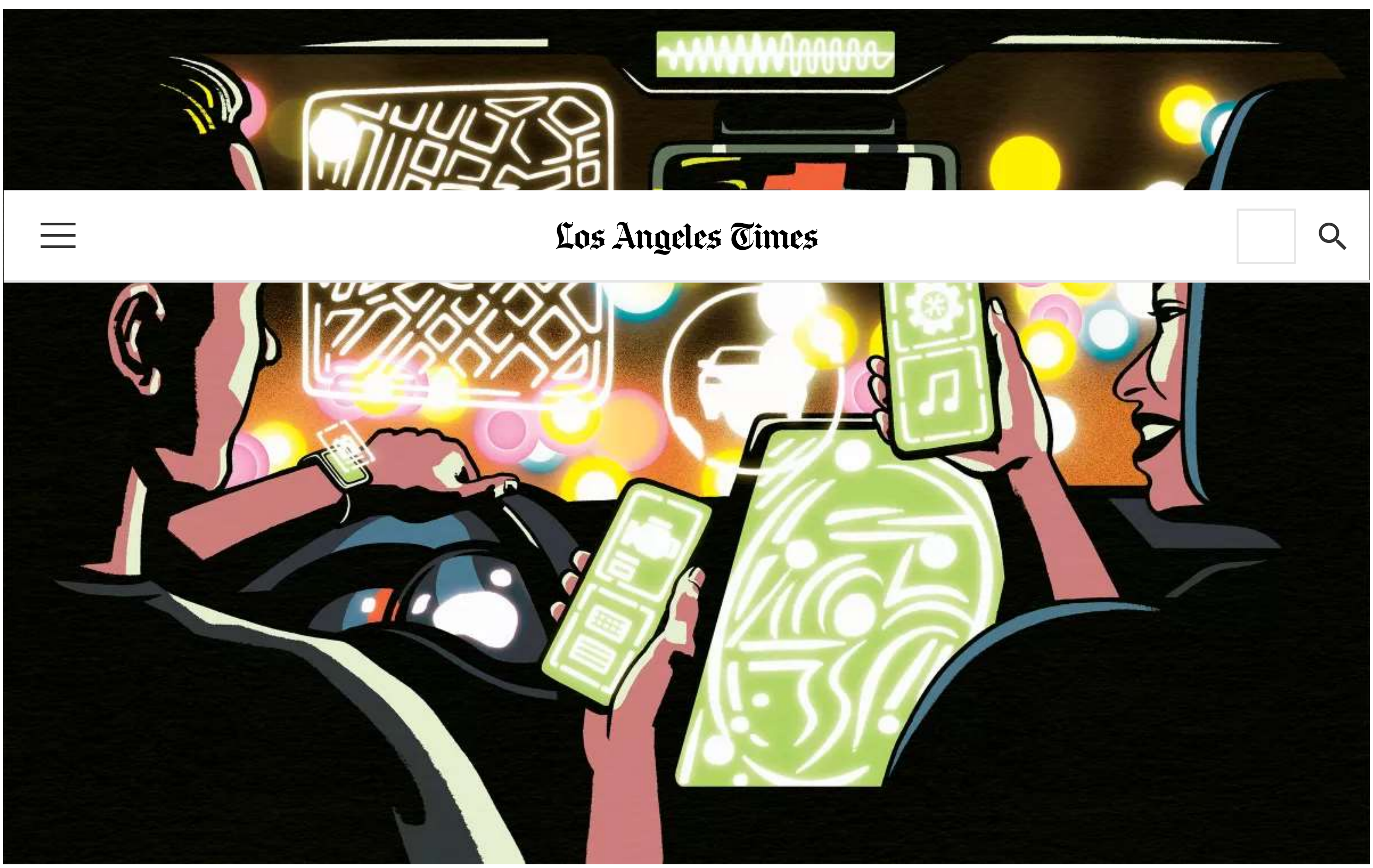
HRDS-07/02-09(WEB)E

BUSINESS

‘We are killing people’: How technology has made your car ‘a candy store of distraction’



(Lily Qian)

BY RUSS MITCHELL | STAFF WRITER

JULY 6, 2022 5 AM PT

In the late 1980s, the U.S. Army turned to outside experts to study how pilots of Apache attack helicopters were responding to the torrent of information streaming into the cockpit on digital screens and analog displays. The verdict: not well.

The cognitive overload caused by all that information was degrading performance and raising the risk of crashes, the researchers determined. Pilots were forced to do too many things at once, with too many bells and whistles demanding their attention. Over the next decade, the Army overhauled its Apache fleet, redesigning cockpits to help operators maintain focus.

For the record:
4:48 p.m. July 6, 2022 *An earlier version of this article said a poll found that 63% of drivers use their cellphones while driving, with that figure increasing to 73% among those who use their cars for work; the correct figures are 70% and 86%. The article also incorrectly credited Advocates for Highway & Auto Safety for a poll finding that 70% of drivers have never used a do-not-disturb feature on their phones; that poll was conducted by Nationwide Insurance.*

Cognitive psychologist David Strayer was among those called in to help the Army with its Apache problem. Since then, he has watched as civilian cars and trucks have filled up to an even greater extent with the same sorts of digital interfaces that trained pilots with honed reflexes found so overwhelming — touch screens, interactive maps, nested menus, not to mention ubiquitous smartphones. In his lab at the University of Utah, he's been documenting the deadly consequences.

"We are instrumenting the car in a way that is overloading the driver just like we were overloading the helicopter pilots," said Strayer, director of the university's Center for the Prevention of Distracted Driving.

"Everything we know from pilots being overloaded we can apply to motor vehicles," Strayer said. But rather than apply it, makers of smartphones and automobiles largely have ignored the research, persistently adding popular but deadly diversions. "They've created a candy store of distraction. And we are killing people."

To be sure, new automotive technology also includes innovative safety features such as lane-departure warning and blind spot detection. Yet, despite these and other crash-prevention systems, the highway death count continues to rise.

After decades of falling fatality rates, U.S. roads have become markedly more dangerous in recent years. In 2021, motor vehicle crashes killed nearly 43,000 people. That's up from about 33,000 in 2012, and a 16-year high.

Theories about why range from bigger vehicles — mammoth SUVs and pickup trucks on steroids — to aggression caused by COVID-era trauma. But no one in the safety field doubts that distracted driving is a main ingredient.

Reported fatalities due to distracted driving have remained flat for the last 10 years, 3,000 to 4,000 a year. But there is good reason to consider those figures a major undercount, as they rely on people admitting they were distracted, or a police officer or someone else witnessing a driver with phone in hand before a crash.

"It's against people's self-interest to say, 'I was on the cellphone' or 'I was using the infotainment system'" after a crash, "because there can be serious consequences," said Cathy Chase, who heads Advocates for Highway & Auto Safety.

"I don't think we're getting an accurate picture of what's happening on the roads," she said.

Other measures point to a much higher toll. In early 2020, the National Safety Council said cellphones were involved in more than a quarter of crashes. A poll by Nationwide Insurance shows its agents believe 50% of all crashes involved distracted driving. And safety experts say the problem has only grown worse since the start of the pandemic.

BUSINESS

The DMV said it would investigate Tesla over self-driving claims. Then, crickets

May 26, 2022

Pretending that the toll is only a few thousand people a year makes it more difficult to change policies that could improve safety, Mark Rosekind said. He ran the National Highway Traffic Safety Administration during the Obama administration and is now chief safety innovation officer at driverless car company Zoox.

"People will use those low numbers as a way to minimize this, that it's not a big problem," he said.

Most people know distracted driving is bad — 98% of those polled told Advocates for Highway & Auto Safety they are extremely or very concerned about it as a safety issue.

But most do it anyway. Seventy percent of polled drivers said they use their cellphones while driving. That increased to 86% of people who use their cars for work.

State Farm in April released survey statistics even more disturbing. More than half of respondents said they "always" or "often" read or send text messages while driving, 43% said they watched cellphone videos always or often while driving, and more than a third said they always or often drove while engaged in a video chat.

Elene Bratton's 5-year-old son Jamie died in a car crash back in 2002 caused by a driver distracted while using a cellphone. She thought the mounting deaths would lead to serious action by lawmakers and safety regulators but instead has watched the problem grow much worse. "We act like there's nothing to be done with car crashes like this, like we all have to deal with it," said Bratton, who runs a website, jamiesjoy.org, in part to raise money to help push policy changes.

How do the companies behind all those distracting screens and apps — the automakers and smartphone manufacturers — view their responsibility for the problem and their role in solving it?

It's hard to say. The Times asked the five top-selling carmakers in the U.S. — General Motors, Ford, Toyota, Stellantis and Honda — to provide an executive to speak about what they're doing to help prevent distracted driving. All declined, offering instead to make written public relations material available. Apple and Samsung, the two leading smartphone makers, also declined interview requests.

When companies do talk about distracted driving, they tend to frame it as a problem with cellphones. Their solution: Integrate the same functionality and more into dashboard interfaces and voice-recognition systems.

Apple executive Emily Schubert, in a flashy video internet presentation in June, announced major new features for the company's CarPlay infotainment system. Apple declined to make Schubert or any other executive available for an interview, but in an email a spokesperson called CarPlay "the smarter, safer way to use iPhone in the car." What makes it safer, and to what degree? No details were provided.

The company did note it provides Driving Focus mode on its phones, which, if engaged by the customer, keeps the phone silent and doesn't allow notifications to come through. A Nationwide Insurance poll showed 70% of respondents had never used such a feature.

A Honda spokesperson said by email that "the biggest thing we can do to reduce distraction is to reduce the likelihood of a driver looking at their mobile phone while driving" by putting more focus on infotainment systems, through which the company is making "an attempt to minimize distraction while satisfying the driver's ease of use and access to desired information."

Honda offered few details and declined an interview about the subject. The company did say it's working with researchers at Ohio State University on the infotainment interface. The professors involved declined to offer details as well, saying their work for Honda is proprietary.

One problem with relying on infotainment systems to improve safety is that they don't work very well. "Infotainment systems remain the most problematic area" for new car customers, auto market research firm J.D. Power wrote in its latest new-car quality report. Customers complain about frequent problems with connectivity, Bluetooth syncing, touch screens and built-in voice recognition.

The ability to control features such as air conditioning and music playlists via voice commands theoretically improves safety by letting drivers keep their eyes on the road. But with the technology still a work in progress, scientists are learning it can be just as dangerous as fiddling with a smartphone.

In a 2019 paper, Strayer's team reported that completing tasks using voice commands took much longer than other kinds of interaction with smartphones and infotainment systems. The extra time significantly increased the driver's cognitive load. Believing that verbal communication doesn't interfere with driving shows a "naive understanding of how language works," Strayer said. Brain scans show that "language uses a lot more of the parts of the brain than driving does."

State laws that ban holding a cellphone or texting while driving give the impression that the danger stops there. But what the Apache research showed, and decades of subsequent research on automobile distraction has confirmed, is that the distracted driving problem is more than mere distraction. The problem is asking the brain to do too many things at once. The technical term is cognitive overload, which includes distraction and multitasking and sensory input from a variety of sources.

As part of its 2019 study, Strayer's team assembled data on driver use of infotainment systems in more than two dozen cars. Drivers were fitted with sensors attached to the head and the chest, and data on driver heart and brain activity were collected to assess distraction and cognitive load.

Although some systems were more distracting than others, all hampered the driver's ability to safely pay attention to the task of maneuvering a two-ton vehicle on public roads, the study found.

Meanwhile, building the distractions into the car has the effect of sanctioning its use in the eyes of drivers. Thomas Goeltz, a Minnesota man whose 22-year-old pregnant daughter, Megan, was killed by a distracted driver in 2016, said that although people know talking or texting on the phone while driving is dangerous, the options offered on a car's dashboard offer a false basis for complacency. "People think, it came with the car, it must be safe," he said.

In a glancing acknowledgment of their shortcomings, NHTSA in 2015 issued guidelines on infotainment systems that recommend they be designed so a driver's attention is not distracted for more than two seconds out of six.

The guidelines are voluntary, however. Strayer said that many of the actions tested in his research require drivers to take their eyes off the road for 12 seconds or more.

Any company hoping to do something about driver distraction must grapple with the majority of U.S. drivers who refuse to stop scrolling and swiping behind the wheel. For now, smartphone companies, auto companies, app makers, advertisers, retailers — just about the whole consumer information ecosystem — are happy to fill the demand. Consulting firm McKinsey projects in-car advertising, entertainment and consumer data sales will generate $11 billion in annual revenue by 2030.

By then, it's conceivable consumer cars will be equipped with a version of the autonomous driving technology that's beginning to be deployed in robotaxis and delivery vehicles in limited areas. At that point, turning the interior of a car into an immersive infotainment bubble makes perfect sense.

What can be done in the meantime? The National Transportation Safety Board has called for a total ban on in-car device use — excluding built-in infotainment systems — while driving, except in emergencies. At least, the NTSB says, companies should restrict device use by employees.

In Europe, automakers will soon be required to install monitors to detect driver distraction in order to receive top safety scores. No such move is being publicly contemplated in the U.S.

Safety advocates say education campaigns aren't nearly enough to deal with the enormity of the problem but are one necessary component. They also call for stricter enforcement by police. Above all, they say, drivers need to be more responsible for their own safety and to keep from harming others.

Without major changes in driver behavior and public policy, uncounted tens of thousands of people will die each year, with devastating results on their families and their friends. That's part of the cost of the infotainment culture — which, thus far, Americans have been willing to accept.

BUSINESS AUTOS TECHNOLOGY AND THE INTERNET

Russ Mitchell

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Russ Mitchell covers the rapidly changing global auto industry, with special emphasis on California, including Tesla, electric vehicles, driverless cars and vehicle safety, for the Los Angeles Times.

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Big Sign Firm Accused of Corruption

BY TED ROHRLICH

OCT. 23, 2005 12 AM PT

TIMES STAFF WRITER

In the quiet of New Year's Eve morning on the Sunset Strip, hours before partygoers celebrated the arrival of 2005, Brian Kennedy tried to give himself a present -- a new billboard that could bring him a million dollars a year.

It didn't matter that he had no permit. Kennedy had gotten his start in the sign business many years earlier by going out at night and pasting movie posters on construction fences without permission.

The scofflaw approach seemed to suit him. He could build his 40-foot billboard now and let the city of West Hollywood take him to court later while he raked in profits.

Kennedy picked a day when City Hall was closed. He had canvas draped over a see-through fence to mask what he was doing.

He might have gotten away with it if Joan English, a deputy city manager, hadn't driven by the lot Kennedy owned at Sunset Boulevard and Queens Road. English could see the top of a crane lifting a billboard pole into place.

She got out of her car and peeled back the canvas to see a sopping-wet Brian Kennedy directing workers in the rain.

"I said, 'Brian, what are you doing?' "

First, Kennedy claimed he had a permit, she said. Then he said he didn't need one because West Hollywood's restrictions on billboards were unconstitutional.

Kennedy and his brother, Drake, co-own Regency Outdoor Advertising, the largest family-owned billboard company in Southern California, worth an estimated half a billion dollars.

The brothers have bulled their way to success, letting little stand in their way. They have donated hundreds of thousands of dollars to causes of politicians who control where signs can be placed. They have filed lawsuit after lawsuit asserting 1st Amendment rights to bombard motorists with slogans.

And, according to sworn statements in lawsuits by a former Regency executive and an attorney who represented the firm, the Kennedy brothers have paid off politicians, bribed the Caltrans billboard inspector for Los Angeles and Orange counties and even poisoned palm trees obstructing some of their most lucrative signs outside Los Angeles International Airport.

On the Sunset Strip that rainy morning, Kennedy was unmoved by English's demand that he and his crew stop work.

"It became obvious they weren't going to listen to me," English recalled, so she called the L.A. County Sheriff's Department. Only when three deputies arrived and threatened them with arrest did Kennedy and his crew relent, according to the city attorney.

Nearly a year later, the billboard pole English saw being lowered into place is still standing. The fight has shifted to courtrooms. Kennedy faces trial on a misdemeanor charge of trying to erect a billboard without a permit. He is also suing the city, alleging that it violated his civil rights.

The Kennedy brothers declined to be interviewed for this article. In a letter, Brian Kennedy asserted that he and his brother "categorically deny any wrongdoing or the bribing of public officials, or civil servants, in order to obtain favorable treatment. That said," the letter continued, "we can say that the outdoor advertising industry is heavily regulated and that, as a result, we work closely with government officials and civil servants at all levels."

The Lords

of the Sunset Strip

The Kennedys work out of headquarters without a sign, across from Tower Records in the heart of the Sunset Strip.

In the world of outdoor advertising, the Sunset Strip is a prime showcase, in a league with New York's Time Square and Tokyo's Ginza district. Billboards and ads on the sides of buildings are so much a part of the Strip's visual distinctiveness that six years ago, the West Hollywood Chamber of Commerce started awards for the best billboards and "tall walls" signs.

Regency, which owns more billboards on the Strip than any of its competitors, has won its share of honors.

The company does not have the reach of Viacom or Clear Channel, publicly traded giants that reportedly lease about 5,000 billboards each in the Los Angeles area. But Regency's inventory of 500 sign faces is seen by some as the most valuable, sign for sign, in Southern California.

Brian Gurnee, who once ran part of Regency's sales team and is suing the firm in a financial dispute, estimates that the Kennedy brothers, with their high concentration of valuable freeway and Sunset Strip signs, net tens of millions of dollars a year. A full-size billboard costs $40,000 to $100,000 to build but, in the right location, can pay for itself in a month. Regency asks advertisers for $3,000 to $80,000 a month, depending on the exclusivity of the neighborhood and how many motorists pass by.

Brian Kennedy, 64, is the firm's public face. A robust man with a hail-fellow-well-met manner, he is in charge of selling billboard space to advertisers and securing sign locations along the Strip. Drake Kennedy, 62, is the behind-the-scenes brother. Slightly built, with eyeglasses so large they resemble small windshields, he is in charge of arranging locations and permits everywhere but the Strip.

The brothers grew up in San Gabriel, immersed in the billboard business and in local politics. Their father, George, owned a small billboard company, Kennedy Outdoor Advertising, and later sat on the commission overseeing the Los Angeles Department of

Water and Power. Their mother, Helen, served for 17 years as a councilwoman or mayor in San Gabriel.

Both brothers attended USC. Drake has said he dropped out to help his ailing father sell his sign business. Brian graduated and has donated hundreds of thousands of dollars to Trojan football. The defending national champions practice on Brian Kennedy Football Field.

Regency Christmas party. It invited callers to "press one" if Regency was suing them, "two" if they were suing Regency, and so on, concluding: "If you have never been involved in any litigation with Regency Outdoor Advertising and do not anticipate any action in the future, please check the number you are calling and dial again."

In building and defending what they regard as their billboard "boutique," the Kennedy brothers relied heavily on J. Keith Stephens, for years Drake Kennedy's right-hand man, and Paul E. Fisher, Regency's principal lawyer.

Stephens, 46, came to the firm after he built his own signs without permits. His job included overseeing Fisher, 45, Regency's outside counsel and a 1st Amendment specialist who had convinced several courts that laws restricting billboards were unconstitutional limitations on free speech. Things went well for Stephens, Fisher and Regency for several years.

But in 2001, Regency lost two civil trials involving Regency signs. Drake Kennedy blamed Fisher and Stephens, telling Stephens in a letter that Fisher's poor performance had cost the brothers millions. The Kennedys dismissed Fisher in early 2002 and sued him for malpractice in a case they dropped just as it was to go to trial. Fisher unsuccessfully countersued, claiming the Kennedys owed him money.

Soon after Fisher was fired, Stephens quit. He sued Regency after Drake Kennedy demanded that he turn over some of his own billboards to make up for Regency's losses.

Regency quickly settled that case, agreeing to let Stephens keep his billboards. But an embittered Stephens has repeatedly sued Regency on other matters. One of his current suits alleges that Regency engaged in bribery and vandalism.

In interviews and in pretrial testimony taken in these legal battles, Stephens and Fisher told of alleged Regency bribery schemes and acknowledged their own roles in one of them.

The Kennedys, through spokesmen, asserted that Stephens and Fisher were con artists with records of making false statements under oath. Their bribery allegations, Regency contends, are part of an attempt "to extract financial settlements" from the firm.

A review of court documents shows that Fisher and Stephens have made contradictory statements about business dealings under oath. A civil court jury recently discounted their testimony and found that they were secret partners in a scheme to swindle a small rival firm out of some signs. Mitzi McCook, a billboard executive from yet another small firm and former friend of Stephens, also alleged improper conduct.

In a sworn declaration in 2003 to the State Bar, McCook said Stephens told her Fisher submitted inflated bills to Regency, which Stephens approved. In return, she said, Fisher did free legal work for Stephens.

McCook also said that Stephens told her that Brian and Drake Kennedy had engaged in "illegal activity" and that if need be, "he would use this information to put them in jail."

Secret Financier

in Monterey Park

In Monterey Park, home to stretches of the 60 and the 710 freeways, billboard opponent Judy Chu remembers a war that Regency waged against her in the early 1990s over the city's billboard ban.

Chu, now a state Assemblywoman, was then Monterey Park's mayor and a member of its five-person City Council.

Regency was campaigning to get the council to lift the ban and allow it to build freeway signs.

The firm employed a veteran lobbyist, Robert Katherman. He began popping up at political and charitable functions offering large donations to council members' favorite charities, Chu said.

"For me he said, 'Oh. I could make a big donation to the Asian Youth Center,' " she said.

Chu, who regards billboards as an aesthetic "abomination," said she was appalled by the way he attempted to curry favor. Katherman declined to comment. Her council colleagues supported lifting the ban.

When Chu countered by helping to organize a voter initiative to retain the ban, Regency launched a "campaign of terror" against her, she said.

It included an 18,000-piece barrage of political mail just before election day 1997, when both Chu and the billboard initiative were on the ballot.

One mailer sought to stir racial passions. The headline: "What's Judy Chu's Problem with Latinos?" The state Fair Political Practices Commission investigated and concluded in 2001 that Regency had secretly paid for most of the mailers. Drake Kennedy at first told a state investigator he didn't know anything about the mailers, records show.

However, Katherman, others who worked on the mailers and eventually Regency itself provided records that showed Regency paid for them.

The commission fined Drake Kennedy $18,000 for illegally concealing his role.

Chu was reelected handily to city office despite the attacks and the billboard ban survived.

Alleged Bribes

in South El Monte

In nearby South El Monte, Drake Kennedy seemed to become fixated on erecting a billboard on the property of a man who didn't want it.

To get his way, Kennedy allegedly bought control of the city government.

Sandy Bettelman's family owns a three-acre miniature golf course whose green- and blue-carpeted holes are visible from the 60 Freeway, near the Peck Road exit.

Regency approached Bettelman in the late 1980s and again in the early 1990s, offering compensation if the family would allow a billboard on its land. Bettelman declined, explaining that he was concerned a billboard would draw attention from his own much smaller sign.

Kennedy would not take no for an answer.

In 1996, Regency persuaded the city to sue the Bettelman family for possession of a dirt road next to the golf course so that Regency could put a billboard there, court records show.

Kennedy testified that Regency paid about $50,000 on the lawsuit. The city lost when Superior Court Judge Irving Feffer ruled in 1998 that the Bettelmans owned the road; the city just had a right to maintain it. Kennedy sought city permission to build anyway, court records show. When a majority of the five City Council members balked, he allegedly decided that the two who were coming up for reelection had served long enough.

Stephens testified in one of the lawsuits he brought against Regency that Kennedy told him he secretly bankrolled the 1999 campaigns of challengers.

Al Perez and Raul Pardo were elected and joined holdover Mayor Art Olmos to form a pro-Regency majority. Neither man reported campaign contributions from Regency.

In February 2000, the council voted 3 to 2 to allow Regency to build its billboard on the road, despite a second ruling by Feffer that such approval would be “a legal impossibility.”

Regency agreed to pay the city $100,000 immediately and $20,000 a year for the sign.

In interviews, Olmos and Perez said they did not know about the judge’s rulings. “I would have never gone against the ruling of a judge,” Perez said.

City records show council members received written notice of one of the rulings as they prepared to vote on Regency’s request. William Vallejos, then city attorney, said in an interview that he also told council members about the ruling. Two members who opposed Regency, George Lujan and current Mayor Blanca Figueroa, backed Vallejos’ account.

Several months after the council vote, Regency built its sign.

Bettelman couldn't believe it. "The judge told them they didn't have the right to do it, and they did it anyway," he said.

He sued Regency.

One of his lawyers, Frank Nemecek, posed a question to the jury: "How did they get the city to agree to something that a judge had said five months earlier that the city couldn't do?"

Fisher, Regency's lawyer in the case, provided a possible answer in depositions in the malpractice case Regency brought against him. Regency, he said, bribed the City Council.

Fisher testified that Stephens and Drake Kennedy told him Ernie Moreno was Regency's bagman. A former legislative aide, Moreno was tried in the 1970s on federal perjury charges related to allegations that he'd taken payoffs for political favors. A jury could not reach a verdict and prosecutors dropped the case.

Fisher testified in his malpractice case that he once saw Drake Kennedy counting out stacks of $100 bills in Moreno's presence.

He also testified that conversations with Moreno and Kennedy left him convinced that the money was going to members of the South El Monte City Council.

Drake Kennedy has testified Moreno was a Regency consultant who helped get government permission to build signs.

Olmos and Perez said in interviews that they are friends of Moreno's. But both denied ever speaking with him about the Regency deal or taking money.

Pardo declined to be interviewed. Moreno did not respond to requests for comment.

In ruling against Regency in the Bettelman lawsuit in late 2001, Superior Court Judge John Shook found that the Kennedys had trespassed and asked the jury to decide how much Regency should pay. The jury awarded the family $1.5 million.

Regency took down its sign once its appeals were exhausted three years later.

Bettelman said his family spent $600,000 on litigation to fight the Kennedys.

“They thought we’d knuckle under,” he said. “They just hit the wrong person. How many people have the money to fight them?”

A Hardball Squeeze Play in Baldwin Park

City officials in Baldwin Park asked that question when Regency threatened them with a lawsuit. Ultimately, the city decided it did not have enough money to fight, and Regency’s billboards went up.

The dispute arose in 2000, when the firm asked the City Council for permission to build billboards along the 10 Freeway.

Regency had watched as the council allowed another firm to build signs along the 605 Freeway for fees of $50,000 per sign.

But even with Regency offering $100,000 per sign, it could not line up the necessary votes.

Finally, it seemed, the Kennedy brothers’ patience wore thin.

At dawn on the start of a long Fourth of July weekend in 2000, crews and cement mixers arrived at most spots Regency coveted and started erecting billboards without permission.

Baldwin Park Chief of Police Mark Kling, then a captain, recalled running into a cocky Stephens directing workers. Work stopped before the signs could be finished when authorities threatened arrests.

Stephens said in an interview that he then disclosed Regency's strategy of spending the city into submission.

Stephens said he told City Atty. Arnold Alvarez-Glasman that Regency was prepared to spend half a million dollars on legal fees to attack the city's sign law as unconstitutional. In a longshot bid for financial help, the cash-strapped city turned to its legal insurance carrier, the Independent Cities Risk Management Authority, which was designed to help cities defend against conventional lawsuits, not constitutional claims.

The city's request for help put Regency's lobbyist, Ken Spiker Jr., in an awkward spot. Spiker stood to make $100,000 for every sign Regency won in Baldwin Park. His firm also made hundreds of thousands of dollars administering the risk management authority. If the authority helped the city fight Regency, he could be harming himself.

Spiker fired off a letter to the city saying he had nothing to do with Regency's decisions to build and to sue.

Regency's Stephens, however, testified in one of his lawsuits against the firm that Spiker told him he would work against Baldwin Park's interests.

Stephens testified that Spiker and an associate, David Neal Smith, told him they would see that the risk management authority denied Baldwin Park's bid for insurance coverage.

Spiker and Smith denied the allegations through their lawyers, and the insurer's general counsel, J. Kenneth Brown, said Baldwin Park's claim was denied routinely, with no pressure from Spiker or Smith.

There is no evidence to contradict them, but there is evidence that Spiker bragged he had the city over a barrel.

However, another billboard firm owner, Mark Kudler, said in a lawsuit against Spiker that Spiker told him he was involved in an effort to threaten Baldwin Park financially to force the city to cave in.

In any event, the city capitulated after its claim was denied.

Alvarez-Glasman, the city attorney, said the council directed him to negotiate with Regency rather than fight.

Baldwin Park gave Regency permission for six signs -- one more than it originally requested -- as part of a deal in which Regency increased its promised contribution to youth services.

Spiker and Smith also worked for Regency in Lynwood, to which Regency agreed to pay $5 million for permission to build billboards along the 105 Freeway.

The signs never went up because enemies of then-Mayor Paul Richards canceled the deal. City Council and other records show that Richards and his allies arranged to divert $1 million of the fee to a company owned by the mayor’s sister.

Richards is on trial in federal court for this and other alleged acts of political corruption.

Smith pleaded guilty in August to a charge of giving a $7,500 “illegal gratuity” to Richards for backing the Regency deal.

Smith also testified at Richards’ trial that Regency agreed to pay the Spiker firm $25,000 in “consulting fees” that would actually be used to support Richards’ reelection campaign.

Neither Spiker nor Regency has been charged.

When Trees

Got in the Way

In 2000, with the Democratic National Convention slated for Los Angeles, the city planted 160 Canary Island palms on city property along the Century Boulevard approach to LAX to impress conventioneers. The trees cost $10,000 apiece.

For Regency, the beautification program was a problem. It blocked sight lines to valuable signs. Regency, represented by Fisher, sued the city, seeking $18 million in damages.

Superior Court Judge Jean Matusinka ruled in 2002 that under California law, Regency could not collect for "loss of visibility."

Soon after, two of the trees blocking Regency signs died.

Airport landscapers called in Donald Hodel, a palm tree specialist from the University of California Cooperative Extension. He couldn't figure out what caused the deaths. He said it might be Fusarium wilt, a fatal disease affecting some other palms in the area. But a lab test by a plant pathologist found no evidence of the disease.

Stephens provided another explanation last year when he testified in a deposition in a lawsuit he brought against Regency. He testified that Brian and Drake Kennedy each told him Regency was responsible for poisoning the trees.

"Drake ... was really proud of the fact," Stephens testified.

Pathologist Paul Santos said in an interview that the tests he did would not detect poison.

Regency, meanwhile, appealed the trial court decision but offered to drop its appeal if the city would allow it to replace many remaining palms with smaller trees.

It was up to the Airport Commission to accept or reject Regency's offer. Two members appointed by then-Mayor James K. Hahn -- Peter Weil, a real estate lawyer, and commission president Ted Stein, a lawyer-developer -- saw no reason to settle, Weil said. After all, the city had won at trial.

Their stance left Brian Kennedy fuming, according to two people close to Hahn who asked not to be identified. The Kennedys had provided $260,000 worth of billboard space in 2001 to help Hahn get elected.

They had also given $125,000 in billboard advertising to help the election campaign of City Atty. Rocky Delgadillo.

Kennedy personally negotiated with the city attorney's office, which had won the case against Regency at trial. The city attorney's office submitted four settlement proposals to the commission in 2003 and 2004.

City officials, speaking on condition of anonymity, said only one commissioner privately pushed for a settlement -- the late labor leader Miguel Contreras. Campaign finance records show Regency had donated $31,000 in billboard space to promote Martin Ludlow, Contreras' protege, in his successful 2003 run for a City Council seat.

Months after settlement efforts failed, a third palm tree died in front of the same Regency signs. Airport landscapers again sent samples to a lab, which again found no sign of disease.

A few months later, the state Court of Appeal ruled against Regency. The state Supreme Court has agreed to hear the case, and the city attorney's office said it has reopened talks.

Regency has had problems with other city-owned trees at LAX. Coral trees next to the elevated extension of Century Boulevard had grown so tall by 2000 that they blocked views of a Regency billboard at the entrance to the airport.

In a 2003 memo to Stephens, apparently prepared as they sought to help each other in litigation involving Regency, Fisher wrote that Drake Kennedy had told him he "had an employee who was taking a chain saw and destroying the coral trees."

Two LAX landscape supervisors recalled in interviews that someone had repeatedly sawed part way through branches so they eventually fell off of their own weight. Over time, said supervisor Ed Manara, trees that once stood 35 to 40 feet tall were reduced to 5 feet in height.

The landscapers complained about the vandalism to airport police, whose reports estimated the damage at $100,000.

The culprit never was caught.

West Hollywood has had similar troubles figuring out who has illegally and often radically trimmed 43 of its trees along the Sunset Strip during the middle of the night in recent years.

Twenty-seven of the trees were in front of Regency signs. Two were palms that were decapitated and died.

Billboards, Public Toilets and the MTA

When it wasn't trying to protect its own billboards from visual obstruction, Regency sometimes worked hard attacking competitors' plans.

In one instance, Regency tried to keep a small Philadelphia company, Strategic Technologies International, from completing a multimillion-dollar deal with the Metropolitan Transportation Authority for billboards on MTA rights of way along freeways.

It called upon Moreno, its alleged bagman in South El Monte, for an introduction to a legislator willing to help.

Drake Kennedy has testified that Moreno introduced him in 2001 to Richard Polanco, a Los Angeles Democrat who was then the state Senate majority leader and dean of the Latino Caucus.

Polanco agreed to carry a bill written by Regency that would require the MTA to get approval for its signs from local governments, some of which were hostile to more billboards.

Spiker, Regency's lobbyist, helped line up the Independent Cities Assn., an alliance of small Southern California cities managed by his firm, to support the bill.

Polanco said his interest was in preserving local control.

At a hearing, Senate Transportation Committee Chairman Kevin Murray (D-Culver City) expressed skepticism about Regency's motives.

"Why would a billboard company want to restrict the amount of billboards?" he asked.

The Regency lawyer who drafted the bill, Michael Tidus, answered that his client believed its competitors should have to jump through the same hoops it did. Regency, he added, believed in local control.

“You’re for good government, huh?” Murray asked.

“Yes,” Tidus said, smiling.

“I understand,” Murray said, chuckling.

With the support of municipalities, the bill sailed through the Legislature and was signed into law in 2001.

The new law killed the billboard deal and, with it, the MTA’s plans to use revenue from the signs to pay for the first public toilets at its subway and light rail stations so riders would not have to relieve themselves in “station elevators and planting areas,” as one MTA memo put it.

A few months after the bill passed, Drake Kennedy testified, Polanco contacted him. “I believe that we were requested to make out two checks to certain PAC [political action committee] groups,” Kennedy testified.

In late February 2002, records show, Regency gave $25,000 to the California Latino Alliance, which transferred $25,000 the next day to the Latino PAC, controlled by the Latino caucus of state legislators. In March, Regency gave another $25,000 directly to the Latino PAC.

At the time, the Latino PAC was waging a campaign against Democratic Assemblyman Mervyn Dymally, a political rival of Polanco’s.

Polanco did not respond to requests for comment.

Chicanery in

West Hollywood

In early February 2003, Steve Martin, then a West Hollywood city councilman, said he received a phone call from an old acquaintance who wanted to see him urgently.

Martin named the acquaintance privately but would identify him publicly only as a former city planning commissioner.

Martin said the man drove to his house and insisted that they go for a ride. As the man drove, he delivered what he said was a message from Brian Kennedy, Martin recalled.

Martin said he was told that Kennedy would pay him $10,000. All he had to do was vote against a Regency competitor's request for city permission to maintain ads on the side of a building on Beverly Boulevard.

At the time, Martin was running for reelection and Brian Kennedy was supporting his opponents. Martin said he feared he was being set up.

A lawyer, he recounted the alleged bribe offer to three fellow city officials, one of whom reported it to the Sheriff's Department. But when a detective interviewed him, Martin did not mention Kennedy and declined to identify the intermediary, records show. The investigation was dropped.

Kennedy prevailed in the wall ad controversy on a 3-2 council vote without Martin's help. In the recent interview, Martin said he did not name the intermediary because he had no way to prove he had been offered a bribe. It would be his word against the other fellow's.

But he said he had no doubt about what had happened.

"It was very clear," he said. "I was being offered money for my vote."

Inspector Accused

of Taking Bribes

A civil servant named Raj Champaneri is an influential figure in Regency's world.

He is a billboard inspector for the California Department of Transportation, the only one for all of Los Angeles and Orange counties.

Fisher said in a recent interview that Champaneri approached him in the late 1990s and suggested he could use extra cash.

Fisher said he delivered Champaneri's message to Stephens and Drake Kennedy. He testified in one of Stephens' lawsuits against Regency that Champaneri complained to him some time later that his monthly bribe from Regency was late.

Stephens testified in the same lawsuit that he delivered bribes from Drake Kennedy to Champaneri three times. Stephens testified that on one occasion, he watched as Drake "counted out several thousand dollars, put it in an envelope" and gave it to him to deliver to the inspector.

This spring, at the imposing new Caltrans building downtown, Stephens and Champaneri came face to face in the hallway before a public hearing. Stephens was there to appeal a ruling the inspector had made against his company and in favor of Regency.

Stephens introduced Champaneri to a reporter as the inspector who was on the Regency payroll for $5,000 a month.

Asked whether the allegation was true, Champaneri turned and walked away. Pressed for a response, he glanced back and said, "Of course not."

Stephens repeated the accusation while sitting across a table from Champaneri at the hearing.

Afterward, Caltrans asked the California Highway Patrol to investigate. Champaneri has been assigned to a desk job pending completion of the probe, a Caltrans spokesman said. Stephens said CHP officers accompanied by FBI agents and federal prosecutors recently interviewed him about this and other allegations.

To illustrate what he said were favors that Regency obtained from Champaneri, Stephens directed a reporter to two Regency billboards along the 10 Freeway in El Monte.

Champaneri and his Caltrans superiors permitted the billboards on the condition that they advertise only businesses in El Monte's redevelopment area.

Regency has not complied. Stephens provided a copy of a letter he said he hand-delivered to Champaneri in 2003 telling him that the Regency signs were carrying ads for movies and a store out of town.

Champaneri took no action. A Caltrans spokesman said they found no such letter in their files.

Recently, the signs advertised a television show and new Cadillacs.

There are plenty of Cadillac dealerships in Southern California.

There are none in El Monte.

*

(BEGIN TEXT OF INFOBOX)

Regency's reach

Government officials and former associates of Regency Outdoor Advertising, the largest family-owned billboard company in Southern California, have accused the firm of a variety of illegal activities, including building signs without permits, poisoning trees that obstructed views of some of its signs and secretly financing a smear campaign.

- Joan English, a West Hollywood city official, noticed Brian Kennedy putting up a billboard without a permit last New Year's Eve morning and turned him in.

- Steve Martin, a former West Hollywood city councilman, says a former city planning commissioner offered him $10,000 in 2003 to vote the way Brian Kennedy wanted on a matter coming before the council.

- Donald Hodel, a palm tree specialist with the University of California Cooperation Extension, said the death of three Canary Island palms blocking Regency signs on Century Boulevard near LAX is a "perplexing and vexing case. ... It could possibly be Fusarium wilt," he said, referring to a fatal palm disease in the area. "But

- Ed Manara, LAX landscape supervisor, said vandals repeatedly and radically cut back coral trees blocking sightlines to a Regency sign near the airport entrance. "I got so tired of it that we used to call airport police," he said.

- David Neal Smith, an associate of lobbyist Ken Spiker Jr., has pleaded guilty to giving an "illegal gratuity" to former Lynwood Mayor Paul Richards to thank him for backing a Regency proposal to put billboards along the 105 Freeway.

- Judy Chu, now a state assemblywoman, was Monterey Park's mayor in the 1990s and an opponent of a Regency billboard plan. Drake Kennedy secretly financed a smear campaign against her, according to the state Fair Political Practices Commission.

- Sandy Bettelman, whose family owns a miniature golf course along the 60 Freeway in South El Monte, told Regency he did not want one of its billboards on his property. Regency built one anyway.

- Ken Spiker Jr., whose firm provided management services for an alliance of small Southern California cities, represented Regency as a lobbyist in two of those cities, Baldwin Park and Lynwood.

Source: Times reporting

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(BEGIN TEXT OF INFOBOX)

Among the players

Regency Outdoor Advertising owns billboards in some of the best locations in the L.A. area. The company has donated hundreds of thousands of dollars to causes of politicians who control where signs can be placed.

To protect its interests, it has filed lawsuits asserting its 1st Amendment rights to bombard motorists with commercial slogans.

- Drake Kennedy secures most sign locations.

- Brian Kennedy mainly deals with advertisers.

- Richard Polanco carried a Regency bill.

- Paul E. Fisher was Regency’s chief lawyer.

KTLA anchor Mark Mester fired after emotional on-air defense of Lynette Romero