Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs

FINAL REPORT

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ACKNOWLEDGEMENTS AND NOTES

The author is grateful to the members of the peer review committee. Their thorough review of this paper, during its initial draft stage and again when the draft final report was submitted to them, pointed out numerous errors, weaknesses, and statements in need of clarification or documentation.

We have tried to make all the suggested corrections, and to incorporate all of the changes recommended by the reviewers. Several commenters offered suggestions that were excellent and appropriate, but could not be accommodated in the body of the actual paper. They are mentioned here, with our thanks and concurrence.

It was proposed that FHWA offer a short course for traffic engineers to understand the human factors issues associated with outdoor advertising signage, to assess the existing roadway environment for safety issues, and how to work with local businesses to improve signage and safety at the same time. We agree that this is an excellent and timely suggestion.

It was recommended that roadway signing and human factors (MUTCD) experts should be collaborating with the advertising industry to promote signs and their placement with appropriate lettering and symbol guidelines or standards that will increase readability while minimizing distraction. In a similar vein, future research should address DBB design criteria that will provide travelers with needed information while at the same time minimizing driver distraction. We note that such collaboration has existed between human factors experts and the on-premise sign industry, but we are not aware of any such relationships in the billboard (off-premise) field.

Another reviewer proposed that TRB conduct a Webinar on this topic in the future. This, too, would provide an excellent forum for the dissemination of this, sometimes arcane, information, in a manner that has practical applications.

Reviewer #5 proposed an interesting thought experiment that addressed the difference between the question: “What is the statistical relationship between digital billboards and traffic safety?” and the question: “Are accidents more, less, or equally likely to occur near digital billboards compared to conventional billboards?” The reviewer suggests that these two questions are not necessarily incongruent, as we stated in the report, and that the second question is both technically correct (as is the first), and more *useful* because it addresses the safety issue in a manner closer to real-world driving; i.e. with the recognition that conventional billboards are a given part of the landscape. While we do not disagree with the reviewer’s position, we question the underlying assumption that the presence of conventional billboards is the accepted and acceptable norm. Most of the research reviewed for this report studied driver distraction and other safety-related measures with real-world or simulated conventional billboards, and many of these studies (as have studies going back decades) identified safety concerns; the fact that control and enforcement may be lax should not de facto make the presence of these billboards the accepted baseline. As well, there are several States and local jurisdictions that ban all billboards, so this baseline is not universal, even in the US. But our greatest concern is with the industry's efforts to raise the bar that research must be meet before, in their view, digital billboards could be found to have adverse traffic safety impacts. The study by Lee, et al., discussed at length in our report, compared digital billboards, not only to conventional billboards, but to "comparison" sites. When the research demonstrated that driver eye movements and vehicle control issues were similar between the DBBs and these comparison sites, the authors proclaimed the digital signs "safety neutral" because, as they defined them, the comparison sites contained "items you might encounter in everyday driving." But a careful reading of the report shows that these sites included digital on-premise signs, tri-vision signs and video boards. In other words, they were rather the same as DBBs, except that they included on-premise signs. In our opinion, this subtle "criterion creep" is unprofessional and inappropriate.

EXECUTIVE SUMMARY

In July 2007, the Highways Subcommittee on Traffic Operations (SCOTE) of the Association of State Highway and Transportation Officials (AASHTO) issued a proposed policy resolution on outdoor advertising. This document recognized that inattentive driving was a major contributor to highway crashes, and that new technologies were enabling the outdoor advertising industry to display more attention-getting messages that were likely to cause drivers to be less attentive to the driving task. The document further noted that national interest and concern about the safety implications of these advanced outdoor advertising displays had been expressed by FHWA and TRB as well as by State and local government agencies. Because the subcommittee recognized the potential safety implications of such signs and the lack of "substantiating evidence" for determining appropriate guidelines for their control, SCOTE resolved to support the undertaking of research as quickly as possible into the safety and operational effects of these technologies and to forward its resolution to the AASHTO Standing Committee on Highways to be considered a high priority project for consideration by the Standing Committee on Research of the National Cooperative Highway Research Program (NCHRP). The SCOTE resolution became a Research Problem Statement [(NCHRP 20-7 (256)], which led to the undertaking of this work in February 2008.

The specific objective of the study was to develop guidance for State Departments of Transportation and other highway operating agencies with respect to the safety implications of digital display technology being increasingly used for outdoor advertising signs. The objective was to be achieved through the conduct of a critical literature review of existing guidelines and research results, including, separately, research undertaken and published by the outdoor advertising industry; an identification of the human factors elements related to the operational characteristics of such signs; a review of the experiences of other countries with this outdoor advertising sign technology; and the preparation of a final, peer reviewed, report documenting the work conducted and including recommended guidance related to the safety aspects of digital display technology for outdoor advertising signs.

Earlier reports published by FHWA in 1980 and 2001 had extensively reviewed the research literature in the field of outdoor advertising, and an FHWA study that ran concurrently with this project also included a review of the more recent research literature. The goals of the FHWA study, however, were quite different than those of the project reported here. Whereas this study had as its objective the development of guidelines that State and local government agencies could adopt immediately, the FHWA study sought to identify unmet research needs with regard to the potential impact of these signs on driver attention and distraction, and to propose a research strategy to fill these knowledge gaps. Thus, the two studies, conducted concurrently, were complementary - this one seeking to develop readily useable guidelines that could be implemented at the State and local level based on our existing knowledge base, and the other seeking a more comprehensive understanding of the safety implications of these signs that might lead to guidance and/or regulation at the Federal level.

Because the technologies used in the signs of interest in this report are relatively recent, and because these technologies have advanced quickly in key performance characteristics (e.g. brightness, resolution, off-axis viewing) and have become much more affordable in recent years, research, too, has increased dramatically since the 2001 FHWA report. Indeed, of the 150 references cited in this report, more than 20 represent original, empirical research, conducted roughly within the past decade, that directly or indirectly address the potential for driver distraction from outdoor advertising signs. Ironically, and consistent with the research studies cited in the prior FHWA reports, the technology continues to lead both policy and research, and only a small number of these studies actually dealt with these advanced digital display technologies. Such research was, however, sponsored by government agencies as well as industry, in the laboratory and in the field, using controlled experimental techniques as well as statistical analysis of crash summaries. In addition to research conducted in the US, the report reviews studies performed in England, Scotland, Finland, Australia, Canada, South Africa, Brazil and The Netherlands. Because of the complexity of the issue, the number of variables present in every real-world situation, and the difficulties of statistical and methodological control in the conduct of such research, we have attempted to make our review of the literature critical as well as comprehensive.

Several conclusions can be drawn from the extensive literature on this topic. First, there are strong theoretical underpinnings in the psychology of cognition, perception, psychophysics, and human factors, to suggest why stimuli such as roadside digital billboards can capture and hold a person's attention, even at the expense of primary task performance. Second, it is difficult to perform a study in this domain that does not suffer, at some level, from weaknesses that may affect the strength or generalizability of its findings. Third, the research sponsored by the outdoor advertising industry generally concludes that there are no adverse impacts from roadside digital billboards, even when, in one case, the actual findings of such research indicate otherwise. Conversely, the conclusions reached in research sponsored by government agencies, insurance companies, and auto safety organizations, especially in those studies performed in the past decade, 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. Fourth, the recommendations from research, and the existence of guidelines or regulations that stem from that research, are quite consistent, although not fully so, both in the areas in which digital billboards are suggested for control (e.g. brightness, message duration and message 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), and with regard to the specific constraints that should be placed on such signs' placement and operation. Several countries have developed comprehensive, thoughtful policies for control of roadside advertising, and their efforts can serve as models for State and local governments within the US. A number of US counties and cities, too, have developed policies and regulations for the control of digital outdoor advertising that comport with the research. In some cases, such local regulations are forward looking, in that they address technologies, or applications of technology, that are not yet in widespread use.

During the course of this project, we identified several recent extensions of digital advertising technologies that may add further to the distraction potential of these displays. The growing use of LED technology for advertising in on-premise applications is of concern because such signs may be larger than traditional billboards, closer to the right-of-way and to roadway sections with high task demands, and may include animation and full motion video. At least one State is considering the use of its official changeable message sign network for the display of digital advertising. And an unknown number of private or toll-road operators are also contemplating the sale of advertising within their rights-of-way. In addition, we are seeing the deployment of LED displays, often featuring video, on vehicles moving in the traffic stream. Vehicles as diverse as small trucks and vans, public transit buses, and large, over-the-road trailers, are now being outfitted with LED advertising, and the potential for driver distraction grows with each such installation. Our review suggests that, with few exceptions, government agencies have no regulations or guidelines in place to address these new uses. The newest digital billboards are also increasingly capable of "interacting" with approaching drivers. In some cases, the Radio Frequency Identification Device (RFID) embedded in a vehicle's key or on-board computer system, can trigger a personalized message on a digital billboard; in other cases, the billboard can display a message tailored to the radio frequency of passing vehicles. Still other billboards encourage drivers to interact with the sign by texting a message or calling a number displayed on the billboard. A patent that incorporates cameras mounted to billboards, together with eye-movement recording devices, claims to be able to capture images of drivers, and their eye movements, as they approach the billboard. Our review has not identified any government agencies, in the US or abroad, that have addressed these new technologies or their applications.

The report consists of ten parts. After an introduction and background presentation in Section 1, the literature in the field is comprehensively and critically reviewed. General research is discussed in Section 2, and research sponsored by the outdoor advertising industry is presented in Section 3. The key human factors issues that inform the potential response of drivers to digital roadside billboards are summarized in Section 4. Section 5 of the report reviews a representative sample of guidelines and regulations that currently exist in a number of foreign countries as well as in several jurisdictions within the US. This is followed by a series of recommendations for potential regulations and guidance in Section 6. These recommendations are those that (a) have worked elsewhere, and (b) are based on sound research or science, and therefore might have practical applications for those jurisdictions seeking guidance to inform their own decision-making. Section 7 addresses issues of digital advertising on-premise and on right-of-way. Section 8 discusses some of the newest roadway-related applications of computer-controlled LED advertising that have begun to appear on and adjacent to public roads in the US and abroad, and for which little policy has yet been considered. Section 9 summarizes the report's conclusions, and Section 10 presents the list of references cited in the body of the report.

SECTION 1.

INTRODUCTION AND BACKGROUND

Nearly 30 years ago, the Federal Highway Administration (FHWA) published the first comprehensive review of the literature on the safety impacts of electronic billboards. FHWA, through the Highway Beautification Act, had, and still has, the authority to regulate off- premise advertising signs (billboards) adjacent to Federal Aid Highways, and these regulations prohibited, in part, any signs that utilized "flashing, intermittent, or moving lights" (Wachtel and Netherton, 1980, p. 16-17). In the late 1970s, the sign display technology in common use permitted little more than digitally displayed time and temperature information, although some signs could display several lines of text and crude, cartoon-like graphic images. Even then it was possible to change the displayed sign messages simply and quickly in real time, and it was possible for these signs to display a number of different visual effects, such as fade, dissolve, flash, and others. The billboard industry took the position that signs using this technology did not present any of the visual characteristics prohibited in the FHWA regulations, and, therefore, should be permitted under the existing regulations. Because the manufacturers of such signs and their potential users saw a bright future for this technology, and because of FHWA's concern about their potential to distract drivers, the industry presented its case to the U.S. Congress. As a result, the FHWA Office of Research was asked by the agency's Office of Right-of-Way to investigate what was known about such signage when used for roadside advertising, in anticipation of a possible update to the agency's regulations. The product of this effort was a comprehensive and critical review of all available literature in the field, some dating back 30 years or more. Wachtel and Netherton termed these new signs "commercial electronic variable message signs," or "CEVMS." Because this technology was so new, the authors found little research that had been done with such signs, and therefore had to rely on research that had been conducted with traditional, fixed, billboards. As a result, although they were able to identify specific safety issues and concerns raised by CEVMS, especially when combined with their review of accepted psychological principles of attention, the authors suggested that additional research was needed, and recommended a specific program to accomplish this. Unfortunately, the proposed research was not pursued.

In 2001, with outdoor advertising signs using newer, more powerful technologies, and capable of much higher fidelity displays with higher luminance levels and immediate wireless display and message updates transmitted remotely, FHWA undertook a follow-on project to bring its understanding of the state-of-the-art and –practice up to date, and to again propose a direction for research. Although this study did not undertake a critical review of the literature, it brought to bear recent research and psychological constructs on inattention and distraction. The product of that work (Farbry, et al., 2001), in conjunction with the earlier document, became the basis for a preliminary, scoping, research study by FHWA (Molino, et al., 2009), and a follow-on research study that was recently initiated.

The 1980 project reported that several of the identified research studies had identified a relationship (correlation) between the presence of billboards and crashes, whereas several other cited studies found no such relationship. Wachtel and Netherton, with the assistance of an FHWA statistician who reanalyzed the data reported in a number of these early research studies (Weiner, 1979) concluded that those research studies that had been more rigorously designed, controlled, conducted, and analyzed, seemed to suggest that a relationship between roadside billboards and traffic safety was present, and that safety was adversely affected by such billboards. The findings pointed to an adverse effect when billboards were bright, close to the roadway, and visible to approaching drivers for considerable distances; and when they were located near intersections, interchanges, or horizontal curves. Further, when the driver's task demands were elevated, as might be the case in heavy traffic, adverse weather, or with challenging traffic movements (lane drops, merges, etc.), the more robust research seemed to show the potential for adverse safety impacts from roadside billboards.

During the 20 year gap between the publication of the first two FHWA studies, as well as more recently, a number of other researchers have reviewed the same early studies (along with more recent studies that have since become available), and reached essentially the same conclusions. (See, for example, Bergeron [1996a], Wallace [2003]). In fact, only one researcher (Andreassen, 1984) is known to have reviewed this literature and reached the conclusion that there is no linkage between roadside billboards and traffic safety, and his colleagues at the Australian Road Research Board (now ARRB Transport Research) (Cairney and Gunatillake, 2000) have expressed strong disagreements with his conclusions.

The latest LED technology enables roadside billboards (and on-premise signs using the same technology), to (a) present images, symbols and characters that are extremely bright (such that they can be easily viewed in full sunlight), (b) with visual fidelity on a par with broadcast video, (c) on displays that can be changed instantly and kept on the screen for as long (or short) as desired, and (d) on signs that can be much larger than traditional 14 ft. by 48 ft. billboards.[1] As a result, the question has again arisen as to whether and how these signs should be regulated in the US. Presently, the States are asking FHWA for guidance. While it proceeds with its current research project FHWA has issued interim guidance that addresses characteristics of CEVMS including: message duration, transition time, brightness, spacing, and allowable locations (Shepherd, 2007). Unfortunately, these guidelines are based on little sound empirical data, and, in several cases, are so subjective as to be open to multiple interpretations.

As suggested above, the potential impact from these latest technologies goes far beyond a simple replacement of traditional, static billboards. On-premise advertising signs, traditionally given much more freedom by FHWA and local authorities, are increasingly using the same LED technology now appearing on billboards. Shopping centers, auto malls, and many other local businesses are finding that such signs are affordable, and that the display capabilities they offer are unprecedented in their attention-getting power. In

[1] One on-premise sign in New York City measures 90 ft. by 65 ft. and is mounted 165 feet above grade where it is visible for two miles from the adjacent Interstate highway (Business Wire, 2002).

addition, these technologies are now beginning to appear on moving vehicles, and some LED billboards can tailor a "personalized" message to approaching traffic by "reading" the digital signal produced by in-vehicle entertainment systems, RFID keys, and other devices. Our research suggests that such alternative, increasingly powerful and compelling uses of the newest technologies for outdoor advertising to the traveling public will continue to evolve at a rapid pace, and that regulators must be prepared to deal with these developments. This paper, however, is limited to a discussion of traditional billboards along the roadside, albeit those with the latest technological capabilities. Although some such signs use scrolling characters across a screen, and others use rotating panels (called Tri-Vision or Roller-Bar signs), it is the LED technology that has the greatest potential for capturing attention, and therefore, distracting the driver. Whether such signs are called digital billboards (DBBs), electronic billboards (EBBs) or CEVMS, they refer to the same types of signs.

Because of the pressures being put on State and local Governments to issue permits for DBBs, and because of the threat of litigation should such permits be denied or revoked, the States have asked for an update about the state of knowledge that results from the latest research. In addition, the States would like to know what guidelines and/or regulations exist in other jurisdictions with regard to DBBs, and have asked for recommendations for appropriate, realistic, data driven guidelines that they might consider adopting for their own streets and highways, and pending updated guidance from FHWA.

The present report, therefore, represents a comprehensive, critical review of the most recent research literature in this field. To a large extent, the research discussed herein has been conducted since the most recent (2001) FHWA report was published. Several earlier studies are discussed, however, either because they were not captured in the two FHWA reports, or because their methods and findings are directly relevant to the questions now being asked. A number of these studies have not been widely reported or are controlled, internal documents. We are grateful to their authors for making them available to us.

After the critical literature review in Section 2, subsequent sections of this report address: research performed on behalf of the outdoor advertising industry, human factors considerations relevant to driver response to these technologies, guidelines and regulations in place or under consideration in other jurisdictions, recommendations for guidance that States and local governments might adopt in the near term, and new technologies and applications for outdoor advertising. After a brief summary, the final report section identifies the references cited in this study.

SECTION 2.

REVIEW OF THE LITERATURE.

The review and critique of the studies below are presented in chronological order. As requested in the Research Problem Statement that led to this study, research undertaken and published by the outdoor advertising industry is treated separately. These studies are discussed in Section 3, Industry Sponsored Research.

Perception Research Services, 1983.

This paper is discussed in Section 3, “Industry Sponsored Research.”

Cole and Hughes, 1984

The authors conducted a series of experiments in which 50 participants drove a vehicle along a predetermined route in Melbourne, Australia. Prior to the data collection, the authors placed a series of 35 disc targets along the route. These discs were of three different sizes and three different reflectances. They were positioned where typical traffic signs would be likely to occur. The participants were divided into two different groups at random; each group was given slightly different instructions. Group A received instructions oriented toward *attention conspicuity*, whereas Group B received instructions oriented toward *search conspicuity*.[2] Results showed that the hit rate, the frequency with which the disc targets were reported, was three times higher in Group B than in Group A, demonstrating the benefits of directed search. It was also found, however, that directed search produced its greatest benefits when the targets had low attention conspicuity, and showed the least gains for targets with high attention conspicuity. Although early efforts to define conspicuity tended to consider it to be strictly a quality of the object, more recent work, such as this study, have demonstrated that conspicuity cannot be measured independently of the observer’s state of attention.

Several other findings from this study are relevant to our present project. The first is that the angle of eccentricity of the object to the viewer’s line of sight is an important factor in its conspicuity; more so than the object’s size or reflectivity. Second, the authors found that the visual environment in which the target was located was an important contributor to its conspicuity. They suggest a thought experiment to demonstrate that the predominant location factor that affects conspicuity is visual clutter. In the case of attention conspicuity, for an object in the periphery of the visual field to command attention, it will first provide a stimulus to the eye that is strong enough to arouse the viewer’s attention and generate an eye movement toward the object to move the object into central (or foveal) vision, where it is fixated. This action, which the authors describe

[2]Cole and Hughes define attention conspicuity as the capacity of an object to attract attention when the object is unexpected; and search conspicuity as the property of an object that enables it to be quickly and reliably located by search.

as a quasi-reflex(ive) response, is known as an *optically elicited eye movement*. The authors argue that visual clutter adversely affects both search and attention conspicuity equally, because the clutter causes a loss of prominence of the target object, thereby reducing both the attention-getting quality of the object and its accessibility to visual search.

What is the relevance of these findings to our present concern with DBBs? First, since billboards are most likely identified through the process of *attentional* rather than *search* conspicuity, it suggests that it is this semi-reflexive behavior of the optically elicited eye movement that first brings a billboard into a driver's visual attention, and that the owner of a billboard would prefer to locate it in an area that is otherwise low in visual clutter. Second, it suggests that billboard designers are likely to design their messages in such a way as to make them as conspicuous as possible, both to stand out from their competitors and to successfully trigger this reflexive eye movement to move the image or message on the billboard into a driver's foveal vision. Third, it is understood that billboards are, by definition, contributors to visual clutter in the driving environment, and, as such, they are likely to contribute to a degradation of search conspicuity of official traffic signs, signals and markings, as well as other traffic, obstacles, and hazards, which become conspicuous to drivers as a result of such directed search. Finally, the reported finding that the degree of eccentricity of an object to the driver's line of sight is an important contributor to its conspicuity lead Cole and Hughes to suggest that: "in order to achieve conspicuity, the designer is better advised to locate the target where it will have a small eccentricity to the observer's line of sight…." Small angles of eccentricity are afforded by minimizing lateral offset and by ensuring a long observation distance" (p. 310). An understanding of this concept may contribute, along with other factors, to the desire of the billboard owner to locate such signs as close to the road edge as possible, and along horizontal curves and tangent sections that afford potentially longer sight distances for approaching drivers.

Young, E. 1984.

This paper is reviewed in Section 3, "Industry Sponsored Research."

Pottier, A. 1988.

The impetus for this research study was a series of findings from three prior studies that demonstrated that the conspicuity of road signs depends on the visual environment in which they are located. Pottier notes that road signs are frequently located in settings that make them less conspicuous due to extraneous elements that she calls "static visual noise." She defines visual noise as "constant background noise derived from a multitude of cues, interfering with or preventing the driver from processing the information from the cue significant to him" (p. 581). She considers "billboard advertisements" to be a type of visual noise.

Pottier evaluated the abilities of twelve participants to detect the shape and location of a number of official traffic signs, as quickly as possible, under four different test conditions. These conditions included: (a) a simple or complex visual environment; (b) different shapes (three) and sizes (three) of the signs; (c) different degrees (three) of eccentricity from the central point of fixation; and (d) different time periods (three) in which the signs were visible. Eye movements were recorded as well. Some of the findings of this study were as expected – specifically, that longer observation time improves detection performance, larger signs are more easily detected than smaller ones, and certain shapes (circle and triangle) are more easily detected than others (rectangle).

For our present purposes, the most relevant findings were related to the visual angle from which road signs were most easily detected. Pottier found that, when there was no visual noise in the (simulated) environment, the optimal detection zone was located between zero and ten degrees (0^{o}- 10^{o}) from the participant's central point of fixation; however, in the presence of visual noise, this optimal detection zone shrunk to zero to four degrees (0^{o} - 4^{o}) from the fixation point, regardless of the time available for observation. A related finding was that, when a road sign is "superimposed" on a component of visual noise, "the latter prevents the former from being detected" (p. 582), and the greater the distance between the visual noise and the highway sign, the greater the conspicuity of the sign. The author's conclusion is that "visual noise reduces the functional field inducing a kind of 'tunnel vision' for the driver" (p. 582). Pottier's work foreshadows more recent research in visual clutter (see, for example, Edquist, 2009) which demonstrates that relevant targets (such as official traffic control devices) take longer to find, and that responses to such signs are more error-prone, when visual clutter is high.

Transportation Environment Consultants (TEC), 1989

This "Review of Roadside Advertising Signs" was prepared for the Roads and Traffic Authority (RTA) of New South Wales, Australia. At the time this project was begun, the RTA did not "encourage" advertising signs within the "road reserve" of "classified roads." The Authority had been repeatedly approached by the advertising industry, which submitted proposals for "well designed modern technology advertising sign displays" on road reserve locations and buildings on property owned by the Authority. Because of the potential for such signs to generate revenue for RTA programs, TEC was engaged to investigate the appropriateness of the RTA allowing or supporting such signs in the future. A multi-part study was undertaken, which addressed many aspects of outdoor advertising, including environmental design, aesthetics, town planning, tourism, revenue potential, marketing of road safety promotions, and others. This review will address only the safety and human factors aspects of the project.

The authors briefly reviewed nine studies that dealt with the safety aspects of outdoor advertising signs, and quoted extensively from the early FHWA report on this subject (Wachtel and Netherton, 1980). In addition, they conducted interviews with members of the outdoor advertising industry and experts from the Australian Road Research Board (ARRB).

Their conclusions from these activities include the following:

- 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.

Brown, 1989

After a brief but useful review of the relevant literature, Brown describes the purpose of his study as: "to assess the momentary distractive effects of electronic billboards on driving performance" (p.3). He used a laboratory setting in which the driving task was represented by a tracking task in which the participant had to move a joystick to track a target spot which moved in pseudorandom fashion within a constrained area on the screen. This task was superimposed on a continuous video image of a moving road scene. The distracters were a series of white on black "advertising signs" presented in the lower left area of the screen, overlapping the road and shoulder, and directly adjacent to the screen area used for the tracking task. Sixty different signs were each displayed for two seconds, at a rate of one sign every six seconds. Three different experiments were conducted under the same basic conditions, in which a secondary task (response to a red signal) was present or absent, and in which the advertising signs appeared in a fixed position or were "scrolled" onto the screen. The author found no effect of the presence of the advertising sign alone on tracking performance, but did observe a negative effect on performance when a secondary task was required.

In discussing possible reasons why the advertising signs alone did not distract the drivers and impair their performance, Brown suggests that, as demonstrated in prior research (Gasson and Peters, 1965), concentration on a central task can lead to an effective reduction in the size of the visual field. In other words, because the principal tracking task in this study required a higher level of concentration than that of a normal driving situation, it might have led to a reduction in the participants' awareness of the images presented in their peripheral vision (i.e. the simulated digital billboard), leading to a failure to notice them. This postulation is similar to the recent findings of Chan et al. (2008), where the authors reported that objects that are not fixated or attended to receive little cognitive processing, and that reduced attention to such objects impairs the speed of identification.

Although this argument can be used to explain why, when a driver concentrates on the driving task by attending to the forward roadway view, he or she may not be distracted by a billboard, the reverse may also be true. That is, a highly attention getting billboard, or one conveying a message of high salience to a driver, may assume a degree of primacy for that driver such that the billboard, and not the road and traffic ahead, becomes the central focus. With a driver now attending to a visual object in the periphery, the forward view may temporarily assume the periphery position, and attention to it may be delayed.

There were a number of limitations to this study, several of which are identified by the author. One stated weakness was that the motion in the video scene and sign presentation was not linked to the tracking task, and thus could be ignored by participants. Additionally, we have concerns that the appearance of the "electronic billboards" which were represented in the simulation by simple white on black text presentations is quite different than the bright, dynamic properties inherent in real-world DBBs. Also, the distracter signs were located in the participants' field of view directly adjacent to the target tracking task and at the road edge, thus not requiring the driver to look away in order to observe these signs. The fact that the study participants could visually observe the billboards and the forward view simultaneously could account for the negative findings.

Rahimi, Briggs, and Thom, 1990

These authors were concerned primarily with the over involvement of motorcycles in fatal crashes with automobiles, and with the results of prior research showing that the predominant cause of such crashes was the car driver's violation of the motorcycle's right-of-way. Further, one driving situation accounts for the majority of such crashes; that is, where the car driver executes a left turn directly across the path of an oncoming motorcyclist. In many of these cases, the car driver claims not to have seen the motorcycle. The authors wanted to investigate the hypothesis that left turns at "busy" intersections would heighten the likelihood of such crashes compared to left turns at "quiet" intersections. In addition, they wanted to test the viability of a new eye/head movement data collection system that they had developed. A full explanation of this data recording and analysis system is beyond the scope of the present paper. In brief, however, their approach involves the simultaneous recording and time synchronization of drivers' head and eye movements with the visual scene presented to the driver, which is recorded with a separate camera. In the laboratory, the eye/head movement recordings are embedded into the scene video, enabling the researchers to know with precision the driver's head and eye position throughout the drive. Because this was a pilot study, only one test subject was used, and this male, 33 year old driver with 20/20 vision drove a vehicle through a sequence of 40 left turns, alternating between previously selected quiet and busy intersections. The principal differences between the two intersections were in the number of dynamic and static distracters. The pattern of head and eye movements differed significantly at the two intersections. At all 20 trials at the busy intersection, head movements were identified as "straight ahead toward left (SATL)" and at 17 of the 20 quiet intersections, head movements were categorized as "left-right-left (LRL)." Although the driver's head position remained consistent across intersection types, eye movement frequency at the busy intersection was nearly twice as high (significant at the .004 level) as at the quiet intersection. The authors conclude that the two different types of intersections place different constraints on driver behavior. At the quiet intersection, the environment is searched systematically with a combination of head and eye movements. At the busy intersection, however, a stationary head position occurs with frequent and rapid eye movement activity to identify targets and distracters. Their analysis indicated that "the busy intersection contains potential for information overload" (p. 273), and they imply, although do not state, that "busy" intersections, such as those with environmental targets and distracters, may contribute to a greater percentage of automobile-motorcycle intersection crashes due to driver distraction than "quiet" intersections. Although we can't fault the study methods used since this was a pilot study to test a new data recording system, the findings, based as they are on only one participant, should not be generalized beyond the immediate circumstances of this study. Nonetheless, conclusions that demonstrate a correlation between numerous distracters at intersections and poorer driver performance have been shown in several other studies (see, for example, Holahan, et al., 1979).

Wisconsin Department of Transportation District 2, Freeway Operations Unit (1994).

This study tabulated and analyzed crash rates for eastbound and westbound segments of I-94 in the vicinity of County Stadium (since demolished) near Milwaukee, Wisconsin. An electronic billboard began operation on April 13, 1984. Crash rate data was collected for approximately three years prior to sign operation (from 1/1/81) until three years after operation began (12/31/87). Effects were broken down by type of crash (side-swipe, rear-end). Data were analyzed for the one year after the sign became operational, to analyze any novelty effect, as well as for the three year periods before and after the sign became operational. Crash rate was calculated as number of crashes per million vehicle miles of travel (VMT).

The sign is described as a variable message sign that changed images on average 12 frames per minute. This suggests that each image was displayed on the sign for five seconds. No information is provided as to the sign's display technology, brightness, or method of change. It is not known, for example, whether message changes occurred instantly, or whether some visual special effects, such as wipe, dissolve, etc., were employed. Neither the size of the sign nor its height above grade is specified. The sign is obviously two-sided since it is visible to both eastbound and westbound traffic. It is located adjacent to the westbound traffic lanes.

The study used the crash rate in the three years prior to the sign's operational date as the baseline. Findings showed that for eastbound traffic, total crashes increased by 43% in the first year, and 36% over the three year post-operational period when compared to the baseline condition. In the same periods, side-swipe crashes increased 80% and 8%, and rear-end crashes increased 60% and 21%. For westbound traffic, total crashes decreased by 12% in the first year, but increased by 21% over the three year post-operational period. Sideswipe crashes increased 123% in the first year, and 35% over the three year interval, whereas rear-end crashes decreased 29% in the first year, and then increased by 35% over three years.

The author posits two reasons why westbound crashes were generally lower than those for eastbound motorists. First he describes a merge area for westbound drivers caused by northbound and southbound traffic on US-41 merging onto westbound I-94, and states that the roadway configuration causes this traffic to slow as it enters the area, thus reducing congestion through what he describes as "metering." Second, the author indicates that the sign was more readable to eastbound than to westbound traffic.

The author concludes 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," and suggests that "it may be beneficial to introduce traffic responsible variable message signs into the area. Signs could function at rates proportional to traffic flow and density in the viewing area."

This study has the strengths of a typical crash rate analysis. Although it cannot address questions of crash causation, the study can be used to determine that there were correlations between the operation of the advertising sign and the increase in crash rates in areas where the sign was visible.

Apparently five types of crashes were coded from the accident reports: rear-end, sideswipe, fixed object, other, and unknown. The report reviews only the data for the first two crash types, and this is appropriate. Both side-swipe and rear-end crashes are indicative of driver inattention or distraction, although this roadway section includes a complex interchange where merges and lane changes are likely. Poor signage and markings, difficult geometry, lane drops and other roadway characteristics could have been present (these roadway and traffic characteristics are not described) which might suggest elevated crash rates of these types.

When the goal is to determine whether a particular object or feature (in this case an electronic changeable message sign) caused crashes to occur, or caused the overall crash rate to increase, a study that is limited to an analysis of crash rates cannot answer this question. This is because the study is limited to post-hoc statistical tabulations. The study does not address, and clearly did not control for, the possibility that other changes took place in the roadway section studied in addition to the operation of the billboard. For example, changes to speed limits, police enforcement activities, reporting methods, use patterns, construction, development adjacent to the roadway, and many other factors, might have been present, and might have contributed to changes in crash rates. There was apparently no attempt made to identify whether any such factors may have occurred during the study period. In addition, the study apparently did not utilize a control section of roadway that might have overcome some of these potential weaknesses. Had the authors chosen a similar section of I-94 in the same general vicinity as the study section, but in which no advertising sign was introduced, they might have been able to compare before-and-after crash rates for the same period, but without the presence of the sign. This would have strengthened their ability to demonstrate that it was the presence of the sign, rather than some other factor, that related to the elevated crash rates.

The author states that the study areas included "all places where the variable message sign can be viewed by a motorist…." Since the precise billboard location is not identified on the site maps included with the report, it is not possible to determine whether all crashes occurred at locations where drivers would have had a clear view of the billboard prior to the crash.

Although the study evaluated crash rates before and after the introduction of an electronic variable message billboard with a message change interval of approximately every five seconds, no additional information is provided to enable the reviewer to determine the type of sign, the display technology, or the operational characteristics. As stated above, although crash rate data can supply valuable information relative to overall traffic safety in an area, it is not possible to identify a cause and effect relationship without far greater control of other, possibly relevant, variables – something that is quite difficult to do in a real world environment and with a post-hoc analysis of police accident reports.

Akagi, Seo, Motoda, 1996

These authors believe that, because of a combination of limited land, intense land use, and weak regulations, billboards are more prevalent along roadsides in Japan than they are in Europe and the U.S. They set out to study whether official road signs are more difficult to recognize when they are "hidden" among commercial signs and other roadside clutter such as buildings, utility poles, etc. To perform their analysis, they developed a visual noise ratio, defined as the ratio of the area of noise in a visual environment to a driver's field of view. They determined field of view from prevailing driving speed, e.g. 75º at 65 km/h, the speed limit on the road they studied. Their target sign was a typical national highway route marker, and they instructed their nine subjects (5 male, 4 female, and age range 21–66) merely to report as soon as they were able to confirm the route number. Eye movements were recorded from a point 400 meters upstream of each of six signs that appeared along the route, within predefined sections. The visual noise ratio was measured at intervals of 20 m throughout each section. The authors found a statistically significant decrease in the detection distance of the sign as the visual noise level increased along the 400m approach to that sign. They further found that older drivers were significantly more adversely affected by the visual noise, and that males were more adversely affected than females. The authors conclude that visual noise along highways can be dangerous because it reduces the detection distance of important roadside information. While this study provides a unique approach to assessing the impact on driver performance of roadside distracters, and visual clutter, it suffers from several limitations. First, the number of subjects was quite small, and the distinction between older drivers and others is not defined. (There were only two subjects above the age of 60, for example). The definition of visual noise was somewhat vague, and the methodology used for measuring eye glances was unclear. Nonetheless, this is a novel, real-world approach to measuring the impact of roadside visual clutter, with a dependent measure (identifying the route number as early as possible) that is natural and reasonable.

Bergeron, J. 1996a

Bergeron undertook this study at the request of the Government of Quebec, which was considering whether to grant a permit for an electronic advertising sign adjacent to an expressway in Montreal. This project was not a research study; rather it reviewed the published literature in the field and applied the author's understanding of accepted theories and principles of psychology to address issues of driver visual perception and attention, and their role in traffic safety.

The majority of the studies reported on were those previously reviewed by Wachtel and Netherton (1980), and many of Bergeron's statements and conclusions parallel those of the earlier study. However, Bergeron (reporting 16 years after the Wachtel and Netherton study was published) also cites a small number of newer studies, and includes reviews of one study published in France that was not included in the earlier report. Further, Bergeron discusses some of the published literature in the field of driver performance in general, and with regard to official highway signs and other traffic control devices, and he applies the understanding gleaned from these studies to his interpretations about the role of advertising signs. The author reexamines the applicability to this issue of some of the key theories of attention and perception as previously discussed by Wachtel and Netherton, and expands upon this discussion. In addition, he cites the work of Wickens and others, and explains clearly the applicability of these theoretical constructs to issues of driver attention and distraction.

Although the report title suggests that the focus is on advertising signs in general, the principal interest is electronic signs, which Bergeron calls variable message signs, or VMS.

Bergeron's findings largely reflect those of other psychologists, cognitive scientists and traffic engineers who have addressed these issues. His primary conclusions are:

- 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.

At some levels, this paper seems simply to restate many of the points already raised in other review articles on this topic. But Bergeron goes to greater lengths than several other authors to apply the theoretical underpinnings of attention, sensation, perception, and distraction, to the conclusions, however flawed, of many of the statistical, on-road, or laboratory studies undertaken over the past 50 years on the impacts on traffic safety of roadside advertising. These analyses are useful and appropriate, and provide a fuller picture of the concerns with traffic safety from the roadside use of DBBs than other studies. On the other hand, his writing suggests a clear bias against roadside advertising, and it appears that his dismissal of certain studies and his complementary reviews of others are affected by this bias. One minor concern is that he sometimes shifts his focus from billboards to official VMSs without affording the reader a clear understanding of this shift, thus leading to some confusion in interpretation. Bergeron provides no photographs or detailed descriptions of the types of DBBs that he studied. Thus, we do not know how similar the signs that he addresses are to those that are of principal interest in the present report. At one point, he describes VMSs as: “attractive, colourful, dynamic, sequential, and (able) to meet the needs of several merchants at the same time” (p.19). Clearly, these sign characteristics seem to fit those of digital billboards, but further comparisons are not possible. Despite these shortcomings, this thought paper is a useful contribution to our knowledge in this field.

Bergeron, 1996b

Whereas the Bergeron paper discussed above (1996a) is a thought paper that applies relevant psychological theories and concepts to the findings of research about the relationship of outdoor advertising to road safety, this paper reports on the author’s analysis of two DBBs proposed for a specific location in Montreal, Quebec, Canada.

After a first-hand review of the site, the adjacent expressway, and architectural and engineering drawings for the proposed signs, Bergeron recommends that permits not be issued. He describes the site as possessing many of the characteristics that he, and others, have suggested would be inadvisable for the placement of billboard:

> …complex geometry of the road environment, heavy traffic, high speed of traffic, merging and diverging traffic, areas with road signs and signals where vehicle operators are required to make decisions. Given these situational factors, we must avoid creating confusion in the visual field. In these conditions, road signs and signals must be clear and the nature of the information communicated must only serve to assist drivers in their task of driving. In like conditions, outdoor advertising signs can represent a threat to the safety of road users.

Bergeron suggests that billboards at this location can have adverse impacts on driving safety from several standpoints.

- At a perceptual level, they can make the response to official traffic control devices more difficult by adding to visual complexity.

- At an attentional level, they can lead to driver distraction; in a road situation such as that present at this site, the level of mental loading is already substantial, and the billboards would generate an unnecessary demand on a driver's limited attentional resources.

- The billboards could add to the drivers' mental workload, which, in turn, can lead to declines in selective, shared, and sustained attention, decision-making, and motor activities.

- Drivers who are unfamiliar with this location may have the added burden of time sensitive decisions that may be necessary to move into the appropriate lane for exiting or merging.

- Because this expressway section is elevated, the demands on the driver are further increased because there is little or no space to pull over in the event of mechanical or other failure, and because bridge structures are known to contribute to feelings of insecurity among drivers.

Schieber and Goodspeed IV, 1997

This study addressed the nighttime conspicuity (i.e. detection) of official highway signs under two different conditions of sign brightness. Although concerned only with official, not commercial, signage, there are valuable points made by these authors that are relevant to the discussion of DBBs. Using a specialized, in-house apparatus that was capable of reproducing most of the dynamic range of roadside environment visual stimulus luminance values, the authors compared "bright" and "ultrabright" signs under three different conditions of environmental (background) complexity: low (representative of a 2-lane rural highway); moderate (depicting a typical commercial street in a small city); and high (simulating a downtown street in an urban area with many businesses and illuminated commercial signs). The principal hypotheses were confirmed. That is, although enhanced sign brightness offered no advantage either for response time or accuracy in the low complexity background, it was significantly better than the lower brightness sign in both categories under moderate or high complexity environments. The results also confirmed that older drivers may be more susceptible to the interfering effects of higher levels of background complexity when they are looking for information on highway signs. The results suggest two concerns about DBBs. First, these signs tend to be located in complex visual environments, and public complaints have suggested they are often too bright. Second, in an effort to stand out from this complex background, i.e. make them more conspicuous; DBB operators often believe that, the brighter the sign, the better. Our concern is that an excessively bright DBB in a visually complex, typically urban environment will succeed in drawing attention to itself and away from other signs in the environment, including official signs. Third, as this study, and others, have demonstrated, older drivers have a particularly difficult time detecting official highway signs in complex environments. Unfortunately, the trend in the U.S. is to increasingly more complex environments, which does not augur well for our aging society.

Theeuwes, et al., 1998, 1999

In a series of related laboratory studies, Theeuwes and his colleagues have demonstrated behaviors that may help to explain why the human eye may be drawn to a DBB at the expense of the driving task even when a driver has no intention, or desire to look at the billboard, and how this unintentional response can delay one's reaction time to time-critical on-road events. Their experiments also shed light on the finding that their participants were unaware that their eyes had been drawn to the distracter at the expense of the object that was their task.

In summarizing the relevant literature, the researchers describe findings that show that the human visual system is sensitive to events that exhibit sudden change; that a visual object presented with a transient luminance change captures attention automatically and reflexively. Even when observers have no intention to look for what Theeuwes call an onset, such an abrupt onset, when visible among other visual elements in the scene is processed first. Thus, it has been argued, sudden luminance changes (and this characterizes all DBBs at the point of message change) capture attention in what is known as a "stimulus-driven" manner, as opposed to being attentionally driven.

The studies reported here were conducted to determine whether such an abrupt-onset object that was irrelevant to the task being performed, would also capture the eye movement of the participant.

The experiment required participants to view a display containing six gray circles. After a set time, five of the circles changed to red (one remained gray), and all six simultaneously displayed a letter in their center. Participants were instructed that, as soon as the colors of the circles changed, they were to direct their gaze as quickly and accurately as they could toward the one circle whose color did not change, and push a button to identify the letter that appeared in that circle. (The five other circles displayed randomly chosen distracter letters which were never the same as the letter in the "target" circle). Eight participants performed 64 practice and 256 experimental trials. In half of the trials, a new red circle was added to the display at the same moment that the others changed and the letters were revealed. This new circle could appear at one of four possible locations within the display. This new circle was the "onset" or distracter.

The results showed that, when no new object was added to the display (the control condition), the participants were able to move their eyes directly to the target; however, in those trials where the new object was introduced (the experimental condition), participants' eyes often went toward the new object, stopped briefly, and then went on to the target. In other words, with the new target present, two different eye movements were made, the first to the new, irrelevant target, and the second to the target that was the object of the task. Reaction time to the task (the identification of the letter inside the gray circle) was significantly slowed when the new, irrelevant target was present. The authors note that the task irrelevant stimulus attracted this initial eye glance even when it appeared in the direction opposite the target. At the end of the experiment, the researchers explicitly asked the participants whether they were aware that the new object affected their eye movements. The answers were that they were sure that their eye movements were not affected by the onset object. Their conclusion from this first experiment was: "Both the goal directed allocation of attention and the movement of the eyes to a clearly defined target can be disrupted by the appearance of a new but task-irrelevant object in the visual field, even when this object appears quite distant from the target" (Theeuwes, et al., 1998, p. 381).

In a second study using a similar paradigm, the researchers found that the attentional capture effects by the appearance of the task-irrelevant onset could be overcome when observers had sufficient time in advance to attend and program an eye movement to the location of a subsequent target stimulus. In other words, the distracting effect of the novel, task-irrelevant object can be offset when a person can, in advance of that distraction, focus on and attend to the principal target.

Cairney and Gunatillake, 2000

On behalf of the Royal Automobile Club of Victoria (RACV - the approximate equivalent of the AAA in the U.S.), Cairney and Gunatillake of ARRB Transport Research (formerly the Australian Road Research Board) undertook a review of the literature with the goal of generating recommendations for guidelines for the control of outdoor advertising in the Australian state of Victoria and its local jurisdictions.

The authors cited two prior, comprehensive reviews, one by Wachtel and Netherton (1980) in the U.S. and one in Australia on behalf of the ARRB by Andreassen (1984). Their search of three databases (INROADS in Australia, IRRD in Europe, and TRIS in the U.S.) uncovered no new studies in this field. What had changed since the two cited reviews, however, was the technology used for the display of roadside advertising, as well as the presence of more potential distracters within the vehicle itself. In addition, the authors report that some jurisdictions have made progress in the development of regulations "which are acceptable to advertisers while avoiding obvious distraction problems for drivers…" (p.2). They explain that, although these guidelines are not generally based on empirical evidence, they are based on solid human factors data and practical experience.

The authors identify, and briefly describe, six different types of signs, and suggest that different guidance or regulation is needed for each. Only two of the sign-types, the variable message and tri-vision signs, are relevant to our current study. They further discuss illuminated signs, and the types of motion or apparent motion that can be achieved by such signs, including: flashing, chasing, scintillating, etc., and they discuss the appropriateness of restrictions on dazzling or glare impacts on motorists, and on maximum luminance (brightness) levels that should be appropriate for the ambient roadside environment. Finally, they suggest that the lighting color displayed on such signs should never mimic that of official traffic control devices, although they say nothing about the shape of images displayed. For all signs, Cairney and Gunatillake concluded that the common concern is the effect that a sign may have on a driver's visibility of other road users, the roadway, and traffic control devices, and that appropriate regulations generally prohibit signage in areas near where the demand for driver concentration is high, "such as intersections, interchanges, and level crossings" (p.3).

Although this report is not primarily concerned with recommendations of research methodology that might be used to study the effect of roadside advertising signs on traffic flow and safety, they mention three different types of investigative approaches that might be followed, and point out certain difficulties and disadvantages of each.

> The case-study approach involves the review and analysis of accident investigation reports. The lack of results from such studies does not, they believe, demonstrate that distraction from roadside advertising is not an issue, because drivers may be reluctant to admit that they were distracted or may not have been aware of being distracted. Further, distraction has not traditionally been an issue that accident investigators have drawn attention to, and thus it is likely that it is underreported.
>
> The site investigation approach involves the examination of crash rates; particularly crash rates of the types of crashes that might be expected to be related to distraction such as rear-end crashes, along different road sections distinguished by advertising sign presence or density. The authors point out that the major difficulty with this approach is that high advertising density tends to be correlated with other factors that might contribute to a high accident rate – i.e. a more demanding driving environment. Not stated is that such studies are typically unable to identify or control for variables that are outside the scope of the actual study, such as police enforcement, road construction, or weather conditions.
>
> The laboratory simulation approach enjoys the benefits of complete control over the experimental design, but presents the difficulty of generalizing from the simulated, artificial task in the laboratory to performance in the real world. In addition, although not discussed in this report, there is the difficulty of recreating the legibility, brightness and contrast of today's sophisticated advertising signs in simulation.
>
> Other research approaches, such as naturalistic studies, controlled-course studies, and unobtrusive observation, among others, are not mentioned.

The authors state that the majority of their review of the literature is based heavily on the Wachtel and Netherton (1980) study. Indeed, of the 14 studies reviewed by Cairney and

Gunatillake, all had been previously analyzed by Wachtel and Netherton. Accordingly, these re-reviews will not be discussed here. The conclusions of Cairney and Gunatillake, having re-reviewed these studies with the benefit of 20 years of hindsight, is that the conclusions reached by Wachtel and Netherton were appropriate, and still relevant to the development of guidelines in Australia in 2000. Among their specific conclusions are these:

> The best of the studies reviewed to date (Weiner, 1979) demonstrates that, when all confounding variables are controlled statistically, sites with advertising signs have higher crash rates than sites without. Indeed, the number of billboards did have a significant effect, and the number of crashes increased in proportion to the number of billboards. The effect size, however, is modest.
>
> Because the effect size is small, this suggests that large, well-controlled studies will be required to detect significant effects. "There is a risk that small studies will not produce sufficient effects and be misinterpreted as showing that there is no significant effect when the proper conclusion is that there is insufficient data to reach a conclusion" (p.9).
>
> Changeable message signs may have a more direct bearing on crash rate than static signs.
>
> The outcome of the laboratory studies complements those of the (on-road) correlational studies. Although drivers are resistant to distraction, simulated advertising has a small but consistent, and adverse, effect on performance, particularly where task demands are high, and on peripheral tasks. Further, advertising material that is similar in appearance to traffic control devices, or that is proximal to such TCDs in the driver's visual field, may be particularly troubling.

In summary Cairney and Gunatillake believe that the cited findings suggest that unregulated roadside advertising has the capacity to create a significant safety problem. Interestingly, they state that their results "run directly counter to Andreassen's (1984) conclusion that 'There is no current evidence to say that advertising signs, in general, are causing accidents'" (p.9).

The remainder of this study addresses the existence of guidelines and regulations, and puts forward recommendations for future controls. This will be addressed in Section 5 of the present report.

Farbry, et al., 2001

This report, by the Federal Highway Administration's (FHWA's) Human Centered Systems Team, reviewed the literature related to the safety implications of electronic billboards (EBBs), presented findings, and recommended a research plan to address knowledge gaps. It was a follow-up to an earlier FHWA report (Wachtel and

Netherton, 1980), and it complemented contemporaneous driver distraction studies that addressed in-vehicle displays. The project included tri-vision signs within the broader category of EBBs.

The literature review included: an assessment of state billboard regulations and policies relevant to EBBs and tri-vision signs; billboard-related crash analyses and potential safety factors such as distraction, conspicuity, and legibility; and driver and roadway characteristics. Because there was a limited amount of available research on external (to the vehicle) distraction, the review included an assessment of studies of in-vehicle distracters as a surrogate to understand how potential distraction may affect the driver.

The knowledge gaps were categorized into three areas: roadway geometry, sign characteristics, and driver characteristics. Each of these areas was reviewed and preliminary research plans were proposed, including goals and research questions. The roadway characteristics identified for future research included horizontal and vertical curves, intersections, work zones, and EBB and tri-vision sign spacing. Sign characteristics for needed study included content and comprehensibility, exposure time, motion, and sign maintenance. Driver characteristics related to age and route familiarity.

The authors describe the capabilities of EBBs, both complex and simple, and state that the simpler technologies used in some EBBs are similar to those employed in changeable message signs (CMS) used by roadway authorities in both permanent and portable installations to communicate official traffic information to motorists. The report notes that such signs may also be called variable message signs (VMS) or dynamic message signs (DMS). Tri-vision signs are described as more limited in capability, but of interest because of: (a) the rotation (movement) of their cylinders to present three different messages, (b) the presentation of two partial messages simultaneously (during the change interval), and (c) potential variations in light reflected back to the driver as the panels rotate.

A review of State practices concerning regulation of EBBs demonstrates that, unlike with static (fixed) billboards, there is little consistency from one jurisdiction to the next.

The literature review, while updating that in FHWA’s 1980 study, differed from the earlier study in three ways. First, the newer study did not review the literature critically as did the previous study; and second, the newer study reviewed a subset of the literature whereas the earlier study attempted a comprehensive review of the extant literature. On the other hand, the newer study synthesized the prior research in a manner that the analytical and chronological approach of the earlier study did not. The 2001 study grouped the reviewed work into common topics areas, permitting the reader to more easily grasp the multifaceted nature of DBB issues, and to better appreciate the existing knowledge gaps with regard to the safety implications of these devices.

The authors identified relevant research in other aspects of road safety that might not, at first, seem to relate to the possible safety implications of roadside electronic billboards. Areas of research interest such as older and younger drivers, distraction due to in-vehicle technology, and display and lighting characteristics of changeable message signs used for official purposes, are all discussed. Clearly, these areas of research *are* relevant to DBBs, as will be discussed below.

Specific attention is given to other technologies (such as in-vehicle distracters) as they may be relevant to the potential threat of distraction from electronic billboards. For example, the study summarizes work by Wierwille and Tijerina (1998) that calculated the total number and average duration of eye glances required to operate specific in-vehicle devices (such as climate controls, HVAC, mirrors, and others). “Exposure” was defined as the number of glances multiplied by the time per glance, and the researchers found that there was a linear relationship between exposure and number of crashes. The FHWA authors suggest that a similar approach might be undertaken to assess the maximum amount of time that a driver could attend to a distraction source outside the vehicle. Similarly, the authors review several studies that examined the relationship between cellular telephone use and crashes, and they divide such phone-related distraction into three categories: manual manipulation of the phone; glancing at the phone (which requires looking away from the roadway), and engaging in conversation (which may disrupt concentration on the driving task). They conclude that the latter two contributors to distraction due to the use of cell phones may have parallels with distraction from roadside electronic billboards.

They also identify research methodologies used in other applications that may be applicable to studying the impacts of EBBs. For example Olsson and Burns (2000) developed a “peripheral detection task” designed to measure visual distraction and mental workload; with appropriate modifications this approach might be useful for the study of distraction and workload effects of roadside electronic billboards, along with classical driver performance measures of lane deviation and speed maintenance.

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 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.

One of the principal purposes of this project was to identify needed research and propose approaches to conduct such studies. The authors describe the goal of such research as determining whether there are conditions under which EBBs are a safety concern as demonstrated by crashes or other types of degraded driver performance. They identify *research findings*, information that is available in an area that may be relevant to studies of EBB safety, and *research questions*, goals of research still needed. They appropriately note that, because findings from some otherwise relevant prior research studies did not directly address EBBs, it may still be necessary to replicate some of the earlier work with these newer billboards. The authors identify relevant characteristics of the roadway environment, sign design and operation, and driver-related issues, and identify the research needs in each area. This section of the report ends with a brief overview of four research methods that the authors suggest might be appropriate for future research. These include: documentation analysis (accident analyses of EBB locations with controls); field studies (data collection by observers in the field); test track studies; and simulation. Because this was intended only as an overview of the four methods, they are not described in sufficient detail for the reader to understand the advantages and limitations of each method for studies of this complex real-world issue.

Beijer, 2002

Beijer undertook a comprehensive, on-road investigation with 25 participants who had their eye movements recorded while driving along a heavily traveled expressway in Toronto, Ontario, Canada. Advertising signs visible to drivers were evaluated for the number and duration of eye glances made to each. The signs varied in size, distance from road, and side of road. Signs using four different display technologies were included: conventional billboard, scroller, roller-bar, and video. There were apparently no signs studied featuring the technology of most interest to the present report, DBBs or CEVMS. Because much has been written about the likelihood of different driver response to outdoor advertisements based on temporal driving demands, Beijer operationally defined demand in a simple, effective, and naturalistic, although somewhat limited, manner. Specifically, he identified the distance between a participant's car and the vehicle immediately ahead of it in its lane. If that distance covered one skip line and space, he considered the task demand on the participant to be high; two skip lines and spaces was called medium; three skip lines and spaces was deemed low; and anything beyond three skip lines and spaces was defined as no demand. Although Beijer recorded this data for all three lanes of traffic moving in the same direction as the participant, he analyzed only the same-lane data. As stated above, while this operational definition is somewhat crude and doesn't account, for example, for the demands imposed by traffic immediately behind and/or adjacent to the participant's car, or for demands created by changing traffic speeds or roadway geometry, it has the advantage of being easily measured and naturalistic.

As background for his study, the author reviewed earlier eye-movement research that addressed visual demand on drivers. He cites work by Rockwell (1988) and Wikman et al. (1998) each of whom suggested that, when drivers have spare visual capacity, one second was about the maximum for safe non-driving related glances. Separately, he cites work by Zwahlen (1988) and the same paper by Rockwell that suggest that two seconds is a practical maximum, because glances longer than this are associated with lane-keeping errors. Since the presence of other vehicles in the traffic stream increases demand, Beijer suggests that, in heavy traffic, "glances at (advertising) signs may be inappropriate (p.3), and the measurement of such glances was one of the key objectives of this project.

One concern with Beijer's adoption of the "two-second rule" (p. 14) is his reliance on the Rockwell study that suggested that drivers' visual glances are affected by four factors, one of which is the sampling of in-car electronic devices. Beijer's assumption that glances at roadside advertising is similar, and therefore should produce quite comparable results to, the in-car displays studied by Rockwell, is overly simplistic, given that the eye and head movements required may be quite different, that in-vehicle displays can be viewed at any time, whereas a compelling roadside advertising sign can be viewed only while the sign is being approached, and given the understanding, as expressed by Chan et al. (2008) that drivers looking down at in-vehicle displays know that they cannot see the road ahead and thus may be motivated to return their gaze to the forward roadway view as quickly as possible, whereas drivers looking at roadside advertising signs, particularly signs close to their line of sight, are likely to still have the forward roadway view in their peripheral vision, and thus may feel less need to return their gaze quickly to the foveal view.

Again citing Rockwell (1988) Beijer distinguishes between two measures of eye gaze. The mean number of glances (MNG) is sensitive to demand, and increases with the complexity of the task, whereas the average glance duration (AGD), in Rockwell's work, was relatively insensitive to changes in demand. Rockwell reported that, as traffic conditions become more demanding, drivers increase the MNG while shortening the AGD, although the total off-road viewing time remains nearly the same. This suggests that drivers are able to modulate their glances as task demands build, so as to better "time-share" these off-road glances with attention to the forward visual field as necessary. Conversely, one might expect that drivers who engage in long AGD behavior even when confronted with high task demands are less willing or able to devote the appropriate visual resources to the driving task.

Beijer tested two basic hypotheses:

> 1. The most distracting signs will be those that are larger, active rather than passive, closer to central vision, and on the right side of the roadway.
>
> 2. Signs located in an area with a low density of other signs, and with less demanding traffic, would receive more attention. (He states: "Signs that receive attention despite a heavy traffic density or a demanding route are referred to as receiving 'inappropriate attention' [p. 28]).

The 25 participants in this study drove a 6 km section of the Gardiner Expressway, and passed a total of 61 commercial signs. These included 24 small and 18 large billboards (sizes were not specified), 5 video, 12 scrolling text, and 2 roller bar signs. The signs were equally divided (30 left and 31 right) on both sides of the highway.

Based upon the related work of Smiley and her colleagues (Smiley, Smahel & Eizenman, 2004; Beijer, Smiley & Eizenman, 2004) Beijer defined "long glances" as any glances of duration greater than 0.75 second. Overall, he found that 22 (88%) of his participants made long glances at one or more signs; and five (20%) made glances of longer than two seconds to one or more of the advertising signs. The longest recorded glance was 2.07 seconds. As expected, the "active" signs commanded more, and longer glances per sign than did the "passive" signs (large and small conventional billboards). Scrolling text signs amounted to 20% of the total, but commanded 42% of all glances, and 40% of all long glances. Roller-bar signs represented only 3% of the total, but captured 6% of all glances and 6% of long glances. Video signs represented 8% of the total, and captured 19% of all glances, and 31% of long glances. Small and large (static) billboards combined represented 69% of the total, but captured only 32% of all glances and 23% of long glances. In essence, these findings demonstrate that static signs captured a percentage of glances and of long glances amounting to about half of their representation on the road, whereas all three types of active signs attracted a percentage of glances and of long glances approximately equal to at least twice their representation on the road.

In terms of statistical significance, the roller-bar and video signs received significantly more long glances per sign than did the billboard or scrolling text signs. Beijer expresses some surprise that the roller-bar signs would capture as many glances (and long glances) as the video signs because, "unless a subject actually catches the Roller Bar sign during a change, it could very well be mistaken for a Billboard" (p. 71). He suggests, however, that "anecdotal evidence points to some people (saying) they anticipate and watch (the Roller-Bar sign) for the change to a new message/advertisement" (p. 71).

When task demands increased, the author found that the number of glances made per sign decreased significantly; average and maximum glance durations appeared to decrease, but not significantly.

Beijer finds that his results differ from earlier studies, particularly those of Andreassen (1984) and Hughes and Cole (1986), and attributes this to the differences in sign technology. He states: "Certain signs are much more distracting than those studied in previous experiments" (p. 68).

One of Beijer's main hypotheses – that signs on the right side of the road would receive more glances than those on the left – was not confirmed. In fact, the two signs (of 61 in the study) that were the most frequently viewed were both on the left side of the road. The author believes that this may have been attributable to sign placement – both of these signs were positioned close to the drivers' line of sight. Conversely, the signs on the right side of the road, particularly the active signs, were not typically placed as close to the road as those on the left, and were farther from the drivers' central line of sight. This finding of more views for signs on the left is not only counter to what the author expected at the start of the study, it is contrary to data found in previous studies (e.g. Mourant and Rockwell, 1970), that found that drivers tend to concentrate their glances on the right portion of the road. Beijer suggests that this somewhat surprising finding may be because modern day drivers are more used to looking at official signs that are mounted overhead above the travel lanes vs. older signs that were typically mounted on the right. Of course, it is also possible that the signs on the left were simply more distracting, and more capable of attracting the drivers' attention than those on the right.

A finding of safety concern is that, although higher levels of task demand were associated with a reduction in the *number* of glances made to the signs, the average and maximum *duration* of these glances was not reduced as task demands increased. As the author states: "This would seem to indicate that drivers are comfortable turning their attention away from the road for a set period of time, regardless of the demands of the driving task (i.e. traffic conditions)" (p. 76).

Of the 926 total glances made by the 25 participants in this study, 198 of them (21.4%) were 0.75 seconds or longer, and 10 were longer than two seconds. Since these very long glances were made by five different participants, and the long glances were made by 22 out of 25 of the participants, the author concludes: "… distraction (from advertising signs) is not just an isolated incidence by one or two participants" (p. 77).

When only long glances were considered, the differences between sign types became highly significant. The video signs received more than five times as many long glances as the large static billboards. In fact, one of the five video signs received the majority of the long glances. This sign was positioned close to the drivers' field of view, where it could be seen for a considerable distance, and where there was very little visual clutter, enabling the sign to dominate the visual space. The author concludes that sign placement within an approaching driver's field of view may be more important than the sign's lateral distance from the road edge. Signs in the center of the field of view tend to receive more glances, regardless of distance, than those farther in the periphery. Beijer notes that current policies regarding the distance of commercial signage from the road does not distinguish between straight sections and curves and does not account for the sign's location within the line of sight. He suggests using line of sight, or angle from the center of the lane.

Young and Regan, 2003

Although this paper is concerned only with in-vehicle distraction, it is addressed briefly here because of its clear explanation of driver distraction and inattention, and its potential consequences. The authors cite Stutts et al. (2001) who define distraction as occurring "when a driver is delayed in the recognition of information needed to safely accomplish the driving task because some event, activity, object or person within or outside the vehicle compelled or tended to induce the driver's shifting attention away from the driving task." It is the required presence of this triggering event or activity that distinguishes distraction from the broader category of driver inattention. There are generally four types of driver distraction that are considered: visual, auditory, biomechanical, and cognitive. When considering the potential distraction due to roadside billboards, we are talking about visual distraction. The authors summarize their short paper by recognizing that converging evidence suggests that driver distraction contributes to crashes, and that the prevalence of distraction as a risk factor is likely to increase as new technologies are brought to market. Although they are addressing in-vehicle distractions, their statements can apply to external distraction, including DBBs, as well.

Wallace, B., 2003a, b

Wallace describes this paper as a literature review and meta-analysis, based on research that he carried out for the Scottish Executive's Central Research Unit. The goal of this study was to answer the question: Is there a serious risk to safe driving caused by features in the external environment (focusing on billboards) and, if so, what can be done about it?

The author states that this subject has been under-researched, but that there is evidence that, in certain cases, "over complex visual fields can distract drivers" and that it is unlikely that current guidelines or regulations are adequate to deal with this concern.

Wallace cites a number of the early U.S. accident analyses, most performed in the 1950s and 1960s, which generally showed that higher road complexity, especially that related to intersections, curves, and roadside development, was associated (correlated) with higher accident rates. He interprets and groups the conclusions of several of these studies to suggest that the presence of billboards adjacent to such roads, especially when the billboards were located at or near curves or intersections, contributed to these higher accident rates.

After reviewing seven on-road and statistical studies and two laboratory studies, the author concludes that, despite certain weaknesses in each study, they "start to tell a story," which is, as Wallace puts it, that when drivers are looking for something (i.e. a traffic sign or signal) their reaction times will be slowed by the presence of distracting advertisements." This conclusion is supported by the more recent work of Crundall and his colleagues (2006), discussed later in the present report.

After summarizing his conclusions from these studies and experiments, Wallace turns to theories that might help explain these findings. His interpretation is that theories of attention and perception suggest that drivers may be susceptible to distraction from their driving task at any time, but that this is most likely to occur when such drivers are searching for something, and especially when they do not know what they are searching for and when there is a great deal of clutter in their visual field. He interprets the Holahan (1978) and Johnston and Cole (1976) laboratory studies as demonstrating this effect, and the field studies as further supporting these predictions by finding higher correlations between billboards and accidents at intersections. Further, he cites the Ady (1967) study for actually demonstrating that an advertising sign with bright lights, positioned at a curve in the road, was shown to have caused accidents. He believes that this finding supports Berlyne's theories of the orientation reaction, where the human brain functions in a manner to modulate arousal levels. In the case of the one billboard (out of three) found by Ady to have caused accidents, Wallace describes the situation as being a stretch of road where drivers were operating in conditions of low arousal, where they might have succumbed to "highway hypnosis." The sign, according to Wallace's interpretation, might have caused these drivers to experience phototaxis (also called the "fascination phenomenon") in which the large, bright billboard captured their attention to such an extent after a long, monotonous stretch of road, that drivers became "absorbed" in the sign, and simply failed to notice or respond to the curve in the road where the sign was located.

Wallace's review of early accident studies is open to challenge for several reasons. He finds fault with the fact that these studies demonstrated only correlations between advertising and accidents, rather than proving a cause-and-effect relationship. While it is true that correlation cannot prove causation, it is wrong to think of this as a weakness in the research. The flaw, if any, is in the misinterpretation or misuse of this data. Further, Wallace seems to attribute certain methodological weaknesses in some of these studies (e.g. not controlling for traffic flow or roadside development) to the fact that these studies were correlational by design. In truth, because a study undertakes a correlational rather than causation analysis is independent of whether its methodology is flawed. The types of statistical oversights that Wallace attributes to these studies are real, but they are not a result of the researchers' choice to undertake correlational analyses only.

It is of further concern that Wallace's review of these earlier studies, and his critique of previous reviews of them, seems intent on demonstrating his main point, which is that outdoor advertising signs at intersections are a problem that warrants attention. If a study, or a critique of a study, did not support this argument, then Wallace tends to be dismissive of it. This is not to say that his point is wrong; it is simply to suggest that his reviews seem colored by an effort to reinforce his conclusion, and his critiques are selective as a result.

Wallace dismisses correlational studies, apparently because he believes that only studies that can prove causation have merit. By extension, he dismisses on-road studies because it is difficult, if not impossible, to undertake such a study with the degree of experimental control that might support findings of causation. In this same vein, he praises "experiments" (i.e. controlled laboratory studies) for their ability to demonstrate causation. He does, however, recognize that, with their abstraction from reality, it may be difficult to generalize findings from such experiments to the real world. As Wallace states it, such experiments lack ecological validity, i.e. the degree to which they reflect real world driver behavior.

Despite these criticisms, Wallace does a reasonable job of bringing together the predictions that come from theory, and the findings of laboratory studies and accident analyses to support his major thesis; that roadside billboards can be a major threat to road safety under certain, situationally specific, conditions.

In summary, his major conclusions are:

a. The adverse effect of billboards is real, but situation specific.

b. Too much visual clutter at or near intersections can interfere with drivers' visual search and lead to accidents.

c. It is "probable" that isolated, illuminated billboards in an otherwise boring section of highway can create distraction through phototaxis.

The principal points made by Wallace, both in his summaries of past research and in his interpretation of psychological theories of attention and distraction, are that outdoor advertising signs are likely to create dangerous levels of distraction for drivers when they are placed at complex or challenging road locations such as intersections or curves, or when they exist in the midst of otherwise understimulating sections of roadway.

While there has been little research into the possible role of phototaxis on driver performance, there is broad agreement by researchers that billboards, in general, can create inappropriate levels of distraction when placed in areas of high driver task demands. Wallace identifies two such areas – intersections and curves. Other conditions and circumstances, such as merges, lane drops, and decision points, have been cited by others.

Although this study was silent on billboard technologies, the text suggests that Wallace was principally concerned with traditional fixed billboards (with the exception of his citations of prior research). And, while digital billboards are not explicitly discussed, it is reasonable to assume that the situation specific conditions addressed in this study would apply equally, if not more strongly, to these newer technologies.

CTC & Associates, 2003

Prepared at the request of the Wisconsin Department of Transportation (WisDOT), Transportation Synthesis Reports (TSRs) serve as brief summaries of currently available information on topics of interest to the WisDOT technical staff. The reports are compiled from sources such as NCHRP, TRB, AASHTO, other state DOTs, and related academic and industry research. The impetus for this particular report was a concern raised about the predicted safety impacts of outdoor electronic advertising signs, called electronic billboards (EBBs) in this report, as well as tri-vision signs.

The report summarizes a highly selective set of studies in several areas. These are identified as: Overview, State and Local Studies, Driver Distraction, and Avenues for Research. In addition, a brief summary is provided of pertinent Wisconsin regulations that address two types of electronic outdoor advertising, "multiple message signs" (tri-vision) and "variable message signs" (electronic billboards or EBBs).

In the Overview section, the report references the Federal Highway Administration's (FHWA) Office of Real Estate Services (ORES) website for a detailed history of the federal outdoor advertising control program, and the ORES 1996 and 1998 policy statements on changeable message signs.

Summaries are also provided of the FHWA 2001 report titled "Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction" (Farbry et al., 2001). Among the key findings of this report were that: (a) determining the effect of roadside billboards on safety is difficult due to both theoretical and methodological reasons; (b) there does not seem to be an effective method appropriate for evaluating the safety effects of EBBs on driver attention or distraction; (c) the legibility requirements used for official changeable message signs may be relevant to the design of EBBs; (d) there is potential in the use of methods to assess distraction from in-vehicle information systems for EBBs; (e) although the 42 states surveyed have generally consistent regulations for traditional (static) billboards, there are no common guidelines governing EBBs and tri-vision signs across states; and (f) few states even define the term "electronic billboard."

Based on the FHWA survey of states, the report identifies issues that may pertain to EBBs. These include: red, flashing, intermittent or moving lights; glare; use of traffic control device symbols or words; illumination or sign placement that might interfere with a traffic control device; spacing and timing.

The report summarizes a study performed for the South African National Roads Agency Limited (SANRAL) (Coetzee, Undated) that looked at the content of outdoor advertising "based on driver characteristics," and it discusses a number of the articles previously reviewed in the FHWA report of 1980. In addition, the report discusses a 1999 survey conducted by the National Alliance of Highway Beautification Agencies (NAHBA), which reviewed state regulations regarding tri-vision signs, and which included a discussion of the Minimum Exposure Dwell Time and the Maximum Transition Twirl Time boundaries contained within the policies of several of these states.

In the section on Driver Distraction, the authors quote from the 2001 FHWA study and the website of the Outdoor Advertising Association of America (OAAA), both of which describe the intention of outdoor advertising to catch the eye and draw attention. The quotations from OAAA go further, and describe newer technologies that permit such signs to "talk to you," and include other interactive features.

The report then reviews several studies of driver distraction, some of which employed accident analyses from Federal databases and others which employed actual on-road research using a variety of methods to measure distraction. The American Association of Automotive Medicine (AAAM, 2001) analyzed crash data from the national Crashworthiness Data System (CDS) from 1995-99, and determined that 12.9 percent of drivers were distracted at the time of their crash, and that 29.4 percent of those drivers cited "persons, objects or events outside the vehicle" as the source. Other studies are cited, with differing results reported.

Other studies were reviewed that analyzed driver eye and head movements, and showed that greater visual complexity associated with a high volume intersection required drivers to search the environment more than at lower volume intersections. The authors, citing the 2001 FHWA study, state: "it can be conjectured that additional visual stimuli such as billboards, may add additional demand to driver workload in high-volume intersections" (p.6)."

Although still in the section on Driver Distraction, the authors next discuss several studies that dealt with information processing demands for reading dynamic message signs with unfamiliar messages. Human factors research carried out by FHWA is cited that found that the 85th percentile driver on a low-volume highway could read signs with word messages at the rate of one major word per second. Interpretations are made (it is unclear whether these belong to CTC or to the original study authors) to suggest how many words or symbols could be read by drivers approaching signs under different conditions (e.g. day vs. night; 100 vs. 80 km/h speed; perfect vs. degraded vision; 14 vs. 6 inch letter height). The authors list other factors, including driver workload, message familiarity, and message format, that can affect the time needed to read a sign message, and conclude this discussion by citing another study, which states: "it is important that the message must be legible at a distance that allows sufficient exposure time for drivers to attend to the complex driving situation and glance at the sign a sufficient number of times to read and comprehend the message" (p.6).

Brief mention is made of a number of states that have attempted to identify a relationship between EBBs and safety using traffic conditions "as a surrogate measure" (although it is not clear what this means in the context of this report). States variously reported no evidence of increased traffic problems, or an inability to identify a relationship between crashes and EBBs. However, no information is provided as to how this information was obtained, or whether any actual research or analysis was conducted to address these questions. Again, it is not clear whether these statements are those of the authors of this report or the cited study.

Finally, in a section titled "Avenues for Research," the authors return to the 2001 FHWA study, which suggests several needed studies. A study conducted in 2000, using a methodology called a peripheral detection task to measure visual distraction and mental workload is cited as a promising approach. The authors suggest that this approach might be useful in addressing distraction due to in-vehicle systems and, if so, "it may also be applicable to stimuli external to the vehicle such as EBB and tri-vision signs" (p.7). The authors note that research is needed about the effects of EBBs in highway work zones. Since work zones are known to be high accident locations due to many factors, it is reasonable to assume that these are very high driving demand environments where safety challenges could be exacerbated by additional sources of visual distraction. But the report merges a discussion of work zone demands with those of other complex highway environments including horizontal and vertical curves, and interchanges and intersections. Thus, the focus of the suggested research is unclear. "Changeable message signs" (CMSs) are discussed next, and although not stated, it seems clear from the context that these are official highway signs rather than billboards. A number of research studies are cited that address the legibility requirements of such signs, including issues such as character font, number of characters per line of text, number of lines, luminous contrast, positive contrast orientation, etc.

Because this paper does not represent original research, there is no criticism of the methods used or the assumptions made. It is unfortunate that the authors seem to use multiple terms when referring to the same technology – terms including electronic billboards (EBBs), variable message signs (VMS), dynamic message signs (DMS), and CMS (which, although not defined, presumably refers to changeable message signs). Another source of some confusion for the reader is that it is often not possible to know whether statements made in the report are those of the authors of the studies under review, or those of the reviewers who prepared this report.

Lansdown, 2004

Following a similar thread to the earlier work by Cole and Hughes (1984), Lansdown suggests that the significance of information presented by roadway signage should be explicitly linked to a hierarchy of priorities. Safety information should have the highest priority for signage, followed closely by regulatory information and then travel efficiency. Sign design should meet the conspicuity needs of the driver, as, by example, safety and warning signs possessing high attentional conspicuity (i.e. they are conspicuous to all drivers whether or not they are expected, and whether or not the driver is looking for them), whereas signs conveying navigational information need only meet the lower standard of search conspicuity, in that they contain information that is only relevant to the subset of drivers that is looking for it. Lansdown suggests that irrelevant information such as advertising signs should be treated as low-priority information and “constrained in its attention-demanding capacity” (p. 76).

Finnish Road Administration, 2004

This two-part study was conducted on behalf of the Finnish Road Administration (VTT) to provide background material for policies about roadside advertisements. The goal of the project was to conduct a general assessment of prior studies on the effects of roadside advertisements on safety, and to determine whether advertisements are the cause of fatal accidents.

The first part of the study was performed by Docent Juha Luoma of VTT Building and Transport, and consisted of a critical summary of existing research, an assessment of the need for policies, and a discussion of the problems related to studying the safety effects of roadside advertisements. The second part of the project was an extract of a previous project performed for VTT by the Helsinki University of Technology. This earlier work reviewed the accident investigation committee reports of fatal accidents that occurred in 2000-01, the objective of which was to determine if there was evidence that advertisements were partial causes of the investigated accidents.

The effects of roadside advertisements (billboards) have been previously studied in Finland in the 1970s by Lehtimaki and in the 1980s by Luoma. In a 1984 article, Luoma summarized the findings as follows:

- In general, the number of accidents near roadside advertisements has not been observed to be higher than at reference sites (those without advertisements).

- The negative effects of advertisements are visible in accident statistics if they are focused on intersections.

- The effects of advertisements are apparent in driver behavior, but the effects measured under normal traffic conditions are small.

- Advertisements distract the detection of traffic signs and possibly also other objects relevant to the driver's task.

The last conclusion above was based on similar results obtained from both real world observation (under normal traffic conditions) and a simulation study (under high workload conditions). The authors surmise that "small effects visible in a normal situation may in exceptional situations become significant from the standpoint of safety (p.11), but Luoma predicted that the similar outcomes from these two studies would not be accepted as sufficiently conclusive that it would lead to clear-cut measures of control.

In a later study, Luoma (1988) studied drivers' eye movements and responses to a survey in the vicinity of different kinds of observed objects. The results indicated that "drivers looked at roadside advertisements for a long time compared to traffic signs" (p.10). These results suggested that the information presented in the advertisements could not be perceived quickly or easily.

The authors reviewed a small number of other studies, and summarized them as follows:

- The Federal Highway Administration study of 2001 (FHWA, 2001) "did not include clear conclusions on the effects of roadside advertisements on road safety" (p. 11).

- A study by Boersema et al. (1989) found that, at a railway station, "object recognition slowed as the number of advertisements increased" (p. 11).

- A study by Lee et al. (2003) concluded that roadside advertisements do not change driver behavior. "However, their conclusion is contradictory to the results, since there were differences between the results near the advertisements and the reference sites." In addition, "the test setup apparently was unsuitable and insensitive… and the analysis of eye movements compared average focusing of vision to the right, centre and left, which hardly indicates the effects of advertisements situated on different sides of the road" (p.11).

From their review of earlier work in this field the authors suggest research strategies that might be most successful in the future. They believe that accident studies, driver interviews and questionnaires are not sufficiently sensitive to measure the possible effects of billboards on road safety. They also dismiss laboratory tests and simulator studies because they doubt that such studies will produce stronger evidence than those that have been previously undertaken. Another approach, involving experimental field research with test drivers is not recommended, in part because data collection is time-consuming and expensive. Instead, these authors believe that the most promising research methodology for studying the potential impact of roadside advertising on traffic safety is by measuring the behavior of normal traffic without interfering with the traffic in any way. (This is what we would call unobtrusive observation). They believe that the most difficult challenge will be to find appropriate measures of driver behavior.

The second phase of this project analyzed fatal accidents at intersections. We will address this only briefly. Apparently, the research team reviewed the reports of the "accident investigation committee" of fatal accidents that occurred in 2000 and 2001. (It is not known whether this committee reviewed only fatal accidents or whether the researchers chose to examine only that subset of the committee's work that reviewed only fatals). Of 405 fatal accidents identified by the committee and reviewed by this research team, six were identified in which it was concluded that advertisements were a partial cause. In those six accidents, there were nine fatalities and two injuries. In four of the six cases, it was found that the advertisement obstructed the visibility of traffic on the cross road; in one case it was concluded that an advertisement distracted the driver's attention away from the road; and in the final case it was found that both factors were present. We are unable to evaluate the efficacy of this part of the study, since we do not know how the studied accidents were selected, how the reviews were conducted, or how the conclusions were reached.

Smiley, Smahel, and Eizenman, 2004

This study was performed on downtown streets and an urban expressway in Toronto, Ontario, Canada. The researchers studied 16 drivers, all drawn from the age group (25-50 years) with the lowest accident rate. Eye movements were recorded as the participants approached and passed four sites with video advertising signs (three on local streets and one on the expressway) and, with the exception of the expressway location, the same sites in the opposite direction, where the video signs were not visible.

The authors found that 76% of all glances captured were made looking ahead at traffic, whereas drivers glanced at the video signs on 45% of the occasions when such signs were present. Glances at outdoor advertising signs, including the video signs, amounted to only 1.2% of total glances. The mean glance durations were generally between 1/5 and 3/5 seconds. The distributions of glances and glance durations were similar for the video sign and non-sign approaches. Approximately one-fourth of the glances at video signs were greater in duration than 0.75 seconds, a value which the authors consider to be of concern because this represents the minimum required perception-reaction time (PRT) to a slowing vehicle ahead. Although some glances at video signs were made with short headways to the vehicle ahead (one second or less), at large angles (up to 31º) off the line of sight, and for long durations (as long as 1.47 seconds) there was no evidence that these glances compromised the drivers' recognition of potential conflicts with pedestrians or bicyclists, and no evidence that the glances at the video signs reduced the proportion of glances at traffic signs or signals.

The authors caution that only a small number of subjects participated in the study, that these subjects were drawn from the safest age range of drivers, and that the subjects knew they were being observed and their glances recorded. In addition, the four video signs differed from each other in characteristics such as size, height above grade, proximity to the road edge, sight and legibility distance, and the complexity (or clutter) of the visual environment in which they were located. Although the signs' sizes are not presented, the figures in the report suggest that the video signs were quite small in comparison to others that are in growing use. Finally, the authors refer to an earlier study that found that a video sign in the drivers' line of sight and visible for an extended period was "very distracting" (p.83). That study (Beijer, 2002) is discussed above.

Beijer, Smiley, & Eizenman, M., 2004

This study evaluated eye glances toward four different types of roadside advertising signs through the use of eye movement recordings as subjects drove along an urban expressway in Toronto, Ontario, Canada. The road was a six lane elevated expressway in downtown Toronto with a speed limit of 80 km/h and a prevailing traffic speed of 90-95 km/h. The study was conducted between 10 AM and 2 PM, when traffic flows were described as "medium to light." Drivers were exposed to 37 outdoor advertising signs, on both sides of the road. A total of 25 drivers participated, and ranged in age from 25-50 with a minimum of five years of driving experience. Subjects were classified as familiar or unfamiliar based on their prior frequency of using this route. Three dependent measures were analyzed based upon a review of the real-time videotapes of the drives with eye glance data superimposed – average glance duration, maximum glance duration, and number of glances. Each of these measures was calculated for each of the 37 signs.

Four types of signs were present among the 37 encountered. These included: fixed billboards (N=18); Video signs (N=5), Roller Bar signs (apparently similar to Tri-vision [N=2]), and Scrolling Text signs (apparently lamp matrix signs, some inset within larger fixed billboard faces and some independent [N=12]). From these descriptions, it seems that there were no LED-driven digital signs in this study, the type of sign increasingly common in the U.S., and of principal interest in the present report.

As an indication of just how important it is to take note of individual differences, the authors reported that one subject made a total of three glances for all 37 signs, and another made 87 such glances.

The active (all but billboard) signs consistently received longer glance durations and a greater than average percentage of total and long glances, whereas the billboard signs received fewer than average such glances. And, although there were no significant differences in either average glance duration or maximum glance duration for the different sign types, the billboards received significantly fewer glances than any of the other three sign types. This suggests that drivers attended to the active signs longer, possibly in anticipation of the next message to be presented. With a fixed billboard, of course, the message will not change as a driver approaches it.

When only long-duration glances were considered (those longer than 0.75 second), the authors found that 22% of the total glances were in this category. Of these 194 cases, five (20%) lasted for longer than two seconds. The authors express concern that long glances can pose a serious hazard in close following situations. 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.”

The authors compared their findings to several past studies that found that distraction from advertising signs was no greater than other roadside distracters studied, and they conclude that these other studies did not consider active signs as a separate category. The authors suggest that their results demonstrate that active signs may result in greater distraction than past studies of the effects of commercial signing might indicate.

The number of glances per sign per subject showed the greatest sensitivity to sign characteristics. The three active sign types received significantly more glances per sign than did the fixed (billboard) signs. The authors attribute this finding to the knowledge that “human visual systems have evolved to be sensitive to movement in the periphery” (p.6). They postulate that another possible cause of this finding is that the fixed billboards, being an older and cheaper technology, may have been located in less prominent locations than the active signs. In their efforts to explain why roller bar signs captured so many glances when they are essentially fixed signs that are active only during the period of transition from one message to the next, the authors cite anecdotal data from individuals who “say they anticipate and watch for the change to a new message/advertisement” (p.7) on such signs.

The authors’ analysis of the angle of glance data indicates that proximity to the central axis of a driver’s vision, rather than actual distance from the driver’s eye, was a major factor affecting the attention given to a sign.

From the photographs accompanying the published article, it appears as if the measurement of angular displacement from the driver’s line of sight understates the true angle. Whereas one would expect zero degrees to be aligned straight ahead of the driver and within the vehicle’s lane of travel, the viewing angle designated as zero degrees appears to actually shift out of the driver’s lane to the side of the road. This would have the effect of understating the actual angular deviation from line of sight to a given sign.

The authors stated that the signs studied “were all of a similar size when viewed and measured in a video taken prior to the study.” Figure 1, however, suggests that this was not the case. Further, some signs were considerably closer to the road edge than others, suggesting that perceived size also must have differed. To the extent that size of a sign (and the consequent size of the largest images or characters that may be displayed on it) might relate to the number and duration of glances made to it, further explanation would be needed.

The authors did not identify or measure brightness, color, or contrast of the different signs, or indicate how the fidelity of the displayed images compared. While these characteristics might be considered more important at night or in inclement weather, and this study was conducted only during daylight hours, such sign characteristics nonetheless might have contributed to observed differences in glance response.

As discussed above, the authors found that longer glances were consistently made to the three types of “active” signs than to the fixed billboards. This suggests that the study participants were distracted by such signs for longer periods, possibly due to anticipation of the next message to be presented, a condition that does not exist with fixed billboards. 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.

Smiley, A., Persaud, B., Bahar, G., Mollett, C., Lyon, C., Smahel, T., & Kelman, W.L., 2005

After a previous study raised concerns about the number and duration of glances made to video advertising signs along an expressway in Toronto, Ontario, Canada, the City government requested this follow-up study. It included five components:

> 1. Drivers’ eye movements were recorded as they drove past video advertising signs at three downtown intersections and along an urban expressway. Several questions were addressed, including: Do drivers look at video advertising signs; if so how often and for how long? Do these glances come at the expense of glances at traffic related targets?
>
> 2. Traffic conflicts were analyzed at two of the intersections, comparing the approach where video signs were visible to the approach where they were not. The question addressed was: Is there an increase in conflicts (that might indicate a lower level of safety) on approaches where video signs were visible?

3. Traffic speeds and headways were measured on the urban expressway before and after the installation of the video sign and on a control section in which no video sign existed. This addressed the question of whether speed variance and short headways increased in the presence of the video sign.

4. Crash data were collected at the three intersections and one expressway location before and after the installation of the video sign to address the question of whether the presence of the video sign was correlated with changes in crash patterns.

5. The public was surveyed at the three downtown intersections to learn about public perception of video signs' effect on traffic safety.

Sixteen test subjects, aged 25-50 years, participated in Study 1. The study was conducted in the summer months, during dry, daytime conditions, between 1-4 PM. Data included recordings from 69 intersection approaches and 14 freeway approaches. The overall findings are as follows:

1. Eye Fixations. All of the video signs attracted attention; the probability of a driver's looking at such a sign upon approach to it was nearly 50%. (This compares to percentages of time looking at official traffic signs (76%), traffic signals and streets signs (7%), and pedestrians who did not threaten conflict (6%). The average glance duration was 0.5 second, similar to glance lengths for official traffic signs, although one-fifth of the video sign glances lasted longer than 0.75 second, and some lasted as long as 1.47 seconds. Since the generally recognized range of minimum perception-reacting time (PRT) of a driver to slowing traffic ahead is 0.75 to 1.5 seconds, glances of 0.75 seconds or longer were considered by the authors to be unsafe. About 38% of glances at the video billboards were made when headways were one second or less and 25% took place when the signs were more than 20º off the line-of-sight; these, too, were considered to be unsafe acts. The authors note, however, that glances at static billboards and bus shelter ads were made at even greater angles and shorter headways. No evidence was found that glances at the video signs reduced the proportion of glances at traffic control devices, although this data is not reported.

The authors discuss the one intersection video sign that was the most distracting as measured both by the percentage of subjects who looked at it and the total number of glances made to it. Surprisingly, this sign was visible for less time than the others studied, was smaller than the other intersection signs, was mounted lower (closer to the driver's line of sight), and was in a less cluttered environment, making it more conspicuous. It was also farther from the driver's line of sight than the other intersection signs. The authors describe it as having "less entertaining" content, although they do not discuss any of the characteristics of its imagery such as its brightness, resolution or contrast. One possible explanation for this seeming inconsistency can best be explained by a comparison of the distracting effects of in-vehicle devices (e.g. entertainment systems) to external-to-vehicle sources (such as the DBBs of interest in this paper). As discussed elsewhere in the present report, one key difference between these two types of distracters is that, to a large extent, a driver may choose when to divert his attention from the roadside to engage with in-vehicle devices, but can attend to the external distracters only when these are visible to him. In other words, if the momentary task demands on a driver are high, that driver may postpone (or cease, if already begun) his interaction with the non-essential in-vehicle technology. But a billboard, electronic or not, is in a fixed position and, like a call to a driver's mobile phone, the distraction occurs independent of the momentary degree of demand on the driver as the sign is approached. If that billboard is highly attention getting or highly salient to a driver, that driver does not have the luxury of postponing his gaze at the sign; the window of opportunity to view the sign is, in essence, "now or never." And, as reported by Smiley and her colleagues (2004), some drivers will divert their attention from the road for long periods of time *despite* the task demands that they may be facing. Applying this analogy to the unexpected results found for this particular video sign, it is possible that drivers paid more attention to this sign precisely because it was visible to them for less time than the other video signs studied, and therefore provided approaching drivers with a shorter window of opportunity to attend to it once it had captured their attention.

2. Conflicts. The authors looked at the video approaches to two of the intersections to evaluate whether traffic conflicts increased. Conflicts may be seen as indicators of potential crashes, and are increasingly used by traffic safety researchers as surrogates for actual crashes. Conflicts typically examine the kinds of behaviors that are thought to contribute to crashes. In this study, the authors looked at: braking without cause, unwarranted lane deviations, and delayed start-up on green. For five of the six sets of observations (three types of conflicts x two different intersections), no significant differences were found between the video and non-video approaches. However, at one of the intersections, the authors reported a statistically significant increase of drivers who applied their brakes without cause on the video approach. Since the authors chose intersections that had comparable speeds, geometries, and pedestrian activity for the two approaches, they state: "the only reason that could be found for increased braking … was the presence of the video sign" (p. 108).

3. Headway and Speed. Headways and speeds were assessed for the single video sign located on the freeway. Data for these measures was captured from in-road traffic detectors in both northbound (sign visible) and southbound (sign not visible) directions. The results were inconsistent and inconclusive.

4. Crashes. For the three urban intersections, total crashes, injury crashes, and rear-end crashes were studied. Crashes were studied before and after the video signs were erected, and in both the sign visible and sign not visible directions. In the aggregate, there was a non-significant increase in injury crashes and rear-end crashes in the video approaches, as well as a negligible increase in total crashes. When the three intersections were evaluated individually, two demonstrated increases in both total and rear-end crashes; the third showed a non-significant decrease in such crashes. The authors state that the lack of statistical significance may be due to the small numbers of crashes identified. For the freeway environment, crash data on the video approach were compared to crash data for

three different non-video approaches, one of which was deemed the most comparable segment. On this comparison, the authors report a negligible increase in injury collision crash frequencies on the video approach.

5. Public surveys. A total of 152 persons were surveyed at the three studied intersections. 65% of the respondents felt that video advertising signs had a negative effect; 59% said that, as a driver, their attention is drawn to such signs, and 49% of those felt that such signs had a negative effect on traffic safety. The authors were surprised to learn that a large number (9 out of the 152 respondents) stated that they personally had experienced near-crashes, and two had experienced actual rear-end crashes that they associated with video advertising signs. 86% of the respondents suggested that restrictions should be placed on such signs; especially location restrictions (not on highways and not at intersections) and restrictions on brightness levels at night.

In discussing their results, the authors point to an earlier study (Beijer, 2002), discussed earlier in this section, that evaluated a video advertising sign along a different highway in Toronto, and produced dramatically different results. The earlier study found five times the number of glances per subject than did the present study, and three times the glance duration. The authors attribute these differences to the longer sight distance available for the sign previously studied, the uninterrupted view, and the location of this sign on a curve so that it appeared close to the center of an approaching driver's line of sight.

From the single figure included with the report, it appears that the video signs at the three urban intersections were rather small and inconspicuous (sign sizes and dimensional relationships to the roadway are not given). Even given the constraints of image reproduction in the published paper, the exemplar video sign shown was difficult to identify without a circle drawn around it by the authors. In fact, several much larger and more prominent advertising signs were visible in the photograph – signs that were not included in the study. It is not known whether the subject video sign shown in the photograph, and the complex urban environment in which it appears, was representative of all three intersections studied, but at this intersection, at least, it is possible that the presence of larger and more distracting signs might have competed with the studied video sign for an approaching driver's attention.

The single freeway sign studied is described as the only commercial sign visible to northbound traffic. It is further stated that the driver's view of this sign is intermittently obstructed by buildings and overpasses, and that the best visibility occurs during a 5-7 second period before the driver passes the sign. Although data is provided to indicate visibility and legibility distances to each sign, no indication or operational definition is provided as to how these distances were determined. (Given the continuously changing nature of images on a video display, legibility distance would likely vary with changes in the displayed font and letter sizes). In addition, the visibility and legibility distances for the freeway sign excluded times when the sign was obscured from view upon approach, thus suggesting that these distances were discontinuous. It is not known how this discontinuity might have impacted drivers' efforts to view and read the sign as they approached and passed it.

The authors selected their three urban intersections to be similar in speeds, pedestrian activities, and geometry for the video and non-video approach to each. However, this study was conducted in an urban area, and if Figure 1 is representative of the types of intersections studied, there were likely many more potential differences in the built environment that might have contributed to different driver behavior (at the detailed performance levels measured) independent of whether such drivers could or could not see video signs as they approached the studied intersections. This serves as an indication that caution is required when collecting performance data in the real world, because it is rarely possible to recognize, no less control, all possible variables that could have a meaningful effect on performance.

The choice of traffic conflict measures to study is always somewhat subjective. Of the three measures used by these authors, one might question whether other behaviors might have proven more sensitive, or whether the measures chosen might have been confounded by factors unrelated to the video signs under study but more related to characteristics of the urban environment.

Regarding crashes, although statistical significance was achieved in only one measure (rear-end crashes at two of the three intersections in the video approach), seven out of the nine measures taken demonstrated higher numbers of crashes for the video than for the non-video approaches. While these data may point to the contribution of such crashes by the presence of video signs (the lack of significance was attributed by the authors to small data sample sizes), they also point to the difficulty of using crash statistics to study causation. There are many reasons for this. For example, the authors provide no information about how the crash data were reported, obtained, or analyzed. They indicate that they reevaluated one of the intersections because they believed that, due to the placement of the video sign on this one approach, drivers might have seen it earlier than in other cases, and the authors felt that they needed to adjust the location at which they began to collect crash data. While this did not change the results, it suggests just how many subtle and non-controllable factors may influence crash data analysis. Similarly, for the freeway crash analysis, the authors found it difficult to identify comparable sections for the video and non-video approaches. Differences in roadway geometries, driver task demands, and other factors all contribute to the difficulty in interpretation of their findings.

Although the authors provide little information about the actual questions asked, the results of their public survey suggest that drivers and pedestrians are concerned about the safety impacts of video advertising signs, particularly at intersections and on highways, and about excessive brightness at night. Although such findings are clearly subjective, a more complete description of the questions and responses would have assisted the reader in gaining more insight into the respondents' opinions.

The authors, during a brief discussion of the results of an earlier study conducted with a different video sign on a different Toronto area highway, highlight the difficulties facing researchers' abilities to conduct definitive studies of this subject. They state: "Clearly, some video signs are more distracting than others.” While this would appear obvious, it carries with it the concern that there can be no “one size fits all” solution with regard to sign design or operation or with the regulation and control of such signs. It does remind us, however, that there are certain characteristics of sign design, operation, and placement that can be generally understood to contribute to greater distraction and inattention, and that sign operators as well as highway authorities should concentrate on these factors in their efforts to ensure the highest levels of traffic safety in the presence of roadside advertising signs.

It bears repeating that this study evaluated signs that display full-motion, real-time video, something that is prohibited on most billboards in the U.S. although, not, significantly, on on-premise signs. Whereas video advertising might be expected, *a priori*, to be more distracting than fixed message signs, the many variables involved in sign design, operation, and location, make this an empirical question.

The conduct of well controlled, objective studies in this field is notably difficult; it is nearly impossible to find any published study without methodological, analytical or statistical flaws, and devoid of the kinds of real-world variability that makes each sign location different, and contributes to the challenge of conducting definitive research. This study is notable because it includes several different research approaches, including: driver eye movements, traffic flow as measured by speed and headway data, conflicts and crashes, and public opinion. Nonetheless the authors identify several aspects of their study that, because of sample size limitations, roadway geometry incompatibilities, urban environment differences, and even sign size, placement and display properties, made comparisons difficult.

Even though non-video digital billboards were not studied or addressed, several of the findings suggest issues to consider when addressing the potential safety implications of such DBBs. Long sight distances, horizontal curves, and proximity to the road shoulder all suggest higher levels of concern for safety, as do signs at intersections and those that are bright at night. These findings are consistent with results obtained in studies dating back more than 50 years.

This study, as is true for most such investigations, took place during dry weather in daylight conditions, in which driving task demands are likely to be lower than might have been found in the same settings at night or in inclement weather. During daylight conditions, even the brightest signs do not “stand out” from their surroundings as the same signs might do at night and in poor visibility conditions. Since many of the complaints about digital billboards concern their night-time brightness levels (especially when compared to their surroundings), and since inclement weather adds to the driver’s cognitive demands, it would be worthwhile to conduct research into the safety aspects of these signs under such “worst case’ conditions, since that is what highway designers, traffic engineers, and human factors experts, must design for.

Klauer, Neale, Dingus, Ramsey, & Sudweeks, 2005

This paper, one of several to emerge from the large-scale project known as the "100-Car Naturalistic Driving Study," provides preliminary information about the role of driver inattention in crashes and near-crashes.

The authors discuss the generic limitations of most human factors and traffic safety research that rely upon epidemiological (crash) data or experimental approaches (e.g. simulation, instrumented vehicles); specifically that such studies cannot provide a direct linkage between the types and extent of distraction and a resultant crash or near-crash. Epidemiological studies are constrained by the limited extent and detail of information contained in post-hoc police accident reports which, in turn, are limited by the truthfulness or recall of an involved driver, and by constraints of police time, training, and departmental policies; whereas experimental studies are often limited by restricted sample sizes, an inability to control for extraneous variables, and a necessary reliance on surrogate measures of crash risk, such as speed and lane variation, hard braking, and steering reversals. The 100-Car Study, in contrast, equipped that number of vehicles with sophisticated and unobtrusive instrumentation packages, and placed them in the hands of volunteer drivers for months at a time. These drivers were to use the vehicles however, whenever, and wherever they wished, without constraints and without the presence of an investigator or observer in the vehicle at any time. Data captured by the vehicle's hidden instruments was uploaded periodically to remote computers when the vehicle was parked. With these controls in place, the 100-Car Study met the researchers' operational definition of naturalistic: "Unobtrusive observation. Observation of behavior taking place in its natural setting" (Klauer, et. al., 2006a, p.xv). Of course, this naturalistic method has disadvantages of its own; primary among them is the inability of the researcher to control potentially important variables that may influence the behavior of the participants. As one example, it is unlikely that all participants will pass the same billboard under similar road, traffic, and weather conditions, or that such drivers will be in a similar state of health or alertness at the time.

The results of this phase of the larger study showed that 78% of all crashes and 65% of all near crashes listed driver inattention/distraction as a contributing factor, a much larger contributor, by a factor of three, than previous research had suggested. (Crash database research, for example, suggests that distraction is a factor in approximately 26% of crashes). The authors conclude that the 100-Car Study provides the first *direct* link (i.e. without reliance on surrogate measures) between distraction/inattention and crash causation. Because of the enormous volume of data from the study, it will be left to future analysis to determine the types of inattention most highly associated with crash risk, as well as specific characteristics of inattention events such as long glance durations, following too closely, environmental factors, etc.

Klauer, S.G., Dingus, T.A., Neale, V.L., Sudweeks, J.D. & Ramsey, D.J., 2006a.

This is one report of several that have been presented and/or published from the "100 car naturalistic driving study." This seminal study, and the data that it has generated, has become a landmark in the assessment of road safety and driver behavior, made possible by advanced, miniaturized data recording technologies that have only recently become widely available. (As this is written, preparation is underway for a greatly expanded follow-up study using this methodology). The authors describe a *naturalistic* study generally as one of unobtrusive observation of drivers in vehicles, in which their behavior is observed (by video cameras) and recorded (by multiple instruments) as they drive normally over an extended period of time. Although the cameras and recording devices were discretely mounted within each of the 100 vehicles driven, these studies are not completely "unobtrusive" in the classical definition of behavioral studies, because the volunteer drivers were aware of their existence. Nonetheless, the study participants used these vehicles daily for their normal routines, over a period of 18 months, and clearly paid little attention to the presence of the onboard recording equipment over time.

This particular project report focused exclusively on driver inattention and its contribution to incidents including crashes, near-crashes and conflicts. Data from crashes and near-crashes were grouped together because it was found that the "kinematic signatures" of each were similar, and using both served to increase the statistical power of the analysis. The data used for analysis was taken directly from the measurement of driver inattention in the five second period immediately prior to a crash or near-crash. For purposes of this study, the authors defined driver inattention as one of four different behaviors: (a) driver involvement in secondary tasks (i.e. tasks irrelevant to the primary driving task); (b) drowsiness; (c) driving-related inattention to the forward roadway; and (d) non-specific eye glance away from the forward roadway. We have some concerns with the authors' operational definition of inattention, for several reasons. First, their definition differs somewhat from definitions of inattention used in other studies. For example, there is no behavior identified here that might be considered "daydreaming" (difficult as that might be to identify), yet this activity is often considered to be a type of inattention. On the other hand, most definitions of *distraction* identify it as a type of inattention that is triggered by some specific event or activity – thus the involvement in secondary tasks, considered inattention here, might be considered distraction elsewhere. Finally, the behavior called "driving-related inattention to the forward roadway," is often considered to be a positive, or appropriate behavior, as discussed below. We also note that some of the same authors, in another report from the 100 car study, use the term distraction interchangeably with inattention (Klauer, et al, 2005).

Among the principal findings were that driving while drowsy increased a driver's near-crash/crash risk by four to six times over the baseline, and engaging in secondary tasks increased this risk by two times for "moderate" secondary tasks, and by three times for "complex" secondary tasks. These findings, of course, are not directly relevant to a study of distraction from roadside billboards, but are reported here because they are representative of behaviors often associated with driver distraction. The study further found that "driving-related inattention to the forward roadway" was *safer* than normal driving – but when this behavior is defined, this finding becomes more plausible. This behavior was characterized by the experimenters as including actions such as checking the rear-view mirror, side view mirrors, vehicle instruments, and other traffic through the vehicle's side windows or the sides of the windshield. As the authors state: "drivers who are checking their rear-view mirrors are generally alert and engaging in environmental scanning behavior" (p.x). Thus, it is somewhat puzzling that the authors chose to include these behaviors together with other distracters.

Little discussion is provided for the category of most interest to the question of roadside billboards as sources of distraction. Indeed, in their comprehensive listing of all sources of distraction that were categorized in the study (all identified under "secondary tasks" in Appendix A), there are five behaviors identified under the heading of "external distraction." These include specific items (presumably easily identified from the video logs) such as looking at a previous crash or highway incident, looking at a pedestrian or animal outside the vehicle, or looking at a construction zone. There is only one, non-specific, behavior included in this category that might include roadside billboards. This is described as: "driver is looking out of the vehicle at an object of interest that may or may not pose a safety hazard. Objects may or may not be in the forward roadway" (p.134). No further description is provided for this fourth category of distracters.

The findings demonstrated that drowsy driving was a contributing factor in 22-24 percent of crashes and near-crashes during the study, and that secondary-task distraction contributed to more than 22 percent of all crashes and near-crashes. In total, the study found that inattention contributes to more than 45 percent of all crashes and near-crashes that occur in an urban environment. Specific findings for individual secondary task types identified the following categories as indicating a "higher individual near-crash/crash risk when a driver engages in these activities." These specific secondary task types were: "reaching for a moving object, looking at an external object (i.e., long glance), reading, applying makeup, dialing a hand-held device, and eating" (p.34).

This report, part of a much larger study, is comprehensive and data rich. It provides a breakthrough in research methodology that overcomes many of the limitations of previous research. It is, however, time consuming and expensive to conduct, necessarily limited in the number of subjects who can participate because of the costs and commitments involved, and it presents an enormous amount of data that can provide nuanced results but can be difficult and time consuming to reduce and evaluate.

With regard to the potential for distraction from DBBs, the authors report one finding of direct relevance. They state:

> The analysis of eyeglance behavior indicates that total eyes-off-road durations of greater than 2 seconds significantly increased individual near-crash/crash risk whereas eyeglance durations less than 2 seconds did not significantly increase risk relative to normal, baseline driving. The purpose behind an eyeglance away from the roadway is important to consider. An eyeglance directed at a rear-view mirror is a safety-enhancing activity in the larger context of driving while eyeglances at objects inside the vehicle are not safety-enhancing. It is important to remember that scanning the driving environment is an activity that enhances safety as long

> as it is systematic and the drivers' eyes return to the forward view in under 2 seconds (p. xi).

If we substitute the term *digital billboards* for the term *objects inside the vehicle* in the quote immediately above, we can readily see the concern about the potential attention getting properties of DBBs. In addition, if we bring to bear Wierwille's empirically derived limit of 1.6 seconds eyes-off-road time (Wierwille, 1993), reported in Horrey and Wickens (2007), we begin to identify the upper limit of a tolerable level of distraction when looking at DBBs. Adding in the eyes-off-road value of 0.75 second proposed by Smiley and her colleagues (Smiley, Smahel, & Eizenman, 2004; Beijer, Smiley, & Eizenman, 2004) we have perhaps identified the lower and upper bounds of *acceptable* limits of driver distraction from their principal task. When we couple this range of values with a statistical approach that looks at the tails of the distribution instead of, or in addition to, the means, as suggested by Horrey and Wickens (2007), and discussed below, we may now have, subject to validation, both a criterion measure of driver distraction to DBBs and an approach to analyzing empirical data against this criterion.

SWOV Institute for Road Safety Research, 2006

The impetus for this study was a controversy in the Dutch town of Ede. In 2002, seven "life-size" advertising billboards were attached to the façade of a cinema building adjacent to a motorway in this town. The Directorate General for Public Works and Water Management determined that these billboards distracted passing drivers and thus could have an adverse effect on road safety. Thus, the agency asked the town to prohibit them. At the request of both the town and the agency, the research organization TNO investigated the distraction. Four experts concluded that seven billboards were too many, and that drivers had to look away from the road to observe them. They also opined that drivers could choose to ignore the billboards. TNO advised the town to allow a maximum of two billboards, each containing limited information. However, the town granted a permit for all seven. Because this was not an isolated example of questions posed to SWOV about the distracting effect of billboards, the organization undertook this effort to examine the issues and report the results.

The authors begin by stating that the answer to the distraction question is not straightforward, and that it is made more complex because even official roadway information signs can distract motorists from their driving task and thus negatively influence road safety – even though such signs exist to give drivers information intended to improve road safety. The authors write that both advertising and information along the road are intended to draw the attention of passing drivers, thus leading them to shift their attention away from the road and traffic. The difference between these two types of distracters, however, is that roadside information (official traffic signs and signals) "guides the drivers' attention to traffic relevant matters" whereas advertising does not. Therefore, they conclude, it is logical to expect advertising billboards to increase the crash rate.

The report reviews the work of several recent authors, including Wallace (2003), Smiley and her colleagues (2005), and Tantala & Tantala (2005). They summarize these studies by saying that the first two studies found a negative effect of advertising signs at busy intersections and at places where advertising signs might have a similar design or color to traffic control devices; the latter two studies found no *causal* relationship between the signs studied and crashes. Their review of a study by Crundall, et al. (2006) indicated that billboards at eye level captured the attention of drivers both longer and more frequently than billboards elevated three meters above the road surface, particularly for drivers who were given the task of identifying dangerous situations. The SWOV conclusion was: "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).

They further cite work in Dutch by Wildervanck (1989) who looked at the alerting effect of billboards when placed along a straight and deserted motorway in a monotonous environment, where the driving task is boring and understimulating. Here, according to Wildervanck, the distraction caused by a billboard may have the effect of increasing arousal.

The authors summarize the Dutch regulations on outdoor advertising control. In essence, the Ministry of Transport has authority to regulate billboards only within the national road network. In other cases, complete authority rests with the cognizant province or municipality. After providing examples of the codes and regulations in representative areas of the country, the report suggests future research that may be undertaken.

If crash studies are performed, they should be of large-scale and long duration since such studies are very complicated methodologically. They suggest several possible ways to carry out observational and behavioral research: One is to present two groups of subjects with photographs of the roadside, some with, and some without, billboards. These subjects would be tasked with finding something relevant to traffic. Measurements of reaction time would give an indication of the degree of distraction. A second type of study would show moving images in a driving simulator; the benefit here, the authors report, is that actual changes in driving behavior could be measured. Finally, field experiments could be conducted using instrumented vehicles.

In conclusion, the authors restate that both advertising and information billboards along the road are intended to draw the driver's attention, and this could cause diminished attention to the driving task. This diminished attention could result in more crashes near such billboards. The difference between these two types of billboards is that advertising is irrelevant to the driving task whereas information signs are not. Previous studies have suffered from methodological problems, thus preventing them from reaching reliable (valid) conclusions. It is therefore advisable to do additional research.

They suggest, based upon the strongest findings from past research, that it is better not to place billboards at busy traffic spots, and that billboards should not resemble traffic signs or other traffic indicators. Further, blinking and moving objects have proven to be difficult to ignore, and thus dynamic billboards are ill-advised. In the past, different levels of government have employed their own guidelines for the placement of billboards along the roadside; unambiguous guidelines are advisable.

This report summarizes and extrapolates from prior research, most of which has been discussed in greater detail elsewhere. As might be expected from such a summary, the report reinforces some of the stronger, more consistent points made in several studies – billboards should not be placed near challenging road settings, especially at or near intersections, and should not resemble official traffic signs in pattern or color. Further, dynamic signs which display motion or include moving parts should not be permitted.

However, while it acknowledges the weaknesses of past accident studies and recognizes the difficulties of conducting such studies in the future, the report makes some questionable suggestions about methods for performing future research. The three types of studies suggested have all been attempted in the past, some with greater success than others, but all suffering from some degree of methodological weakness that causes concern about the validity of their findings. By following the suggestions for future research contained in this report, it is possible that some of these past weaknesses will be repeated.

Because this was primarily a report to summarize and interpret the results of other research and to apply it to the Dutch experience the relevance of this study to our concern about DBBs in the United States is somewhat low. For example, there is no discussion of brightness, display technologies, or message change intervals, and so it offers little applicability to issues related to digital billboards. Nonetheless, this report reaches similar conclusions to other studies in its recommendations to avoid placing billboards near intersections or what the authors call "busy traffic spots," to avoid dynamic or moving billboards, and to prohibit billboards that may be confused with official traffic signs or signals. One principal contribution of this report is its discussion of the billboard regulatory policies in The Netherlands, which may be useful for comparison with policies in other countries and their local jurisdictions.

Road Safety Committee, 2006

In 2005, the Road Safety Committee of the Parliament of Victoria, Australia was tasked with investigating all aspects of driver distraction and producing a series of recommendations to the Parliament for dealing with this growing concern. Their comprehensive report was published in 2006. The report addressed: methods to define and measure distraction, sources of distraction, laws and enforcement issues, vehicles of the future, and long range approaches to address the problem. One chapter addressed "road signs and advertising," and that is the focus of this review. It should be noted that this was not a research project, but rather a compilation of knowledge obtained from numerous sources (research, Government reports, focus groups, specific submissions to the committee's inquiries, etc.) world-wide. The reporting of these reviewed sources was not critical or comprehensive, but was well focused on the specific topics of concern.

The report made mention of outdoor advertising in many forms – including signs on moving vehicles such as those "whose sole purpose is to carry a mobile sign or billboard" (p. 108). In their summary reviews of several studies, and from correspondence with a number of individuals, the Committee concluded:

> The above evidence illustrates a lack of clear and consistent scientifically-based conclusions with respect to the effect of billboards on driver performance. This may be due to methodological deficiencies, lack of sufficiently large or adequately recorded crash circumstances, or unsuitable experimental environments (p. 109).

In a separate subsection, the Committee addressed "video signs/electronic billboards." Although in the U.S. we have traditionally distinguished between electronic billboards (which we may refer to as CEVMS, DBBs or EBBs) and video signs, the Committee considered video signs and electronic billboards together. During its inquiry, the Committee received a presentation from ITS Australia about one particular such sign, and noted that the Committee itself was aware of at least two other large video-style screens. Their conclusion was that "these screens (are at) the high end of potential visual distraction and accordingly, present a risk to drivers" (p. 110).

The committee received a presentation from the Manager of Road User Behavior of VicRoads, who stated, in part:

> What we do know is when there is movement involved, such as flicker or movement in the visual periphery, that this is more likely to capture a driver's attention. We actually are hard-wired as human beings to movement, so particularly moving screens and information that scrolls at intersections and in highly complex driving situations – these are risky, and in particular researchers have been most concerned about those sorts of advertising materials (p. 110).

The report provided an extensive summary of two Canadian studies (Beijer, et al., 2004; Smiley, et al., 2004), and reported that, as a result of the findings of these studies, the Toronto City Council Works Committee introduced interim guidelines for commercial advertising next to expressways and placed a moratorium on new video installations. These two studies are reviewed elsewhere in the present document.

At the conclusion of this section of the report, the authors note that the use of eye-glance technology is enabling new research on the possible distracting effect of road signs and advertising devices, and suggests that "further conclusive studies should be carried out to develop definitive scientific conclusions" (p. 111). They note, however, that some policy implications are already evident, including: (a) the need for separate assessment of sign installations depending on location, (b) that VicRoads and other governmental agencies at the municipal level (should) "develop a more consistent and stringent approach to the installation, use and content of scrolling, moving and video-style advertising within and adjacent to road reserves," and (c) that any such advertising sign installations should be monitored for their effect on safety.

Finally, the report includes an extensive discussion about guidelines and practices for advertising signs. This will be discussed in our separate review of guidelines in Section 5 of this report.

Klauer, Sudweeks, Hickman, & Neale, 2006b

This variant of the 100-Car Study concentrated on specific unsafe driving behaviors. The authors provide a succinct and highly readable overview of the assumptions, equipment, methods and measures of the 100-Car Study, and then report, in detail, about the four specific unsafe behaviors that were found to contribute to crashes and near-crashes. These behaviors were: driving at inappropriate speeds, driving while drowsy, driving aggressively, and, the factor of greatest interest to the current study, inattention/distraction, as measured by the driver's eyes off the roadway for greater than two seconds. Under these conditions, the odds of a crash or near-crash were nearly twice those when the driver attended to the forward roadway.

Highlighting some of the limitations of previous research approaches (particularly post-hoc, epidemiological crash studies and in-vehicle human factors studies) the authors presented several interesting findings. For example, whereas previous studies tended to show that distraction/inattention was a factor in approximately 20% (Treat, et. al., [1979]) to 23% (Hendricks, et. al., [1999]) of crashes, the 100-Car study (Klauer, et al, [2006a]) found that inattention and secondary task engagement (grouped together for analysis) contributed to nearly 60% of crashes. There are two interrelated reasons why these differences were found. First, the 100-Car Study demonstrated that the "kinematics" of crashes and near-crashes were similar; i.e. they involved comparable levels of driver emergency actions such as swerving and hard braking. And second, of the 69 crashes recorded in the 100-Car Study, 57, or 83%, were not reported to the police. Thus, research studies that analyze crash data are likely to substantially underreport the percentage of crashes attributed to inattention/distraction, both because they are unable to obtain data on near-crashes (sometimes called near misses or traffic conflicts), and because those crashes that do occur are reported to police less than 20% of the time. This characteristic also suggests that studies that examine near-crashes as surrogates for actual crashes can be useful in studies of distraction and inattention. As the authors explain: "The primary difference between a crash and a near-crash is a successful evasive maneuver. Thus, crashes lead to property damage, injury, and possibly death, but near-crashes do not, even though they have similar properties. Including both … greatly improves the statistical precision of the estimates, and appears to be a promising technique for use in future research" (p.11).

Interestingly, despite demonstrating a level of contribution to crashes from distraction at rates only about one-third as high as the 100-Car Study, both Treat and Hendricks and their respective colleagues found that driver distraction/inattention was the most-frequently cited contributing factor to such crashes.

Restating one of the key findings of this study, (and the one most relevant to the present project), the authors explained that looking away from the forward roadway for greater than two seconds was associated with a near doubling of the odds of being in a crash or near-crash, and Klauer, et. al. [2006a]) concluded that there is increasing evidence that "tasks requiring longer and more frequent glances are detrimental to safe driving" (p.72). Citing Stutts, et al. (2003), the authors state: "Driving a vehicle is a psychomotor task, and continually monitoring the roadway and anticipating the actions of other drivers are critical for operating a motor vehicle safely. A distracted or inattentive driver is likely to have delayed recognition or no recognition of information necessary for safe driving" (pp16-17).

Crundall, Van Loon, and Underwood, 2006

This English laboratory study addressed a type of outdoor advertising that is not directly related to the DBBs that are the subject of the present study. Specifically, Crundall and his colleagues looked at fixed posters mounted either at street level ("street-level advertisements," or SLAs) such as those on bus shelters, newsstands, or telephone kiosks, and posters located above ground on poles or streetlights ("raised level advertisements," or RLAs). The size of the advertising posters studied was 1.8m x 1.2m (approximately 6ft. x 4 ft.) in a vertical format. As such, these advertising signs were more representative of signs that might be seen in urban environments in the U.S., rather than the typical 14ft. x 48ft. size digital billboards that are the subject of the present study. Nonetheless, the hypotheses made by these authors offer a different perspective than those that have generally been adopted by researchers in this field, and their conclusions shed new light on the issue of roadside advertising and driver distraction.

The authors discuss the potentially detrimental effects of roadside advertising in a manner similar to other researchers. As they describe it, in undemanding situations drivers have "spare attentional capacity" that they can use to permit their eyes to wander to objects in the visual field, including those, such as advertisements, that are irrelevant to their driving task; however when the cognitive demands imposed on the driver (such as from traffic, weather, roadway geometry, vehicle performance or personal factors such as fatigue) become greater, this spare capacity diminishes, and eye movements must focus on the task at hand. If an advertisement within the driver's visual field attracts visual fixations under these conditions, sufficient spare capacity may not be available to attend to it, and thus the advertisement draws from the limited attentional capacity that is needed to safely perform the task. Thus, although the authors initially suggest that roadside advertisements are intended to attract a driver's spare capacity, they go on to describe the interest that advertisers have in placing their signs in locations where the driving task demands may be high. They cite (as have others) the 1967 before-and-after study by Ady, who found that an "eye-catching" billboard at the apex of a curve led to more accidents than similar signs in control locations.

The authors suggest that, because it is possible to identify fixed roadside "hazards" (such as dangerous curves, complex interchanges, etc.), it is therefore possible to ensure that roadside advertisements are not located in such areas. Their greater concern, however, is with what they call transient hazards, such as changes in traffic density, path intrusion from another vehicle, or a pedestrian crossing the driver's path from between parked cars. Transient hazards cannot be predicted in time or location. Because such unforeseen events can directly influence a driver's probability of an accident, "if attention is distracted by an advertisement during the onset of a sudden (transient) hazard, the chance of an accident occurring will increase" (p.672). Knowing that roadside advertisements do attract driver's attention (as per Hughes and Cole, 1986, and others) and that drivers' glances at such advertisements may be made under unsafe conditions such as short headways (as per Smiley at al., 2004), the authors set out to determine whether SLAs or RLAs tend to attract more attention when drivers are looking for hazards.

The most relevant environmental (including traffic and roadway) information important to hazard detection is distributed primarily along a horizontal plane, with the straight-ahead view (the focus of expansion) at the center of this distribution. As a result, as the authors have demonstrated in prior research (Chapman and Underwood, 1998), the majority of visual fixations will fall within a horizontal window when the driver is looking for driving-relevant information, including potential hazards.

These earlier findings lead to their belief that, if an advertisement is located within this "horizontal window of inspection" it will receive more fixations than will other advertisements. Although such fixations on the advertisement may be immaterial to safety when the driver has spare attentional capacity, those fixations that occur during a visual search for hazards and other driving-relevant information are likely to be unintentional and may distract the driver and serve to interrupt this critical visual search activity.

The principal research hypotheses tested, therefore, were that, during high demand conditions, when drivers were primed to look for hazards, SLAs would receive the most attention, whereas during periods of reduced demands, when spare capacity was greater, the attention given to RLAs would increase.

The study was conducted in a laboratory, where participants viewed video clips that had been previously recorded from the dashboard of a moving car. Of 34 clips created, half included SLAs and half depicted RLAs. All were essentially equal in size (1.8m x 1.2m), and all were filmed during daylight. The clips ranged from 42 to 61 seconds in duration, and the time when an advertisement first appeared within each clip was randomized. The clips were projected onto a screen 2m in front of the participant and subtended a visual angle of 33º x 27º horizontal. Participants' eye movements were recorded and superimposed on the video for analysis. Two different test conditions were established via the instructions given to the participants. In the "hazard group" the participants were instructed to concentrate on the hazardous nature of each video clip. In the "advertisement group" participants had less emphasis placed on the hazard perception task and, in addition, were told to watch out for advertisements that they might pass. The intent of the instructional set was to create differences in the task demands during visual search – high demand when scanning for hazards; lower demand when still looking for hazards but also attending to irrelevant stimuli.

Results showed significant differences between the two groups in several areas. SLAs were fixated earlier, received more fixations, and received a greater total gaze duration compared to RLAs. In addition, the mean length of advertisement fixations was greater than the mean length of fixations for the entire clip, with one exception. Fixations on the RLAs were lower than the clip averages for the hazard group, suggesting that, as had been found previously, the scanning for hazards takes place essentially within the horizontal plane in front of the driver. A post-drive hazard rating showed that clips with SLAs were judged more hazardous than clips with RLAs.

Our review raised a number of questions about the methods and protocols used in this study, and about their possible effects on the findings. For example, the authors do not provide the text of the actual instructions given to the participants; as a result it is unclear just what the task was for those in the “advertisement” group. There is no description of any of the visual information (except the advertisements) within any of the clips shown, and thus one does not know the implications of the finding that the SLAs were fixated to a greater degree than the clip average, a potentially important observation. Further, with clip durations of one minute or less, the presence of advertisements within the scene may have become expected during the course of the trials, despite their randomized placement within each clip. Finally, as discussed elsewhere in the present report, it might have been useful to have comparisons between values in the tails of the distribution (e.g. the longest glances) in addition to the means.

Despite our uncertainty about some of the details of this study, one relevant finding in particular is a cause for concern regarding the potential effect of roadside advertising on traffic safety. The authors describe, based on their prior research (Chapman and Underwood, 1998, Crundall et al, 1999) hazard perception searches in visually cluttered environments as displaying higher sampling rates and shorter fixation durations than in less complex environments, until a hazard is detected, at which point the fixation durations of the hazard itself increase. The findings of this study suggest that the SLAs showed “similar effects on fixation durations as an actual hazard, stopping search for other hazards, and potentially reducing peripheral attention, as increased resources are devoted to the fixated stimulus” (p.675). In other words, when scanning the environment for hazards, drivers in this study unintentionally attended to a roadside advertisement that was within their scanning window, and then increased the duration of their glances at the advertisement to the same extent that they would have done to an actual hazard, and at the expense of their continued scanning for hazards, even when they were instructed to search for the hazards. This finding is quite similar to that expressed by Beijer (2002), who reported that, although higher levels of task demand were associated with a reduction in the *number* of glances made to the signs, the average and maximum *duration* of these glances was not reduced as task demands increased. As Beijer states: “This would seem to indicate that drivers are comfortable turning their attention away from the road for a set period of time, regardless of the demands of the driving task” (p. 76).

Another finding from Crundall, et al. also raises concern. The authors cite a study by Boersma (1989) that suggests that visual clutter in the observed environment tends to increase the visual search time for a target of interest, and studies by Eriksen and Eriksen (1974) and Logan (1996) that demonstrated that the proximity of distracters to a target increases the amount of time required to respond to the target. Crundall, et al. conclude that the embedded nature of SLAs within a complex scene may produce the same result, i.e. increasing the time required for a driver engaged in proper scanning behavior to locate and respond to a real hazard that may be present.

If the two findings of this study can be replicated in other research more germane to the U.S. roadway network and to the type, size, and location of typical DBBs, then the implication is that such signs can attract and hold drivers' attention, even unintentionally, at the expense of their need to scan the environment for immediately relevant hazards, and that the mere presence of a DBB in the visual environment can increase the time required to identify and respond to a present hazard.

Horrey and Wickens, 2007

This paper does not address billboards of any kind; rather it discusses the duration of glances to irrelevant stimuli inside the vehicle. It is reported here because it proposes a novel statistical methodology that is highly relevant to future studies of the potential impact of roadside DBBs. In fact, two of the relevant studies discussed in the present report make use of this analysis technique (Lee, et al., 2007, Chan, et al., 2008).

The assumption underlying the authors' approach is simple and logical. Motor vehicle crashes are rare events, in part because the unsafe circumstances or conditions that lead to a crash do not usually lie at the mean (or center) of a given statistical distribution; rather at the extremes, or tails. In other words, many crashes are a result of unusual or unexpected conditions, not conditions that we would think of as normative. The authors cite, as one example, that it may be the unusually slow response time to a traffic obstacle, not the average response, which results in a crash. And they discuss a recommendation from a consortium of automobile manufacturers that in-vehicle "infotainment" systems not require a driver's glance duration that exceeds two seconds. In short, our concerns in road safety are typically with "upper limits" of the metrics used to describe behaviors – we are generally not interested in mean following distances, or mean reaction time to hazards, or mean BAC levels of drivers. In all these cases, and many others, we are interested in cut points that enable us to distinguish the safe from the unsafe – and these are typically found in the upper limits of a distribution. The authors find it puzzling, therefore, that many research studies continue to report on the average response, rather than the extreme. In short, it is often the slowest response, or the longest glance, that enables us to reach meaningful conclusions about safety related concerns.

In this study, the authors collected data in a driving simulator to study glance durations to an in-vehicle display. They then set out to show how an analysis of the average or mean glance duration could produce results, and therefore lead to conclusions and recommendations, that were quite different than using the same experimental data but analyzing the tails or extremes of the data. Their results showed that analysis of the mean glance duration did not clearly distinguish between tasks of varying difficulty. When analyzing the tails of the distribution for the same experimental data, however, the authors found very large differences, and these differences had implications for hazard response time and, therefore, crash potential. As a result of their findings, the authors revised a crash risk model that they had previously proposed. The revised model has not yet been validated due to a lack of data, but the results from this study demonstrate its viability.

With regard to our interest in the potentially distracting effects of DBBs, this revised model bears direct relevance. Based on the findings of recent studies (Smiley, et al., 2004; Wierwille, 1993; Klauer, et al., 2006a) we have reason to believe that when a driver takes his eyes off the road for a certain extended period (0.75 second, 1.6 seconds, or 2.0 seconds, respectively), he has a much higher crash likelihood than would be expected from distractions of shorter duration. Thus, in future studies of driver response to DBBs, we should be looking, not only for mean values of the number and duration of glances at such signs, but at the greatest number and longest duration glances, values which are found at the tails of the data distributions. As stated above, the recent study by Chan and her colleagues (2008), discussed below, has made use of this methodology. And the industry-sponsored study by Lee et al. (2007), discussed in Section 3 of the present report, recommended this approach to data analysis, and collected data that supported such an analysis, but did not actually perform this tails analysis on maximum glance duration, a key measure in the understanding of distraction from DBBs..

Clark and Davies, 2007

The purpose of this study was to investigate how a driver's reaction time to driving relevant information was affected by different levels of out-of-vehicle distraction, and whether these impacts were related to a driver's level of expertise.

The study was a laboratory simulation in which participants (54 college students, half male and half female, with three different levels of driving experience) responded to official road signs in the presence and absence of distracter signs. There were four types of each sign. The principal driving task was to use the simulator's steering wheel to keep a crosshair in the center of a target that followed the road curvature. The response task was to tap the brake pedal as quickly as possible in response to the appearance of one of the official road signs, which were selected from the UK Highway Code website (http://www.highwaycode.gov.uk).

We had a number of concerns with the design and execution of this study, most of which are acknowledged by the authors. One concern that was not addressed is that the road sign stimuli could appear in any one of 10 different positions on the display screen, a far different case than exists in the real world. A second concern is that each stimulus (both road sign and distracter) appeared suddenly on the screen and remained visible for exactly two seconds. In the real world, signs appear in the distance, often before they can be read, and become clearer and larger as they are approached. In this study, the sudden "on" and "off" appearance of signs of interest might well have influenced participant behavior in ways that would not occur on the road. Further, in the four "load" conditions (no load featuring no distracters, low load with three, high load with six, and “overload” with ten), all of the distracter signs, as well as the target official sign, were presented at the same time, around the perimeter of the display. Responses to this rather unrealistic display might not translate very well to the real world in which signs appear in fairly limited and well defined locations, and in which they appear at different times and for different intervals. Nonetheless, the study produced some interesting findings; findings which are quite consistent with the results of other studies employing very different methodological approaches, and discussed elsewhere in the present report. Whereas driving expertise had no influence on response (reaction time to the simulated road stimuli), the number of distracters did. Specifically, a significant increase in reaction time was found between the no distracter condition and the two highest distracter conditions, although there was no significant difference between the no-load and low-load conditions. There was, however, a consistent increase in reaction time to the road signs as load from distracting stimuli increased, suggesting that the higher loading driving tasks (as represented by the number of advertisements visible) were “detrimental to road safety.” The implications of this study are that advertisements should be kept to a minimum at busy junctions and areas where drivers need to concentrate” (unpaginated).

Lee, McElheny, & Gibbons (2007).

This paper is discussed in Section 3, “Industry sponsored research.”

Perception Research Services (2007)

This paper is discussed in Section 3, “Industry sponsored research.”

Shinar, 2007

In his recently published, comprehensive book on the human factors of traffic safety, Shinar devotes a chapter to distraction, its definitions, causes, and effects, and a section within this chapter on distraction from road signs and billboards.

The author poses a paradox that has confronted researchers in this field for many years. Because roadside commercial billboards, particularly the latest digital billboards, are specifically designed to attract a driver’s attention (and billboard owners and operators tout their success at doing so in their promotions to potential customers), we would expect them to be a significant source of distraction. Indeed, as discussed elsewhere in the present report, numerous studies have shown that drivers do direct their gaze to billboards as they drive. Yet several studies have demonstrated that despite drivers’ glances toward billboards, there has been little observed adverse impact on driving performance. In an effort to better understand this paradox, Shinar and his colleagues conducted an on-road study using 16 experienced drivers and an instrumented vehicle. The route took the participants past a large, attention-getting billboard in one direction and then followed the same roads in the opposite direction from which the billboard was not visible. A camera hidden below the vehicle’s rear-view mirror recorded the participants’ direction of gaze. Results showed that drivers looked to the right (in the general direction of the billboard) 23% of the time when the billboard could be seen, but only 10% of the time when the billboard was not visible to them. Drivers' time spent looking forward at the road and traffic was effectively the same regardless of whether or not the billboard was visible. Shinar believes that the billboard attracted the drivers' spare attentional capacity that might otherwise have been spent looking at other objects equally irrelevant to the driving task. He concludes: "Thus, drivers were able to allocate a significant amount of their attention to the sign but they did not do that at the expense of the attention that they allocated to monitoring the road and traffic" (p. 528).

Shinar's discussion suggests that drivers are willing and able to devote their attention to billboards when their task demands are low, and when the billboard provides greater interest than other roadside objects, but that, as their cognitive demands increase, drivers will devote less attention to these roadside distracters. Other studies, and the billboard industry, have suggested the same thing. And this may well be the case for some drivers, some of the time. But this begs the real question. Because of the considerable expense of new, digital billboards, they tend to be placed only in areas with high traffic volumes. In addition, because advertising space (and, with digital billboards, time) is sold to advertisers based on the number of eyes that will pass the billboard each hour or each day, such billboards tend to be located where they can be seen by the greatest possible number of drivers. This explains why billboards are often placed near highway interchanges and along horizontal curves where they can appear directly within the cone of vision of approaching drivers for extended distances. Thus, DBBs tend to be located in areas where task demands are likely to be high, and, billboard owners claim, (and present data to show), they attract the gaze of large numbers of drivers.

Conducting the kind of research that would be necessary to prove that drivers attend to billboards when they have spare capacity, and concentrate on the road when they do not, is a challenge that, to our knowledge, has not yet been undertaken. We do know, however, that several recent studies (e.g. Smiley, et al. 2005; Lee, et al. 2007; and Chan, et al., 2008) have produced data showing that some drivers attend to billboards for extended glance durations that have been shown, in other studies (e.g. Klauer, et al., 2006a) to be unsafe. To date, however, only the Chan, et al., study controlled for and reported on the task demands that their participants faced while engaging in these glances toward external distracters. Further, we know of only one study (Lee, et al., 2007) that collected data on drivers passing DBBs at night, when such signs can be most conspicuous (because of their location, size, and brightness), and may be most likely to cause high levels of distraction. Although their data was preliminary and based on only a few participants, Lee and her colleagues showed that DBBs, as might have been predicted, captured more and longer glances at night than other roadside distracters, and they have suggested that, had a full study (rather than the pilot study that they performed) been conducted, these differences might have reached statistical significance.

Also, we must recognize that not all drivers are willing or able to safely switch their attention from roadside distracters to the driving task itself when needed. In particular, younger drivers, not yet sufficiently skilled to understand risky situations, and older drivers who may be more easily distracted and who are typically poorer than their younger cohort at quickly shifting attention, may be particularly at risk under such circumstances.

Finally, although accidents are (thankfully) rare events, they are, by definition, unexpected. As Shinar states: “One way to reduce the effort involved in driving, is to estimate the amount of attention that is required and then allocate to the driving a portion of our capacity that is somewhere between the minimum required and the maximum we have. … The problem we encounter in driving is our inability to anticipate many of the rapid changes in the amount required – as when a driver ahead of us suddenly and unexpectedly brakes” (p. 518). It is precisely this difficulty that leads traffic safety experts to be concerned about the compelling power to distract a driver when it is always possible that such distraction cannot be tolerated at the moment it occurs.

Tantala & Tantala (2007).

This paper is discussed in Section 3, “Industry sponsored research.”

Young, M.S., & Mahfoud, J.M., 2007

This well controlled, well documented study includes excellent summary of the literature, and particularly the most recent literature. It employed a fixed-base, interactive driving simulator with a 60º forward field of view (FOV) horizontal, and a 40º FOV vertical. Forty-eight participants drove three simulated routes in either the presence or absence of four roadside billboards. The routes consisted of 3.0 miles of urban driving, 5.7 miles of motorway driving, and 2.8 miles of rural driving. All participants experienced all six conditions, the order of which was counterbalanced across participants. Participants were not told the purpose of the study, but were asked to drive as they normally would, and to maintain the posted speed as closely as possible. The typical run lasted between five and six minutes.

The independent variable was the presence or absence of billboards. Billboards were fixed (static) signs, three on the left side of the road and one on the right. The billboards were placed into the route at semi-random locations, ensuring that they were spaced apart at relatively equal distances, and that they did not cover, nor were covered by, other road signs. Since it appears as if all runs were conducted under simulated daylight conditions, lighting of the billboards was not considered.

Dependent variables included those to evaluate driver performance and attentional factors. Longitudinal control was assessed by time to contact (TTC). Lateral control was assessed by the number of lane excursions, and time out of lane; the metric used for this determination was not specified. Only left edge excursions were recorded and analyzed, since right lane excursions could have been indicative of intentional passing maneuvers. (The study was conducted in the UK, where vehicles drive on the left). Total crashes were also recorded.

Driver attention was assessed in several ways. Mental workload (MWL) was measured through the NASA-TLX scale, given to each participant at the end of each run. Participants were also asked to recall the last road sign that they passed, and, when present, the last billboard. Driver eye movements were also recorded, and provided data on number of glances and glance durations.

The study found that the presence of billboards adversely affected driving performance in terms of lateral control and crashes. Longitudinal control was not adversely affected. These findings would suggest an increase in side-swipe crashes vs. rear-end crashes, but no information is provided as to the types of crashes found. The presence of billboards also had an adverse impact on driver attention in terms of the number of glances made at billboards. This finding is consistent with earlier work by Wierwille who noted that drivers respond to the demands of in-car tasks by altering their attention such that they made more short glances. The presence of billboards was also associated with higher subjective mental workload. In addition, the recall of road signs was adversely affected by billboards on the motorway and rural routes. The authors interpreted this finding to mean that drivers were attending to billboards instead of relevant road signs under these conditions.

The authors conclude with a “persuasive overall conclusion that advertising has adverse effects on driving performance and driver attention” (p.18).

Because this was a simulator study, it represents the expected strengths (full control over independent variables, assurance that all participants experienced the same conditions, etc.) and weaknesses (artificiality of the visual environment, two-dimensional representation of three-dimensional space, etc.) of this technology. Simulator limitations may be of particular concern when studying DBBs because the signs being investigated require high visual fidelity of both the stimuli and the environment in which they are located. In addition, the simulator used in this study was limited to a 60º horizontal and a 40º vertical field of view. It is possible that a wider field of view would have yielded different results, in that the field of view might have better represented a driver’s scanning behavior while driving.

Although the report depicted examples of the official signs and billboards used, it would have been helpful for the authors to have included a chart showing all signs that were used together with more details about their sizes and placements. As written, important issues such as sign and billboard size, distance from the road edge, and elevation, are unknown. Although the authors kept track of crashes that occurred (they did not perform any statistical analysis of crashes due to low absolute numbers [8]), they did not indicate whether or not the crash characteristics were consistent with driver distraction or inattention. Thus, it is not possible to know whether crash types were correlated with the findings of lateral and longitudinal control.

The study examined only traditional, fixed, billboards; electronic or digital billboards were not analyzed. Thus, the direct relevance of its findings to DBBs cannot be assessed. As suggested above, we believe that simulation may not be the ideal methodology to study EBBs because it is difficult, if not impossible, to faithfully reproduce the visual characteristics of such signs (brightness, depth and fidelity of the graphic image) in the simulation environment due to limitations on the graphics processing capability of most simulation systems. Indeed, even in today's most sophisticated driving simulators, it is necessary to design signs that are oversized in order to realistically represent sight distances at which the messages on such signs can be read in the real world, and the complexity of the real world visual environments in which DBBs are most likely to be found remains a challenging task to recreate in simulation.

Chan, Pradhan, Knodler, Pollatsek and Fisher, 2008

In an important new study on this issue, Chan and her colleagues review the literature on driver distraction caused by both in-vehicle and external-to-the-vehicle events, and report that distraction has increasingly been shown to be a particular problem among young, novice drivers. They cite a recent Finnish study (Wikman, et al., 1998) which found that, although the *average* duration of distraction episodes did not differ between experienced and inexperienced drivers, the *distribution* of such glance behavior differed significantly between these groups. Only 13% of experienced drivers had distraction episodes of at least 2.5 seconds, vs. 46% of the inexperienced drivers. Similarly, none of the experienced drivers had distraction episodes of 3 seconds or longer, whereas 29% of the inexperienced drivers did (p. 8).

The purpose of their study was to compare the distribution of distraction episodes of newly licensed and experienced drivers specifically for distracters external to the vehicle. The authors were particularly concerned with the behavior of newly-licensed (16-17 year old) drivers because this cohort presents greatly elevated crash risk, and because extended episodes of distraction were thought likely to further degrade their demonstrated poor hazard anticipation skills. And, although there is considerable literature that addresses distraction of younger drivers from sources and activities inside the vehicle, there is no comparable literature for external to the vehicle distraction. The authors theorize that the data for external distraction may well be different from findings of internal distraction. They believe that this may occur, in part, because when drivers are looking within the vehicle, it should be obvious to them that they are not processing relevant roadway information; whereas, when a driver is looking at sources outside the vehicle, whether an advertising sign, a street sign, or some other scene or object, it is likely that the forward roadway is still somewhere within the driver's field of view, and thus it may not be obvious to him (particularly if inexperienced) that this important information is not being fully processed since it is peripheral, unattended, or both.

The authors review the extensive literature that demonstrates that objects that are not fixated or attended to receive little cognitive processing, and that reduced attention impairs the speed of identification of an object or even an event such as a change in brightness. They cite a study by Muttart, et al. (2007) that demonstrated that drivers are slow to respond to a car ahead of them that has stopped slowly when they are performing a simulated cell phone task, even when that task does not require any visual processing.

In the present study, a total of 24 participants, half male and half female, were divided into a younger, inexperienced group (newly licensed drivers or those with learner's permits) and an older, more experienced group (at least five years of driving experience). They drove a high-fidelity driving simulator along a five mile route that included both urban and rural sections. Five in-vehicle and 18 out-of-vehicle tasks were used as distracters. The latter consisted of a target search in which the participants had to search for and indicate the presence or absence of a target letter in a 5x5 letter grid that appeared on the side of the road. The grid simulated a sign 10 feet wide by 10 feet high, located eight feet from the left or right road edge. When driving at the posted speed limit, a participant would have been able to view the sign for 4.5 seconds.

Since the authors were primarily interested in the longest glances away from the forward roadway (since these have been implicated in prior studies [see, for example, Horrey and Wickens, 2007] as major contributors to crashes), they used as their dependent measure the maximum time that drivers spent continuously looking away from the forward roadway during a specific distraction task. They used the mean length of these maximum episodes to compare their experienced and inexperienced drivers on the in-vehicle and out of vehicle distraction tasks. The results were enlightening and somewhat surprising.

For the in-vehicle distracters they found, as they had anticipated, that there were significant differences between the experienced (1.63 seconds) and inexperienced (2.76 seconds) drivers. None of the experienced drivers had average distraction durations of more than 2.3 seconds, but eight of the inexperienced drivers did. They also looked for patterns in these distributions and found that the inexperienced drivers showed a consistent pattern of looking away from the roadway for longer periods of time than the experienced drivers. Finally, when looking at episodes of distraction lasting longer than two seconds (the threshold of concern in some prior studies), they found substantial differences. A highly significant difference of 20% of scenarios in which experienced drivers looked away from the roadway for more than 2 seconds vs. 57% of scenarios for inexperienced drivers added to the confirmation of their hypothesis.

For distraction external to the vehicle, the topic of most interest in the present report, the data was very different, and very informative. The two most important differences from the in-vehicle glance behavior were that: (a) there was very little difference in the duration of distraction episodes between the experienced (3.41 seconds) and inexperienced (3.67 seconds) drivers on the outside-the vehicle distraction tasks, and (b) the maximum episode distraction durations were significantly longer for the out-of-vehicle tasks (3.54 seconds) than for the in-vehicle tasks (2.19 seconds). The two experience cohorts also showed few differences in the percentage of distraction episodes longer than 2, 2.5, and 3 seconds, in all cases longer for the external than for the in-vehicle distracters. These findings, the authors conclude, demonstrate that "drivers are more willing to make extended glances external to the vehicle than internal to the vehicle" (p. 17).

In discussing their results, Chan and her colleagues compare their findings to those of Wikman et al. who performed their analysis on-road. The data from the two studies is in strong agreement, and provides evidence to support the viability of using a driving simulator to study driver viewing behavior. In reviewing their data on external distraction and relating it to the earlier work of Klauer et al. (2006a), Muttart et al. (2007), and others, these authors express concern 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).”

Lazarus, 2008

As a result of the erection of four DBBs on major arterial roadways in Salem, Oregon, one of which was visible to traffic on I-5, the Oregon Department of Transportation (ODOT) and the City of Salem undertook a literature review to better understand national perspectives on the issue and to assist local and State officials to determine future actions that they might take. This review (Lazarus, 2008) was issued in June, 2008. The concern that prompted the report is based on the premise that newer, larger DBBs are clearer from greater distances than older billboards, and that their intent, to relay advertising messages to the consumer, places them “in direct competition for the attention needed to operate a motor vehicle” (p. 2). Lazarus expresses concern that, in certain cases, DBBs installed in a city and intended for city arterials are also visible to drivers on other nearby highways. This raises questions of the applicability of billboard control laws governing different roads and operating under different jurisdictions. Because these signs are larger and brighter than previous advertising devices, questions are also raised about a driver’s line of sight to the sign, and about the potential for distraction.

Lazarus briefly reviews some of the relevant research in areas of traffic safety and current regulations and guidance, He cites a web log which discusses some of the diverse billboard laws and guidelines, and points out the lack of uniformity in controls that exist from State to State (Webpavement WebBlog, 2005, cited in Lazarus, 2008).

Speirs, Winmill & Kazi, 2008

On behalf of the Highways Agency (HA) of the United Kingdom, WSP Development and Transportation prepared a report which addressed the relationship between billboards and driver distraction (Speirs, Winmill & Kazi, 2008). The report included a discussion of, but was not limited to, DBBs, and investigated the issue from multiple directions:

- A review of policies and guidelines on outdoor advertising in place at various local and national agencies
- A review of published research on driver distraction and roadside advertising, with a focus on work performed in the UK
- A review of decisions by the body (The Planning Inspectorate) that decides “to either grant or refute express consent to display roadside advertisements” (p. 24).

- An investigation of the relationship between outdoor advertising clusters and accidents at two specific locations
- Interviews with diverse stakeholders, and
- An exploration of public opinion through a series of three focus groups and an on-line survey.

Although much of the content of this study is outside the scope of interest for our report (e.g. considerable attention is paid to illegal roadside billboards painted on the side of trailers in farm fields), there are numerous insights gained, largely from focus groups and surveys, that add to our knowledge.

The report begins with a useful discussion of the concept of driver distraction, and an excerpt from a statement by the Royal Society for the Prevention of Accidents (RoSPA) that

> distracted drivers underestimate the effects that distraction has on them and do not perceive their reduced awareness or ability to spot hazards. Distracted drivers also have difficulty controlling their speed and their distance from the vehicle in front, and their lane position can vary drastically. … The more complex or involved a driver becomes with a distraction, the more detrimental the distraction is to his or her ability to make observations and control the vehicle safely (p. 5-6).

This language is not dissimilar to hypotheses described by Chan, et al (2008) in their recent simulator-based study. The discussion of distraction further references the work by Crundall, et al, 2006) who found that drivers become distracted because of their compulsion to stare at something due to the psychological difficulty in abandoning a task which has not been completed. (This is known as the Zeigarnik Effect, and is further discussed in Section 3 of this report. The authors also discuss a study by Theeuwes, et al. (1998), who found, in a laboratory study, that participants did not have voluntary control over distraction; that even when they were tasked with concentrating on one colored shape while ignoring shapes of other colors, "they were unable to ignore the 'distracters' regardless of their effort to do so" (p. 379). These findings, if generalizable to the real world, suggest that drivers may not be as able to ignore the messages on attention-getting billboards as some have claimed. Recent work by Wallace (2003a, 2003b) is also discussed, specifically with regard to personal factors such as driver age, level of fatigue, and alcohol consumption, all of which are believed to play a role in distraction. Finally, the authors cite current work by the UK Department for Transit (DfT), which is attempting to identify gaps in existing research on distraction and will initially involve the development of an operational definition of the term driver distraction.

Within a brief discussion of internal- and external-to-the-vehicle distraction, the authors discuss the growing concern with cognitive overload – which Wallace (2003b) suggests can occur when too much information is presented in certain situations, leaving the driver with insufficient time to process the available information and make time-critical decisions. Such decisions, which may involve maneuvering for exits, merges, or lane drops, also include what Crundall, et al. (2005) have called "transient hazards" such as a pedestrian or bicyclist suddenly entering the road, or a vehicle failing to yield the right of way. Wallace believes that visual clutter, which contributes to cognitive overload, is growing worse, with an increasing number of billboards, on-premise signs, and, as well, official highway signs.

Of course it has long been known that official signs can distract drivers and add to their cognitive workload if they are poorly designed, improperly located, unnecessary, redundant, or irrelevant. This can be a particular problem with official changeable message signs (CMS), which are often reported to cause drivers to slow to read their message if too much information is conveyed or undue attention is drawn to the sign. Despite the fact that official signs (including CMS) have benefited from decades of human factors research to ensure that their design and operation is optimized for the driver's needs, distraction remains a concern, and to an increasing extent with the growth of CMS installations.

Wallace, and others, believe that driver distraction, as much of a concern as it is, is likely underreported. This may be because, he suggests, the distraction may be unconscious, or because social and legal pressures may contribute to a driver's unwillingness to admit distraction for fear of consequences such as increased insurance rates, penalty points on their driver's license, or being found responsible for an accident. For these reasons, Wallace believes that it will be difficult to find empirical evidence for the contribution of distraction by a roadside billboard to an accident. Although this is a key reason to question the use of accident data to assess the relationship between DBBs and crashes, there are many others, discussed later in the report by Speirs and her colleagues, and elsewhere in the current report.

The report next discusses the range of planning policy and guidance regarding roadside advertising in the UK. Although of relatively minor relevance to regulations and guidance in the U.S. because of the highly localized nature of such guidance in the UK, we do find that many of the same principles have been applied. For example, roadside advertising signs may be discouraged at locations such as: complex road sections, intersections, pedestrian crossings, or locations where the cognitive demands on the driver may be high. In addition, a Circular (DCLG, 2007) that provides guidance on the control of advertisements suggests that outdoor advertising signs that may pose a danger to the public include those which:

> because of their size or siting, would obstruct or confuse a road-user's view, or reduce the clarity or effectiveness of a traffic sign or signal, or would be likely to distract road users because of their unusual nature (and) (t)hose illuminated signs (incorporating either flashing or static lights) which, because of their size or brightness, could result in glare and dazzle, or distract road users, particularly in misty or wet weather.

The Circular is apparently based, in part, on findings from a study conducted by the Privilege Insurance Company, which found that 83% of drivers responding to a survey had admitted being distracted by roadside advertisements, with 23% of those reporting that they had veered out of their lane as a result of the distraction. (Privilege Insurance, 2005).

Numerous other regulatory and guidance documents are cited in this section of the report. Although many of these make reference to traffic safety concerns, none of them provide objective definitions of key terms sufficient for regulators to act to control roadside billboards. One such document, for example, requires that local planning authorities must "consider such matters as the likely behaviour of drivers of vehicles who will see the advertisement" and states that "the vital consideration … is whether the advertisement itself, or the exact location proposed for its display, is likely to be so distracting, or so confusing, that it creates a hazard to, or endangers, people in the vicinity who are taking reasonable care for their own and others' safety" (PPG, 1992).

In line with the discussion above, it is useful to note that one of the documents cited in this section of the report deals exclusively with official signs, and provides guidance to roadway authorities on the proper use of such signs throughout the UK (DfT, 2003). This document, known as the Traffic Signs Manual, explicitly recognizes that official traffic control devices (TCDs) can also serve to distract drivers if they are used inappropriately or to excess. Among other guidance, the manual suggests that information signs should not be permitted in construction zones, and that roadway authorities should ensure that signs are limited to those that are considered necessary, because such signs can cause overload and lead to distraction.

Speirs and her colleagues reviewed the decisions of The Planning Inspectorate in 11 cases. Although their summary and discussion of these decisions makes for interesting reading, there is little consistency from one decision to another, and the diversity of issues on which decisions were based (size, illumination, viewing time and change cycle, content, and location, among others) provides little basis to extract principles that might be applicable in the United States. Of the 11 cases cited, however, one billboard was allowed, two were allowed with certain restrictions, and eight were disallowed.

The authors' efforts to review accident data to determine the presence or absence of a relationship between billboard locations and accident occurrences proved to be largely fruitless, for reasons discussed elsewhere in the present report. Some of the key arguments against the use of accident data cited by Speirs and her colleagues are:

- 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 POR to clear traffic lanes, thus further degrading the potential accuracy of identifying the true location.

- The point of rest (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.[3]
- 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).

For these reasons, and others, the authors recommend against the future use of accident data "as an area for further research due to these practical and statistical issues that would cast doubt over any apparent relationship…" (p. 35).

The authors briefly discuss the potential for the use of CCTV data recorded from fixed locations along the highway network in close proximity to roadside advertising signs. This data, it is suggested, would allow the observation of vehicle braking movements, lane deviations, and other losses of vehicle control, although there is no way to know, from such recordings, whether other causes of distraction were present as contributors. They suggest that, in order for this methodology to be feasible, it would be necessary to collect data along road sections both with and without the presence of roadside advertisements.[4]

The authors conducted interviews with representatives of various stakeholders. These organization types included, but were not limited to, the following:

- Road User Groups, e.g. Automobile Association, RAC Foundation
- Road Safety Groups, e.g. Parliamentary Advisory Council for Transport Safety (PACTS), Royal Society for the Prevention of Accidents (RoSPA)

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[3] This weakness in the use of accident statistics should not be ignored. Unless an accident involves major property damage, serious injury or death, police in the US will rarely endeavor to find the "root cause," which would include the point at which an involved driver first lost control and/or was first distracted. The vehicle of a driver who crashes as a result of distraction by a roadside billboard may not come to rest for a considerable distance after the distraction occurs, but it is the point of rest that is most likely to be (erroneously) identified in the Traffic Collision Report as the actual accident location. The use of such information will lead to an artificial reduction in any correlation since it captures an accident data point and associates it with a road location that is not coincident with a billboard. As pointed out in the study by Klauer, et al. (2006b), discussed earlier in this Section, accidents may be underreported by 80% or more.

[4] We have suggested, in other contexts, the potential for the use of roadway CCTV data in billboard distraction studies because of the growing number of CCTV locations coupled with the potential for cooperation from DBB owners, through which signs might be turned on and off, and their displays varied in the key parameters of brightness and message display interval in accordance with a carefully developed experimental design. Specific recommendations along these lines were made to researchers in the City of San Antonio, Texas, which has a comprehensive system of CCTV cameras as part of its traffic monitoring network, and which is engaged in a project to monitor the safety impacts of recently erected DBBs.

- Local Authorities, e.g. Local Authority Road Safety Officer Association (LARSOA)
- Planning Officers, e.g. London Borough of Wandsworth (LBW)
- Central Government Departments, e.g. the Department for Transport (DfT)
- Highways Agency
- Amenity Groups, e.g. Campaign to Protect Rural England (CPRE)
- Advertising Industry, e.g. Outdoor Advertising Association, Outdoor Advertising Council, Advertising Standards Authority
- Research Community, e.g. Brunel University
- Motorway Operators, e.g. Midland Expressway Ltd.

Summarizing the results of these many discussions, the authors identified the following broad conclusions:

- 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.

The focus group discussions provided much information of relevance, summarized below. Three groups were assembled, each including a balance of males and females, and a mix of urban and rural residents. The first group included young, less experienced drivers (ages 17-25) with little motorway driving experience; the second included experienced drivers aged 50 and above who did not regularly use the motorway; and the third included regular motorway users (100 or more miles per week) aged 35-55. Each group included eight participants who were told that the sessions were to discuss sources of driver distraction, without initial mention of a specific focus on outdoor advertising.

Relevant examples of the key points made during the focus group sessions include:

- The younger drivers found motorway driving boring, and felt quite relaxed.
- The older drivers, despite much greater exposure to motorway driving, found it to be stressful and sometimes dangerous, primarily because other drivers take too many risks.
- When asked how long they thought they took their eyes off the road to look at the surrounding environment, the young drivers estimated “several seconds,” although they also agreed that this was probably longer than they should.
- When asked what they would consider “too long” a period to take their eyes off the road, the regular motorway users replied “1-2 seconds.”

- Several members of the younger driver group described situations in which they had been distracted by something external to the vehicle while driving on the motorway and found their vehicle moving out of its lane and/or having to brake suddenly.
- Some participants in each of the other groups also reported having made driving errors while distracted by something either inside or outside the vehicle.
- One regular motorway user reported several occasions in which he had a near miss as a result of looking away for “too long.”

After the initial discussions, highlighted above, the focus group facilitators directed the discussions toward roadside advertisements, and showed photographs of particular installations. Highlights of the discussions that followed are presented below:

- Regular motorway users felt that it was not appropriate to have certain types of advertisements close to the roadway, given the prevailing speed of traffic.
- These users felt that outdoor advertising could pose a distraction to younger, less experienced drivers, although not to themselves.
- Younger drivers, on the other hand, felt that, although outdoor advertising could potentially cause a crash, their effect was no greater than other sources of driver distraction.
- Most of the participants agreed that they did notice and look at roadside advertisements.
- Most of the regular motorway users stated that they tended to look at advertisements when they were waiting in a traffic queue, but confirmed that they read these advertisements even in free-flowing traffic conditions.
- One regular motorway driver felt that it took 2-3 seconds to read an advertisement, but some of the younger drivers felt that ads could be absorbed more quickly (in a “split second”).
- Although drivers agreed that they tended to look at every advertisement, they could rarely recall the specifics.
- Drivers in all three groups believed that the decision to look at a roadside advertisement was not made consciously.
- Younger drivers expressed the view that it was inappropriate to have advertisements within a driver’s line of sight when he should be paying attention to traffic.
- Most participants across all groups agreed that the potential for distraction from an advertisement was dependent on its size, content, location, and type of display. In addition, bright colors, and “sexual undertones” were thought to attract more attention.
- Younger drivers in particular said that they spent longer looking at advertisements for products or services in which they were interested, or if the advertisement featured something that was new or unusual.

- Younger drivers commented that advertising campaigns which told a story that extended over a period of time or a series of billboards attracted more attention.[5]
- Regular motorway users were concerned that advertisements with a lot of detail posed more of a risk because it was more difficult and time consuming for drivers to absorb all of their content; specific questions were raised about the wisdom of including details such as telephone numbers.
- Electronic billboards were considered more of a potential distraction than fixed displays. Younger drivers, in particular, stated that they looked out specifically for these displays and that they waited for the subsequent advertisement in the cycle to appear.
- One participant in the older group expressed a view that was representative of his group: "When they're about to change, you want to see what they are changing to. It's strange… you might not be interested in the adverts, but when things are changing, you watch it… and they'll distract you... But if it's fixed, and you can see that from half a mile away…, I'm not going to be that distracted by it. It's not drawing my attention because I can see from a distance what it is" (p. 80).
- Regular motorway users felt that an important issue was clutter, caused by a proliferation of roadside advertisements in close proximity. They believed that such a situation, especially when combined with a lot of information from road signs, can cause information overload and result in confusion.
- Younger drivers in particular, but with the agreement of those in other groups, felt that internal distractions (such as mobile phones, navigation systems, maps, or adjusting vehicle controls) were, overall, more distracting than roadside advertisements.
- Younger drivers expressed the view that it is the driver's responsibility to pay attention while driving.
- Participants in all three groups agreed that "few drivers would ever admit to being distracted by an advert and therefore felt that any such incidents are likely to be under-reported" (p. 84).
- The commonly held view was that roadside advertising is not necessary, and should not be seen to be part of the motorway network. (Interestingly, the older drivers tended to believe that roadside advertising provided a source of revenue to the government and that revenues raised should be directed toward highway improvement).
- "Overall, it was felt that roadside advertising might well be distracting to some drivers, but not personally to those who participated in the focus groups" (p. 85).
- With regard to the imposition of control or regulation, regular motorway users suggested that the amount of detail in an advertisement is of concern, and suggested imposing a limit on the number of words allowed; a limit of 4-6 was deemed appropriate.

[5] This is the issue of "sequential" advertisements discussed elsewhere in the present report; the phenomenon that describes how one's interest is held during such a sequence is known as the Zeigarnik effect, discussed in Section .

- Similarly, older drivers and regular motorway users expressed the greatest concern about electronic advertisements, and felt that it was inappropriate to permit this kind of advertisement on the highway network.
- Regular motorway users as well as older drivers believed that roadside advertisements should be located only within the view of queued traffic, and not in the vicinity of free-flowing traffic.
- There was support for regulation on the spacing of advertisements, in terms of a minimum distance between advertising signs, as well as a minimum distance away from highway signs so that "they do not detract from the information which is provided for the driver's safety" (p. 87).
- Participants in the older driver group felt that roadside advertising should not be permitted on the motorway unless it provides directions or information of use to the driver; in addition the presence of advertising along motorway sections that require concentration by drivers was seen to be at odds with road safety.
- Some females called for the removal of all roadside advertising; others accepted that it was unlikely that all could be removed, but supported greater regulation of advertising signs in general, including brightness, spacing, and content. Electronic billboards were singled out as a key concern due to their ability to distract (p. 88-9).
- Regular motorway users felt that the driving environment would be safer without advertisements, but believed that simple ads that could be quickly absorbed, when placed along uncluttered roads, did not pose a safety issue.

In addition to the three concentrated focus groups, the authors conducted an on-line survey, hosted on the HA website. The survey was designed to examine respondents' views on potential sources of in-vehicle and external-to-vehicle distraction, followed by a more specific focus on roadside advertising. Because of a large sample size (1371 responses) the authors were able to report a sampling error of only +/- 2.65% at the 95% confidence level. In other words, if 50% of the survey respondents gave the same answer to a question, the authors could be 95% confident that, if the survey had been conducted with the entire population, the responses to that question would fall within the range of 47.3% and 52.7%. This degree of accuracy is even greater when a larger or smaller percentage of the respondents has given a particular response, but 50% is used as a benchmark because it has the greatest sampling error.

Demographically, the respondents tended to be male, and between the ages of 25 and 59. They drove between 10,000 and 25,000 miles per year, and used the motorway more than five times per week.

At the outset of the survey, respondents were given a list of 14 possible sources of distraction (both within and outside the vehicle) and asked to select those which they considered to be most distracting. The top five identified sources, and the percentages of respondents who provided those answers were: Rubbernecking at accidents (75%), child passengers in their vehicle (68%), hands-free mobile phone use (67%), roadside billboards 61%), and roadwork (50%). When asked about the single greatest source of distraction, 24% said mobile phones, 18% reported other passengers, 13% said rubbernecking at accidents, and 9% selected roadside billboards. No other distracters were considered the most important by more than 5% of the respondents (in-car navigation systems and actions by other vehicles).

Once the topic of outdoor advertising was introduced, a series of questions sought to examine whether some types of roadside advertising were considered to be more distracting than others. Participants were asked to select the types of advertising, if any, that they had found to be personally distracting while driving, and then to identify the single most distracting type of roadside advertising. The results are shown below:

- Billboards with changing images (DBBs) were reported to have distracted 72% of all respondents; 53% of the respondents found DBBs most distracting.

- Conventional billboards had distracted 61% of the respondents, and 17% found these to be the most distracting.

- Advertisements on vehicles had distracted 38% of respondents, but only 3% found these to be the most distracting.

- Advertisements on bus shelters had distracted 24% of the respondents; 9% found these to be the most distracting.

Seven percent of the respondents found none of the advertising types to be distracting, and 11% mentioned other types of advertisements (such as ads on street furniture, on-premise signs, and small temporary roadside signs) as having been a source of distraction to them.

Roadside advertising characteristics that contributed to distraction were: location (59%), size (49%), content (39%), changing images (29%), color and information provided (25% each), and lighting (16%).

Respondents were given the opportunity to include narrative statements to highlight their answers. The authors summarized these statements, and reported more than twice as many comments expressing concerns about DBBs (9) than for any other aspect of roadside advertising – content (3), location (4), and size (1). Representative quotes about DBBs included:

> “Changing signs draw attention to themselves; they are not part of the traffic and amount to a serious distraction. I cannot understand why they are allowed!”
>
> “Those with images that change over a period of time tend to attract a longer spell of attention whilst waiting for the next image. If one’s vehicle is actually moving at the time this has the effect of driving blind while watching the particular sign.”

> "You can look quickly at a static board and take in a fair amount of information, however, if you know the image will change you are tempted to keep looking until it does which means taking your eyes off the road for longer."
>
> "A quick glance is enough to know it is an image changing billboard but then the temptation is to keep looking to see what it changes to" (p. 102).

Respondents were next asked to rate the extent of distraction that they believed was due to different aspects of the "content" of roadside advertisements. Ratings were to be made on a five-point Likkert-type scale from 1 ("not at all distracting") to 5 ("very distracting"). Advertisements with changing images were rated by 56% of the respondents as very distracting. Those with complex graphic images were rated very distracting by 42% of the respondents, ads with small text by 28%, ads with lots of details (e.g. telephone numbers) by 26%, and those with more than 10 words by 20%. Of equal interest to Speirs and her colleagues was the difference between those who found each type of content distracting or very distracting, compared to those who rated the same type of contact as "not distracting" or "nor at all distracting." This difference was largest for DBBs; 79% found such signs distracting or very distracting, whereas only 8% found them to be not or not at all distracting – a difference of 71%. The equivalent differences were 67% for signs with complex images, 32% for those with small text, 31% for signs with more than 10 words, and 27% for ads with lots of details.

In order to evaluate the effects, if any, of roadside billboards on general driver performance, a series of statements were presented to the participants, who were asked to state whether they thought each statement was true or false. The statements, and the levels of truth assigned to them, were as follows:

- Can be confusing in urban environments (83%)
- Can be detrimental to overall driving performance (82%)
- Electronic ads with changing images are more distracting than static ads (82%)
- Is an unwelcome distraction to the driver (75%)
- A driver may steer slightly out of lane to read a roadside ad (58%)
- A driver may brake to read a roadside ad (53%)
- Keeps drivers alert (14%)
- Is not distracting in rural environments (12%)
- Is not distracting in urban environments (11%)
- Improves a driver's concentration (4%)

When asked whether their own driving performance had been adversely affected by roadside advertising signs, 17% (201 respondents) said that their performance had definitely been affected, 29% felt that it had probably been affected, 34% stated that it had possibly been affected, and 20% believed that it had not been affected.

For those 913 respondents who stated that their driving performance had been affected by roadside advertising, they were presented with a series of seven statements and asked to indicate whether they felt each was true or false. The statements, and the level of truth assigned to them, were as follows:

- Distracted my visual attention whilst driving (96%)
- Occasionally been detrimental to my driving performance (72%)
- Affected my speed whilst driving (42%)
- Affected my steering whilst driving (33%)
- Made me more alert whilst driving (7%)
- Have, at times, made me a better driver (5%)
- Have never impacted upon my driving performance (4%)

In summarizing the survey, Speirs et al expressed surprise at the dominance of the reported views that roadside advertising has a negative impact on driver performance; prior to conducting the survey, they expected to find highly polarized opinions. Their key findings were described as: 80% (926 individuals) admitted that their own performance is likely to have been affected by roadside advertisements; 76% of all respondents (878 individuals) admitted that they took their eyes off the road to read such advertisements; and 30% (347 respondents) had deliberately slowed down to look at advertisements. In particular, “electronic/digital billboards with a series of rotating images are considered to be particularly distracting” (p. 115).

In short, the authors conclude that this survey, with its large sample size and resultant small sampling error, suggests that there is cause for concern when the responses of the study participants are projected to the UK population at large.

We have spent considerable time discussing this report, in part because it is so comprehensive and current, and in part because it is the first study of which we are aware that has engaged in large scale sampling of the public’s views of roadside advertising, including DBBs, and, specifically, the public’s perception of how such outdoor advertisements have adversely affected their own driving behavior. It will be recalled that one reason why accident data is thought to be of relatively little value in studies of driver distraction is that it is widely accepted that, for several reasons, drivers will be reluctant to admit their own distraction when it is connected to possible crash involvement. In this survey, on the other hand, where responses were anonymous and there was no risk to the respondent, the answers can be considered to be more objective and truthful.

Among their principal conclusions, Speirs and her colleagues suggest that current guidance and policy is insufficiently detailed to address the different types and characteristics of outdoor advertising devices, particularly DBBs. As a result, further research is needed to quantify the level and significance of the risk. They believe that post-hoc accident studies would not be useful to pursue unless the researchers had direct access to the involved drivers in near-real time. They point to the most recent research studies that they reviewed, those by Young and Mahfoud (2007) and Clark and Davies (2007) as producing “statistically significant results which suggest that the level of distraction caused by advertising does present a genuine road safety concern” (p. 117). These studies, however, have been criticized by some stakeholders as being “unrealistic” in that they were simulator based and thus their applicability to the real world may be compromised. Nonetheless, the authors recommend that further research build on Young and Mahfoud's work "to explore and quantify the effect of different characteristics of advertisements on levels of driver distraction" (p. 122). They argue that a future study, if properly funded and conducted on an advanced driving simulator, should be able to overcome some of the limitations of this earlier work – small sample size, limited number of variables, stimulus material not fully representative of actual billboards, and a simulator of somewhat limited flexibility and fidelity. The authors review three UK-based driving simulators, and recommend that future work be undertaken at the University of Leeds Driving Simulator (UoLDS). In their discussion of the strengths and weakness of a driving simulator study, the authors argue that simulators permit the different types and sizes of billboards of interest to be studied to examine the effects on drivers, a task that would be more complex in a test track or on-road study. Finally, the authors present a suggested approach for the conduct of a driving simulator study.

Although it is beyond the scope of the current project to recommend future research (the reader is referred to the recently published FHWA report [Molino, et al. 2009] for this discussion), we respectfully disagree with recommendations put forth by Speirs and her colleagues. It is our opinion that, when studying critical issues of roadside billboards, particularly DBBs, that even today's most sophisticated simulators are incapable of rendering the key characteristics of such signs at a level of visual fidelity sufficient to lead to findings that can be generalized to the field with confidence. This is because the levels of brightness of which today's DBBs are capable exceed the capacity of the display systems used in simulators. Thus, because DBB brightness has been hypothesized to be a key contributor to possible driver distraction, this is of concern. A second concern, one that is touched on by Speirs, et al., is that of the naturalistic aspects of the driving task encountered by participants in the experiment. For several reasons, including visual fatigue and the risk of simulator sickness, experimenters tend to keep scenarios relatively brief. In order to expose the participants to a reasonable number of experimental variables (in this case, variants of DBB displays), it then becomes necessary to incorporate an unusually large number of such variables into these brief scenarios. But, because the impacts of DBBs on driver distraction, if they exist, are likely to be highly context sensitive, the inclusion of several such signs into relatively brief scenarios is likely to create an unrealistic visual environment which may lead to driver responses that are not representative of those that might occur in the real world. It is this author's opinion that initial studies, if funded, should be done in the field, with carefully selected and controlled sites in which before and after comparisons can be made, and in which matched roadway sections with and without DBBs may be studied. If differences in distraction are found, we believe that it would then be appropriate to move to a driving simulator to study the impact on driver performance of different levels of display cycle times, sign size, proximity and angle to the traveled way, etc.).

Dudek, C., 2008

Dudek (2008) reviewed the state-of-the-practice for the use of official, permanently mounted changeable message signs (CMSs) during "non-incident, non-roadwork" periods. Practices relating to the display of AMBER (America's Missing: Broadcast Emergency Response) alert messages were included, The report was based on a review of the literature and a survey of State DOT traffic management centers (TMCs) and agencies that operate toll roads. Overall, responses were received from 40 States and six toll road agencies with a total of 100 TMCs operating 3,023 urban and 821 rural CMSs.

In principle, the study of practices regarding official CMSs is somewhat removed from a review of commercial DBBs; yet there are important areas of overlap between the two uses of this technology that bears discussion.

Dudek describes the primary applications for CMSs as serving to notify motorists of:

- Non-recurrent problems caused by random, unpredictable incidents such as crashes, stalls, or spills; and temporary, preplanned activities such as construction or maintenance.
- Environmental issues such as fog, floods, snow, or ice.
- Traffic problems caused by special events, such as parades or sports events.
- Special roadway operations such as reversible, high occupancy, or contraflow lanes; or certain design features such as drawbridges.
- AMBER alerts.

His review was undertaken because, although guidelines are available for the design and operation of CMSs when used for their principal purposes, there are no guidelines available, and little understanding of existing practice, for the use of these signs under non-incident, non-roadwork conditions. The primary purpose of this synthesis of practice was to identify those practices that have proven effective and ineffective, and to serve as a guide to State and other operating agencies in the more effective use of their CMSs, as a first step toward the possible development of guidelines for such uses.

Guidelines for the design and operation of CMS were initially developed in 1978, and have been refined several times over the past 30 years. Because CMSs are part of the official highway information system, they must communicate a meaningful message that can be quickly read and understood by drivers. It is well understood that the design of effective messages requires the application of proven principles for each of the following display features:

- Message content
- Message length
- Message load; units of information
- Message format
- Message splitting

Although traditionally left blank when not in use for their intended purpose, there has been an increase in the use of these signs by transportation agencies over the past 10 years to display messages when the signs are not otherwise needed. Such messages have been predominantly those that indicate travel time, and these are recommended by FHWA. However, other, non-essential messages have seen growing use, including information about congestion, speed, traffic ordinances, safety campaigns, and public service announcements (PSAs).

Examples cited of safety campaign messages included (dashes indicate line breaks):

- CLICK IT – OR TICKET
- BUCKLE UP FOR – SAFETY – IT'S THE LAW
- U DRINK – U DRIVE – U LOSE

Examples cited of PSAs included (ellipses indicate more to the message than shown):

- REPORT DWI …
- AIR QUALITY ALERT …
- BLOOD DRIVE …
- BURN BAN IN EFFECT …

The rationale for leaving CMSs blank when not in use for their primary purpose is that, when essential information is presented on the sign, it will be more attention-getting, drivers will be more likely to notice it, and the message will be more effective. The question always raised about this traditional practice, however, has been whether drivers will question the sign's functionality. In addition, Dudek found that some agencies experienced negative public opinion from those who felt that the expensive investment in this technology was being underutilized.

Dudek notes (p. 3) that the FHWA discourages the display of PSAs on these signs. Two important concerns about this use of CMSs have been that the signs lose credibility with motorists when used for other than their intended purposes, and the risk of "change blindness," the potential that a motorist will fail to see that the message on the CMS has changed from something that is non-essential to something that is highly relevant and, perhaps, time critical.

The author cites the experience of Caltrans, which posted transportation-oriented PSAs (e.g. "RELIEVE CONGESTION-RIDESHARE") on CMSs in the Los Angeles area so as to avoid leaving the signs blank. Public reaction was "quite negative" (p. 15), and the agency's traffic operations personnel believed that using the signs to display messages that were irrelevant to freeway operations led the public to disregard the signs, thus reducing their effectiveness when they were most needed.

The display of safety messages on CMSs falls into a middle ground – not discouraged by FHWA, but allowable under specific circumstances. If used, agency respondents say, such messages should be current, and displayed for only a limited time.

One unfortunate consequence reported by agencies that displayed safety messages and/or PSAs was that these practices led to a proliferation of requests from other agencies and organizations to display their own non-traffic-related messages.

Although the present study addresses commercial advertising signs, specifically DBBs located off the right-of-way, there are lessons to be learned and applied from Dudek's review of official CMSs located within the right-of-way. He says:

> If CMSs distract drivers from more critical tasks while traveling at prevailing speeds, or if the messages are erroneous or outdated, then driver acceptance can be compromised. In addition, if the messages are too long, complex, and/or confusing to read and comprehend, drivers may reduce speed to read the messages and this could result in a potential safety problem (p. 3).

While all of these concerns have relevance to the design and operation of DBBs, they convey a special precaution for the potential future use of official CMSs for the display of commercial advertising messages when not in use for the primary purposes (see Section 7 of this report for a fuller discussion of this issue). If transportation agencies have reported to Dudek that the use of CMSs for the display of safety campaigns and public service messages can have negative safety consequences in terms of change blindness or CMS credibility, and if FHWA discourages the use of CMSs for the display of PSAs, one must question the reasonableness of the current consideration being given for the use of these signs to display commercial advertising.

Dudek asked his respondents about their experiences with public reaction to leaving CMSs blank when not in use for their principal purpose. Thirty-nine percent of the TMCs responding received "somewhat" to "very" favorable responses from the public; twenty-four percent received a neutral response, and none received unfavorable responses. (Thirty-seven percent had insufficient information). Favorable comments about their experiences included (p.17-18):

- Drivers pay more attention when a message is displayed, messages are more effective when displayed, frequent display of non-essential messages results in drivers ignoring important messages (15 respondents)
- The conspicuity and message urgency of the CMS is preserved (1 response)
- Credibility of the message is the key to success (1 response)
- Relevant, timely information enhances driver respect (1 response)
- Displaying messages unrelated to motorist's travel could increase disregard for the CMS when messages are relevant (1 response)

He also asked about experiences with safety campaign messages on CMSs. Twenty-nine percent of the reporting TMCs received "somewhat" to "very" favorable responses from the public; eighteen percent received a neutral response, and two percent received unfavorable responses. (Fifty-one percent had insufficient information). Comments about their experiences included (p.34-35):

- Messages should be displayed for a short time, and not often (18 responses)
- We get negative feedback from the public (8 responses)
- They should be displayed only for well-organized statewide safety campaigns (7 responses)
- The public is generally receptive to the messages (6 responses)
- They open the door to other requests that are not transportation related, and denying such requests is a problem (6 responses)
- Messages should be kept simple and easy to understand (4 responses)
- Post such messages only off-peak (or in the off-peak direction) to minimize unintended congestion (2 responses).
- Display only safety-related or agency-supported messages (2 responses)
- Make sure message is not distracting to motorists (2 responses)
- Make sure there is value in the message to the public (1 response)
- We receive and deny requests for advertising messages (1 response)
- Message must have broad public impact (1 response)

One expressed concern, for both safety campaign messages and PSAs, was that the decision to display such messages was overwhelmingly due to administrative/upper management requests (93% in the case of PSAs, 99% for safety campaign messages), occasionally against the judgment of operations personnel, and with little or no support from research.

With regard to AMBER alert messages, Dudek reports (p. 41) that 84% of those TMCs that display such messages exceed the maximum recommended (four) units of information on a CMS. As a result, "the majority of motorists will not be able to read and comprehend the messages while traveling at typical freeway speeds" (p. 41-42), and "those drivers who attempt to read the messages before passing the CMS may reduce speed" (p. 40). This is simply because the type of information typically displayed on a CMS-based AMBER alert message may include a license plate number (equivalent to more than three units of information) and a 10-digit telephone number (equivalent to more than three units of information). He cites two previous studies (Ullman, et al. [2005] and Dudek, et al. [2007]) that found the average reading times for AMBER alert messages containing a license plate number or a 10-digit telephone number were significantly longer than the reading times for signs without this information.

There are several lessons to be learned from this study that have direct relevance to DBBs. Long messages containing information such as telephone numbers take longer to read and may cause drivers to slow in an effort to read the message. The amount of information on signs should be strictly limited to minimize its distraction potential. Even official traffic signs can overload drivers. In addition, there are specific lessons that can inform projects currently being considered that would allow commercial advertising to be displayed on official CMSs within the right-of-way. Messages that are irrelevant to traffic safety or flow that are broadcast on official CMSs are strongly opposed by motorists, and the decisions to accept such messages (including safety campaign messages and PSAs) are generally imposed by senior administrators or managers regardless of the concerns of operations personnel. There is concern about change blindness – that motorists will not notice a sign whose message has changed from something irrelevant to something of importance to them. And there is considerable concern about the loss of credibility of official CMSs when they display messages that the public believes are not timely and not related to traffic safety and flow.

Edquist, J., 2009a, 2009b

For her recent doctoral dissertation, Edquist (2009b) performed a study using a high fidelity driving simulator to assess the effect on driver response to road signs and to vehicles ahead of them when in the presence of ambient visual environments that represented different degrees of clutter. Edquist describes three types of clutter that are present to different degrees in different driving settings. *Built clutter* is clutter caused by the complexity of the man-made environment – buildings, wires, bridges, storefronts, billboards, utility poles, etc.); *designed clutter* is clutter created by road authorities through the number, size, placement, and diversity of traffic control devices (signs, signals and markings); and *situational clutter* is caused by the number and mix of vehicles in the traffic stream, the number of lanes of travel, weather, etc. While holding situational clutter constant in the simulator, Edquist varied the extent of built and designed clutter, and measured the changes in the participants' responses to traffic control devices and to the behaviors of vehicles in the traffic stream. Four types of vehicle changes were presented: the car directly in front of the participant moved closer or farther away, and vehicles in adjacent lanes appeared or disappeared from view. She found that high levels of designed clutter slowed the participants' detection of changes to official signs. In other words, it was more difficult and time consuming to identify and respond to the relevant traffic control device when there were many such TCDs competing for the driver's attention. Conversely, she found that high levels of built (environmental) clutter delayed the participant-driver's detection of changes in both signs and other vehicles. Because the changes to these other vehicles were highly visible, relevant to the participants' driving task, and "not minor" Edquist found that the adverse impact caused by additional built clutter to be of concern.

Edquist summarized the literature about older drivers that showed that this cohort has difficulty with divided attention and rapid task switching both of which are important for safe driving. These concerns are exacerbated under conditions of high workload. In comparing older to young, novice drivers (those with probationary licenses), she found that in the presence of high visual clutter the older drivers had more difficulty both finding and responding to official road signs, and in detecting changes to nearby vehicles in the traffic stream. The novice drivers did not experience these difficulties to the same extent.

In a simulator-based driving study performed to try to confirm or refute an earlier study using still photographs, Edquist found that, when billboards were present, participants drove more slowly, took longer to change lanes in response to direction to do so by road signs, made more errors when changing lanes, and spent more time looking at the roadside and less at the road ahead of them. Older drivers in particular made more errors when changing lanes when billboards were present. The author notes that, due to limitations in the simulator platform, her scenarios depicted relatively low complexity environments. In addition, there was not enough traffic in the simulated road scenes to create elevated levels of driver workload, and the billboards depicted were simpler than those typically found on actual roads. Thus, she concludes, her experiment likely underestimated the adverse effects of billboards on driver response to traffic conditions. The author notes that there are often questions about the extent to which simulator results can be generalized to the real world; however, in this case, since both the visual and cognitive workloads in the simulator were lower than they would be in the real world, she believes that the real effects of these distracters are probably larger than what she observed. Edquist summarizes her study by stating that visual clutter adversely affects where drivers look, what they see and how quickly they see it, and negatively impacts their driving performance in terms of speed maintenance and response to traffic signs.

Fisher, D., 2009

Fisher (2009) reported on work conducted in his laboratory regarding the effects of external distractions on novice drivers. Using their high fidelity driving simulator, Fisher and his colleagues measured glance durations to such distracters, vehicle behaviors, attention to the forward roadway, and attractiveness of the distractors.

When comparing the maximum glance duration toward the distracter (the simulated billboard or the in-vehicle infotainment device) for older and younger drivers, Fisher found that younger drivers were considerably worse (i.e. a larger percentage of them took long glances toward the distracter) than older drivers. However, when the distracter took the form of an external distracter (the billboard), the performance of both younger and older drivers deteriorated. Specifically, using the two second target value identified in the 100- car study, Fisher found the following:

Percentage of Drivers Making Glances Longer Than 2.0 Seconds to:	Older Drivers	Younger Drivers
Distracters Inside the Vehicle (Infotainment Devices)	22%	55%
Distracters External to the Vehicle (Billboards)	80%	80%

In analyzing the longest glances toward the distraction source, Fisher found the following:

Percentage of Drivers Making Glances Longer Than 5.0 Seconds to:	Older Drivers	Younger Drivers
Distracters Inside the Vehicle (Infotainment Devices)	4%	11%
Distracters External to the Vehicle (Billboards)	17%	27%

These findings suggests, of course, that older drivers are less likely to be distracted by inside the vehicle sources than are younger drivers, but, when the distracter is a billboard, older drivers are just as likely to be distracted as younger drivers, and the percentage of drivers who engage in excessively long glances to such billboards is substantially higher for external than for inside-the-vehicle distracters. Fisher hypothesizes that drivers looking inside their vehicle at a navigation system, entertainment device, etc., are aware that their eyes are off the road, but when the distracter is outside the vehicle, along the roadside, drivers may be able to observe the forward view including traffic in their peripheral vision and therefore believe that they are attentive to the driving task. This will be a subject for future research.

Martens, M., 2009

As part of an effort to develop guidelines for the control of visual distracters adjacent to the roadside for the Dutch Ministry of Transport, Martens and her colleagues at TNO performed a literature review of the human factors principles to be followed. She summarized the key findings of this review as follows:

1. Visual information processing can be of two types –
    a. Central processing in which the object being viewed is fixated, and
    b. Peripheral processing, in which the object is not fixated

2. In order to read the object being viewed, the object must be fixated.

3. Elements such as color, shape, movement, lighting, can be identified without fixations.

4. Attention precedes an eye fixation on an object; first attention is drawn, then the eye follows

5. During saccades (the quick movement of the eye between objects) the eye is “blind”

6. In measuring eye movements and fixations, we can measure the “fixation” but we cannot know with the focus of attention – i.e. what the person is attending to.

7. Part of the driving task (e.g. lane keeping) can be done with peripheral vision.

9. Our attention can be drawn to an object through a “top down” process, i.e. where we have chosen to attend to it because of personal interest ; or via a “bottom up” process, where the object itself attracts our attention via its inherent properties such as brightness, conspicuity, or movement.

10. In driving, “bottom up” distracters should be avoided.

The recommended guidelines that the TNO personnel developed from these core principles are discussed in Section 5 of this report.

Molino, Wachtel, Farbry, Hermosillo & Granda (2009).

This report reviews recent research about the possible effects on driver safety of roadside DBBs. The report updates earlier work, reviews potentially applicable research methods, and recommends an approach to future research. The study examined a range of

DBB-related independent variables that might affect a driver's response to such signs, and a range of dependent variables that might serve as measures of driver distraction or inattention. The potential research methods and the independent and dependent variables were weighted and integrated into a matrix to produce a set of alternative future research approaches. For a proposed initial study, three candidate methodologies were compared: an on-road study using an instrumented vehicle; a naturalistic study; and a study using unobtrusive observation. The on-road study was determined to be the best choice for the proposed initial study.

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.

SECTION 3.

RESEARCH UNDERTAKEN OR PUBLISHED BY THE OUTDOOR ADVERTISING INDUSTRY

Over a period of many years, the outdoor advertising industry has commissioned a number of research studies from universities and private consulting organizations. To a large extent these studies, their methods and results, are not released to the public. Occasionally, or upon request, the OAAA will release the report of a commissioned study. In addition, internet research occasionally identifies excerpts of such work or information provided by manufacturers or sellers of space on billboards oriented to potential clients. Finally, patent searches occasionally identify new technologies of relevance in the field.

The on-premise sign industry, through its representative organizations such as the International Sign Association (ISA) and the United States Sign Council (USSC), has also sponsored research, some of which is available to the public for a fee through the organizations' web sites. The USSC website currently lists 15 documents available for purchase by the general public. Examples of such studies include those by Garvey, Thompson-Kuhn & Pietrucha, (1995), Garvey (1996), and Kuhn (1999). In addition, the ISA publishes a periodical called *Signline*, which reports on new developments, and often highlights legal challenges to on-premise signage.

Perception Research Services (1983), Young (1984).

A series of studies conducted by Perception Research Services (1983), and separately reported by its President (Young, 1984) was intended to "observe the attention-getting ability of outdoor boards from the perspective of the individual in an automobile (Young, 1984, p. 19). This work measured the eyegaze behavior of 200 licensed drivers who viewed a 27 minute video of a drive through three metropolitan areas to "observe the stopping power of outdoor" (p. 19). Although insufficient detail was presented in the published reports to independently review the research, the results are illuminating. First, the author suggests that recall scores (based on questioning of the participants immediately after the simulated drive) "grossly (understates) the true impact of outdoor advertising … that outdoor is generating approximately two and one-half times as much attention as recall scores would ever indicate" (Young, p. 20). Second, the research found that "outdoor advertising located near highway signage tends to generate *greater* attention. We hypothesize that the highway signage tends to wake up the driver; his state of alertness increases and his attention to advertising and signage in the immediate area tends to get enhanced" (Young, p. 21). Finally, the research found that outdoor advertising attracts attention regardless of whether the displayed message is of interest/relevance to the driver or not. These findings, and particularly the last, obviously intended for an audience within the billboard industry, provide a useful comparison to the findings of several of the studies discussed in Section 2 of this report. In particular, Young's finding that billboards attract a driver's attention whether or not the message is of interest or relevance, is quite similar to the findings of Crundall, et al. (1999), and Theeuwes, et al. (1998, 1999), both of whom showed that drivers do not, and cannot, ignore such irrelevant stimulation, even during the performance of a high priority task. Interestingly, Young's findings run directly counter to arguments routinely made by industry representatives in discussions with regulators – that there is no adverse safety consequence of billboards because, when a driver is engaged in a demanding task, he simply ignores the advertisement. An updated version of this report was issued in 2000, but has not been made public.

In addition to Perception Research Services, there are an unknown number of organizations that offer testing and assessment services to the billboard industry, or provide technologies to assist in such testing. Numerous technologies have been developed to perform such analysis, including simulator studies (PreTesting Company, Undated) billboard-mounted eye-tracking devices (Skeen, 2007), and others.

We are aware of only two billboard industry sponsored research studies that have addressed DBBs empirically. These studies have been comprehensively reviewed previously by Wachtel (2007), and the full details of those reviews are not repeated here. The interested reader can examine the full reviews at: http://www.sha.state.md.us/UpdatesForPropertyOwners/oots/outdoorSigns/FINALREPORT10-18-GJA-JW.pdf . Below, we have summarized the concerns that were discussed in the earlier reviews, as well as the comments of other independent peer reviewers. Overall, the reviewers have found serious weaknesses in both studies; weaknesses that call their findings into question. Conversely, in one of the two studies, data was collected but not fully analyzed or reported that should have led the researchers to conclude that there were, indeed, adverse safety consequences of roadside digital advertising signs.

Tantala & Tantala (2007)

This study was performed for the Foundation of Outdoor Advertising Research and Education (FOARE), an arm of the Outdoor Advertising Association of America (OAAA). 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. These issues are discussed below.

Limitations of Post-Hoc Accident Analysis.

Any post-hoc accident study, in which researchers review statistical summaries of traffic collision reports (TCRs) is limited, not only by the detail and accuracy of the original reports, but also by the inherent simplifications imposed by the coding system used to summarize the data in the first place. When a third party excerpts this summary data for inclusion in a statistical data base, as is the case here, the level of detail and specificity that may have originally been present is further compromised. When such summary data are used to relate crashes to driver distraction that may or may not have been caused by the location and operation of DBBs, the interpretation of crash data is subject to further limitations, discussed below.

In addition to the general methodological concerns discussed above, there are several other important limitations to the viability of post-hoc accident analyses. These include:

- It has long been known that the majority of traffic collisions are never reported to, nor investigated by, the police. However, it was not until the conduct of the 100-car study (see, for example, Klauer, et al. 2006b) that researchers developed a “real world” understanding of the magnitude of this issue. The study documented 69 crashes that occurred to participants while driving their instrumented cars. Of these, 57, or 83%, were not reported to the police. If this statistic is applicable to the driving population at large in the U.S., then the fact that less than 20% of all crashes are reported to the authorities suggests that post-hoc crash studies are underreporting crashes by a factor of five. We believe that this problem is likely to be exacerbated with distraction accidents, for reasons to be discussed below.

- Unless a reported crash involves major property damage, serious injuries, or fatalities, any police investigation is likely to be cursory. In most States, only a serious crash requires a specialized investigative team to examine the precursors to the accident (evidence such as skid marks, debris fields, etc.) and to prepare a supplemental report. For the vast majority of police investigated accidents, no in-depth investigation is performed.

- As a result of the typical limited investigation, the crash location is generally identified as the point of rest (POR) of the involved vehicle(s) after the impact rather than the upstream location where the driver or drivers initially lost control or failed to pay attention. For a study of driver distraction or inattention, what matters is the location where the inattention or distraction occurred. The POR of the involved vehicle(s) is meaningless. In fact, since the POR may be a considerable distance downstream from the “distraction location,” not only will the TCR (and its statistical summary) fail to provide the relevant information needed, but this summary data may lead to an artificial understatement of the relationship between the source of the distraction and the accident, should one exist. This is because more crashes will be coded as having occurred at a roadway location that is not related to the source of the distraction.

- Drivers who are involved in crashes as a result of their inattention or distraction are unlikely to willingly report their pre-crash behavior to an investigating officer (Wallace, 2003b, Speirs, et al. 2008), due to concerns about legal liability, insurance surcharges, or points on a driver’s license.

Indeed, the driver may not even be aware of having been distracted or inattentive.

- As a result of a driver's inability or unwillingness to recognize distraction as a potential factor, an investigating officer is likely to check a box on the TCR such as "failure to yield right-of-way," or "following too closely" for expedience.

For these reasons, it is likely that the traffic collision summaries evaluated in this study represent a substantial underreporting of the true total number of crashes that occurred on the road sections studied within the analysis period. Further, it is likely that the classification scheme (using vehicle point of rest as the accident location) artificially reduces any true correlation between DBB distraction and driver errors that result in loss of control, and, at the same time, artificially increases correlations shown to be unrelated to DBBs.

Erroneous Underlying Assumptions.

The roadway sections for which data (accident report summary statistics) were collected for this study rest on two basic underlying assumptions made by the authors. The first assumption rests, in turn, on their determination of the distance from which a DBB could be seen by an approaching driver. The second rests on the researchers' decision to exclude from their data analysis those crashes that resulted from what they called "data bias" or "intersection bias." We believe that these determinations, and the assumptions based upon them, were seriously flawed. Each will be discussed in turn.

Assumptions about the Visibility Distance to DBBs.

The authors, justifiably, intended to analyze those crashes that occurred in the vicinity of DBBs, i.e. those roadway sections in which an approaching driver could first *see*, and subsequently *read* the message on such billboards. In other words, the crashes of interest would be those that were initiated (i.e. where a driver first lost control or first failed to attend to the driving task) during the time and within the road section that a DBB was within the visibility or legibility range of an approaching driver. We would want to compare such crashes to those that occurred on comparable roadway sections where no DBBs were visible or legible.

It is imperative, therefore, that the researchers identify, in advance of data collection, those roadway sections which were, and those which were not, within the visibility and legibility ranges of the seven DBBs that they studied. To support their determination of these locations, the authors provide the reader with five different terms, none of which are clearly defined in the report. These terms are: "visible range from route," "viewer reaction zone," "viewer reaction distance (VRD)," "viewer reaction distance zone", and "viewer reaction time (VRT)." The only one of these terms that is given a definition is this tautological and confusing description of VRD: "… Viewer Reaction Distance (is) how far from a billboard that the driver is potentially within the 'influence' of the billboard" (p. 45, 79). In other words, viewer reaction distance is the distance in which the viewer can react to the DBB. Instead of providing a meaningful or operational definition of this key term, the authors explain that "reasonable values for VRD were previously determined in previous studies, and are a function of the driver's speed." But no such previous studies are cited, and no other basis for the VRD formula is offered. Regardless of the basis for the determination of VRD, however, the researchers' statement that it is a function of speed is simply wrong. Clearly, the *distance* at which a driver can first see, and then read, any sign (DBBs included) is independent of speed; it is only viewer reaction *time* that would be affected by speed. This is a critical error, because this false assumption led the authors to identify those road sections upstream of each DBB for which they would collect and review the accident summary data. If these roadway sections were inappropriately truncated, and we will show below that this was the case, potential billboard-related crashes would be missed, and the identified correlation coefficients would be artificially and incorrectly reduced.

But the consequences of this error are even greater because of other mistakes made by the authors.

They report that, at 65 MPH, the VRD is approximately 0.2 miles with a VRT of 10 seconds (p. 79). But calculation demonstrates that, at 65 mph (95 ft/sec), 0.2 miles is traversed in 11 seconds, not 10. In addition, if the actual speed limit was 60 mph (88 ft/sec) and not 65 mph (see below), 0.2 mi requires 12 sec to travel. Thus, reviewing only those crashes that occurred within a 10 second VRT window would exclude an unknown number of crashes that might have occurred when a DBB was visible to an approaching driver. Further, the accuracy of the authors' selected VRD is further reduced because they made no allowance for the fact that billboards on the opposite side of the roadway from the driver's direction of travel (what they termed "left readers") have a longer viewing time than those on the near side, and by their commingling of VRD with their measurement of "distance to the nearest billboard" (pp. 45-46) - a term which they do not define.

But their error in relating VRD to speed exacerbates this problem. Although Table 2-3 (p. 15), "Visible Range of Billboards Along Interstate Routes;" is never discussed in the report, a review of its content sheds light on the issue. The table shows the "visible range," in miles and feet, for each of the seven DBBs in the study. Although never defined, visible range appears to represent the maximum distance at which each of the seven DBBs studied could be seen by an approaching driver; these distances range from a low of 0.28 to a high of 2.15 mi upstream of the sign. Translating these distances to time at 65 mi/hr, the DBB with the shortest visible range (#4) would be within an approaching driver's visual range for 15.6 seconds, and the billboard with the longest visible range (#5) would be visible for 118.9 seconds, nearly two minutes. Thus, the researchers' decision to review only those crashes within 10 seconds upstream of any billboard is insufficient even to assess the potential influence of billboard #4, the one with the shortest visible range - no less any of the other six, all of which were visible for greater distances, in one case more than ten times the limit chosen for data collection.

In summary, the consequences for compromising the validity of the data of this study are potentially high because the researchers' erroneous assumptions, even in light of their own documented sight distances, led them to exclude all crashes that might have been initiated in roadway segments further upstream from each of the billboards than they chose to study, but well within the visibility range of those billboards.

In addition to issues of sight distance, it should be obvious that every visible DBB along the route will have a different VRD and VRT depending upon numerous other factors, for example, sign location, elevation, angle toward the driver's eye, brightness, size of characters, roadway geometry, etc. None of these factors are addressed in the report.

If we look at legibility distance rather than visibility distance, the problem with the researchers' assumptions is similarly problematic. To take one example, if we assume (based on accepted industry practice) that 1 in of character height on a sign permits a legibility distance of 40 ft, and that a 14 ft tall billboard face (as were all seven in this study) with a character height of 75% of the available height or 10 ft 6 in (a reasonable assumption based on scaling the DBB images in Figures 2-4 and 2-8 of the report), then the legibility distance of such a sign would be 5040 ft (0.95 mi), nearly *five times* the VRD assumed by the authors.

So, if even the *legibility distance* of some of the DBBs studied is greater than the *visibility distance* accepted for analysis by the authors, there is a serious problem with the data that forms the basis of their conclusions. Further, given the size, brightness, and frequently changing imagery on DBBs, it is reasonable to assume that crashes initiated within a given sign's visibility distance must be considered, well beyond the legibility distance. In short, it is reasonable to assume that the gaze of an approaching driver might be attracted to, and that such a driver might be capable of reading, a DBB at far greater distances and for far longer periods of time, than the authors chose to evaluate in this study. It is reasonable to conclude, therefore, that the crash data accepted for inclusion in this study, based on the researchers' artificially constrained assumptions of VRD, has resulted in a substantial understatement of the true number of crashes that have occurred within the visibility and legibility range of the DBBs studied.

Finally, because Viewer Reaction Zone is never satisfactorily defined, the results reported in Tables 4-1 to 4-4 cannot be verified. Similarly, because the Visible Range is not defined, the results reported in Figures 4-2 to 4-9 must also be questioned.

"Data Bias" And "Intersection Bias"

One of the more troubling decisions made by Tantala and Tantala was to exclude from analysis any reported crashes that were attributed in the accident summaries to what they called "data bias." The reader cannot know exactly which such biases were excluded, because they are never clearly defined and because the descriptions of them change throughout the report. Indeed, as shown below, some of the stated biases are listed in certain report tables but not others. Their "data biases" included:

- Deer hits (sometimes called animal related)[6]

[6] Discussed in Tables 4-5, 4-6, pp. 45, 49, 77

- Driving under the influence of drugs or alcohol[7]
- Adverse weather[8]
- Speeding[9]
- Senior related[10]

While it might be argued that deer hits, speeding, and DUI-related crashes were appropriately excluded from the data analysis, it is understood that most crashes have multiple causes, and it is possible that driver distraction may have played a role in some or all such crashes as secondary factors even if it had not been identified as the primary cause in the original TCR. On the other hand, it is recognized that adverse weather conditions place higher perceptual and cognitive demands upon the driver, the very kinds of increased workload for which researchers, traffic safety experts, and regulatory authorities express the greatest concern about the potential distracting effects of DBBs. In addition, older drivers (as well as young, novice drivers) may be at higher risk for distraction-related crashes, particularly when driving demands are high (see, for example, Chan, et al., 2008, Speirs, et al., 2008, Fisher, 2009). Thus, the exclusion of such "data bias" from their analysis raises additional questions about the basis for the researchers' underlying assumptions. The authors' supporting statement that: "A more fair and unbiased comparison of accident data would exclude accidents from known causes" (p. 63) is neither explained nor justified.

But it is their decision to exclude accidents in the vicinity of interchanges, called "interchange bias" (pp. 49, 77), that is particularly troubling. In their own words, the authors excluded interchange-related crashes because interchanges are where "drivers undertake additional tasks such as changing lanes, accelerating/decelerating, negotiating directions, and attention to others undertaking these additional tasks" (p. 78). It seems obvious that such driver demands associated with intersections are the very types of challenges that are of concern to the traffic safety community, and because interchange areas are among the prime locations for high visibility billboards, their elimination from this study is a cause for concern. If there is one issue about which all of the research about billboard distraction and all of the published guidelines and regulations agree, it is that billboards, and particularly DBBs, should not be located near interchanges, precisely for the reasons that Tantala and Tantala excluded such accidents from their analysis. Indeed, the Farbry, et al., (2001) study for FHWA specifically noted that intersections and interchanges were highly demanding road locations, and that such locations should be included in any study of electronic billboards. Thus, the authors' decision to ignore all such data is of concern.

Although the decision to exclude crashes in the vicinity of interchanges is problematic for the "temporal" (before-and-after) study that the authors conducted, it is more harmful in that section of the report that deals with "spatial" factors. One concern is that the reader cannot know which accidents were excluded due to "interchange bias" because the

[7] Discussed in Tables 4-5, 4-6, pp. 45, 49, 77
[8] Discussed in Table 4-5, pp. 49, 77 ("snowfall" and "icy roads" on pp. 49, 77)
[9] Discussed in Table 4-6
[10] Discussed in Table 4-6 (age 65 and above)

authors describe this exclusion zone in two conflicting ways within the same sentence. They state, in part, that they excluded “those accidents and billboards on interchanges (entrances/exits) within one mile (1/4 mile on each side of an interchange)” (p. 78). Regardless of whether they actually excluded accidents within ½, 1, or 2 miles from interchanges, any resulting findings are confounded by the fact that at least three of the seven billboards chosen for study (#3, Figure 2-8; #4, Figure 2-10; #7, Figure 2-16) appear, from photographs, to be in close proximity to interchanges. Thus, given that some percentage of accidents in the vicinity of these DBBs was excluded due to the signs’ proximity to the nearby interchanges, this artificially lowers the true number of crashes that may have been contributed by driver distraction due to these DBBs. As a result, the data for “bias adjusted” crashes in Tables 4-7 through 4-10, and in Figures 4-11 through 4-17 must be questioned.

Figure 1 below, taken from the ClearChannelOutdoor website, shows the researchers’ Billboard Number 3 and its proximity to an I-90 interchange. As discussed above, Billboards 4 and 7 are also close to interchanges. This leads to the rhetorical question – if accidents in the vicinity of interchanges are excluded due to “interchange bias,” and if DBBs are very close to interchanges, how can one capture and analyze accidents that occur close to the billboard? (Note that the authors provide no information about the proximity of any of the DBBs studied to the nearest interchange).

Figure 1. Proximity of DBB #3 to an interchange. This same DBB is shown in Figure 2-8, p. 16, of the Tantala study. It is also Site # 22 from the Lee, et al (2007) study, discussed in detail below.
(Source: http://www.clearchanneloutdoor.com/products/digital/don/cleveland/index.htm)

Decades of research into driver distraction has shown that alert, experienced drivers can tolerate some distraction when their task demands are not high, but that all drivers have upper limits on their cognitive capacities, and that there are certain road, traffic, and environmental conditions that may increase cognitive demands to the extent that additional sources of distraction should be avoided. Thus, the exclusion from analysis of some of the very types of crashes that might be *expected* to occur in the vicinity of DBBs is troubling, and, as with the decision to artificially truncate the data collection in road sections upstream of DBBs, results in a likely substantial understatement of the actual crash statistics that took place in road sections where drivers were able to observe these DBBs. Taken together, the choice of crash types to exclude is a serious weakness of this study, given that some of the very kinds of crashes excluded are those that would be of direct relevance to the potential for distraction caused by billboards.

In summary, the authors' decision to exclude from study crashes that may have been affected by certain "biases" is critically flawed because it overlooks a basic understanding of traffic crashes – that they are frequently multi-causal – and it is precisely when such multiple factors are at play – adverse weather, older drivers, complex interchanges, speeding - that cognitive demands on the driver are increased and that irrelevant distraction cannot be tolerated. In other words, one should not exclude such factors because they cause "bias" – these are exactly the factors that interact to increase the likelihood of a crash when other factors such as inattention or distraction are present, and they must be investigated.

Inappropriate Statistical Methods, Assumptions, Analyses.

A key concern, raised by peer reviewers, about the findings of this study is that because of the limited before-and-after data collection periods (24 months) the sample sizes obtained are too small to conduct a meaningful statistical analysis. In addition to this concern, however, there remain others about the appropriateness of the research methods used and the results reported.

The analysis performed in this study is based on what the authors call "commonly accepted scenarios relating accident density to billboard density, to 'viewer reaction distance,' and to billboard proximity (how far the accident is from the nearest billboard)." But none of these terms is defined, no references to prior research are provided, and the conceptual drawing used to explain these assumptions in Figure 4-1 (p. 46) provides nothing more than a visual illustration of the authors' narrative statement. Thus, it is not possible for a reader to form an independent opinion of what was actually done, what assumptions were made, and how the data was collected and analyzed.

There are numerous examples of the erroneous use of statistics, both in terms of assumptions made, errors in application, and misuse of findings.

For example, the researchers define annual average daily traffic (AADT) as "the total volume of traffic in both directions of a highway or a road for one year divided by 365 days" (p. 33). But in their calculation of accident rates at "digital-billboard locations" (a term that they do not define), they fail to account for the fact that the seven DBBs studied were single-sided (i.e. they faced only one direction of travel). Thus, the authors have overstated the actual AADT by a factor of two, and the actual accident rate is therefore twice as high as reported.

In a section of the report titled "Accident Density and Billboard Density," it is clear that the researchers have inappropriately commingled DBBs with traditional billboards along the route. By including all billboards in their metric for billboard density, they nullify both their ability to compare digital with conventional billboards, as well as their opportunity to compare digital billboards with the absence of billboards (an expressly stated objective of the study). This weakness is exacerbated because of their failure to control for the roadside environment (geometry, interchanges, presence of other objects in the roadside environment that might attract a driver's attention, etc.) in areas where billboards were present from those where they were not. For these reasons their statement that: "If a noticeable correlation between billboards and accidents exists, then one would expect a significantly larger number of accidents in areas with relatively high billboards densities" (p. 78) is unsupportable.

As part of their statistical treatment of the data, the authors invent meaningless terms such as "noticeable correlation" (p. 78). Further, despite their correct understanding that correlation does not imply causation, they suggest otherwise on several occasions (see, for example, pp. 2, 98). Further, they inappropriately suggest that no correlation less than 1.00 is indicative of any relationship. For example, they state: "Statistically, a correlation coefficient of 0.7 or smaller is considered to indicate 'weak' correlation, at best, and does not indicate much difference from correlation coefficients of zero" (p. 81). Quite to the contrary, results from traffic safety research in the real world would typically consider correlation coefficients of 0.7 to be quite high.

The researchers undertook both a "spatial analysis," discussed above, and a "temporal analysis" to examine the incidence of crashes at locations where billboards had undergone conversion from traditional (fixed) to digital display. Data was collected for 18 and 24 months prior to, and after, the conversion. Although this before-and-after analysis is a necessary component of such an analysis, it is not sufficient. There is, in fact, an essential weakness to the temporal analysis performed in this study. That is that the researchers failed to compare the data at the billboard conversion sites to data at comparable locations at which there were either no billboards present, or billboards that were present but not converted to digital. It is possible that crash rates remained essentially the same in road sections featuring converted billboards (as these authors reported), but actually decreased in sections that included non-converted billboards, or at non-billboard locations, during the same before-and-after study period. This very result has been found in an earlier study of a single digital billboard near Boston (Massachusetts Outdoor Advertising Board, 1976), and led directly to the order that the sign be removed.

This failure of the temporal analysis underlies the authors' inability to answer the question that they posed early in the report: "…what is the statistical relationship between digital billboards and traffic safety?" (p. 4). This question is the one that should have guided this research. However, the next sentence, also posed in the form of a question, asks: "Are accidents more, less, or equally likely to occur near digital billboards compared to conventional billboards?" Unfortunately, it was this second question that guided the research, not the first. In other words, this study was not designed to investigate the potential impact on crashes of digital billboards compared to the *absence* of billboards; rather, it made the unjustified and unstated assumption that conventional billboards were the acceptable baseline for comparison with DBBs. As a result of this assumption, the research methodology did not include true comparison sites where billboards were absent, and thus any assessment of the contribution to crashes from DBBs against a true baseline were impossible.

The announcement of the availability of this report on the website of the OAAA stated that this study “offers conclusive evidence that traffic accidents are no more likely to happen in the presence of digital billboards than in their absence.” Clearly, since the researchers made no comparisons between crashes in the presence and absence of DBBs, this claim is unsupportable.

Oversights, Omissions, and Evidence of Bias.

As discussed above, the metrics that the authors used to define the roadway sections for which accident report summaries were analyzed were called "viewer reaction distance" and "viewer reaction time". Obviously, each of these values is determined, in part, on the posted speed limit or on prevailing speeds. The authors claim that they used speed limit as their determinant, and that the posted limit was 65 MPH in all cases (p. 79). But this is incorrect. Figure 2 below clearly shows the posted Speed Limit to be 60 MPH. Although the reader cannot know whether this speed was in effect at all of the studied sites, it was clearly the case for DBB #4. The significance of this error would differ for each site, depending upon the sight distance for drivers approaching the billboard in question. At 60 MPH, a driver approaching a DBB will be able to see and read the billboard for a longer period of time than would be the case at 65 MPH, thus requiring data to be collected and analyzed for a longer roadway section upstream of the billboard, and far longer than any section that the authors chose to use. In other words, possible driver distraction from a DBB might well have occurred earlier than the authors reported, and, as a result, possible distraction-related crashes were artificially excluded from the database.

Figure 2. Image showing DBB #4 adjacent to posted Speed Limit signs. This image shows the same DBB depicted in Figure 2-10, p. 17 of the Tantala study. Interchange signs can clearly be seen, as can an additional billboard in the driver's view. This is the same sign represented as Site No. 42 in the Lee, et al. report discussed below. (Source: http://www.clearchanneloutdoor.com/products/digital/don/cleveland/index.htm)

The authors fill their report with information irrelevant to the study, while ignoring information of interest. For example, on pages 23-27 and in Tables 3-1 and 3-2, they describe in detail the total number of miles of interstate highways in the state and county, the terminus of each roadway, and the base and surface type of all pavements. On pages 29-31, they provide cursory information about the location of each of the studied billboards – again providing data on road surface and previous state work projects, and repeating, verbatim, information already presented on pages 10-11. However, no information is given about relevant concerns such as horizontal and vertical curvature, merges or lane drops, presence of official signage, proximity of DBBs to interchanges, multiple billboards within a driver's line of sight simultaneously, or intersection characteristics such as entrances, exits, gores, etc., either for the system as a whole or within the vicinity of the studied DBBs.

Bias is evident throughout the report. For example, the authors' state that their numbering system for the billboards studied was "arbitrary" (p. 10), but a review of the website of the billboard owner, ClearChannelOutdoor, shows that this information was supplied by them. Several figures and tables in the report are taken directly from the ClearChannel website, and a ClearChannel executive was quoted as saying that his company had "hired" the researchers to perform the study (Slobodzian, 2007).

It is typical in a research study such as this for the authors to identify prior research and other sources that have informed their assumptions, methods, and conclusions. However, despite listing 17 references, none are actually cited in the text. In addition, references made within the report of prior research are not accompanied by citations; thus it is not possible for the reader to verify the basis of the authors' claims.

Author Response.

One of the two authors of the paper, in a letter sent to the Director of Right-of-Way for the Texas Department of Transportation (Tantala, 2007) responded to the previous Wachtel (2007) review and took issue with a number of statements made in that review. This section discusses the Tantala response, and our conclusions based on a review of the response and a resultant re-review of the paper and our comments to it.

The Tantala letter takes issue with two major criticisms that were included in the Wachtel report (and are discussed in detail above). First, Tantala argues that the Wachtel criticism of the report's exclusion of accident analyses beyond the VRD (approximately 0.2 miles upstream of the DBBs at 65 mi/hr) "misrepresents our analysis, because we did not exclude larger ranges. In fact, our analysis compiled statistics for a <u>wide range</u> of vicinities" (p. 1). A review of the Tantala letter and a re-review of the original report reinforce our original criticism. The key phrase in the Tantala letter is: "…we examined accident data and statistics…" While that may be true, any such data and statistics were not analyzed, and no supportable conclusions could be drawn from them. Indeed, the Tantala letter refers the reader to two report Tables (2-3 and 4-11) and two Figures (4-24 and 4-25) in support of his arguments. Our re-review of Table 2-3 (p. 11) confirms that this table merely identifies the "visible range" for each of the seven DBBs. Table 4-11 (p. 84) shows "correlation coefficients of various comparisons," and the one of relevance here, accident density vs. VRD, simply reaffirms our criticism. Finally, the two cited figures (pp. 90, 91) present nothing more than summary statistics (raw accident counts) without analysis.

The second point made in the Wachtel review with which Tantala takes issue is that "the review opines that our analyses should not exclude 'bias' factors because accidents are often multi-causal and those are the very factors that increase the likelihood of accidents" (p. 2). Tantala expresses his agreement with Wachtel's opinion, and states "we did include this in part of our study. In fact, we performed an analysis that included <u>all</u> data collected and compiled by the State of Ohio…. This robust, comprehensive and all-inclusive data-set includes the very multi-causal accidents that the review references" (p. 2)." But the Tantala letter provides no link or reference to any pages, tables, or figures in the report where a reader might find these all-inclusive analyses (those in which the stated biases were included in the analyses). Indeed, our re-review of the paper, undertaken as a result of the Tantala letter, finds no such analyses. In fact, only Table 4-5 (p. 54) addresses the all-inclusive vs. bias-adjusted accidents, and it merely presents the summary statistics of raw accident counts and accident rates with no accompanying analysis. In contrast, after stating: “A more fair and unbiased comparison of accident data would exclude accidents from known causes” (p. 63), the report presents a series of four tables (4-7 through 4-10) and seven figures (4-11 through 4-17) that present “the number of accidents with statistical bias events excluded within the visible range” (p. 63). If there was any comparable presentation of the all-inclusive data within the report, this reviewer could not find it.

In summary, Tantalus’s letter defending the study against Wachtel’s criticisms does nothing to challenge the points made in the review and, as a result, reinforces the original concerns raised by Wachtel.

Lee, McElheny, & Gibbons (2007).

As is the case for the Tantala and Tantala study discussed above, this study was performed for the Foundation for Outdoor Advertising Research and Education (FOARE), an arm of the Outdoor Advertising Association of America (OAAA). It, too, has been previously reviewed (Wachtel, 2007), and the complete report can be accessed at: http://www.sha.state.md.us/UpdatesForPropertyOwners/oots/outdoorSigns/FINALREPORT10-18-GJA-JW.pdf . Below we will review the major reported findings of the Lee, et al., study, and discuss our principal concerns about the efficacy of this work.

The approach to this study was completely different from that of Tantala and Tantala, although the two studies used the same DBBs. In this study, an instrumented car was driven along a prescribed route by a volunteer sample of drivers, and some of their driving behaviors and eye glances were recorded as they passed previously identified and defined locations.

Study Overview.

In the main study, 36 participants drove an instrumented vehicle along a pre-determined 50-mile route on surface streets and interstate highways in the Cleveland, Ohio area. During the drive, the participants passed a number of DBBs, conventional billboards, “comparison” and “baseline” sites. In the final 8 sec of their approach to each of these sites or “events,” the direction of their eye glances was recorded, along with their lane keeping and speed maintenance performance. A subset of 12 participants also drove a similar, but shortened, route at night.

Methodological Concerns.

Eye Glance Recording.

Eye movement recording and analysis is a time-proven method for determining where drivers are looking as they drive. Until recently, however, it has not been possible to obtain precise eye glance data (with a precision of 1 deg or better) without the use of highly intrusive, head mounted equipment. The trade-off is to use recording equipment that is mounted on the dashboard or other interior vehicle structure, but the weakness of this less intrusive system is that eye glance information can then be obtained only for more gross directions of gaze. In other words, while it is possible to record the general direction in which a person is looking, it is not possible to know with confidence the exact object (no less an image within that object) being viewed, or the distance from the eye at which that object is located. Because this study employed such vehicle-mounted equipment, the researchers could report only on the general direction of gaze and could not identify if, or when, a participant was looking at a specific object (such as a DBB) in the visual field.

Eye movement recording equipment must be calibrated separately for each participant, and this calibration should be performed both before and after each participant's drive. This is because eyeglance recording equipment can "drift" over time, vehicle vibration during the drive could have changed the mounting position of one or more cameras, or the driver could have adjusted the seat or otherwise shifted his or her position while driving. Unfortunately, the authors calibrated the equipment only after each participant had driven the route, and thus could not know whether the eye glances that they captured were accurate and reliable.

Lack of control over site variables

The authors conducted their on-road studies on "interstate, downtown, and residential road segments" (p. 27). Given that all five DBBs (study sites) were on interstate highways, the decision to include some of the control sites (baseline, conventional billboards, comparison sites) on roads other than interstates confounded the data collection and made meaningful comparisons across sites impossible. When conducting field research, the goal must be to reduce, wherever possible, extraneous sources of variability. In this study, the decision to include study sites (DBBs) on interstates and some control sites (the reader is not told which or how many) on surface streets leads to additional uncontrolled sources of variability. Some of the significant differences between these two types of roadways, any or all of which may have affected the data, are: traffic speeds and flow; illumination levels; sight distances; access control; at grade vs. grade separated intersections; presence or absence of traffic signals; and divided vs. undivided traffic.

Even for the five DBBs that were the principal focus of this research, the authors seem to have made no attempt to identify, no less control, extraneous variables such as traffic speeds and volume, horizontal and vertical curvature, or other roadway and traffic characteristics that might have interacted with the variables of interest. Further, the distance between adjacent study sites was often very short. For example, using the Haversine formula, we calculated the distance between Site 37, a DBB, and Site 36, a baseline site, as less than 1.2km. Other studied sites might have been even closer to one another. Thus it is likely that the visibility ranges for adjacent sites overlapped, confounding eye gaze and vehicle performance measurements and comparisons.

The researchers selected some study sites on the right side of the road and some on the left, then recorded and analyzed whether drivers glanced in the direction of these sites as they approached and passed them. In some cases they found examples of participants looking in the direction opposite to the site being studied. When such behavior occurred in the presence of billboard sites, they interpreted this to mean that the billboard did not draw the driver's attention. But there is no evidence to suggest that they sought to identify or control for the possible presence of billboards or other attention-getting targets that may have existed opposite from their study sites or otherwise within the driver's field of view simultaneously. In other words, when they selected a study site on the right, there is no indication that they made sure that there was nothing on the left that might capture the driver's attention. If, in fact, they did not identify and control for such opposing sites, then the eye glance data that they captured are suspect. Since they do not report any efforts to evaluate and control for such conditions, one must assume that they did not do so. In short, it is entirely possible that glances to the left when a billboard was on the right (or conversely) were made because there was a competing, perhaps more compelling, site across the road from the study site that was neither controlled nor evaluated. Figure 1, for example, shows the DBB that served as Site # 22 on the right side of the road[11]. But the figure also shows a large billboard on the left side of the road that appears in the center of the image. If the researchers captured eye glances straight ahead or to the left at this location, they might have been due to the participant looking at this uncontrolled billboard. A similar concern exists for uncontrolled sites that might exist on the same side of the road as a site of interest and within a driver's field of view as he or she approached that site. Given the lack of precision of the eye gaze data obtained, there was no way for the researchers to know whether a particular participant was looking at the study site or an unidentified site visible simultaneously for which they did not control.

Although the five DBBs studied were all of the same size, the reader is given little information about other important characteristics of these signs; characteristics that could have had a direct impact on their attention-getting qualities, such as their height, angle to the drivers' line of sight, and proximity to the road. Further, the reader is told little about roadway geometry, prevailing traffic speeds and volume, etc. Any of these factors may have affected the comparability of sites. Even though all five DBBs were 14' high and 48' wide, they were mounted at very different heights relative to the road surface. Further, there was no consistency of sizing of conventional billboards or signs on the comparison sites. Indeed, the researchers state that conventional billboards included a "few" that were of other sizes, including "standard poster, junior paint, and 10'6" x 36' bulletins" (p. 21). Since the size of a billboard or other sign, and thus the size of the characters that can be displayed on it, likely has a direct relationship to the distance from which it can be seen and read, this failure to control for sign size and other characteristics relative to a sign's visibility and legibility range is an important oversight. In our opinion, without any effort to control these basic site and sign characteristics, it is difficult for the researchers to defend any interpretations they may have made from their data in comparing driver responses to DBBs against responses in other locations.

[11] Note – this figure was taken from the ClearChannelOutdoor website – it was not shown in either of the two studies discussed herein although we have confirmed that it is the study location cited in the reports.

Confounding of data collection sites.

The researchers selected four types of "events" or "sites" at which to collect data. For the main (daytime) portion of this study, there were 5 DBB locations, which we have called study sites, and three other types of locations, which we have called control sites. The latter included 15 "conventional billboards," 12 "baseline sites," and 12 "comparison sites." Because the report provides no images or drawings of any of the 44 locations, and because the descriptions and definitions of the site characteristics, particularly for the baseline and comparison sites, are vague and inconsistent, it is not possible for the reader to determine just how these site types compared to one another. For example, at one point, the authors state that baseline sites contained no signs of any kind (p. 6). At another, the reader is told that some baseline sites (the authors do not state how many) in fact, did contain signs. A more serious concern, however, is with the multiple, conflicting definitions and descriptions of the comparison sites. The reader is first told that comparison sites are "similar to items you might encounter in everyday driving" (p. 8). On page 21, these sites are described as "areas with visual elements other than billboards." Later on the same page the reader is told that some of these sites included on-premise signs, variable message signs, and "digital components." Finally, Table 2 (p. 22) describes one comparison site as a "tri-vision billboard" and three others as "on premise LED billboard(s)." To the average motorist, and from the perspective of driver distraction potential, the distinction between an on-premise and an off-premise digital sign display is meaningless. One must conclude that at least some of the comparison sites may have been just as visually compelling and distracting, if not more so, than the DBB sites that were the principle focus of the study. Clearly, this intentional confounding of study and control sites (the researchers selected each of the sites to study) would artificially reduce any adverse findings from DBBs by showing them to be no worse than existing sources of distraction present at the comparison sites.

As expected, the study's findings bear out this concern in that, for many measures, the DBB and comparison sites elicited similar results, and these results differed, often significantly, from those obtained at conventional billboard or baseline sites. The problem for the researchers is how to treat these findings given their *a priori* inappropriate site selection decisions; the problem for the reader is how to interpret them. In our opinion the approach adopted by the researchers is seriously flawed. It takes the clear evidence found in this study that roadside digital advertisements (whether on- or off-premise) are associated with adverse driver performance, and manipulates this evidence to suggest that there is no problem with digital billboards because drivers are equally distracted by other "comparison" sites. In short, the authors' false assumption that their chosen comparison sites were appropriate control locations against which to compare the effects of DBBs enables them to slant their findings to suggest that, because driver performance in the presence of digital billboards is similar to their performance in the presence of these equally distracting "comparison" sites, there is no cause for concern about the safety of DBBs. We believe that the data suggests otherwise, as discussed below.

The choice of an 8-second data recording interval.

The researchers chose a time period of 8-sec in advance (upstream) of each site during which to record driver performance and eye glances. This data recording period ended when the instrumented vehicle passed each event. The assumption that 8 sec was a reasonable data capture interval, and the researchers' ability to define and measure this interval, raises several methodological concerns.

At 65 mi/hr, the presumed speed on the freeways studied, a vehicle travels approximately 95 ft/sec. Thus, during an 8-second interval, a vehicle will travel 760 ft. The accepted practice for highway signs is that 1 in of letter height can be read from approximately 40 ft. So, for a billboard with 24 in high characters, the sign can be read from approximately 960 ft. Indeed, several of the billboards used in this study likely included characters much larger than 24 in and thus could be read at even greater distances (given clear sight lines upon approach). Figure 3, enlarged from Figure 2-4 (p. 13) of the Tantala and Tantala study, depicts characters approximately 84 in high (the DBB face is 14 ft tall). These characters are theoretically legible (no less visible) from a distance of 3,360 ft. At 65 mph, this sign could be read for approximately 35 sec, more than four times the data collection interval used in this study. In addition, because of the brightness, contrast, and image quality of digital billboards, and the fact that (in Cleveland) their messages change every 8-seconds, it is apparent that driver attention to the billboard may be initially attracted at far greater distances than those at which the message can actually be read. As a result, the choice of an 8-sec data recording interval is likely to result in a substantial understatement of the distracting effects of digital billboards compared to other roadside sites including more traditional billboards and on-premise signs.

Figure 3. An enlargement of the DBB that served in both the Tantala & Tantala and Lee, et al. studies. Scaled measurement shows the numerals to be approximately 84 in. high.

The authors state that they chose an 8-sec data collection period because the "digital billboards were programmed to change messages instantaneously once every 8 seconds; an event length of 8 seconds thus made it highly likely that a message change would be captured during the event" (p. 21). This argument is flawed for several reasons. First, as described above, the sight distance and legibility distance, coupled with the size of the signs studied and their character height, demonstrates that digital billboards can be seen and read far earlier than 8 sec in advance of the sign, thus suggesting that the data recording interval should have been much longer. Second, had the researchers selected *any* data recording interval longer than 8 sec, it, too, would have permitted them to capture a message change during each driver's approach to the event. Finally, despite their understanding of the potential importance of a driver observing a message change during his or her approach to the DBB, the researchers never actually reviewed or analyzed any data related to this message change, and therefore had no way to evaluate any possible driver response to it.

Some signs are located perpendicular to the driver's direction of travel. Others, such as some two-sided billboards and many on-premise signs, may be located at other angles, including parallel to the driver's direction of travel (such as when mounted on a building façade). In addition, the lateral distance of each sign from the driver's line of sight varies greatly as a result of factors such as: lateral distance from the road edge, and the number and width of lanes, medians, and shoulders. If the same 8-sec point for passing a sign was applied regardless of sign angle and lateral distance, then some signs would be visible to drivers for less time than others, thus rendering the 8-sec recording interval inconsistent across the studied sites.

In summary, the researchers' choice of an 8-sec data recording interval was inappropriate for several reasons, and resulted in unequal exposure to signs of interest across sites. A more appropriate way to determine the data collection interval would have been to identify the point at which a billboard or other sign of interest fell outside a predetermined angle of view from the driver's line of sight along the road axis, and to define the data recording interval upstream from that point. This would have assured a more equitable, and comparable, identification of sight distance and would not have had the effect of artificially reducing the available glance times and control measurements made for the signs of interest in this study.

Measurement of nighttime luminance levels.

The authors measured the luminance levels of different sites at night. They took these measurements from the participant-driver's eye position, a decision which masked and minimized the actual brightness differences between the DBBs and the other sites. A more appropriate comparison would have been from measurements taken directly in front of each of the signs of interest (as recommended in, for example, TERS, 2002; NYDOT 2008a) so that the authors could be sure that they were comparing sign against sign without the contribution of the general ambient environment. Several other weaknesses affected this measurement approach. First, taking measurements from the driver's position would have yielded non-comparable readings even if every sign had the same luminance, merely because the signs were positioned at different angles to the driver, and were located at different horizontal and vertical distances from the driver's eye. Second, the authors do not state whether some of the (non-DBB) sites measured at night were those on surface streets and whether there were fixed luminaires within the range of the luminance meter at such sites. The presence of fixed lighting would also have reduced the actual luminance differences between DBBs and other sign sites. Third, since the DBB displays changed every 8 sec, the luminance levels on these signs changed accordingly. Thus, unless the researchers measured each DBB with the identical display (highly unlikely), they would have no way to compare the light output of the different DBBs. They would not know, for example, whether measured differences between DBBs were due to actual sign output, different brightness settings, or differences between displayed messages. Despite these limitations in measurement strategy, however, and despite the fact that the digital billboards were automatically dimmed at night, the authors recorded nighttime luminance levels at the driver's eye position that were, on average, 10 times greater for the DBBs than for baseline sites, approximately 3 times brighter than sites with conventional billboards, and approximately 2.5 times brighter than comparison sites. The authors' state: "this probably explains some of the driver performance findings in the presence of the digital billboards" (p. 68).

Inappropriate and Inconsistent Statistical Treatment.

Eye glance recording and long duration eye glances.

One of the greatest weaknesses of this study is the authors' failure to follow their own recommendations as expressed in their review of the work by Wierwille (1993), Horrey and Wickens (2006), and the "100 car study," (Dingus, et al., 2006). This error is compounded by their questionable decision to analyze and present only selected data that they collected, choosing not to report their own findings that might have undermined their conclusions. These actions require some explanation.

The authors collected and recorded four types of eye glance behavior at each of the four types of sites: glance frequency, glance duration, average duration per glance, and total eyes-off-road time. Of these four measures, those that deal with the duration of eye glances off the road are of the greatest relevance because long duration eye glances at distracting stimuli have been implicated as predictive of crash risk in several prior studies, including those by Wierwille (1993), Smiley, et al., (2005), Horrey and Wickens (2006), and Klauer, et al., (2006a). Lee and her colleagues are clearly aware of this work, as they state as early as the study abstract: "Various researchers have proposed that glance lengths of 1.6 seconds, 2.0 seconds, and longer may pose a safety hazard" (p. 6). The authors follow this statement with an overview of their own results, in which they claim to have found no pattern of longer glances to the digital billboard sites: "An examination of longer individual glances showed no differences in distribution of longer glances between the four event types" (p. 6); and: "An analysis of glances lasting longer than 1.6 seconds showed no obvious differences in the distribution of these longer glances across event types" (p. 9). These two statements are misleading, and wrong, as discussed below.

In their introductory description of eyeglance results (p. 52) the authors list the seven questions that they sought to answer with the eyeglance data collected. The seventh question was: “Are longer glances (longer than 1.6 s) associated more with any of the event types?” This is, of course, a key question, because of recent research that identifies such “longer glances” as being associated with a higher crash risk. After listing the seven questions, Lee and her colleagues present a summary and analysis of their findings relative to each. For six of the seven questions, they performed an analysis of variance (ANOVA) to analyze the data, and they report their tests of statistical significance in both graphical and narrative form (see Figures 17-22, pp. 53-58). It is only for the key Question 7, the one that addresses longer glance durations that the authors apparently performed no such analysis and offered no test of statistical significance (see Figure 23, p. 59). The reader might ask why, but the authors provide no explanation. After restating Wierwille’s recommendation that 1.6s be used as a criterion representing a long glance away from the roadway, and after again explaining that their approach in analyzing this data followed that recommended by Horrey and Wickens, “who suggest analyzing the tails of the distributions whenever eyeglance analysis is performed” (p. 59), Lee and her colleagues failed to perform this analysis. Instead, it appears that they performed nothing more than a visual inspection of the data presented in their Figure 23 (p. 59), the figure that depicts the distribution of glance durations for the four different event types. Perhaps as a result of performing only this visual inspection, they state: “As shown in Figure 23, 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). This statement is wrong, as discussed below.

This failure to report key findings is even more surprising because of the results that the researchers obtained in response to their Questions 5 and 6. These two questions asked whether the “mean single glance time” varied according to the type of event. Question 5 asked this question for events on the left side of the road; Question 6 addressed events on the right side of the road. In both cases, the Lee and her colleagues found that digital billboards and comparison events had statistically longer mean single glance times than did baseline or conventional billboard events ($F_{3,73} = 3.59$, $p = 0.0176$ left, and ($F_{3,77} = 3.73$, 0.0147 right), and that the DBB and comparison sites did not statistically differ from one another. In addition, in an effort to “increase power and verify the above findings” (p. 60) the researchers aggregated the left and right eyeglance data. This combined analysis confirmed with statistical significance ($F_{3,91} = 4.98$, $p = 0.0030$) that “digital billboards and comparison sites did not differ from one another, but each differed from conventional billboards and baseline events” (p. 60).

These findings alone should have led the researchers to statistically evaluate the longest such glances, the tails of the distribution, as they said they would in posing Question 7, and as they did for every other question.. But they did not do so.

Figure 4, below, reproduces the authors’ Figure 23 (p. 59) together with its original caption.

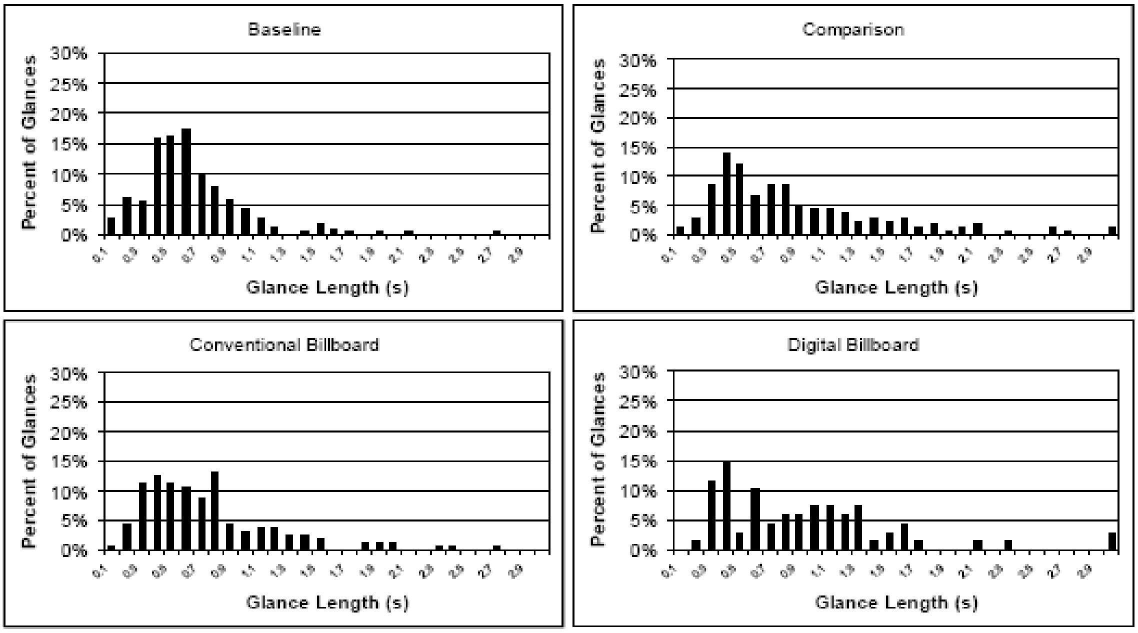

Figure 23. Tails analysis for the distribution of glance duration, (method described in Horrey and Wickens, 2007).

Figure 4. A reproduction, in original size, of the authors' Figure 23 (p. 59), together with its original caption.

The authors do not provide sufficient information about these measured glance durations to permit the reader to perform an independent analysis of their data. However, an inspection of enlargements of these four charts enables a non-statistical independent review of their findings. Using the tails analysis as recommended (but not performed) by the authors (following Horrey and Wickens), and using both 1.6 sec (the Wierwille criterion) and 2.0 sec (the 100-car study cut-point), we find the following:

> Approximately 5.5% of baseline sites and 7.5% of conventional billboard sites captured glances of 1.6 sec or longer compared to 13% of DBBs and 16% of comparison sites.
>
> Approximately 2% of baseline sites and 4.5% of conventional billboard sites captured glances of 2.0 sec or longer, compared to 7% of DBBs and 8% of comparison sites.
>
> No glances longer than 3.0 sec were made to either the baseline or conventional sites, but glances of 3.0 sec or longer were made to both DBBs and comparison sites.

In summary, this visual inspection of the researchers' data suggests that long glances occur two-to-three times more often with DBBs and comparison sites than they do with baseline or conventional sites, and that the longest glances (3.0 sec or longer) occur *only* with these sites. These results suggest important differences for the longest glances, the ones that highway safety experts are most concerned with. One must ask why the authors chose not to perform a statistical analysis of this data, particularly when they did so for every other set of eyeglance data, and why they reported that their visual inspection of these data suggested that there was “no obvious pattern of longer glances being associated with any of the event types” (p. 59). The report offers no explanation.

Misleading and Inconsistent Reporting and Evidence of Bias.

Throughout the report, there are conflicting and inconsistent statements, and evidence of bias.

Was this a “naturalistic” study?

Although described by the authors as a “naturalistic study,” and modeled superficially upon the much larger, 100-car study performed at the same institution – (Dingus, et al, 2006; Klauer, et al. 2006a,b), this study exhibits few of the characteristics of a true naturalistic study (Hanowski, 2009).

Although they used an instrumented vehicle with on-board cameras, and although their participants drove the route without a researcher present in the vehicle, this study differs significantly from the 100 car study in several key ways. First, the four on-board cameras used to record views of the road and of the drivers’ glances were not unobtrusive as they were in the 100 car study. Rather, they were prominently located on the driver’s side A-pillar and adjacent to the rear view mirror. These camera locations are shown in Figures 8-10 of the report (pp. 32-33). Second, the duration of the present study was less than two hours per participant, whereas, in the 100 car study, participants kept their instrumented vehicles in their possession and used them daily for several months. Third, participants in the present study had to follow a prescribed route (to ensure that they would pass the DBBs and other events that were the subject of the study), using a set of printed instructions taped to the dashboard, whereas in the 100 car study, participants were free to drive when and where they chose in the course of performing their daily activities. In short, whereas the participants in the 100 car study may well have become acclimated to their test vehicles over time and ignored the fact that they were participating in a research study, the participants in the current study were fully aware that their performance and behavior was being monitored and recorded – thus their behavior could not reasonably be described as “naturalistic.”

Literature Review.

The authors’ approach to their literature review is illustrative of the bias shown throughout the report. There is a long history of published literature examining the relationship of roadside billboards to crashes and to driver behavior. Relevant studies dating as far back as 1934 have been identified and reviewed by others; and research continues to be conducted and reported to the present day. The authors chose to discuss only a small, highly selective subset of these studies. As will be seen below, it is clear that the studies reported, particularly the early work in this field, were selected because they were supportive of the authors’ position. When they cite studies that reported findings at odds with their position, the authors dismiss them as poorly done or irrelevant;

conversely, studies that report findings consonant with these authors' views are praised with descriptors such as "rigorous."

Their reporting about two early epidemiological studies is illustrative of their approach to the literature. The authors cite an article by Rykken (1951), a two-page interim progress report on a roadside study conducted in Minnesota. They quote from Rykken: "…no apparent relationship was found between accident occurrence and advertising sign type or location" (p. 12). What they fail to say, however, is that Rykken called his result "a very preliminary study of approximately 170 mi. of the 500 mi. study segment (p. 42). Significantly, Lee, et al. fail to cite the final report of the subject study (Minnesota Department of Highways, 1951) which concluded, in part: "An increase in the number of advertising signs per mile will be accompanied by a corresponding increase in accident rate" (p. 31), and "intersections at which four or more (advertising) signs were located had an average accident rate of approximately three times that for intersections having no such signs." This final report has been extensively cited and reviewed by previous researchers. Wachtel and Netherton (1980), in particular, discussed it at length. It is puzzling, therefore, why these authors cited the interim progress report and ignored the final document.

Lee and her colleagues followed the same approach in their review of a parallel study conducted in Michigan. They cite an interim study report by McMonagle (1951) that looked at only partial findings (p. 12), and ignored the study's final report (Michigan State Highway Department, 1952) which found that illuminated advertising signs showed "an appreciable association with accident locations" (p. 6).

In a confusing discussion about a study by Rusch (1951) which analyzed crash reports on Federal and State highways in Iowa, the authors fail to report on Rusch's own published results, and offer no evaluation of his actual study. Instead, they cite a brief review by Andreassen (1985) (ignoring all other published reviews of the Rusch work) which stated, in part: "the greatest number of inattention accidents occurred on the sections where business and advertising predominated as the roadside property usage, but this does not prove anything about the effect of advertising signs on accident occurrence" (p. 13). Given that Rusch's actual findings, despite methodological weaknesses that often affected these early field studies, demonstrated that the number of accidents was more than double in the study section (where 90 percent of the businesses and roadside advertising signs were located) than in either of the two control sections, given that "inattention" accidents predominated over both "business" and "other" accident categories in this study section, and given that the results were confirmed after statistical correction for mileage per segment, the researchers' treatment of this study is puzzling.

Obfuscation of Study Purpose and Intentional Confounding of Study Sites

The stated purpose of this study was to "assess the effects, if any, of digital billboards on driver behavior and performance" (p. 8), *not*, as suggested in the Abstract, to ascertain whether driving performance in the presence of digital billboards was similar to performance in the presence of other, primarily on-premise, digital signs. As discussed above, the researchers clearly found that DBBs *did* have an adverse impact on driving performance, and the fact that this adverse impact was similar to the adverse impact from similarly distracting signs that might have been on- rather than off-premise does not diminish this finding nor make it acceptable. The authors admit that “there are measurable changes in driver performance in the presence of digital billboards” (p. 6), and, as demonstrated in the body of their report, these changes are adverse and statistically significant. It is inappropriate to suggest that such adverse impacts are deemed acceptable (or “safety neutral” in the authors’ coinage) merely because they “are on a par” with the adverse effects of other digital signs that happen to be other than billboards because they may be located on the premises of roadside businesses.

Baseline sites should have been, as stated in the abstract, “sites with no signs.” But, as described elsewhere in the report, an unidentified number of them *did* contain signs, thus diminishing their potential to serve as true control sites and, likely, minimizing the differences in glance behavior between DBBs and true baseline sites.

In direct conflict with a statement in the Abstract, and as discussed in detail above, longer individual glance patterns (greater than 1.6 and 2.0 seconds) *did* show differences (actually, rather dramatic differences) between the event types. In fact, per the authors’ own statements elsewhere in the report, and as shown by several other researchers, these differences at the tails of the distributions for glance duration may be critically important in assessing the true impact of digital billboards on driver performance and behavior. Similar misstatements are made throughout the Executive Summary, and will not be repeated here. However, the expressed “finding” that: “An analysis of glances lasting longer than 1.6 seconds indicated that these longer glances were distributed evenly across the digital billboards, conventional billboards, comparison events, and baseline events during the daytime” (p. 7) is clearly inaccurate. Critically, the data discussed in this “finding” was not analyzed by the researchers in accordance with their own data analysis recommendations, nor was such data even collected for the abbreviated nighttime study, when we would have expected such findings to be even more dramatic than they were in the daytime study.

The authors identified five DBBs for study. These are identified by latitude, longitude, route number, and side of road in Table 2 (p. 22), and shown graphically on a map in Figure 2 (p. 23). With this information, that reader can view images of these DBBs from either the Tantala report or from the website of ClearChannelOutdoor, at http://www.clearchanneloutdoor.com/products/digital/don/cleveland/index.htm . Examination of Figures 1 and 2 in our report may lead the reader to question the accuracy of the authors’ statement that: “The Cleveland digital billboards…were located off to the side of the roadway in straight-away sections of interstate with no interference from hills, curves, or intersections” (p. 19).

The authors provide voluminous data for irrelevant issues (e.g. 124,740 video frames analyzed, 96,228 data points collected, 8,678 eye glances identified, etc.) but offer no information useful to readers who might want to know what was actually studied. For example, there are no images of any of the billboards or other sites studied, there is no indication of the precision with which eye gaze was captured, etc.). It appears as if the researchers intended to overwhelm the reader with useless information in an attempt to avoid questions about the real issues.

There are numerous statements throughout the report that, on the one hand, are irrelevant to the study, and, on the other, demonstrate a clear pro-billboard attitude. Some examples:

> "The lead author of this report recently participated on an expert panel charged with providing recommendations for a minimal data set to be included on police accident reports; billboard were never raised as a possible distraction…" (p. 11).

> "After a long gap in research, there were a few additional studies in the 1960's through the 1980's, none of which demonstrated that billboards were unsafe." (p. 11)

> "The national crash databases do not mention billboards in their list of driver distractions." (p. 14)

Findings that DBBs are "Safety Neutral."

The authors invented the term *safety neutral* (p. 10) to describe their conclusions about the impact of DBBs on driver distraction and performance. They state: "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-premise signs located at businesses" (p. 6). In other words, the authors say, because other roadside distractions such as their "comparison sites" (which, they note elsewhere, contained multiple signs, changeable message signs, and digital, flashing, and video displays) are also associated with difficulties in speed and lane maintenance and excessively long glances away from the forward roadway, DBBs should be considered *safety neutral* because their adverse effects on driver performance are similar to the effects from these other digital advertising signs..

The authors are able to reach this conclusion because of their intentional confounding of the DBB and comparison sites. The intentionality of this confound is demonstrated by the fact that the researchers had complete freedom to select the (50-mile long) study route and to choose the test sites anywhere along that route. That they chose "comparison sites" which often included digital signs, changeable message signs, and flashing and video signs, made it highly likely, even prior to data collection, that they would find similar results from these "control" sites and from the DBB sites, and that they would thus be unable to demonstrate whether the DBBs were more or less distracting to their participant drivers.

As expected, the researchers found quite similar driver performance and behaviors at these two types of sites, and these performance and behavior variables differed, in the critical area of eyeglance behaviors, from the two other types of sites studied (conventional billboards and baseline sites). The clear lesson, had the researchers chosen to accept it, was that sites containing digital imagery with changing messages (whether on- or off-premise) were more demanding and more distracting than sites devoid of such sign characteristics. Yet, the authors took this obvious conclusion and twisted it in favor of their biases by reporting that DBBs were "safety neutral" because the adverse, and potentially unsafe, driver behaviors that they observed at such sites were generally similar to the behaviors that they observed at the comparison sites. This conclusion, accompanied by the authors' contrived term "safety neutral" seems to reflect obvious bias, and flies in the face of efforts to promote highway safety by reducing, not increasing, the number of irrelevant, distracting, roadside stimuli.

Correlation and causation.

Throughout the report, the authors confuse the terms *correlation* and *causation.* Although it is clear that they understand the important differences between these two types of statistical analysis, they often slip into the erroneous mode of citing a study whose sole purpose was to measure correlation, and criticize that study because it failed to prove causation. These fallacious comments are in line with a long tradition in the outdoor advertising industry of suggesting that there can be no relationship between billboards and traffic safety because billboards have never been shown to *cause* accidents.

Nighttime data collection.

Digital billboards are of particular concern to traffic safety experts at night, due to their ability to achieve high brightness and contrast levels, their high resolution imagery, and their visually compelling message changes, all of which can act to capture the attention of the driver at the expense of other targets in the visual scene (such as official signs and signals, pavement markings, and other vehicles). Because of the recent emphasis on the tails of the distribution in research studies and the long-standing practice of road safety considerations for the 85th (or higher) percentile, it is increasingly recommended to researchers that they examine the "high risk" or "worst case" scenarios in their studies, particularly when time, budget, or logistical constraints limit the number of participants. We question, therefore, why Lee and her colleagues chose to perform only a limited night-time study, one which included, *by design*, too few participants to enable the researchers to analyze their data statistically. This decision is particularly troubling because, as might have been hypothesized, the researchers found indications of greater distraction by digital billboards vs. control sites at night. In fact, unlike the daytime study, they found that all four of their eyeglance measures showed that DBBs and comparison sites were more distracting and attention-getting than the conventional billboard and baseline sites (pp. 64-66), and, they believed, at least some of these findings "would show statistical significance" in a larger study (p. 64).

SECTION 4.

HUMAN FACTORS ISSUES

As shown by the diversity of the published literature in this field, concerns about the potential impact of DBBs on road safety are based on a number of human factors concepts and principles. Much of the discussion about human factors issues is captured in the reviews of research and the development of, and recommendations for, guidelines and regulations of DBBs that appear in other Sections of this report. This section presents a brief overview of these key human factors issues.

- *Conspicuity* is often defined as the ability of a stimulus to stand out from its background. Traffic engineers want to ensure that official traffic control devices (signs, signals, and markings) are sufficiently conspicuous, day and night and in all weather conditions, that they communicate their message to the driver unambiguously, reliably, and in a timely manner. But the large size of roadside billboards (typically 14 ft by 48 ft), the placement of some such billboards close to, or directly within, the driver's line of sight, frequently changing messages and images that can appear to be flashing, and extremely high levels of illumination, tend to make such billboards highly conspicuous, particularly at night. As a result, the conspicuity of official traffic control devices and of other visual signals required for safe movement (e.g. vehicle reflectors, brake lights and turn signals as well as the vehicles themselves) may be reduced, with a consequential reduction of safety.

- *Distraction and inattention*. It is important to distinguish between these two terms, which are often confused. 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. Conversely, distraction is a failure of concentration on the driving task that is a direct result of some activity or stimulus that triggers this failure to concentrate. Distraction may be due factors internal to the driver, such as fatigue, medication, illness, alcohol, or a focus on unrelated issues. It may be external to the driver but internal to the vehicle, such as mobile telephone use, adjusting the vehicle's controls or non-safety-related equipment (e.g. radio, navigation system, heating or air conditioning), conversations with passengers, or other non-driving related behaviors such as reading, grooming, or singing. Finally, distraction may be due to factors that are external to the vehicle, including vehicular, pedestrian or bicycle traffic, buildings, scenic vistas, roadside businesses, or advertising signs, including billboards. Whereas it may be impossible to control for the inattention that affects all drivers from time to time, many of the causes of distraction can be controlled.

- *Information processing*. One reason why official traffic control devices are designed as they are is to ensure that they meet certain basic human factors requirements. These requirements are described in the MUTCD, in Section 1A.02, as:

  A. Fulfill a need;
  B. Command attention;
  C. Convey a clear, simple meaning;
  D. Command respect from road users; and
  E. Give adequate time for proper response.

  The MUTCD implicitly recognizes that information contained on official signs will be ineffective, and thus, possibly ignored, if the message demands too much time or effort by the road user to read, understand, and act. To this end, the Manual specifies the language for standardized word messages on signs, prohibits the display of Internet addresses and recommends, for example, the avoidance of phone numbers with more than four characters. The only exceptions to this Standard and its associated guidance are for signs that are intended for viewing only by pedestrians, bicyclists, occupants of parked vehicles, and "drivers of vehicles on low-speed roadways where engineering judgment indicates that drivers can reasonably stop out of the traffic flow to read the message" (p. 2A-2). The requirements and guidance in this section of the Manual also apply specifically to Changeable Message Signs and to logo panels on specific service signs. The demands on a driver's information processing capabilities are addressed in the MUTCD, not only for the content of individual signs, but for the placement and spacing of signs as well. For example, the manual recommends that signs should be located only on the right side of the roadway (with certain exceptions) "where they are easily recognized and understood by road users" (p. 2A-8), and, because of increases in traffic volumes, a priority for sign installation locations should be established. Such a priority suggests that regulatory and warning signs whose location is critical, should be displayed in preference to guide signs where conflicts may occur. Less critical information, such as that on guide signs, should be moved to less critical locations or omitted, because "overloading road users with too much information is not desirable" (p. 2A-11). The Manual also requires that signs requiring different decisions by road users "be spaced sufficiently far apart for the required decisions to be made reasonably safely" (p. 2A-8), and recommends that, with specific exceptions, signs should be individually located on separate posts or mountings. Yet billboards are often placed on the left side of the road, frequently are placed in close proximity to one another, often on the same mounting, are do not generally adhere to good human factors practice that suggests restrictions to the amount of information conveyed on the sign.

- The *Zeigarnik Effect*. In 1927, Russian psychologist Bluma Zeigarnik demonstrated that tasks that have been initiated by humans but, for whatever reason, interrupted before they could be completed, lead to feelings of anxiety and a desire to complete the task. In the years since the original demonstration of what we now call the Zeigarnik Effect, it has been shown that the discomfort related to task interruption has broad implications. For example, it is thought that it is this phenomenon that causes drivers to continue looking at the changing messages on DBBs o learn what comes next; and it is the basis of the technique used in advertising in which a complete message is "sequenced" across several different signs or multiple message changes of a single sign.

- *Brightness and glare*. Brightness is the subjective impression of the luminance of a sign, and glare is a physiological response. The majority of public complaints about DBBs 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. The photograph shown in Figure 5 was taken by the author of a DBB from a distance of six miles. The photograph was taken at 7:52 AM, and has not been altered in any way.

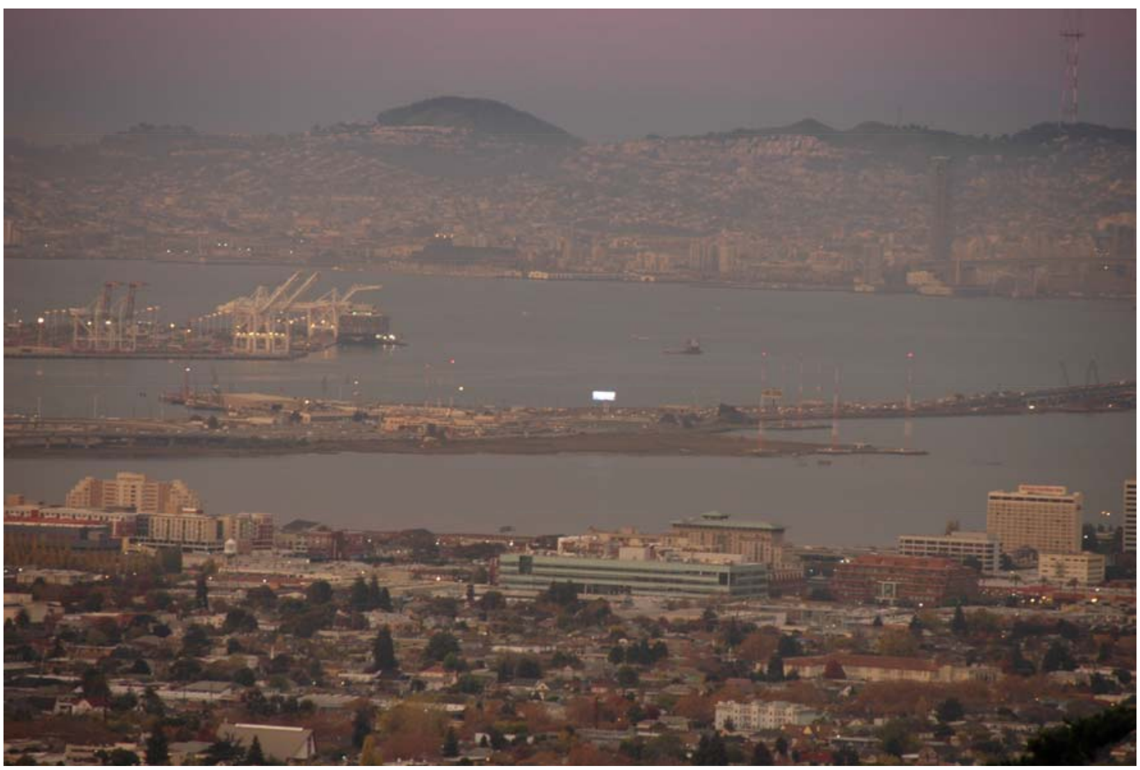

Figure 5. Unaltered photograph of a DBB from a distance of six miles

- *Legibility and readability*. Signs, to efficiently communicate a message, must be legible and readable. Specific design characteristics of official traffic signs such as font, letter size, color and contrast between figure and background, etc., have been specifically selected and mandated after years of empirical testing to be optimized for legibility and readability under all conditions so that they can communicate their messages quickly and unambiguously. As one example among many, the MUTCD suggests that "word messages should be as brief as possible and the lettering should be large enough to provide the necessary legibility distance. A minimum specific ratio, such as 25 mm (1 in) of letter height per 12 m (40 ft) of legibility distance, should be used" (p. 2A-7). Conversely, billboards may display no such properties. Instead, they tend to exploit the same human factors characteristics discussed above to ensure that the signs take more time to read, demand multiple glances to communicate the intended message, etc. Indeed, billboards often mix multiple font designs and sizes, multiple colors of figure as well as background, even text written sideways or upside down on the sign, to achieve an impact that is quite the opposite of that for which official signs strive.

- *Novelty*. In human factors, it is known that a novel stimulus, one that a driver has not encountered previously, is likely to capture attention and lead to a response merely because of its novelty. Hence, when new safety treatments are applied to the roadside environment, the research that is performed to test the effectiveness of such treatments is typically postponed until the "novelty effect" has passed. When traditional, static billboards display the same message to drivers for weeks or months at a time, it is widely believed that drivers begin to ignore the signs. However, DBBs present a new and different image every few seconds, and because such images can be immediately downloaded to such signs from remote locations, the signs have the capability of presenting a unique, novel image and message to a driver every time the sign is approached.

- *Sign Design, Coding, Redundancy*. As discussed above, the key design features of official traffic control devices include size, shape, color, composition, lighting (or retroreflection), contrast, legibility, and simplicity and reasonableness of message. These features are intended to be used, in varying combinations, to draw attention to the devices, to produce a clear meaning, to permit adequate time for response, and to command respect from the road user. TCDs are designed to be uniform, unmistakable, placed and operated uniformly and consistently, and removed if they are unnecessary. "Uniformity of devices simplifies the task of the road user because it aids in recognition and understanding, thereby reducing perception/reaction time" (p. 1A-2). DBBs, on the other hand, follow none of these principles of uniformity or consistency.

- *Visual attention*. Our attention may be drawn to, or captured by, an object such as a billboard either because we make a conscious effort to attend to it ("top down") or because some characteristic of the object (e.g. size, placement, brightness, etc.) captures our attention without volitional intent ("bottom up"). The first type of visual attention is also referred to as "search conspicuity," whereas the second is known as "attention conspicuity." Road and traffic safety experts take advantage of bottom up visual attention capture by: employing unique colors for traffic control devices when challenging conditions are present (e.g. the use of orange for construction and work zones), outfitting emergency response vehicles with flashing lights and sirens, and by using flashing beacons and/or flashing messages on road signs when urgent safety warnings must be communicated. DBBs, 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.[12]

- *Positive Guidance*. Positive Guidance is an analytical tool developed by FHWA in the early 1970s based upon the pioneering work of Alexander and Lunenfeld (1972). The tool is based on the premise that drivers can be given sufficient information about road hazards when and where they need it, and in a form that they can use to enable them to avoid error that might result in a crash. The tool integrates knowledge from both human factors and highway engineering to produce an information system that is matched both to the characteristics of specific roadway locations and the capabilities of drivers. Alexander and Lunenfeld developed operational definitions of the driving task and driver "expectancy," the primacy of needed information and the manner in which that information should be presented, the concept of decision sight distance, and the consequences of system failure. The Positive Guidance tool has been used, nation-wide and internationally, for more than 30 years.

- *The Moth Effect*. Green (2006) reviewed research that suggests that there is a "moth effect" that may cause drivers to not only look in the direction of a bright light source on the side of the road, but inadvertently steer in that direction as well. Perhaps more appropriately seen as a variant of the physiological mechanisms of phototropism or phototaxis, in which the eye is drawn to the brightest objects in the field of view, the moth effect has been described by some as causing crashes as a result of a driver's loss of lane maintenance due to a combination of reduced optic flow and an "intense attentional fixation on a roadside target" (p. 18).

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[12] For more than 25 years, a debate has raged between the outdoor advertising industry and the road and traffic safety community over the issue of whether changeable message billboards present "flashing" messages. Most regulatory documents, throughout the U.S. and abroad, specifically prohibit signs that use flashing lights or messages. And the billboard industry has routinely defended DBB technology by stating that such signs do not flash. The MUTCD defines "flashing" as "an operation in which a signal indication is turned on and off repetitively" (p. 1A-11). The U.S. Coast Guard publishes a "Light List" (USCG, 2006) in which it describes different "characteristics of lights" used in lighthouses and lighted buoys. Two of these light characteristics could be used to define the operation of most DBBs. An "alternating" light is one which shows different colors alternately; an "occulting" light is one "in which the total duration of light in a period is longer than the total duration of darkness and the intervals of darkness (eclipses) are usually of equal duration." Note that the duration of a displayed image and the duration of any dark or blank display between successive images, is not considered in any of these three definitions. Accordingly, if one were to apply any of these technical definitions rather than a more common dictionary definition DBBs would likely be classified as flashing signs.

SECTION 5.

CURRENT AND PROPOSED GUIDELINES AND REGULATIONS

In Section 2 of this report we reviewed recent research about the safety aspects of digital billboards prepared by authors in six countries in addition to the United States. It is instructive to note that, of these countries in which the greatest amount of research has been conducted, we are aware of five of them have developed and implemented guidelines under which such signs may be placed and operated. In addition, many States and local jurisdictions in the US have promulgated guidelines or regulations of their own, or have issued moratoria under which they will evaluate proposed guidance or regulations.

Below we have attempted to cite and explain all of the guidelines and/or regulations that we have found in countries outside the US. Because of the large and growing number of such regulatory documents in cities and counties in the US, however (we understand, for example, that 45 cities and counties in Texas alone have issued or are currently considering regulations on the control or prohibition of DBBs [Lloyd, 2008]), it is possible only to report on representative examples and, for these, to summarize only their most salient sections.

International Guidelines and Regulations

Queensland, Australia

Of all of the policy documents reviewed for this report, the most comprehensive was that prepared by the Traffic Engineering and Road Safety section of the Queensland (Australia) Government's Department of Main Roads. The purpose of this "Guide to the Management of Roadside Advertising" (TERS, 2002) is to assist the Department of Main Roads and local government agencies in their evaluation of proposals for roadside advertising, to assist in the development of roadside advertising management plans, and to provide information to advertisers to enable them to achieve their goals with a minimal adverse effect on traffic safety and movement.

Unique to the TERS document are a number of operational definitions that serve as a basis for the analysis which resulted in the guidelines and regulations promulgated. For example, four categories of roadside advertising are defined in the report. Given our focus on DBBs, we are concerned only with category 1, which includes "large free-standing devices" such as billboards and trivision signs.

Other key definitions include:

> Advertisements are considered to *directly distract* drivers if they convey information that is contrary to or in competition with information conveyed by *important official traffic control devices.*
>
> *Important official traffic control devices* are major regulatory, warning, or guide signs. For example, an initial regulatory speed sign is considered important, whereas repeater signs are not. The decision as to whether specific TCDs are or are not important is to be made by Main Roads district officers.
>
> Advertisements should not distract drivers in the proximity of *designated traffic situations,* such as "areas in which merging, diverging and weaving traffic maneuvers take place, 'open' railway level crossings, road intersection driver decision-making points in the vicinity of important official traffic signs, and reading and interpreting official traffic signs" (p. C-2).

Appendix C to the document, titled "Driver Distraction Potential," provides a specific and comprehensive series of flow charts (decision trees) 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. The identification of driver distraction potential and the resultant regulations is based on extensive human factors research, experience, and engineering judgment. The stated goal of these regulations is "to ensure that a high level of safety for the road user is maintained by managing competition for drivers' attention in locations where driving demands are great or where the road authority needs to convey important information to motorists on official traffic signs" (p. C-2).

Different categories of roads are described, with correspondingly different restrictions on advertising signage. 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).

In Australia, official signs are placed in accordance with a specific methodology described in the Austroads Guide to Traffic Engineering (AUSTROADS, 1988) which takes into account travel speed, sign content, and legend height. Accordingly, the TERS report identifies "longitudinal exclusion zones," roadside areas in the vicinity of official TCDs in which advertising devices are not permitted. The length of these exclusion zones is typically 1.2v on local streets, and 2.5v on multi-lane freeways (where v = speed), and increases to 5.0v in advance of on-ramps and 7.5v in advance of exit ramps. The report provides specific justification for each recommendation, and that given for ramps is typical:

> Estimating the speed of entering traffic on a high speed road is a complex task which requires a fair amount of preview free from extraneous information. The 5V requirement will provide a motorist travelling at 100 km/h with 18 seconds preview time in which to identify an on-ramp and change lanes if necessary. The downstream 2.5V separation distance allows for traffic to stabilize following the merge (p. C-3).

Although not every description is quite so comprehensive, the reader can, nonetheless, understand both the guidelines proposed and the rationale for them.

Sign brightness is discussed in detail in Appendix D, and the rationale for the development of guidelines is based, in part, on the work of Johnson and Cole (1976) who reported that "brightness from illuminated Advertising Devices directed at road traffic should be minimized under all conditions" (p. 20, reported in TERS, 2002).

The authors provide a clear distinction between two often confused key terms - luminance and brightness. Luminance is described as a characteristic of the advertising device itself that is independent of the environment in the vicinity of the sign. Luminance levels may vary across the face of the sign and the direction from which the sign is viewed. It is at a maximum when viewed from a direct frontal position, and falls off (diminishes) as the viewing angle becomes more oblique. Brightness, on the other hand, is a visual sensation experienced by the observer, which is affected by the sign's luminance (and the uniformity of that luminance across the sign face), as well as by its size, contrast, the viewing position of the observer, and characteristics of the observer him/herself (such as the effect of phototropism [the involuntary movement of the eye toward the brightest points in the field of view]). Since brightness is a subjective value, it cannot serve as a basis for regulation.

The report identifies three different "Lighting Environment Zones," and Table D1 identifies the maximum average sign luminance permitted in each zone for advertising signs visible from State-controlled roads. The authors state that the maximum levels were established following field investigations in two different areas of the State.

These maximum permitted luminance levels are

> In Lighting Environment Zone 1, 500 cd/m^2
> In Lighting Environment Zone 2, 350 cd/m^2
> In Lighting Environment Zone 3, 300 cd/m^2

for advertising signs of all sizes. Zone 1 is defined as an area with generally very high off-street ambient lighting such as central city locations. Zone 2 means an area with generally medium-high off-street ambient lighting such as major suburban business centers, entertainment districts, and industrial and/or community centers (which may include, for example, large gasoline service stations, parking lots or garages, etc.). Zone 3 is defined as an area with generally low levels of off-street ambient lighting, such as rural and residential areas.

TERS provides a specific methodology for the measurement of luminance against this standard. This methodology is summarized in Section 6 of the present report.

In addressing the characteristics of billboards that may be permitted, the report considers three different location categories:

1. Advertising outside the boundaries of, but visible from, State-controlled roads (except motorways),
2. Advertising visible from motorways, and
3. Advertising within the boundaries of State-controlled roads.

In Category 1, TERS provides an extensive discussion of DBBs, which it refers to as “electronic displays.” It states: “Because electronic displays are conspicuous by design and have the greatest potential to distract motorists, the objective is to limit this potential” (p. 6-3). To achieve this objective, TERS requires that such signs may 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)

TERS further describes acceptable characteristics for signs that display predominantly graphics, with or without text:

- 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

Finally, TERS addresses DBBs that contain only text, as follows:

- 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 non-conspicuous.

Advertising Devices beyond the boundaries of, but visible from motorways “are limited to non-rotating static illuminated and non-rotating non-illuminated formats” (p. 6-4). In other words, TERS does not permit changeable message signs, flashing signs, or DBBs of any type if such devices would be visible by motorists traveling on motorways. In addition, no advertising signs of any type (including those that are static, whether illuminated or not) are permitted within the restriction distances discussed above. TERS states: “In addition to the restriction areas … further restrictions may apply where Main Roads demonstrates that the traffic conditions require additional driver attention and decision making” (p. 6-4).

Finally, where advertising devices are permitted within the boundaries of State-controlled roads, such signs must be non-rotating static illuminated and non-rotating non-illuminated signs. Neither variable-message signs nor trivision signs are permitted on State-controlled roads.

It is with regard to the flash rate permitted for advertising signs that the TERs report differs most significantly from the prevailing guidance and regulations in the US. The authors explain that flashing illuminated advertising signs have the potential to distract drivers, and that the effects of such flashing signs are described by the *Broca Sulzer Effect* and the *Bartley Effect*. The former states that, at high luminance levels, the momentary luminosity shortly after the onset of a flash appears higher than the luminosity of a steady light of the same luminance. The latter states that, if a light is repetitively flashed, for example between four and ten times per second, the apparent brilliance of the light increases by as much as four to five times the actual luminance.

As a result of their understanding of these two phenomena, the TERS report permits a maximum flash rate of two flashes per second for devices visible from State-controlled roads in Lighting Environment Zones 1 and 2, but prohibits any flashing lights on advertising devices visible to motorists on State-controlled roads in Lighting Environment Zone 3. Flashing signs, or signs with flashing lights, are not permitted within the boundaries of State-controlled roads, nor within or outside the boundaries of motorways, freeways, or roads of similar character if they would be visible to motorists traveling on such roads.

In light of recent proposals from the States of California (Kempton, 2008) and Nevada (Martinovich, 2008) to consider public-private partnerships that might result in advertising on State-controlled roads, the TERS report provides useful guidance for “advertising devices provided as part of sponsorship arrangements” (Appendix A). The report describes a program in which “the Department may permit the erection of Advertising Devices for a defined period in exchange for … private sector sponsorship of road infrastructure and/or works (p. A-2). Examples of such projects include construction of a pedestrian footbridge over the roadway, roadside landscaping and tree planting, and rubbish removal including removal of illegal Advertising Devices. Project sponsorship must be based on full and open competition, and the project must be warranted in its own right. For sponsorship of "major infrastructure such as pedestrian overpasses," the Department may permit: "third party advertising on the sponsored structure, on free standing advertising devices, or on existing overhead transport structures within the vicinity of the sponsored infrastructure;" in the case of roadside cleaning and/or landscaping, the Department may permit: "the erection of signs, which contain the sponsor's corporate logo, designating the start and end of the sponsored section of road" (p. A-3). Graphic examples are provided which depict a fixed sign displaying a corporate name on a pedestrian overpass, and four examples of signs depicting sponsorship of cleaning or landscaping projects, which are quite similar to FHWA's "acknowledgement signs" (D-14-1, 2 and 3) proposed for the next edition of the MUTCD (Capka, 2005).

The TERS document has also anticipated the growing use of vehicle-based advertising. Traffic Regulation 1962 s. 126 states, in part: "A person shall not, in respect of a vehicle on which or alongside of which an advertisement is being displayed – drive, or permit to be driven, that vehicle on a road or cause or permit that vehicle to stop on a road in such circumstances that the primary purpose for which the vehicle is being driven or stopped at the material time is business advertising, unless the person is the holder of a permit issued by (the Government)" (p. 3-4, 3-5).

In an effort to minimize driver distraction from billboards which contain lengthy or difficult to read messages, TERS suggests that designers of Advertising Devices consider the relationship between legend height, sign content (i.e. number of words) and speed environment that are used in the design of worded traffic signs and that are contained in the AUSTROADS document. TERS states that the applicant's use of such design guidance "may, in certain circumstances, be considered by the Department in the assessment process" (p. 5-7).

South Africa.

Of the guidelines and regulations identified for the control of outdoor advertising for this report, we found those in South Africa to be quite comprehensive, specific, and, perhaps, the most unusual. Based on a review of practice elsewhere, and reliant to a considerable extent on the work of du Toit and Coetzee (2001) and Coetzee (Undated), the South African National Roads Agency Limited (SANRAL) first issued its "Regulations on Advertising On or Visible From National Roads, 2000" (SANRAL, 2000) to deal with on-premise as well as billboard advertising, and included specific components that address DBBs. The regulations were first issued in July 2000, and were updated and re-promulgated in December of the same year.

SANRAL's terminology is somewhat different than that in the US, and it is important to understand these differences to ensure that the regulations are not misinterpreted. A "billboard," for example, may include "variable messages," and an "electronic billboard" has an "electronically controlled, illuminated display surface which allows all or a portion of the advertisement to be changed, animated or illuminated in different ways"

(p. 4). The term "animated" is used to mean that "the visibility or message of an advertisement is enhanced by means of moving units, flashing lights or similar devices, or that an advertisement contains a variable message" (p. 3) The regulations also distinguish "small" from "large" billboards. For both fixed and electronic displays, any billboard that exceeds 18 square meters in area is considered large. Thus, the majority of roadside billboards in the US would meet SANRAL's criterion for large (a typical US roadside billboard measures 14 ft x 48 ft, or 672 sq. ft, approximately 62.4 sq. meters. South Africa uses the term "road reserve" to mean essentially the same as "right-of-way" in the US.

Part B of the regulations contains provisions that are applicable to all advertisements. Section 6, Subsection 1 of this Part (excerpted below) identifies outright prohibitions on the grounds of "road safety and traffic considerations" by stating 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).

Subsection 2 provides guidance for the reviewing agency to use when reviewing applications for advertisements that will face a national road. The Agency must consider each of the following 13 points to determine whether:

- The size of the advertisement, together with other advertisements in the area, if any, will affect the conspicuousness of road traffic signs by virtue of potential visual clutter
- the size of the advertisement, or any portion thereof by way of its colours, letter size, symbol, logo, graphics or illumination, will result in the advertisement having a distracting effect on the attention of drivers of vehicles to the task of driving and lead to unsafe driving conditions
- the number of road traffic signs and advertisements in any area constitute a driving hazard, due to the attention of drivers of vehicles being deviated from the task of driving and leading to unsafe driving conditions
- the colour, or combination of colours, contained in the advertisement correspond with the colours or combinations of colours specified for road

traffic signs in the regulations promulgated under the National Road Traffic Act

- the speed limit, and the measure of the traffic's adherence thereto, the traffic volume, the average following headway and accident history of the road demand more stringent control of outdoor advertising
- the amount of information contained in the advertisement, measured in bits, is within prescribed limits
- the advertisement is suitably positioned and orientated
- the position of the advertisement will negatively affect the visibility of, sight distance to or efficiency of any road traffic sign, or series of such signs
- the advertisement could be mistaken to represent a road traffic sign
- the illumination of advertisements is likely to distract drivers' attention from road traffic signs which are not illuminated
- the position of an advertisement would disrupt the flow of information from road traffic signs to drivers who encounter a series of road traffic signs intended for traffic regulation, warning or guidance, in cases where the applicable speed limit on the road exceeds 60 km per hour
- the position of any advertisement would potentially distract drivers' attention at places where traffic turns, negotiates curves, merges or diverges, or in the area of intersections or interchanges, or where drivers' uninterrupted attention to the driving task is important for road safety
- The distance of any advertisement before any road traffic sign, an advertisement's position in between road traffic signs or an advertisement's distance behind any road traffic sign is of such a nature as to distract a driver's attention from any road traffic sign (p. 12-13).

Many of these requirements and review criteria in the two categories discussed above are also used in other jurisdictions. In our opinion, some, including some of those in broad use, are somewhat vague and might be subject to differing interpretations. A third group category of SANRAL regulations, however, provides a unique and potentially useful approach to DBB guidance or regulation in the US. Specifically, those requirements that address the "flow of information from road traffic signs to drivers" and the "amount of information … measured in bits" contained within an advertisement have direct relevance to traffic safety and are firmly grounded in human factors research.

The Agency is given additional authority to "increase the minimum spacing between advertisements or place further restriction on the position, size and content of any advertisement it considers necessary, in the interest of road safety" (p. 13).

Where SANRAL's safety review criteria break new ground, however, is in two key areas that focus on the driver's information processing demands and limitations. Specifically, two of the review criteria above address the placement and content of the advertisement in terms of the amount (bits) of information contained on the sign, and the potential for the sign to cause disruption of the flow of information to the driver.

From a regulatory perspective these two evaluation criteria are unique. They are explained below.

Part B, Section 6, Subsection (f) requires that “the amount of information contained in the advertisement, measured in bits, is within prescribed limits” (p. 13). These limits are defined in Section 8, “Advertisement to be concise,” which states, on page 14, that an advertisement visible from a national road must be concise and legible and comply with the following requirements:

> (a) No advertisement displaying a single message may exceed six bits of information in a visual zone and 10 bits on a road other than a freeway;
> (b) No combination sign, or any other advertisement displaying more than one advertisement or message, may contain more than six bits of information per enterprise, service or property, or per individual advertisement or message displayed on a combination sign;
> (c) Numbers longer than eight digits are not allowed;
> (d) A street number indicating specific premises must have a minimum size of 150 millimeters and a maximum size of 350 millimeters;
> (e) No message may be spread across more than one advertisement.

With the exception of item (d), which refers only to address numbers, and item (e), which relates to what we have called message sequencing and is discussed elsewhere in the present report, each of the requirements above impose an upper limit on the number and length of words, numbers, symbols, etc., that can be displayed on a roadside advertisement.

A “bit” of information is defined in Part A, Section 1 of the regulations as “the basic unit for measuring the length of advertising messages and may consist of letters, digits, symbols, logos, graphics, or abbreviations” (p. 4). Bits are operationally defined in accordance with the following table:

Information on Billboard	Number of bits
Words of up to 8 letters	1.0
Words of more than 8 letters	2.0
Numbers of up to 4 digits	0.5
Numbers of 5 to 8 digits	1.0
Symbol or abbreviation	0.5
Large logo and graphics	2.0

The term “bit,” a contraction of the words binary digit, was first used in the 1930s in a paper describing information storage for early computers. In the decades since, it has also been widely used in the science of information processing and human cognition. A further discussion of the term “bit” is beyond the scope of this paper.

In addition to its regulatory control on the amount of information that can be displayed on billboards, SANRAL also controls the placement of billboards with regard to official signs, in a manner that goes beyond other Government agencies. Specifically, Regulation 6(2)(k) states:

> In considering applications for approval . . . the Agency must evaluate whether … the position of an advertisement would disrupt the flow of information from road traffic signs to drivers who encounter a series of road traffic signs intended for traffic regulation, warning, or guidance. . . (p. 13).

In essence, this regulation recognizes that there are categories of official signs in which the information on two sequential signs was linked, and that this information link must not be disrupted. An example given by du Toit and Coetzee is the link between an advance warning sign at an interchange and the actual off ramp. Other examples might include advanced signs for changes in speed limit or for the presence of a Stop sign or traffic signal. Although the South African Road Traffic Signs Manual (SARTSM) recognizes that a 200 m spacing is between two sequential road signs for 120 km/h roads in general, it requires 360m as a minimum distance on such a road for a motorist to react to a warning or information sign in advance of an interchange where lane changes and weaving may be necessary. SANRAL determined that the presence of a billboard between the advanced (1km) interchange signs and the off ramp would reduce this distance below acceptable limits. As a result, the requirement was established that no billboards would be permitted between the 1km advance sign and the gore of the subsequent interchange. This would permit the motorist to safely read and react to the 500m off ramp sign. In addition, because a freeway road sign is typically readable at 200m before the sign, the regulations prohibit billboards closer than 1.2km upstream of the interchange. In short, no billboards are permitted within 1.2km of an interchange, thus preserving sufficient time for motorists to read and respond to advanced warning or information signs (located 1km in advance of the gore), and ensuring that the flow of information between the advanced sign and the actual interchange sign, whose function is linked, is not disrupted.

During their evaluation of the efficacy of the regulations, du Toit and Coetzee (2001) reviewed billboard applications for 248 signs. (Each face of a two-face sign counted as one). Of the 86.7% of the signs that were rejected, 40.8% (the largest category) were rejected for being too close to existing official road signs, 20% were rejected for disruption of the flow of information to the driver, and 7.5% were rejected because they were too close to a ramp gore.

Victoria, Australia.

The State of Victoria specifies a “ten-point road safety checklist” which describes conditions under which it may consider any roadside advertising to be a road safety hazard. These ten points, which are broadly in use elsewhere, defines an advertisement as a road safety hazard if it:

1. obstructs a driver's line of sight at an intersection, curve or point of egress from adjacent property
2. obstructs a drivers view of a traffic control device, or is likely to create a confusing or dominating background which might reduce the clarity or effectiveness of a traffic control device
3. could dazzle or distract drivers due to its size, design or colouring, or it being illuminated, reflective, animated or flashing
4. is at a location where particular concentration is required (e.g. high pedestrian volume intersection)
5. is likely to be mistaken for a traffic control device, for example, because it contains red, green, or yellow lighting, or has red circles, octagons, crosses or triangles, or arrows
6. requires close study from a moving or stationary vehicle in a location where the vehicle would be unprotected from passing traffic
7. invites drivers to turn where there is fast moving traffic or the sign is so close to the turning point that there is not time to signal and turn safely
8. is within 100 metres of a rural railway crossing
9. has insufficient clearance from vehicles on the carriageway
10. could mislead drivers or be mistaken as an instruction to drivers

As discussed by the Road Safety Committee of the Parliament of Victoria (2006), only one of the items in this checklist includes numerical criteria, "making the application of the other criteria wholly subjective" (p. 113).

Of greater specificity, and of more direct relevance to the current project, the State also includes "operational requirements for the installation of Variable Advertising Message Signs" (VicRoads, 2005, cited in Road Safety Committee (2006). These requirements state that such a sign 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

The regulations in place in Victoria are also based, to some extent, on the work of Cairney and Gunatillake (2000), who reviewed the literature and made recommendations for policy, on behalf of the Royal Automobile Club of Victoria (RACV).

New South Wales (NSW), Australia.

In its report for the Government of New South Wales, Transportation Environment Consultants (TEC, 1989) prepared a series of suggested guidelines for the control of roadside advertising signs located within the road reserve. The principal recommendations for electronic variable message signs on conventional roads and on freeways are shown in the table below:

Standard	Roadside – Urban	Roadside – Rural	Overpass	Freeways
Minimum message on-time	2 minutes	2 minutes	2 minutes	2 minutes
Minimum message off-time	2 minutes	2 minutes	2 minutes	2 minutes
Maximum Changeover time	<0.1 sec	<0.1 sec	<0.1 sec	<0.1 sec
Minimum distance to traffic signal	12 m	20 m	30m	NA
Minimum distance to lane drop, official traffic sign, ramp, merge	10m	15m	25m	150m
Minimum distance to another Advertising device	7m	10m	20m	150m

The TEC report also provided guidance for the maximum luminance levels of illuminated advertising devices; their recommendations were based on a report by the Public Lighting Engineers in the UK (1981, cited in TEC, 1989).

Four lighting zones were classified, generally as follows:

> Zone 1: areas with very high off-street ambient lighting, e.g. central city locations
> Zone 2: areas with medium-high off-street ambient lighting such as shopping/commercial/industrial/community centers, car sales yards, car parks, larger petrol stations, etc.
> Zone 3: areas with low-medium off-street ambient lighting, e.g. areas with rather isolated small shopping/commercial/industrial/community centres.
> Zone 4: areas with low levels of off-street ambient lighting; e.g. most rural areas, many residential areas.

For advertising signs with an illuminated area of more than 10 square meters, the maximum recommended lighting levels (expressed as cd/m^2), are 1200 in Zone 2, 800 in Zone 3, and 400 in Zone 4. There is no limit in Zone 1. Note that the most common billboard size in the US is 14 ft. x 48 ft., which, at 672 sq. ft. places US billboards into the largest sign category cited in these guidelines.

The Netherlands.

TNO was recently asked to develop guidelines and “decision criteria” to be used by the Dutch Ministry of Transport, for visual distracters that presented “non-driving related information” (Martens, 2009). Distracters to be considered might be any types of roadside objects, including, but not limited to, billboards. The guidelines were to be developed using existing human factors knowledge and principles (i.e. no new research was to be conducted). The guidelines will be initially applied to motorways, with later extension to other roads in The Netherlands.

The initial work has led to the following recommendations:

- 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). Based upon an assumption of 300m sight distance, traversed at +/- 9 sec, this results in a prohibition of such signs within 50m of the road edge. Any sign within that boundary must be "extremely simple" and no billboards are permitted.

- Assuming a 150m legibility distance, and a maximum permitted sign reading time of 4 sec (presuming multiple glances may be needed) the guidelines suggest that signs contain a maximum of five "items" (letters, numbers, symbols, etc.). This is based on application of the following "reading time formula:"

  $T = N/3 + 2$, where T = sign reading time, and N = number of items

- 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

The rules will be contained in a decision tree format, and specific rules will apply to different categories of roadside distracters, including such diverse features as: buildings, objects of art, wind turbines, information signs and safety campaigns, billboards and other advertisements, tunnels, bridges and walls, airfields, skydive centers and heli platforms. The guidelines are expected to be ready for field testing and validation by mid-2009. Once adopted, software will be developed that will simply take an inspector through the decision process.

Brazil.

Guerra and Braga (1998) address the need for guidance and regulation to control the use of advertising signs within the road reserve. The necessity for such action is brought about by a financial crisis that affects road infrastructure with consequential low levels of service, lack of maintenance, and high accident rates. The authors state that their aim is to assist public agencies since existing laws either do not adequately deal with this subject or prohibit advertising outright. They state: “if suitable regulation is not adopted advertising signs within the road reserve (ASWRR) might bring about undesirable consequences such as accidents” (p. 128). In other words, the authors believe that permitting advertising within the road reserve could raise much needed revenue, but express concern that such revenue should not come at the cost of traffic safety.

The authors review regulations and guidance in other countries, but focus on Brazil. They point out that some states (within Brazil) take no position on the issue, whereas others (such as Sao Paulo) explicitly prohibit ASWRR, and still others (e.g. Rio Grande de Sul) permit such advertising. They also discuss the conflict between regulations and practice, suggesting that advertising signs may be present in certain locations despite prohibitions on their use.

Guerra and Braga review existing advertising signs in Brazil, and point out a number of traffic safety concerns, including:

- Visual intrusion at complex junctions from back-lit signs
- Brightness of the advertising signs reduces the conspicuousness of traffic signals at night
- Confusion with traffic signs
- Lack of control over the predominant colors of the advertising signs
- Insufficient time for drivers to read messages on changeable message signs

The authors express particular concern with the message change interval for changeable message signs, noting that, for example, signs in Australia must have a minimum display time of 200 s at 60 km/h, an interval which is “100 times longer than the 2 s one finds in Rio” (p. 131). A related concern is the risk of the Zeigarnik Effect since a motorist traveling at 60 km/h with a sight distance to a sign of 200 m could see four distinct messages and four changes.

Based on earlier work by the senior author, Guerra and Braga propose a series of guidelines for ASWRR, in five categories:

- Physical protection of highways and road users
- Choice of display sites
- Physical characteristics of signs
- Characteristics of messages and images displayed
- Products being advertised

Of potential relevance for guidance or regulation in the U.S., the authors propose the following:

- 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 speed
- 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.

On April 11, 2008 the New York Department of Transportation (NYDOT) issued for public comment a set of "proposed criteria for regulating off-premise changeable electronic variable message signs (CEVMS)" within the State (NYDOT, 2008a). The proposed criteria were developed "in consultation with the New York Division of the Federal Highway Administration (FHWA)," (Marocco, 2008a) and were based on the provisions of 17 NYCRR Part 150, including Part 150.8 (b). Sections of the proposed criteria that addressed issues of CEVMS lighting and illumination issues were based on a study performed by the Lighting Research Center of the Rensselaer Polytechnic Institute (RPI, 2008).

The proposed criteria were based on the State's position that, whereas "the premise of advertising to motorists conflicts directly with highway safety," the State's goal was to "minimize the effects posed by the unique attributes of (CEVMS)" which were described as having the ability to "constantly convey different information to motorists, thereby increasing driver curiosity; attract attention through their brightness; and attract attention through their temporal changes of light" (p. 1).

The proposed criteria included four key elements and a list of prohibited locations, each of which was presented with its underlying rationale. These are summarized below.

1. Minimum Message Duration of 62 Seconds. This value was based on the State's opinion that it would be best that no motorist be able to see more than one message change as he or she approached any particular CEVMS, while recognizing that the ideal circumstance of seeing *no* message change was impossible to achieve. Making simple calculations of typical billboard size, letter

height, and posted speed limits on State highways resulted in the conclusion that the average billboard would be legible[13] for 5,040 feet, a distance which could be traversed in 62 seconds.

2. Message Transition Time should be Instantaneous. Given that the State believes that the change of message is "one of the elements (that) can lead to motorist distraction, especially among older drivers" (p. 2), and given the capability of the technology, an instantaneous message change would minimize such distraction.

3. Minimum Spacing between CEVMS of 5,000 feet. Given the State's position that a message change may be unsafe because it contributes to distraction, it believes that motorists should not be able to view more than one CEVMS at a given time.

4. Maximum CEVMS Brightness of 5,000 cd/m^2 in Daylight and 280 cd/m^2 at Night. The State believes that CEVMS brightness can have two separate adverse impacts on drivers – that it attracts attention to the sign, and that it can compromise dark adaptation. Thus, it believes that CEVMS brightness should be limited such that the signs do not appear brighter to drivers than existing static billboards. The RPI Lighting Research Center (LRC) was engaged to perform comparison measurements of existing conventional billboards and CEVMS; in addition, the State reviewed publicly available billboard industry data as well as sign codes from numerous municipalities to arrive at its recommended maximum brightness levels.

5. Prohibited Locations. Citing studies by the University of North Carolina Highway Safety Research Center (UNC-HSRC) and the National Highway Traffic Safety Administration (NHTSA) the State summarizes the reported risks to drivers due to distraction or inattention occurring within three seconds prior to a crash or near-crash, and the elevated risk of distraction by objects or events outside the vehicle to drivers over age 65. Using such findings, and relying on proposed changes to the MUTCD for the placement of official changeable message signs (CMS), the State recommends that CEVMS be prohibited at the locations shown below, because these are locations that "already place high demands upon driver attention" (p. 4). These proposed prohibited locations include:

<u>Interstate and Controlled Access Highways</u>

Within 1,100 feet of:

- An interchange
- An at-grade intersection
- A toll plaza

[13] Using legibility distance as a criterion for message duration is a less stringent criterion than the use of visibility distance, given that, without sight obstructions, digital billboards may be visible for several miles.

- A signed curve
- A lane merge/weave area

Within 5,000 feet of:

- Another CEVMS
- An official traffic device that has changeable messages

Primary Highways

Within 1,100 feet of:

- An entrance to or exit from a controlled access highway
- A signed curve
- A lane merge/weave area

Within 5,000 feet of:

- Another CEVMS
- An official traffic device that has changeable messages

Although the State provided no specific citations to research other than the two studies mentioned above and the study by RPI that it commissioned, the criteria presented in the State's draft guidelines closely comport with the recommendations of others, and are based on reasonable underlying human factors assumptions.

On July 18, 2008, the State promulgated revised criteria (NYSDOT, 2008a), which it described as "less restrictive" than those of the draft proposed criteria in the areas of message duration, sign spacing, and prohibited locations. The State's letter transmitting the revised criteria indicates that FHWA concurred with the modifications (Marocco, 2008b).

Although the requirement for an instantaneous message transition and the maximum permitted CEVMS brightness levels did not change, the other requirements did, as follows:

1. Minimum message duration was reduced from 62 seconds to 6 seconds.
2. Minimum spacing requirements of 5,000 feet were deleted and replaced with the statement that "only one CEVMS sign face would be visible to the driver at one time on either side of the highway."
3. The comprehensive and specific list of prohibited locations for CEVMS was eliminated, and replaced with the following guidelines:

   - CEVMS should not be located within an interchange.
   - CEVMS should not be positioned at locations where the information load on drivers is already high because of guide signs and other types of information.

- CEVMS should not be located in areas where drivers frequently perform lane changing maneuvers in response to static guide sign information, or because of merging or weaving conditions.

City of San Antonio, Texas.

Although CEVMS are prohibited within San Antonio, the City promulgated a set of regulations for "off-premise digital signs" under a trial that will permit fifteen such sign permits to be issued for the City's evaluation. Although the regulations, contained at Section 28-125 of the City's sign code, contain restrictions on CEVMS that include provisions for sign conversion and eminent domain, the summary below addresses only those aspects of the code that address the possible safety and traffic flow implications of such signs. These include:

1. The dwell time (message duration) shall be at least ten (10) seconds.
2. The change interval shall be accomplished within one (1) second or less.
3. The sign shall contain a default mechanism that will freeze the sign in one position if a malfunction occurs.
4. The sign may not display light of "excessive intensity or brilliance", which, for a full color display is defined as a maximum intensity of 7,000 nits[14] during daytime and 2,500 nits at nighttime.
5. A sign applicant shall certify that the sign's light intensity has been factory pre-set not to exceed 7,000 nits, and that the intensity level is protected from end-user manipulation.
6. The sign shall not resemble a warning or danger signal or cause a driver to mistake the sign for such a signal.
7. Sign faces may have dimensions up to 300 square feet, or up to 672 square feet in accordance with specified conversion values (not included herein).
8. The sign must not resemble or simulate any lights or official signage used to control traffic in accordance with the MUTCD.
9. A sign must be equipped with both a dimmer control and a photocell which will automatically adjust the display intensity according to natural ambient light conditions.
10. A digital sign may not be within 2,000 feet of another off-premise digital sign facing the same traveled way, and an off-premise digital sign shall not be in a line of sight with another off-premise digital sign. (Spacing requirements in relation to other sign classifications are addressed elsewhere in the regulations).
11. Sign heights are addressed elsewhere in the regulations.
12. The city may require emergency information to be displayed, within the appropriate message rotation, on off-premise digital signs. Such information includes: "Amber Alert emergency information or emergency information regarding terrorist attacks, or natural disasters." Such emergency information messages are to remain in rotation according to the designated issuing agencies' protocols.

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[14] The term "nits" is the accepted equivalent to the older term "candela per square meter," abbreviated as cd/m^2.

It was the city's stated intent to undertake an assessment of the effectiveness and efficacy of its regulations (Simpson, 2008) in a program lasting one year. The one-year pilot program ended on December 16, 2008. Recently, the city decided to extend the program through October 2009 (Sculley, 2009).

City of Flowery Branch, Georgia.

After a moratorium period, the Flowery Branch (Georgia) City Council, on June 4, 2008, amended Article 24 ("Signs") of its Zoning Ordinance (Ordinance No. 348-7) to define and regulate CEVMS. Based on its review of the literature (several articles were cited), the language of the ordinance, in Section 1, offered the City's rationale for its actions, described as its findings. Those findings read, in part:

> Changeable electronic variable message signs, (CEVMS) … have been shown to create possible threats to public safety. Such signs are erected for the purpose of trying to hold the attention of motorists by changing messages and pictures for short durations using a series of bright, colorful images produced mainly via LED (light emitting diode) technologies. Brightly lit signs that change messages every few seconds compel motorists to notice them, and they lure the attention of motorists away from what is happening on the road and onto the sign. Such signs pose safety threats because if they attract a motorist's attention, the motorist will look at the sign and not at the road. (CEVMS) are also a threat to public safety because of their brightness, making them visible from great distances. Due to their nature of brightness and changing displays, changeable electronic variable message signs are more distracting than signs which do not vary the message. … Unless otherwise regulated, such displays can be extremely bright since they are designed to be visible in bright sunlight and at night. Furthermore, the human eye is drawn to them far more strongly than to traditional illuminated signs. Such electronic LED displays can be seen from as far away as six-tenths of a mile, making them distracting. It takes a minimum of six seconds to comprehend the message on an electronic sign, which is three times the safe period for driver distraction.

The ordinance, in Section 24.33, "Changeable Electronic Variable Message Signs," includes commonly seen constraints regarding sign dimensions, separation, and location within zoning classifications. Further, the ordinance establishes permit requirements, and prohibits flashing signs or those with "variation of light intensity of an individual message," both of which it considers to constitute an "animated sign."

Aspects of the ordinance that are unique to CEVMS and of interest for the purpose of this report include the following:

Duration of Message – "Each multiple message shall remain fixed for at least the amount of time that would result in one (1) 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 – "When a message is changed, it shall be accomplished in less than one-tenth (1/10th) of a second and shall not use fading, swiping, or other animated transition methods."

Illumination and Brightness - "No such sign shall be illuminated at an intensity of greater than twelve (12) foot-candles or (sic) illumination, measured from the nearest point of any highway or public road. … All such signs shall be equipped with a dimmer control and a photo cell which shall constantly monitor ambient light conditions and adjust sign brightness accordingly."

Freeze of Display When Malfunction Occurs – "Such signs shall include a default designed to freeze a display in one still position if a malfunction occurs."

Sequencing of Messages Prohibited – "Using two or more successive screens to convey a message that will not fit on one (1) screen shall be prohibited."

City of Oakdale, Minnesota.

On June 10, 2008, the Oakdale City Council unanimously passed an amended sign ordinance that includes regulation of digital billboards within the city. This ordinance is codified in Article 19, Chapter 25 of the City of Oakdale Zoning Code, at Section 25-181 to 25-200. Digital billboards, which the Ordinance calls Electronic/Dynamic Display, are addressed in Section 25-185(b).

In 2007, the city had passed a one-year moratorium to study such signs and their safety issues, and to draft the revised ordinance.

After Clear Channel Outdoor had installed two digital billboards in Minnetonka, Minnesota without permission, the League of Minnesota Cities commissioned a research study from SRF Engineering. Based on the study results, which stated, in part: "billboards can tend to distract drivers, dynamic features contribute to the distraction, and even short distractions can increase the risk of accidents," and based on concerns by state troopers and police chiefs around the (Minneapolis-St. Paul) metro area that the signs were safety hazards (Zillmer, 2008), the city adopted the ordinance in July 2008.

As is common with many other billboard ordinances, this ordinance prohibits any DBB that, "by reason of position, shape, movement or color, interferes with the proper functioning of a traffic sign, signal, or which constitutes a traffic hazard."

To address concerns of excessive brightness, the ordinance sets a limit of 2,500 Nits during daylight ("between the hours of civil sunrise and civil sunset"), and 500 Nits at nighttime ("between the hours of civil sunset and civil sunrise"), measured from the face of the sign. In addition, signs must have installed ambient light monitors which adjust the brightness of the sign based on (ambient) light conditions. Further, the sign must have a system that automatically shuts the sign off when the display "deteriorates, in any fashion, 5% or greater until the … sign has been repaired to its fully functional factory specifications." At the time of permit application, the sign owner is required to specify the lamp wattage and luminance level in Nits, and state that the sign will be operated in accordance with City Codes at all times.

With regard to message duration, imagery, and change interval, the ordinance requires that the minimum display duration shall be 60 seconds, that all messages shall contain only static images, and that the message change be instantaneous "without any special effects, through dissolve or fade transitions, or with the use of other subtle transitions that do not have the appearance of moving text or images" (Sec. 125-85(b)(3).

One uncommon feature of the Oakdale ordinance is the requirement that owners of DBBs must apply for an annual license to operate the signs. This contrasts with the situation in most jurisdictions where a permit is granted, and, once in place, exempts the sign owner from compliance with any future regulations or modifications to the ordinance that may be promulgated. The Oakdale city council took this unusual step because of the rapid changes in digital billboard technology, and to provide the city with the ability to respond to public concerns or new research that may become available. Zillow quoted Bob Streeter, the City's Community Development Director, as saying: "To operate a dynamic sign is not a right, it is a privilege. Because technology changes so fast, we want the ability to respond."

St. Croix County, Wisconsin.

The Sign Regulations of St. Croix County, issued on July 1, 2007 (St. Croix County Planning and Zoning Department, 2007) permit, with one exception, only static signs, for both on-premise and off-premise applications. Additionally, such permitted signs constitute a "customary use of signage" for reasons explained below.

Under the ordinance at §17.65 (C)(3)(f), 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 3.f'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.

The County's findings regarding "customary use" have been interpreted as causing "non-customary use" signs adjacent to federal-aid highways to violate the Highway Beautification Act, even if they are in a commercial or industrial zone, per 23USC§131(d): "Whenever a bona fide State, county, or local zoning authority has made a determination of customary use, such determination will be accepted in lieu of controls by agreement in the zoned commercial and industrial areas within the geographical jurisdiction of such authority."

Two uncommon but increasingly seen restrictions prohibit signs "which emit any odor, noise, or visible matter other than light" (§17.65B.6.a.8) and "A vehicle used as a sign or as the base for a sign where the primary purpose of the vehicle in that location is its use as a sign" (§17.65B.6.a.18).

St. Johns County, Florida.

On May 11, 1999, the Board of County Commissioners of St. Johns County passed Ordinance No. 99-35, a revised sign ordinance providing for the regulation of both billboards and on-premise signs within the County. Although much of the ordinance contains language quite similar to other ordinances examined for this report, including provisions for spacing requirements, two provisions of the ordinance are unusual, and of direct relevance to this project.

First, the ordinance defines, at Exhibit D, an "automatic changeable message device" as "any Sign which through a mechanical, solar, electrical or other power system is capable of delivering two or more various advertising messages which do, or appear to, rotate, change or move at any time in any way, including Tri-Vision, or any Multi-Prism Faces."

Under the ordinance's "General Requirements," Section 3E, "Movement," provides the following statement: "No Billboard shall be Erected, or any existing Billboard modified or operated, that incorporates Flashing, Scintillating, Beacon or Running lights, Animated Copy, or any Automatic Changeable Message Device."

Section XIV, Prohibited Signs, states: "The following signs are prohibited in the jurisdiction governed by this Ordinance and said prohibition shall supersede any conflicting provision of this or other County ordinances. Subsection 19 reads: "Automatic Changeable Message Devices" (p. 27).

Second, the ordinance places specific prohibitions on vehicle mounted advertising. "Signs on vehicles" are prohibited (Section XIV, Subsection 10, p. 26-27) with specific exceptions such as those for parked vehicles not visible from the street, licensed or certified common carrier vehicles such as buses and taxicabs, vehicles temporarily traveling through the county, or vehicles on which signs are placed that identify the business or its principal product(s) if said vehicle is used during the operating hours of the business, provided that the vehicle is not repeatedly parked in a location where it serves as additional signage.

City of Tucson, Arizona.

By Ordinance Number 10481, the City of Tucson's revised sign code became effective January 14, 2008. While broadly reflecting sign codes in many other US jurisdictions, the Tucson code banned DBBs, signs on vehicles, and signs that provided other than visual stimulation. The relevant sections of the code are summarized below.

Section 3-53 is titled: "Prohibited signs enumerated." In addition to specific prohibitions against "intensely lighted signs" and those that are "animated by any means, including flashing, scintillating, blinking, or traveling lights, or any other means not providing constant illumination" (Sec. 3-53, §A.1, A.2), this section restricts Electronic Message Center signs, which it defines as:

> "An electronic or electronically controlled message board, where scrolling or moving copy changes are shown on the same message board or any sign which changes the text of its copy electronically or by electronic control more than once per hour" (Sec. 3-53, §B, p. 23).

Also prohibited in this section are any advertising signs or devices that emit "audible sound, odor, or visible matter" (§H, p. 23), and "signs mounted upon, painted upon, or otherwise erected on trucks, cars, boats, trailers or other motorized vehicles or equipment" (unless specifically allowed in another section of the ordinance) (§I, p. 23).

Billboards are addressed in Section 3-58. The relevant text reads:

> "Notwithstanding any other provision of the Tucson Sign Code, billboards may not change advertising copy by any type of electronic process or by use of vertical or horizontal rotating panels having two or more sides whereby advertising copy is changed by the rotation of one or more panels" (p. 26).

Outdoor Advertising Industry

The OAAA has, from time-to-time, posted certain guidelines for DBBs on its website or in documents distributed in other ways. As this is written, the organization makes available a publication titled "Regulating Digital Billboards" (OAAA, Undated a). In a section of the report titled "Suggested State Language" the document suggests that DBBs conform to the following:

- A displayed message appears for no less than four seconds

- The transition from one message to the next requires at least one second.
- Has spacing between billboards that are consistent with state requirements
- Does not include animated, flashing, scrolling, intermittent or video elements
- Will appropriately adjust display brightness as ambient light levels change

Others

During the course of preparing this Section of the present report, we became aware of a growing number of cities and other local jurisdictions that were addressing DBBs. Some were in the discussion stage, some had issued moratoria on new DBBs or DBB conversions while they considered the issues, some were conducting research, holding workshops or other public forums, and some were in various stages of developing or issuing guidelines or regulations. Despite our efforts to include in this report all of the new regulatory documents that we could find, this task became impossible, and we resorted to reviewing and summarizing a sample. To provide a frame of reference for the interest that DBBs have generated at the local policy level, the list below documents, from news media, the activities of city agencies within the State of Texas between April and December 2008 (Lloyd, 2008).

Cities enacting moratoria on LED billboards or DBBs in general – 6
Cities with DBBs under discussion at city council level -14
Cities imposing restrictions, but not prohibitions on LED billboards or DBBs - 2
Cities enacting total prohibitions on LED billboards or DBBs – 23

The Outdoor Advertising Association of America (OAAA, Undated b) has periodically issued and updated a document called the “State Changeable Message Chart.” This document summarizes the regulations and guidelines in the various States as they affect “changeable message signs” including those with “tri-action” and those with “digital technology.” Summarizing the information contained in this document, one can see that regulations for “dwell time” (the minimum length of time that a static message must appear on the sign before changing) range from 4 s to 10 s, those for “twirl time” (also known as the message change interval) range from “instantaneous” to a maximum of 4 s, with four States apparently having no upper limit; and required minimum spacing distance between signs ranging from “traditional 500 ft” to 5000 ft. According to the document, three states (North Dakota, New Hampshire, and Wyoming) prohibit all changeable message signs (CMS), five (Maryland, Massachusetts, Oregon, Texas, and Washington) permit tri-action signs only, and 38 others permit CMS with digital technology.

Recently, the OAAA (Undated c) posted on its website a list of “Brightness Criteria” for digital billboards, which, it noted, was based on a report submitted to the organization in March, 2008 by Dr. Ian Lewin of Scottsdale, Arizona. Our request for a copy of this report or the underlying analyses that led to the stated criteria was refused by OAAA on the grounds that the author did not want his data to be made publicly available since his had been submitted for publication.

Key provisions of the stated criteria are:

- Light produced by a digital billboard should not exceed 0.3 Footcandles (fc) over ambient light levels.
- Measurement should be taken utilizing a Footcandle (fc) meter from the following distances (perpendicular to the face of the digital billboard):
  - Posters: 150 feet
  - 10’6x36’ Bulletins: 200 feet
  - 14’x48’ Bulletins: 250 feet
  - 20’x60’ Bulletins: 350 feet
- A digital billboard must be able to automatically adjust as ambient light levels change. An automatic light sensing device (such as a photocell or similar technology) should be utilized for adjusting the digital billboard’s brightness.
- Sunset-sunrise tables and manual methods of controlling brightness are not acceptable as a primary means of controlling brightness.

SECTION 6.

RECOMMENDATONS FOR GUIDELINES

Based on the knowledge gained from the research reviewed in this project, as well as research conducted earlier and reviewed previously, good human factors practice, and guidelines or regulations developed or under consideration in jurisdictions throughout the US and world-wide, we have prepared a set of recommendations that State and local government agencies as well as private roadway operating authorities may wish to consider for use. We recognize that there are not yet comprehensive research-based answers to fully inform such guidance or regulation, and, given the complexity of the issue and the number of factors involved, it may be years before such results are available. Nonetheless, we have found, through the work undertaken for this project, that the research conducted within roughly the past ten years has quite consistently demonstrated empirical concern about driver distraction from roadside billboards, and has identified a number of DBB location and operational characteristics that seem to exacerbate the risk and/or consequences of such distraction, that the need for guidelines and/or regulations can be met within our current degree of knowledge. Indeed, of those research studies that have addressed driver distraction and roadside billboards, nearly every empirical study undertaken since 1995, including that by Lee et al., and sponsored by the outdoor advertising industry, have demonstrated that there is an adverse relationship between distraction and digital billboards.

MINIMUM MESSAGE DISPLAY DURATION (MESSAGE ON-TIME).

Perhaps the most contentious issue to be addressed in guidelines or regulations can be found in debates about the minimum duration of a message displayed on a DBB. For it is here that the goals of the DBB owner and those of the highway safety specialist are most at odds. Since roadside outdoor advertising is sold, to a large extent, on the number of drivers that pass the sign on a daily or hourly basis, and since certain times of day (e.g. rush hour) provide a larger audience, it is clearly to the sign operator's benefit to minimize the time for which any given message is presented so as to be able to offer more messages per unit time. There is, perhaps, a minimum display time below which both advertisers and regulators may agree that message display is unreasonable – for the advertiser because the time interval is too brief for a message to be read; for the traffic safety expert because the display obviously appears to "flash," and flashing signs are almost universally prohibited.

We are not aware of any research that has been conducted on the effects on distraction of the duration of time that a message on a DBB remains visible before changing to the next message. The OAAA (Undated a) has, periodically, issued guidance to its members on minimum display duration. It recommends 4 s. The FHWA (Shepherd, 2007) has recommended a minimum 8 s duration, and the OAAA (Undated b) reports that 41 States have enacted message display minima, ranging from 4 to 10 s. To our knowledge there is no empirical basis for any of these recommended or required display intervals. Indeed, as discussed below, good human factors practice would suggest that minimum display duration should differ with sight distance, prevailing speeds, and other factors.

Without the benefit of research, we must rely on human factors principles when attempting to develop a meaningful standard for minimum message duration. There are two human factors concerns that help to inform the analysis for this issue. First, it is widely understood that bright lights and visual change can draw the eye to a stimulus that is brighter than the surroundings, and/or exhibits movement or apparent movement. DBBs possess these properties, particularly at night and when they can be seen from considerable distances. In addition, the Zeigarnik Effect suggests that drivers will be attracted to attend longer to a display whose message changes as they approach it, in an effort to "complete" the viewing experience; in other words, to be able to look at a changeable message sign until he or she has seen the "complete" message. The simple way to minimize both of these potentially distracting effects of DBBs is to reduce to a minimum the likelihood that any given driver will observe an actual message change or to see more than a single displayed image. Given that any driver may come upon a given DBB at the moment of message change, regardless of the message duration, this objective cannot be met. However, it is not unreasonable to place a lower limit on message display duration to ensure that it is highly likely that motorists will be unable to see more than two successive messages (which would, by definition, include one message change). This can be accomplished by determining the sight distance and the prevailing speed (or the posted speed limit) for a road on which such a DBB appears, calculating the time for which a given DBB will be within the view of approaching drivers, and setting the minimum message duration at that interval or greater. Several jurisdictions have adopted this approach (see, for example, TEC, 1989; TERS, 2007). This is also the approach that was followed by the New York State Department of Transportation during the development of its draft regulations (NYSDOT, 2008a). The result of this analysis in New York was a proposed requirement for a minimum message display time of 61 s. (This proposed requirement was substantially reduced after a public comment period [NYSDOT, 2008b]). Of course, for different sight distances and different prevailing speeds, this minimum message duration would be different. Although a case-by-case process of setting minimum display durations would be optimum for traffic safety, it is likely that for both regulatory and enforcement purposes and for the ability of sign owners to establish standardized display intervals (and, hence, standardized advertising rates), it would be more practical for a road authority to establish only a small number of display duration minima, based on roads within their jurisdiction that operate with different speed limits and traffic characteristics.

Recommendation.

It is recommended that the following formula be used for calculating a minimum acceptable DBB display duration:

Sight distance to the DBB (ft) / Speed Limit (ft/sec) = Minimum display duration (sec).

INTERVAL BETWEEN SUCCESSIVE DISPLAYS.

There is little disagreement between those roadway authorities which have promulgated guidance or regulations concerning the interval between successive displays. It is clear and consistent that this time interval should be as close to zero as possible. Some jurisdictions define the change interval as “instantaneous,” others describe it as 0.1 s or less. The reason for this position is simple. Given that it is a combination of brightness and motion (real or apparent) that attracts a viewer’s gaze to a DBB, a perceptible dark or blank interval between successive displays will increase the sense of apparent motion (i.e. bright-dark-bright is more visually compelling than bright-bright).

Recommendation:

Regardless of how it is operationally defined, the interval between successive displays should be essentially zero, such that an approaching driver cannot perceive any blanking of the display screen.

VISUAL EFFECTS BETWEEN SUCCESSIVE DISPLAYS.

Even more so than the case for the display interval, regulatory authorities are in complete agreement that there should be no visual “special effects” of any kind during the transition between successive messages. It is clear that the screen should transition from one message to the next with no perceptible dimming or blanking of the display, and with no visible effects such as fade, dissolve, or animation. Different jurisdictions have described such prohibited effects differently, but the purpose is the same – a seamless, imperceptible transition from one image to the next.

Recommendation.

No special visual effects of any kind should be permitted to accompany the transition between any two successive messages. (Of course, it is assumed that no special visual effects are permitted during the time that any message is displayed on the screen).

MESSAGE SEQUENCING.

Message sequencing is a term used to describe a single thought, idea, concept, message, or advertisement for a product or service that is divided into segments and presented over two or more successive display phases of a single DBB or across two or more individual DBBs. Like the old “Burma Shave” signs that lined the country’s roadways beginning in the 1920s (Vossler, 1997), the use of roadside advertising signs to communicate a message in segments is based on the premise of capturing and holding the driver’s attention throughout the time or distance chosen to present the complete message. This premise is, in turn, based on the understanding of the Zeigarnik Effect; or, as described in the Wikipedia entry, the signs were effective for “drawing the attention (of) passers-by who were curious to discover the punchline” (Wikipedia contributors, 2009).

We believe that sequencing should be prohibited, whether on a single sign or multiple signs. This can be effectively accomplished by establishing minimum longitudinal distances between DBBs, or by ensuring that the minimum message display time is sufficiently long that a driver cannot view more than two such messages on a given passage, or by a combination of both. Even more simply, restrictions can follow those promulgated by SANRAL, which state: succinctly: “no message may be spread across more than one advertisement” (SANRAL, 2000).

Recommendation.

Message sequencing should be prohibited.

AMOUNT OF INFORMATION DISPLAYED.

Other factors held constant, the more information that is presented on a DBB, the longer it will take an observer to read the message, and as shown in studies of official CMS, the more likely it will be that drivers will slow to read the message, adversely affecting traffic flow and safety. This concern is exacerbated in situations when a driver might want to memorize or memorialize part or all of a message displayed on a DBB. Dudek (2008), in discussing official CMSs using the latest LED technology, reports that about 85% of drivers can begin reading a message about 800 ft upstream of the sign if the sign uses character heights of 18 in. At a reading speed of one word per second (demonstrated in numerous studies), this translates to maximum message lengths of eight words at 55 mph, seven at 65 mph, and six at 70 mph (p. 9). One must keep in mind, however, that these message lengths assume a message optimized for legibility and readability. To the extent that message fonts, typefaces, colors, color contrast, and other factors detract from readability, these message lengths must be reduced.

To our knowledge, no US jurisdiction places restrictions on the amount of information that may be presented on billboards, including DBBs. As stated above, the amount of information on official traffic signs is controlled as a result of years of human factors research. Both the outdoor (OAAA) and on-premise sign industries (International Sign Association [ISA]) have, from time to time, provided guidance to their members about the relationship between the effectiveness of a sign and the amount of information presented on it.

Several government agencies outside the US have promulgated regulations or guidance that addresses this issue from the perspective of driver workload. Some limit the number of words or characters permitted on a sign; others restrict the number of bits of information that a sign may contain. Lengthy strings of numbers and/or letters, such as telephone or license plates numbers, or internet addresses, have come under scrutiny in a number of jurisdictions because of the demands that they may place on the driver.

There remains, however, a clear distinction between the efforts of highway and traffic safety experts on the one hand and the creators of outdoor advertising sign content on the other, in the approach that they have followed to the design of messages meant to be read by drivers. The MUTCD and the research on which it relies recognize that road signs are something of a “necessary evil.” They are required to communicate warnings, regulations, guidance and other information to road users. But, because even official signs draw the driver’s eyes away from the principal task, such signs are designed communicate their message quickly, clearly, and consistently. Advertisers, on the other hand, have demonstrated little predilection to follow these principles; rather, their goal is to attract the driver’s attention, and hold it long enough to communicate their message. For this reason, as well as others including brand identification and the need to compete with other signs for attention, billboards, including DBBs, tend to rely on bright colors, bold graphics, attention-getting images, and clever phrases to perform their job. Words and phrases may be presented anywhere on the sign face, including sideways and upside down, depicted in multiple fonts and typefaces that may be difficult and time-consuming to read. Color and contrast may draw attention to the sign and yet prove to be a challenge to the driver to read the message in the time available for it to be seen.

While it is not be within the power of any government agency or road operating authority in the US to dictate the type or nature of display content or presentation, we believe that it is reasonable for such authorities to impose limits on the amount of information that can be presented. Precedent for guidelines on information content can be found in the work of duToit and Coetzee (2001) in South Africa, Martens (2009) in The Netherlands, and Dudek (2008) in the US. The basis for such control as used on official signs is presented in the MUTCD (2003) at Section 2E.21 (p. 2E-20).

Recommendations.

Specific upper limits on the amount of information that might be permitted on DBBs should differ depending upon sight distance, speed limits (or prevailing speeds), and driver task demands imposed by the design and operation of the roadway. Without specific research it would be premature to recommend such limits in this report. However, reasonable guidance based on relevant human factors research, as discussed in Section 5 of the present report, has been developed by SANRAL (2000) and for the highway authorities in The Netherlands (Martens, 2009), and might prove to be a useful starting point for interested agencies. Further, the work by Dudek (2008) and his colleagues provides valuable insights, although this research is targeted at official CMS.

It should be noted that the use of telephone numbers, internet addresses, text message instructions, etc., is potentially harmful to traffic safety because drivers may slow to read, record, or even copy such information while in traffic. Evidence of such traffic slowing has been shown by Dudek, et al. (2007) with regard to AMBER Alert messages on official changeable message signs. Figure 6 shows a DBB displaying a commercial message that includes a number of these elements.

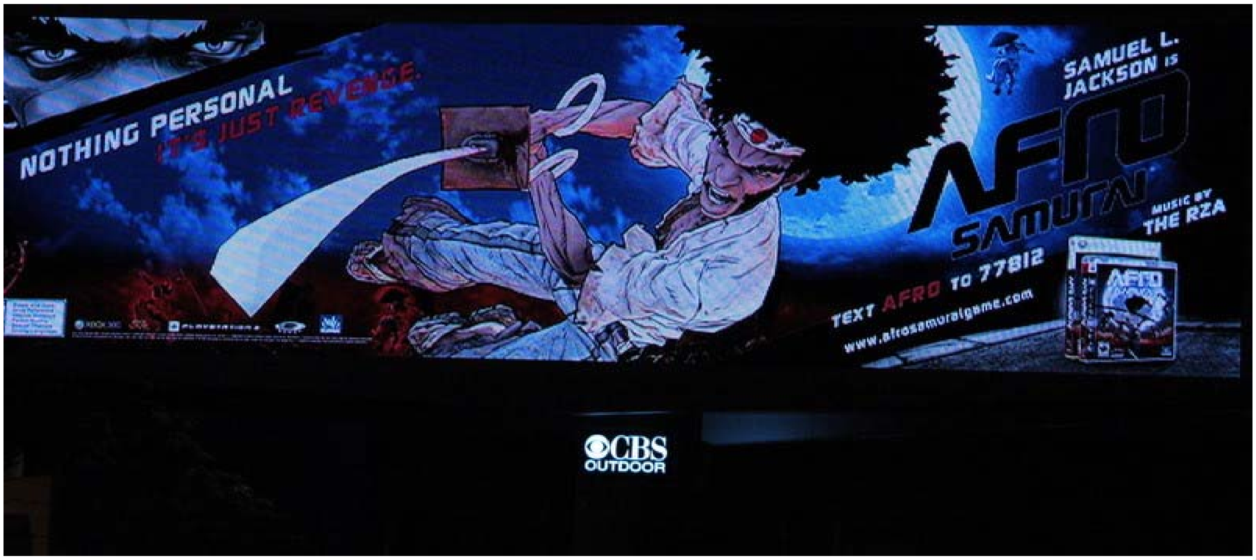

Figure 6. A DBB adjacent to an interstate highway in California. The sign includes an internet address, text messaging instructions, characters in multiple colors, sizes and typefaces, poor figure-ground contrast, and several graphic elements too small to read.

INFORMATION PRESENTATION.

As discussed immediately above, considerable research in both the US and abroad has produced clear and consistent recommendations for display presentation characteristics that facilitate speed and ease of reading and rapid, unambiguous message interpretation. These recommendations, through years of development and constant refinement have resulted in uniform standards for official signs. The lessons learned from this research, and the adoption of the spirit of such standards by the outdoor advertising industry could produce DBBs that 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. Figure 6, above, shows the potential difficulty of reading a message presented on a DBB with several display features that are less than optimum for readability by approaching drivers.

Recommendations.

Specific recommendations for the design of DBB advertisements are beyond the scope of this report, and, possibly, outside the authority of regulators. This is an area, however, where considerable guidance is available to advertisers and DBB owners from sources inside the outdoor advertising industry as well as human factors and traffic safety experts, and the MUTCD itself. Stronger industry guidance and self-regulation regarding the design of information presentation on DBBs could go a long way toward reducing their potential for driver distraction.

DBB Size.

The larger the size of the DBB, the larger the images and characters that can be displayed on it, the brighter it can appear to be, and the greater the distance from which it can be seen and read.

In the US, the majority of DBBs erected to date, and, to the best of our knowledge, the majority of those contemplated in the near term, are one-to-one replacements for, or the same size as, existing conventional billboards. The most common size for such billboards adjacent to roadways is 14 ft by 48 ft in a horizontal format.

Regulations governing DBB size may be based on factors other than sight distance or legibility, such as zoning, land use, structural constraints, etc., and are beyond the scope of this report.

On-premise and vehicle-mounted digital (and video) signs, do not necessarily conform to these standards. The issue of DBB size is this context is briefly discussed in Section 6.

Recommendations.

Since the principal focus of this report is off-premise DBBs, recommendations for maximum sign sizes are inappropriate.

BRIGHTNESS, LUMINANCE AND ILLUMINANCE.

The issue of brightness, luminance, and illuminance is at once the most contentious, the most important, the most "public," and the least well understood aspect of DBB operation and its potential for adverse impacts on approaching drivers. And yet, it is the issue that may be the most amendable to a solution that is satisfactory to DBB owners and operators, traffic safety experts and regulators, and the traveling public.

Brightness is a measure of the *perceived* intensity of a source of light. As described by Halsted (1993), "brightness is a subjective attribute of light to which humans assign a label between very dim and very bright (brilliant). Brightness is perceived, not measured… The response is non-linear and complex. The sensitivity of the eye decreases as the magnitude of the light increases" (p. 2). A DBB is constructed of thousands of Light Emitting Diodes (LEDs) that operate together to produce the myriad colors and levels of light that we see when we view such a sign. Thus, we may consider a DBB to be a source of light, although, in actuality, it is built of many individual sources. If we were to set a DBB to its maximum output and observe the sign in full sunlight, it would appear less bright to the human observer than it would if we viewed the same sign, at the same setting, at night. Similarly, if we viewed the sign at the same setting at night in a bright urban landscape it would appear less bright than if we viewed it in a dark rural environment. Accordingly, when trying to develop guidelines or requirements for the "brightness" of DBBs, what we really mean is that we need 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. Such conditions might include daylight in sun or clouds, dusk and dawn, adverse weather such as rain or fog, and nighttime conditions in urban, suburban, or rural settings. In short, "brightness" cannot be used as a criterion to regulate or provide guidance for the output of DBBs.

Whereas brightness measures the subjective, human perception of the DBB's intensity, two objective measures are available for the actual measurement and establishment of limits. *Illuminance* describes the amount of light coming from a light source that lands on a surface. Horizontal illuminance describes the amount of light landing on a horizontal surface, such as the light reaching the surface of a desk or table from a lighting fixture mounted overhead. Vertical illuminance describes the amount of light landing on a vertical surface. For example, a light shining on a wall, or a vehicle's headlights shining on a non-illuminated road sign. Illuminance is measured in *footcandles (fc)* or *lux (lx). Luminance* describes the amount of light leaving a surface in a particular direction, or reflected off that surface, and can be thought of as the measured brightness of a surface as seen by the eye. Luminance is measured in *candelas per square meter* (cd/m^2), also referred to as the *nits* (one nit = one candela per square meter). A typical LCD computer monitor, for example, has a luminance of 300 nits or higher.

We might think of illuminance as the lighting *of* an object, and luminance as the light coming *from* an object. In the case of a traditional, static billboard that is illuminated at night by floodlights, as well as in the case of a DBB which uses LED technology that is often described as "self-luminous," we are concerned with luminance, the light being emitted from the billboard rather than illuminance. Through a simple example, we can demonstrate how these two different measurement principles work, and why luminance is preferred for our application. If we shine a light onto a white wall, and shine the same light onto a dark grey wall from the same distance, the illuminance (the light falling on the wall) will be identical, but the luminance will be much lower for the grey wall, because it reflects back to the observer's eye much less of the light striking it.

Both the Illuminating Engineering Society of North America (IESNA) in its standard RP-19-01, and the Commission Internationale de L'Eclairage (CIE), in its publication 111-1994 (both cited in Andersen, 2008a), discuss luminance values for road signs – externally and internally lighted signs in the first case, and changeable message signs in the second. In its discussion of sign brightness, the 3M Corporation says: "luminance is the best measure available to judge relative sign brightness" (3M, 2005).

With an important exception discussed below, the luminance of a DBB is relatively unimportant during a sunny day. However, it is precisely because a DBB must have a very high luminance capability to be visible in bright sunlight, that its output must be reduced at night, at dawn or dusk, or in inclement weather.

Through what some have called the "moth effect" (see, for example, Green, 2006) but may be more appropriately seen as a variant of the physiological mechanisms of phototropism or phototaxis, the eye is drawn to the brightest objects in the field of view.

Thus, other things equal, a brighter billboard will attract a driver's gaze earlier and, potentially, longer, than other visual stimuli in the environment that appear less bright.

At night, dawn or dusk, or in inclement weather such as rain or fog, where visibility conditions are poorer than in daylight, a bright sign can draw attention away from the road, official TCDs, and other vehicles, and can render signs lighted to a lesser degree more difficult to discern, particularly when the billboard and the official signs must be viewed at the same time. Similarly, vehicle rear lighting can become more difficult to see, and less conspicuous, if it is to be viewed at the same time, and within the same field of view, as a brightly lit DBB.

There is no single luminance level that can be established as a reasonable criterion because brightness (although not actual luminance) is dependent upon the surrounding environment in the context of which a particular DBB is viewed. Thus, for example, a DBB of the same size and luminance will appear to the driver to be much brighter if it is located in a rural area or along an unlit roadway, than it would if it was in a brightly lit urban environment or adjacent to a illuminated freeway.

All of the research identified in this report, and all of the identified regulatory authorities that have imposed billboard, including DBB, brightness limits, use luminance as their measurement approach. On the other hand, the OAAA uses illuminance. The discussion below highlights these differences and explains the implications of them for the setting of regulations or guidance.

On behalf of the New York State Department of Transportation, the Lighting Research Center of the Rensselaer Polytechnic Institute (Bullough and Skinner, 2008) prepared a document titled: "Technical Memorandum: Evaluation of Billboard Sign Luminance." The principal purpose of RPI's work was to provide NYSDOT with estimates of the luminance levels of existing, static, externally-illuminated billboards adjacent to State highways so that the State could make an informed decision about maximum luminance levels that might be permitted for DBBs using "self-luminous light sources such as light-emitting diodes (LEDs)" (p. 1). The work consisted of three steps – a review of recommendations and methods to calculate luminances from IESNA and industry sources; field measurements of the luminances of several billboards in situ; and a computer simulation of a billboard lighting installation based on industry recommendations.

The report describes the IESNA recommendations (Rea, 2000) for "illuminated billboard signs and other large advertising panels" (i.e. the dedicated, fixed lighting shining on the billboard to illuminate it at night) and identifies two factors that must be considered when applying these values. The first is the degree of reflectivity of the billboard itself – a dark-colored sign will reflect less light than will a light-colored sign (assuming that the lighting sources are equal). The second is the surrounding location – whether the billboard is located in a bright, typically urban, setting, or in a dark, typically rural setting. The IESNA values for billboards in bright surroundings is 1000 lux (abbreviated lx), and for dark surroundings, 500 lx. Assuming that a billboard had a white sign face with a reflectance of 0.8, the luminance (L) of such a billboard (the amount of light reflected back from the sign) would be 250 candela per square meter (cd/m^2) in the bright environment, and 130 cd/m^2 in the dark setting. The authors then reviewed product information supplied by two billboard manufacturers and concluded that industry recommendations were in close accord with those recommended by the IESNA.

The researchers then recorded the luminance values for six conventional billboard faces and four LED billboard faces using a Minolta LS-100 luminance meter. Their measurement methods are well described in their report and won't be repeated here. They found that the LED billboards ranged from 160-320 cd/m^2 at night, with a mean value of 225 cd/m^2. The conventional billboards (excluding two faces that were apparently not illuminated) ranged from 150-240 cd/m^2 with a mean of 182.5 cd/m^2.

Bullough and Skinner next created a computer simulation model to determine whether they could reproduce their field measurements. Their model consisted of a 14 ft. by 48 ft. fixed, illuminated billboard with a white (0.8 reflectance) sign face and a 40 ft. tall mounting pole with reflectance of 0.25. Their virtual billboard installation was created in a simulated dark nighttime setting. They found that the luminance values of the billboard signs were generally consistent across their three tests, and they concluded that "it is probably reasonable to expect that the luminance of a conventional billboard would not be likely to exceed about 280 cd/m^2 during the nighttime" (p. 4).

When discussing luminance measurements for DBBs, the authors make several recommendations:

- Luminance measurements should be made directly in front of a sign.

- Because LEDs have higher light output at lower temperatures, measurements should be made within predefined, and consistent ambient temperature ranges.

- A luminance meter aperture of 1 deg or less should be used.

- Because LED billboards are composed of arrays of LEDs, their surfaces are not uniform. If viewed from very close distances, they will appear as an array of bright points against a dark background. Thus, a viewing distance of approximately 50 ft is suggested, since a 1-deg meter aperture would subtend approximately 10 in at this distance, sufficient to ensure uniformity of the display.

- Since light from the ambient environment adds to the recorded luminance, measurements should not be taken at distances greater than that suggested above.

- Measurements should be made while the sign display is white to present the maximum luminance values.

In its draft regulations, the State recognized that DBBs at night, if excessively bright, could not only cause distraction, but also could compromise dark adaptation, particularly for older drivers. (The potential for discomfort or disability glare was not discussed in the State's proposal, but was briefly addressed in the RPI report). Based on RPI's work and as a result of the State's review of the billboard industry's own published literature, the State initially recommended a "maximum brightness" for DBBs at night of 280 cd/m^2. This upper limit remained in force when the State issued its final regulations.

On behalf of the government of Queensland, Australia, TERS (2002) also described a specific measurement technique using luminance, and identified specific constraints for nighttime luminance levels. Appendix D to their report cites, as a basis for their guidelines, the research results from Johnson and Cole (1976) that "brightness from illuminated Advertising Devices directed at road traffic should be minimized under all conditions" (p. 20).

Similar to the work by RPI for NYSDOT, these authors indicate that the surroundings in which the billboard is located is a major factor that affects its brightness, given a particular luminance level. They have defined three "Lighting Environment Zones"

The maximum recommended luminance levels for billboards of all sizes, measured in cd/m^2, are as shown below:

Lighting Environment Zone 1	Lighting Environment Zone 2	Lighting Environment Zone 3
500 cd/m^2	350 cd/m^2	300 cd/m^2

TERS describes its luminance measurement methodology as summarized below:

- Allow the billboard to "burn in" for at least 100 hours.
- Use a luminance meter with a field of view of 2 degrees.
- Ensure that no ambient background area or spurious light source beyond the billboard is included in the field of view of the luminance meter.
- Take the measurement with the operator standing at the edge of the traveled way, in a direct line, and at a longitudinal distance from the billboard determined by a formula shown as:

  $$x = 28a \text{ meters}$$

  where *x* is the longitudinal distance from the billboard and *a* is the short dimension of the billboard. Thus, for a billboard that measures 14 ft. (4.3 m) in its shortest dimension, the measurement would be made from 120.4 meters (395 ft.) away.

- If the longer axis of the billboard is greater than 1.5 times the shorter axis, take a series of measurements and average the results to determine a mean luminance level for the entire sign face.

Although the luminance measurement distance recommended by TERS is greater than that proposed by RTI, there is a simple explanation for this apparent discrepancy. First, the measurement technique presented by TERS is for use with conventional billboards, and recognizes that there may be wide variations in luminance at different positions across the sign face. Thus, their measurement technique places the luminance meter sufficiently far from the billboard to take in the overall sign face without also including nearby ambient lighting sources. If the TERS measurement methodology were to be applied to a DBB, and if the measurements were to be made with a uniform white sign face, as proposed by RPI, then it is likely that the proposed measurement distances would be closer, recognizing that TERS suggests a 2 deg field of view and RPI suggests 1 deg.

Recommendations.

The measurement of luminance is reasonably straightforward, and, although there are some technical disagreements on how this measurement should be made, these differences are minor. Both New York State (Bullough and Skinner, 2008) and the Queensland (Australia) government (TERS, 2002) use equivalent methods, which are similar to the approach recommended by an FHWA expert in this field (Andersen, 2008b).

These methods can be adopted for use by any jurisdiction, with two caveats. First, although Queensland has explicitly recognized the need for different maximum billboard luminance levels depending upon different roadway environments, such ambient lighting conditions in the U.S. may differ from those in Australia, and State and local jurisdictions may wish to define their environmental surroundings to be in closer accord with local conditions “on the ground.” Second, given that luminance standards must establish maximum acceptable levels, it is important that the any measurement of DBBs in the field be done with the signs set to their maximum output, i.e. displaying a completely white screen. Because digital billboards can display an essentially infinite variety of colors and patterns, it is not appropriate to take field measurements of signs displaying actual messages, since, at any given time, such messages may not represent the maximum luminance values of which the sign is capable. (Figure 6 shows a DBB which, because of its color, may be representative of a low luminance level).

The OAAA, in its “Code of Principles on Digital Billboards” (OAAA, 2008) makes the following statement with regard to DBB luminance:

> We are committed to ensuring that the ambient light conditions associates with standard-size digital billboards are monitored by a light sensing device at all times and that display brightness will be appropriately adjusted as ambient light levels change.

Although not included within its code of principles, the OAAA (2008) states:

> The outdoor advertising industry has established guidelines after commissioning research by Dr. Ian Lewin, a former chairman of the Illuminating Engineering Society of North America (IESNA). Digital billboards, according to the standards, should have lighting levels no more than 0.3 foot candles (fc) above the level of surrounding ambient light conditions."

Unfortunately, this research study is not available on the OAAA website, and OAAA officials refused our request for access to Dr. Levin's research. The language reported by the organization on its website, however, suggests two problems with their approach. First, they used illuminance as their measurement technique, whereas other organizations used luminance. Second, the OAAA expert apparently recommended that DBBs be controlled such that their maximum display output is capped at a fixed amount (0.3 fc) greater than the surrounding environment. This specification may be inappropriate because illumination levels do not increase in linear fashion. Thus, a DBB with an output that is 0.3 fc higher than the ambient illumination in an urban environment (where the majority of DBBs are likely to be located) will appear to the driver to be much brighter than official TCDs and other traffic, whereas a DBB with an output that is 0.3 fc higher than that of a suburban or rural environment may not appear to be so extremely bright, and may be less likely to overwhelm important safety targets and signals of lower luminance.

There is one ambient lighting/weather condition that suggests a need for an exception to the recommendations that DBB luminance controls are unnecessary in daylight. This exception occurs during daytime fog. In daytime fog, the ambient lighting conditions may be described as high brightness and low contrast. The water vapor in the atmosphere scatters light sources and may cause glare. In dense fog, drivers may have difficulty seeing vehicles ahead of them, even when these vehicles have their lights on. Multi-vehicle crashes are not infrequent in dense fog, and this is often attributed to drivers being unable to see vehicles ahead of them in sufficient time and distance to stop. The very high luminance levels of which modern DBBs are capable, and to which they are typically set during daylight so as to be visible in full sunlight, may have a potentially deleterious effect in fog, especially if the DBB is placed so that it is close to the center of the driver's focal vision upon approach, such as might be the case on a horizontal curve

As recommended by the OAAA, DBBs should be equipped with sensors that measure ambient brightness, and dimmers that can control the sign output to predetermined levels. Although necessary, this is not sufficient. These predetermined levels should be established by the means suggested above. Further, if the onboard sensors cannot detect daylight fog and adjust the sign's output accordingly, jurisdictions should develop their own output limitations for these conditions.

The good news is that regulatory bodies and billboard companies seem to reach similar conclusions about the maximum luminance values that billboards should not exceed under defined conditions. If these two stakeholder groups can agree upon measurement methods, environmental descriptors, and means for ensuring that limits are not exceeded, one of the key concerns about the distraction potential of DBBs could be close to resolution.

DISPLAY LUMINANCE IN THE EVENT OF FAILURE.

There are a number of failure modes that can affect the luminance of a DBB, and there have been reported cases of failures in which the display luminance defaulted to a level far higher than intended or permitted.

Although, as discussed above, the OAAA provides guidance on its website and in periodic reports about suggested upper limits on display luminance (which it calls brightness, and suggests that DBBs include a device to automatically control the sign brightness relative to the ambient environment, the organization is silent on the issue of luminance control in the event of system or subsystem failure.

Recommendations.

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. If this cannot be achieved, then the display should be required to default to an “off” position until the problem can be resolved.

LONGITUDINAL SPACING BETWEEN DIGITAL BILLBOARDS.

As noted by the OAAA, different States have widely varying longitudinal spacing requirements for billboards in general and DBBs in particular. These requirements are typically described by the distance in feet that the nearest billboards must be spaced from one another. Often there is a different spacing requirement for billboards on opposite sides of the road. From the perspective of potential driver distraction, however, longitudinal billboard spacing should not be based on absolute distance, but upon whether two or more such billboards are within the driver’s field of view at the same time, and, consequently, whether the unsynchronized changing messages on such billboards can distract by conveying the appearance of flashing. Accordingly, longitudinal spacing minima may vary depending upon prevailing travel speeds, sight distance, and topography, and thus may vary considerably from one location to another, even within the same jurisdiction.

Recommendations.

Governments or roadway operating authorities should establish minimum longitudinal spacing requirements for DBBs such that an approaching driver is not faced with two or more DBB displays within his field of view at the same time. This minimizes the risk of distraction and ensures that a flashing effect (that may be caused by two [or more] different signs cycling through messages on different programs) will not occur. Any such longitudinal spacing requirements should address signs on both sides of the roadway. If a consistent spacing requirement is appropriate or necessary within any particular jurisdiction, then the most conservative spacing consistent with the above requirements should be established.

DBB PLACEMENT WITH RELATION TO TRAFFIC CONTROL DEVICES AND DRIVER DECISION AND ACTION POINTS.

Beyond the design and operational characteristics of DBBs themselves (brightness, display duration, etc.) perhaps the most important DBB characteristic with impact on traffic safety is the placement of such signs in relation to driver decision and action points, and to the traffic control devices (signs, signals and markings) that aid drivers in these decisions and guide them in these actions. Specifically, it is understood that the cognitive demands on drivers is greatest (other factors held constant) when they must position themselves to take an exit, enter a freeway, reduce or drop lanes, merge with other traffic, change route, etc..

The independent research reviewed for this report recognizes the importance of such constraints almost without exception, and the many jurisdictions, in the U.S. and abroad, that have published guidance and/or regulations nearly all address these concerns. And although these guidelines and restrictions are not fully consistent across regulatory agencies, they are remarkably similar. Although some published guidance and regulation is too vague to be useful in terms of enforcement potential or proven safety benefits. Others may well serve as a model that State and local governments, and other roadway authorities might adopt.

We believe that the adoption of objective constraints for DBB placement in relation to official TCDs, to intersections and interchanges, and to decision and action points is firmly justified because, to a great extent, the design and placement of TCDs themselves is the result of empirical research that has led to nationwide standards. Similarly, the design of intersections and interchanges, and of roadway design for safe and efficient traffic movements, is based on long-standing, well-researched, thoroughly documented principles. Accordingly, we believe that prohibitions against the placement of distracting irrelevant stimuli in roadway settings where drivers must make decisions and take actions should be imposed.

Recommendations.

The guidance provided by the government of Queensland, Australia is particularly well researched and documented, and might serve as a basis for US highway agencies. Similarly, the recommendations promulgated in New South Wales, Australia, are relevant, as is the guidance developed in South Africa, with specific regard to the placement of DBBs relative to official traffic signs.

ANNUAL OPERATING PERMITS.

There are several reasons why a Government agency or toll road or other roadway operating agency might want to rescind the operating permit for a DBB after initial approval. For example, traffic delays, crashes, or other operational difficulties may increase and the authority may attribute such difficulties to the presence or operation of the sign. New technologies may become available and used on the sign that the authorities find inappropriate. The sign may experience frequent failures or misoperation. The road abutting the sign may need to handle increasing traffic, or may need to be upgraded with additional lanes, interchanges, or signage, placing the DBB, after the fact, in a location that the authorities believe to be unsafe.

The City of Oakdale, Minnesota, as discussed in Section 5, grants annual permits to operate DBBs; the permits must be renewed each year. This allows the City to maintain oversight of sign operation, and facilitates updates to controlling legislation should new technologies emerge or should new operational data or research findings suggest needed changes to sign location or operation. Without such a process, a permitted sign may continue to operate unchecked, regardless of whether new information would suggest modifications to placement or operation.

Recommendation.

Government agencies and roadway operating authorities might consider the practice adopted in Oakdale, Minnesota, whereby owners of DBBs 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

Digital Billboards as On-Premise Signs.

On-premise signs, those that advertise products or services that are available on the property on which the sign is located, have been a mainstay in the US for generations. The objectives of the current project were to "develop guidance for state DOTs and other highway operating agencies with respect to the safety implications of the digital display technology for outdoor advertising signs." Traditionally, outdoor advertising signs refer to billboards, also known as off-premise signs. As such, on-premise signs are outside the scope of this report. However, to the average motorist, the difference between billboards and on-premise signs is transparent. In addition, as the cost of LED display technology comes down, and as the power of this technology grows, it becomes more likely that roadside businesses, particularly those with multiple users such as shopping centers, auto malls, sports complexes, and entertainment venues, will increasingly install large digital advertising signs on their property.

Generally, despite the fact that such displays may use the same technologies as billboards, the owners/operators of these signs are represented by different organizations, and they have been regulated quite differently than have roadside billboards. 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 DBBs, 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.

To our knowledge, the largest digital advertising sign in the world is an on-premise sign, mounted on the roof of a grocery warehouse and store in New York City. This sign, shown in Figure 7, is 90 ft tall by 65 ft wide[15], and is mounted on a 165 ft tall steel post on the roof of the warehouse, adjacent to a major interstate highway. The sign, claimed to be visible for over two miles, was recently used during a five-month period to present a rotating series of 19 animated spots for a local magazine. The animation took advantage of the "billboard's ability to display high-impact full motion video and graphics." The

[15] The face of this sign measures 5,850 sq ft, nearly nine times the size of a typical roadside DBB.

president of the company that created the commercials said: “It’s really a blast to be driving around the city and suddenly see your work looming over all of this traffic entering and leaving the city” (Black Hammer, Undated).

Figure 7. The world’s largest LED sign; an on-premise sign in New York City. The sign measures 90 ft tall by 65 ft wide and is mounted on a 165 ft tall steel post on the roof of building.

For transportation agencies and traffic safety organizations concerned about the risks of driver distraction, digital on-premise signs should not be overlooked as a potentially important near-term concern.

Strictly from the perspective of driver safety, 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 DBBs, 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

On October 10, 2008, Nevada Director of Transportation, Susan Martinovich, transmitted an SEP-15 project application to FHWA’s Nevada Division Administrator, Susan Klekar, titled: “Auctioning Rights to Construct Enhancements on and within Roadway Interchanges” (Martinovich, 2008).

The heart of the proposed program is the "enhancement" of selected interchanges by private partners that have submitted the highest or best value bids to the State. The application suggests that these enhancements may include landscaping, "architectural facades such as archways, public art or other aesthetic features" (p. 2). In exchange for developing and constructing these enhancements (and, it is suggested, removing them at the end of the lease term) the winning bidder "would be allowed to advertise within the interchange right of way limits" (p. 2). Although the application places no restrictions on the type of advertising that might be considered, the State suggests that this advertising might likely take the form of "incorporating the private partner's trade name, trademark, logo or other similar device into the design of the proposed enhancements" (p. 2).

The application States: "No design or enhancement would be accepted that would create a safety issue for motorists or pedestrians" (p. 2), and "safety will be foremost. No design will be allowed that will compromise safety" (p. 5). Given that the State proposes no *a priori* assessment of potential safety impacts, that the installations will be in place for 10 or more years, and that the only suggested safety analysis would be an undefined comparison of accidents; it is difficult to understand how this commitment to safety could be fulfilled.

Further, although the State's application does not mention that any of the potential enhancements will involve electronic signage, neither are such displays foreclosed. In fact, the final paragraph of the application states: "The tourism based economy of Nevada relies on spectacular displays, be they man-made or natural. Such exceptions (sic) of grandeur make this program an ideal match" (p. 9). When the recognition of man-made spectacular displays is associated, as this proposal is, with "context sensitive design," the potential for the types of enhancements that are associated with Las Vegas and Reno cannot be discounted.

On August 27, 2008, the Director of the California Department of Transportation (Caltrans) wrote to the Secretary of the US Department of Transportation seeking support for the expansion of its efforts "to integrate private sector participation in the provision of infrastructure, service, and ongoing maintenance of the State's transportation system" (Kempton, 2008). One of the "potential opportunities" for such partnership was described as follows:

> The Department's system of changeable message signs could be enhanced through private sector participation. In exchange for use of the space on the signs for commercial purposes, businesses could enhance the level of graphics, provide a steady income source, and use state-of-the-art technology to increase the quality of transportation and safety-related messages that are relayed to the signs.

At the time of the Caltrans request, the popular press (see, for example, McGreevy, 2008, Miranda, 2008) reported that the initiative was proposed by Clear Channel Outdoor, one of the country's largest providers of DBBs. The Caltrans proposal has raised numerous concerns within the highway safety community. A significant concern is that this initiative, if it went forward, would be in direct violation of several key sections of the Manual of Uniform Traffic Control Devices (MUTCD, 2003). Examples include:

> Traffic control devices or their supports shall not bear any advertising message or any other message that is not related to traffic control" (p. 1A-1).[16]
>
> Changeable message signs shall display pertinent traffic operational and guidance information, not advertising" (p. 2E-20).
>
> When a changeable message sign is used to display a safety or transportation related message, the display format shall not be of a type that could be considered similar to advertising displays. The display format shall not include animation, rapid flashing, or other dynamic elements that are characteristic of sports scoreboards or advertising displays (p. 2A-3).

Other sections of the MUTCD, including those that address signage that might be considered closer to messages that are commercial in nature, nonetheless prohibit advertising. For example:

> The content of the legend on each panel (of a Tourist-Oriented Directional Sign) shall be limited to the business identification and directional information for not more than one eligible business, service or activity facility. The legends shall not include promotional advertising" (p. 2G-1).

Indeed, in official interpretations of the MUTCD and its purposes over the years, the FHWA has consistently taken a strong position in opposition to advertising within the right-of-way, and has supported its views with the legal opinion of its chief counsel.

For example, in 2001, in a policy memorandum addressing the purpose of "Adopt-a-Highway" signs and their treatment in the MUTCD, then FHWA Deputy Executive Director Vincent F. Schimmoller stated, in part:

> Recently, it has come to our attention that there are a significant number of Adopt-a-Highway signs throughout the country displaying commercial trade logos, slogans, telephone numbers, Internet addresses, and similar forms of commercial promotion… These signs are clearly intended for advertising to the passing motorists rather than acknowledging the litter pickup service of an organization for which the program was intended…These actions concern us and we would like to clarify Federal Highway Administration's (FHWA) position on this subject.
>
> Adopt-A-Highway signs displaying commercial trade logos, slogans, telephone numbers, Internet addresses, and similar forms of commercial promotion are not in conformance with the 2000 MUTCD.

[16] Note that this "Standard" is the very first requirement specified in the MUTCD and is included in Section 1A.01, titled: "Purpose of Traffic Control Devices."

> Further, the placement of commercial advertisement within the roadway rights-of-way is a violation of Federal law and regulation…. Allowing the use of commercial advertising signs along the roadway is a disservice to the traveling motorist who is relying on roadside signs for regulatory, warning, and guiding information. The Specific Sign Logo program and the Tourist Oriented Destination Sign programs, which are in compliance with the MUTCD, have been developed to provide guidance information to the traveling motorist.

This memorandum was supported by an attached legal opinion from the FHWA Chief Counsel (Malone, 1996). This document stated, in part:

> Signs erected solely as advertising signs do not fit any of the accepted categories of the MUTCD. They certainly do not regulate or warn motorists. Nor do they "give such information as will help them [motorists] along their way in the most simple, direct manner possible"… They are not concerned with promoting "the safe and efficient utilization of the highways"…Advertising signs on the right-of-way therefore are not approved signs under the MUTCD.
>
> It would be ludicrous to suggest that Congress, while mandating the States to control advertising along thousands of miles of Interstate and Federal-aid primary highways, would also allow the States to erect billboards on the rights-of-way of those same thousands of miles of highway.

In closing, the Chief Counsel expressed his belief that "FHWA clearly has the authority to withhold funds from a State that allows the erection of billboards on the rights-of-way, an act which constitutes a failure to comply with Title 23 requirements."

More recently, Federal Highway Administrator Peters (2003) issued in interim policy on Acknowledgment Signs on rights-of-way. She said, in part:

> The FHWA recognizes a distinction between signing intended as advertising and signing intended as an acknowledgment for services provided.
>
> With regards to advertising signs within the highway right-of-way, the FHWA reaffirms its long held position that advertising is not permitted on highway rights-of-way.
>
> Generally speaking, an advertisement has little if any relationship to a highway service provided. The advertiser wants to get its recognizable company emblem or logo before the motoring public, and, if possible, information on how or where to purchase the company products or service. If the acknowledgment sign goes beyond recognizing the company's contribution to a particular part of the highway and includes phone numbers or Internet addresses, the sign would more properly be termed an advertising sign.

Even in her recognition of the acceptable role of acknowledgment signs in specific applications, Peters stated that “a compelling responsibility for public safety” leads the FHWA to find certain locations inappropriate for such signs, including “on the front, back or around the perimeter of any traffic control devices, including but not limited to:

- Traffic signal heads and supports,
- Any regulatory, guide or warning sign,
- Changeable message sign,
- Traffic control device posts or structures
- Bridge piers
- At any site where the acknowledgement sign would obscure the ability of a driver to detect and understand existing traffic control devices.”

Further, she stated that such signs would be “inappropriate and not allowed on public highways…at key decision points where a driver’s attention is more appropriately focused on traffic control devices or traffic conditions. These locations include, but are not limited to:

- Exit and entrance ramps and other lane-weaving areas
- Highway-rail grade crossings
- Work zones
- Areas of limited sight distance

In short, FHWA’s ongoing policy, and its interpretation of the MUTCD and the legislation at 23 U.S.C. § 402(a) and § 109(d) under which the MUTCD was promulgated, have clearly expressed opposition to advertising of any kind within the right-of-way. Regardless of any benefits from the public-private partnerships that California and Nevada have suggested, and regardless of any State budgetary difficulties that might be eased by revenue from such partnerships, FHWA’s position against advertising on the right-of-way has been consistently and, we believe, appropriately, based on its interpretation of the Federal Highway Administrator’s authority to decide which signs “promote the safe and efficient utilization of the highways” (Malone, 1996).

Other highway and toll road operating authorities have been approached by advertising companies (see, for example, Dudek, 2008, p. 35), or have independently considered the use of outdoor advertising on new or existing signage within their rights-of-way (see, for example, The Port Authority of New York and New Jersey (PANY, 2006). There can be little doubt that an official acceptance by FHWA of the ideas promulgated by California or Nevada in their recent SEP-15 initiatives would have important ramifications nationwide. Indeed, there is concern that some roadway operating authorities may not wait for FHWA action and may consider taking steps to approve advertising on their rights-of-way regardless of FHWA's position. The FHWA legal opinion discussed above (Malone, 1996) came in response to "a decision by the New Jersey Turnpike Authority to erect 12 double-sided billboards in the right-of-way of the New Jersey Turnpike…" And the PANY Request for Proposal advised proposers that "for the purpose of this analysis, the Consultant shall assume that the Authority is exempt from local, State, and Federal regulations, including FHWA policy" (Attachment A, Page 1).

Whether the placement and operation of DBBs within the right-of-way is a safety concern is an issue that is central to the present report. In addition, the precedent that would be set by the installation of such signs has important ramifications for the nation's highway system, and for the continued role of the MUTCD as the national standard for the design and use of official traffic control devices on streets and highways. Although a discussion of the history, development, and impact of the MUTCD is beyond the scope of this report, it bears comment that the document is unambiguous when it comes to the potential for commercial messages to be displayed on official signs.

It is the opinion of this author that permitting California to study its proposed exceptions to the requirements of the MUTCD and existing Federal law would bring about several adverse consequences:

- It would undermine decades of human factors research and application that ensures that information important to the driving task is conveyed to the motorist in the most clear, concise, succinct and unambiguous manner possible.

- It would set a dangerous precedent that would lead to similar actions by State and local governments, toll roads, and other private road operators nationwide.

- It would open to challenge the entire basis of the MUTCD, and erode confidence in and respect for the country's only standard for the proper use of traffic control devices on streets and highways.

And, most significantly, it would likely diminish safety and traffic flow on our streets and highways through a direct and immediate increase in driver inattention and distraction.

SECTION 8.

NEW TECHNOLOGY, NEW APPLICATIONS, NEW CHALLENGES.

This project has been focused on the impact of commercial electronic (digital) roadside signs on traffic flow and safety. Such signs, known as billboards in some jurisdictions and off-premise signs in others, are typically located outside the right-of-way, on private property, and they advertise products that are not sold, or services that are not performed on the property on which the sign is located. Billboards, regardless of the technology used to present and change the display, differ from on-premise signs in that the latter must be, generally, located on the premises at which the advertised service is performed, or product sold.

During the course of our research for this project, we learned of the growing use of new applications that increase the power and/or functionality of these digital, predominantly LED signs. These new applications have begun to appear on billboards in the US and abroad, on mobile (vehicle-mounted) displays, and on on-premise signs. Although some of these applications fall outside the charter of this project, this report would be incomplete without mention of them.

In most cases these new technologies and new applications are not addressed in Federal or local regulations and guidance; in some, regulations have already been imposed to address them. In a third category, some new developments appear to be in direct conflict with existing regulations or guidance. This chapter, although not contemplated when this project was initiated, will provide a brief overview of these new technologies and applications.

Billboard Audio and Other Stimuli.

Digital outdoor advertisements are already in use in some US locations that broadcast audio along with their visual messages. It is not unreasonable to assume that audio, and perhaps other attention-getting stimuli, may appear in the future. Internationally, we are aware that the SANRAL (2000) regulations recognize this potential, and prohibit it. Part B, Subsection 4 states: “No advertisement will be allowed that emits a noise, sound, smoke, smell or odours” (p. 13). In the U.S., both St. Croix County, Wisconsin, and the city of Tucson, Arizona, have similar requirements.

Digital Billboards on Moving Vehicles.

Vehicles in the traffic stream, primarily commercial trucks, have long borne advertisements for the truck owner or for the products being carried. One might think of these as mobile “on-premise” signs. In some cases, “supergraphics” (although, not, to our knowledge, digital) have been demonstrated that can convert trucks or large, over-the-road trailers into dramatic mobile visual images. One example is shown in Figure 8.

Figure 8. An over-the-road trailer featuring “supergraphic” imagery.

Urban and suburban taxicabs, buses, and rail transit vehicles may also display advertisements, and increasingly, these advertisements feature LED signage. These are the equivalent of mobile “off-premise” ads in that they advertise a product or service that has nothing to do with the vehicle displaying the ad.

For example, as part of its “Prepare Bay Area,” earthquake preparedness campaign, the (San Francisco) Bay Area Chapter of the American Red Cross faced a truck with a two-sided artist’s rendering of what downtown San Francisco might look like after the next earthquake. The truck drove around the city to attract attention, then parked at a location where the billboard lined up perfectly with the existing streetscape, as shown in Figures 9a and 9b.

Figure 9a. A mobile billboard from the (San Francisco) Bay Area Chapter of the American Red Cross parked in front of a building, depicting what might happen to that building after an earthquake.

Figure 9b. The same mobile billboard shown in Figure 8a looking in the opposite direction.

In the past few years, a number of products have become available that take advantage of the latest technologies to incorporate LED billboards onto the sides and rear of commercial trucks. In many cases, the sole purpose of such vehicles is to serve as a rolling advertisement; in others, the truck may display advertising while in transit, then park at a specific location to use its large-screen display in support of a concert, sporting event, parade, or other special function. In the latest advances, these signs can be raised electrically or hydraulically above the roof level of the truck; in some cases they can also rotate 360º. One company, named GoVision, advertises that its vehicles can display full motion video while in moving traffic. Indeed, news reports indicate that this occurred recently in Boston. On its website (www.govision.com) the company describes two products, a 40 ft trailer with a 9 ft high by 16 ft wide LED screen, and a 48 ft trailer equipped with a 627 sq ft, high definition video (720p resolution) wide LED screen.[17] The smaller vehicle, with its LED screen blank, is shown in Figure 10.

Describing this "moving television" product, the company suggests these uses:

- Get stuck in morning traffic playing a breakfast products commercial
- Drive around a sporting event's traffic promoting the new high powered SUV
- Add GoBig to your Xmas parade playing the latest holiday movie clips

Figure 10. A 40 ft trailer with an integral LED video screen measuring 9x16 ft. The screen shows full motion video while the truck is moving in traffic, and can be raised to a height of 25 ft for viewing while parked.

In other, less dramatic examples, several urban and suburban commuter bus and rail systems have begun to integrate digital billboards onto the sides of their vehicles. Figure 11 shows an urban transit bus displaying a digital advertisement.

[17] A standard size highway billboard, conventional or digital, measures 672 sq ft.

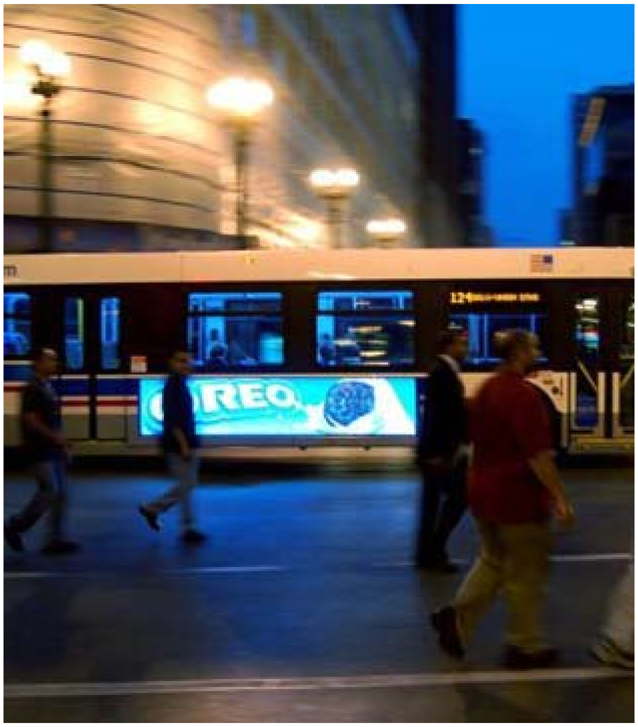

Figure 11. An urban transit bus displaying an LED billboard in traffic.

Although we are unaware of any research that has been conducted to evaluate these mobile display units, it would seem that the potential for driver distraction from the use of this technology within the traffic stream is quite high, not only because the changeable (and video) signs are in physical motion, but also because the presence of the advertising signage at extremely close lateral distances may require an extreme eye and/or head movement for the sign to be seen.[18]

As discussed earlier in this report, several jurisdictions have recognized or anticipated the risk of vehicle-based advertising, and have imposed restrictions on its use. In some cases, these controls are also directed at such vehicles when they are in operation while parked adjacent to roads visible to passing drivers within the jurisdiction's control. See, for example, the ordinances of St. Johns County, Florida, and Tucson, Arizona, discussed in Section 5.

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[18] It is noted that digital display technology using LEDs is also being marketed to the general public as a mechanism both for "personalizing" a vehicle, or for "marketing," "while providing automobile owners with an opportunity to profit from driving their vehicle." (See, for example, LED Wheels, 2004). Although there is clear potential for driver distraction from such vehicle-mounted digital imagery, it is beyond the scope of this project to determine whether such applications would constitute commercial advertising and thus be subject to the controls in place in certain jurisdictions and which may be considered for adoption in others.

“Personalized” And Interactive Billboards.

Interactive billboards, those that permit, support, or encourage personalized communications with the driver *in real-time,* have begun to appear on US roads, although this technology seems to be more progressing more quickly in Europe. Made possible by newer and ever more sophisticated technologies include cellular phones, text messaging, RFID, infra-red cameras, and others, these DBBs may take several different forms. These are briefly discussed below.

a. Signs that convey a personal greeting to the driver.

The popular Mini Cooper automobile, owned by BMW Corporation, has introduced a series of billboards in major US cities that display a static image of the automobile, along with a one line digital display that is normally blank. However, if the owner of a Mini Cooper has “opted in” by expressing an interest in the program, the sign’s digital display will present a “personal greeting” to the approaching driver. Figure 12 illustrates one of these billboards in use in New York City.

Figure 12. Personalized Mini Cooper billboard.

b. Signs that interact with the driver in real time.

In Paris, a trial has begun in which cell phone users who have agreed to participate will receive phone calls from billboards (Christensen, 2006; Crampton, 2006). These calls will offer additional product information, promotions, etc., that are keyed to the users’ location-enabled cell phones. The enabling technology was originally developed by the French National Institute for Research in Computer Science and Control to provide assistance to disabled people. According to the outdoor advertising company that is running the project: “With this project, we are really starting to create the personalized digital city… We eventually will see a rich dialogue running between mobile phone and what are now uncommunicative objects.”

In Belgium, as a driver approaches the digital billboard shown in Figure 13 the sign displays a series of codes. The driver chooses one, and sends a text message to an indicated number. The billboard responds by sending a return message containing a question. The driver then texts his answer to the question. The answer, in turn, triggers the DBB to respond like a pinball machine. A correct answer causes the sign to light up, and the driver is entered into a drawing (in this case, for the pictured car); a wrong answer causes the sign to “tilt”

Figure 13. Interactive billboard in Belgium. See text for details of the sign’s operation.

c. Signs that unobtrusively obtain information from drivers and vehicles.

Adjacent to an exit ramp along US 99 in Turlock, California, a “smart” 20 ft by 30 ft high-definition DBB (Figure 14) monitors the passive “local oscillator” signals emitted by the FM radios of passing vehicles. These signals reflect the frequencies to which the radios are tuned. The system compiles the statistical data, merges it with a media audit database that contains detailed consumer demographic and purchasing pattern information coded by radio station format, and enables the sign to post ads targeted to that demographic. “Smart Signs could inform passing motorists about special offers to shoppers as they approach stores or malls. A Smart Sign could entice consumers to respond via text message to a question posed by the sign. Information can even be pulled off the internet and displayed” (Christensen, 2007).

Figure 14. A “smart” DBB in Turlock, California

Many digital billboards have been equipped with video cameras that can record approaching traffic. A recent service aimed at the outdoor advertising industry permits an inconspicuous billboard-mounted camera, supplemented with an infra-red surround lighting device, to record the eye-movements of drivers approaching the sign (Skeen, 2007). Although this service is currently offered as a means to demonstrate to sign owners the amount of driver attention being given to their sign and its specific messages, it is a small technological step to combine these eye movement recordings with other demographic or personal information to target personalized messages or provide other “services.”

DBB Hacking.

One concern about DBBs, unlike any other in this report, is the potential for computer “hackers” to break into the control or communications system for these displays and change the messages and images displayed. For many years, loosely organized groups like the Billboard Liberation Front have made commercial billboards their targets for mischief. The type of technology that wirelessly controls DBBs has proven vulnerable to such vandalism, although reports of such hacking have been disputed.

Related technologies, such as those used for official portable changeable message signs (PCMS) have been successfully hacked in different jurisdictions on several occasions. Just before this report was finalized, the popular news media reported on a series of such hacks at a construction zone in Austin, Texas (Miller, 2009). Figure 15 shows one PCMS that was affected by this activity. At the same time, several websites published detailed instructions on how to perform such hacks (see, for example, Wojdyla, 2009). Although this latest example of vandals hacking into digital signs was quickly fixed by the sign manufacturer, the fact remains that roadside digital control technology is susceptible to being taken over by criminals or pranksters intent on changing the messages and images displayed on the signs for their own amusement, political or social purposes, or for other reasons. DBB owners and operators should be alert to these challenges, and should design, develop and implement corrective actions. Government agencies responsible for the regulation and oversight of such signs should ensure that any potential vulnerabilities are protected against.

Figure 15. A portable changeable message sign (PCMS) that was “hacked.”

SECTION 9.

SUMMARY AND CONCLUSIONS

This project has focused on three overlapping pillars of support in its effort to develop suggested guidelines for the control of DBBs: (a) human factors practices and principles; (b) guidelines and regulations currently in place in the US and abroad; and (c) the research literature.

Human factors principles have been developed over many years through empirical research, and have seen applications in practice regarding road safety throughout the developed world. Such principles and practices are codified in standards such as the MUTCD and SARTSM, to name but two, which were reviewed for this report. The wisdom of such human factors practices and principles is tested daily on streets and highways, and they are constantly being modified or supplemented when a “better mousetrap” is developed through research (recent examples include the development and implementation of the Clearview font for road signs, and the growing use of wider pavement markings to accommodate our ageing driver population).

And, in the guidelines and regulations that we reviewed, it was rewarding to learn that many of them, too, come from a solid research base. Examples of these empirically grounded guidelines include those in South Africa, Queensland, Australia, and The Netherlands (currently under development). Of course, some guidelines and regulations, even though based on sound research, either don’t get enforced, or don’t make it out of the draft stage. Thus, one of our goals has been to seek out the best supported and most practical guidelines that have been promulgated, review them based on their grounding in research and/or sound human factors practice, and hold them out as candidates that might serve as models for others to consider.

Our comprehensive and critical review of the literature focused on studies undertaken since the FHWA report of 2001, with the addition of several earlier studies that were included because of their relevance and because they were not previously given in-depth consideration in this context. As required by the program Statement of Work, we also separately reviewed research undertaken by or on behalf of the outdoor advertising industry.

Unfortunately, this issue is enormously difficult to study. This is because every billboard, road, and driver is different. A study evaluating a four-second message display interval might obtain quite different results from one using eight-seconds. A study in daylight will almost certainly find different driver responses than the identical study conducted at night. And a study conducted with free-flowing traffic may have a different outcome than one that examines the same road and the same billboard when traffic demands are greater. In addition, the key selling point of DBBs is that they can change messages every few seconds, and it is technically possible for them not to repeat the same message during a several hour cycle. Thus, studying such billboards *in situ* confronts the researcher with the added problem that it may be difficult to compare the experiences of any two (or more) drivers as they pass the DBBs under study for the simple reason that these drivers will, in all likelihood, experience signs with different content, different brightness levels, different graphics, and different font styles and sizes. This suggests that laboratory studies, despite what we believe to be important limitations, may permit better control over these inherent sign design and operational variables. Another alternative, not yet attempted with DBBs to our knowledge, involves a cooperative effort between researcher and sign operator in a field setting, so that the many relevant variables can be controlled and systematically presented to drivers, thus maintaining the validity of the field setting with some of the experimental control more commonly available only in the laboratory. Nonetheless, it is difficult if not impossible to design and conduct a research study whose results can be applied with confidence to DBBs as a whole.

In the recently published FHWA study, Molino and his colleagues (2009) comprehensively assessed the strengths and weaknesses of different research methods that might be applied to this challenge. When combined with the daunting number of DBB-related factors[19] (and levels within each factor), as well as the many measures that might be addressed to provide a complete answer to this research question, we believe that it is unlikely that any agency, private organization, or public-private partnership will have the resources available in the foreseeable future to undertake such a study. At best, future studies may be able to answer questions such as:

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[19] A subset of the number of DBB-related factors that must be studied to fully answer questions about DBBs and traffic safety.

Message change interval
Duration of message change
Sign luminance at night
Sign dimensions
Distance of DBB to traveled lanes
Angle of sign orientation to the approaching driver
Proximity of DBB to official signs, or on-premise advertising signs
Number and width of lanes of travel
Roadway geometry – vertical and horizontal curvature
Speed limits and prevailing speeds
Traffic volume
Traffic mix (e.g. percentage of large trucks, buses)
Proximity of DBB to exit or entrance ramps, gores, lane drops, route divides
Familiarity of the motorist with the roadway
Weather conditions
Environment in which DBB is located (e.g. urban, suburban, rural)
Amount of information presented on a DBB
Information presentation (color, contrast, font, etc.).

- Is a DBB that changes its message every eight seconds more distracting than one whose message is fixed for 60 seconds or longer?
- Is a sign of night luminance X more distracting than one of luminance Y?
- Do DBBs within certain defined distances of entrance or exit ramps contribute to more erratic or delayed vehicle movements than DBBs at greater distances?

In short, the issue of the role of 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. When we recognize that not every study is designed well or conducted rigorously, or where inappropriate assumptions are made or questions asked, there should be little wonder why research has not yet been able to fully “resolve” this issue.

Adding to the challenges of developing empirical answers that will satisfy the criteria for the development of guidelines or regulations is the fact that DBB technology and applications are evolving quickly. As costs come down and capabilities increase, new applications will be found for this technology. What will be the benefit of research that addresses the distracting effects of DBBs when on-premise LED signs will soon be proliferating – signs that may be larger, brighter, closer to the road, and displaying animation and full-motion video? Regulations promulgated for off-premise DBBs may seem quaint almost as soon as they are written. Potential research, even now, is years behind the implementation of the types of signs that are the subject of the research. How will we address the questions posed by roadside digital advertising that interact with the driver in real time by sending personalized messages to mobile phones, and requesting real-time responses by text messaging? And how will (or should) we address issues raised by digital signs that record potentially personal information about drivers passing such signs?

These are not questions that can be resolved in this report. There is hopeful news, however, about progress that has been made in forming and responding to key research questions. Almost without exception, the research studies discussed in this report have made dramatic advances in methodological sophistication, statistical power, and control of extraneous variables compared to those studies discussed in earlier research reviews. As a result, these more recent studies (primarily those completed within the past ten years) typically produce results and conclusions that are more reliable and valid than those of which their predecessors were capable. And, tellingly, the results of the most recent research are remarkably consistent.

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. The first, by Horrey and Wickens (2007) demonstrated that when making decisions that may result in road safety guidelines or regulations, we should be concerned, not with mean performance but rather with the poorest performances, those in the “tails” of the distribution. Of course, in many ways highway, traffic, and human factors engineers have been designing our vehicles and roadways in this manner for many years. Human factors professionals speak of designing systems to accommodate the 95th percentile operator, (e.g. FHWA, 1998), roadway geometric design is often established based upon 85th percentile speeds (e.g. Schurr, et al., 2005), the size of letters on highway signs and the width of pavement markings are being increased to accommodate the older driver's deteriorating visual acuity, and even the duration of push-button actuations for pedestrian crossing signals is now based on research that focuses on the tails of the distribution (Noyce & Bentzen, 2005). Horrey's and Wickens' arguments were made in the context of a study that evaluated eyes-off-road time for interacting with in-vehicle technology, but the implications should be the same for external distracters such as DBBs, and have been so demonstrated by Chan et al. (2008).

The second study, a breakthrough known as the 100 car naturalistic driving study, has produced a number of separate reports (for example, Klauer, et al., 2005, Klauer, et al., 2006a, Klauer, et al., 2006b). Although "naturalistic" driving studies had been conducted on a small scale previously, Klauer and her colleagues at Virginia Tech Transportation Institute (VTTI) were the first to employ this methodology on a large scale. As discussed earlier in the present paper, these researchers placed 100 highly (but unobtrusively) instrumented cars in the hands of 100 people and allowed them full use of these vehicles for 18 months. There were no experimenters present in the vehicles, data was collected without any interference to the driver and was downloaded remotely, and the participants were free to drive these vehicles in any way they wished, as if they were their own. One finding from this work that is of particular interest in our discussion of DBBs is 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.

The third study of relevance here (Chan, et al., 2008), also discussed earlier in the present report, used a driving simulator to study the tails of the distribution when participants drove a five mile route while performing a series of in-vehicle and external-to-the-vehicle distracting tasks. The authors found, as they expected, that younger drivers, when dealing with the in-vehicle task, took their eyes off the road for a significantly longer time than did the older drivers (2.76 seconds vs. 1.63 seconds, respectively, when the measure was the mean length of the maximum episode of continuous inattention). Quite to the researchers' surprise however, were their findings that: (a) the maximum episode durations were much longer for the out-of-vehicle tasks than for the in-vehicle tasks, and (b) that the difference between the older and younger drivers in the out-of-vehicle tasks was small (pp. 16-17). Specifically, they found that the average maximum duration for the out-of-vehicle tasks (for all participants) was 3.54 seconds, vs. that for the in-vehicle tasks of 1.35 seconds, a highly significant difference. The difference in average maximum duration for out-of-vehicle tasks between the older and younger drivers, however, was 3.41 vs. 3.67 seconds, an insignificant difference. The authors' conclusion is that younger and older drivers are "equally bad" in being distracted by external stimuli, in that neither age/experience group has "learned to limit the durations of their glances off to the side of the vehicle" (p.22). Finally, even a study sponsored by the outdoor advertising industry (Lee, McElheny, & Gibbons, 2007), despite an experimental design that sought to minimize the differences between DBBs and other roadside stimuli, has produced results showing 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.

In short, we have made substantial progress in our understanding of the impacts on driver distraction from external-to-vehicle sources since the late 1990s. We now know that extended episodes (two seconds or longer) in which a driver’s eyes are not attending to the driving task greatly increases (by 3.7 times) the likelihood of a crash (Klauer, et al., 2006a). Other researchers have suggested that the upper limit for an acceptable distraction episode may be 0.75 second (Beijer, et al., 2004, Smiley, et al., 2005) or 1.6 seconds (Wierwille and Tijerina, 1998). And, as shown both by Beijer (2002) in an on-road study, and by Chan and her colleagues (2008), in a simulator study, there 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. As stated succinctly by Beijer, his findings seem to show that “drivers are comfortable turning their attention away from the road for a set period of time, regardless of the demands of the driving task” (p. 76). And, as Chan, et al., describe it: “These data … indicate 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).

We also have data to show, despite a lack of analysis by the researchers, that an 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. Indeed, the mean values for these long glance durations proved to be significantly greater for the sites with digital signs than for the others. 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. Because the design of this study minimized the differences between the characteristics of DBB sites and the others, and did not report all of the pertinent data collected, it seems reasonable to believe that the differences found might be more pronounced in a more rigorous experiment.

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.

Beyond the issues of research, however, we also face what we might call a “criterion problem.” States and local jurisdictions must ask themselves this question: What level of knowledge and what degree of certainty must we have before we can be confident in the issuance of guidelines or regulations about DBBs? For example, must we have demonstrable proof that DBBs *cause* crashes? This is the argument raised by the outdoor advertising industry whenever it challenges a local code or ordinance, or goes to court to overturn a permit denial. If crash causation is the standard that must be met, we may never get there. This is not necessarily because DBBs are not a causative factor in crashes; it is, as most researchers believe, more likely that our research methods are not sufficiently sensitive to identify this linkage. This, in turn, is a result of the substantial difficulties involved in conducting post-hoc statistical analyses of crash summaries for an issue that is so profoundly complex. When we know that more than 80% of accidents are not reported to the police, that drivers would not likely admit crashing as a result of such distraction, and that research has clearly shown that our attention as well as our eyes are reflexively drawn to objects such as DBBs even when we have no interest in them and have a more important task to perform, and that we may well be unaware of attending to them at all, it is little wonder that such epidemiological studies may simply be incapable of adding to our knowledge of the traffic safety impacts of DBBs.

Then again, we have rarely required proof of actual crash causation prior to setting speed limits, restricting in-vehicle mobile telephone use, or even developing current billboard operational and location restrictions. The argument against the control of DBBs because studies to date have not proven a cause and effect relationship between DBBs and crashes is simply spurious. It would seem sufficient to initiate action based on a level of consistency achieved in research. And such consistency is now being achieved.

It is likely that those who feel that no guidance or regulations can be promulgated until we have clear proof of causality will continue to argue that there is insufficient information to take any action in this regard regarding roadside DBBs. But those who think that their job is to do what they can to enhance safety for the traveling public based upon the best available information, now have, in our opinion, access to a strong and growing body of evidence, including evidence from industry supported research, that roadside digital advertising, attract drivers’ eyes away from the road for extended, demonstrably unsafe periods of time.

States and local jurisdictions faced with permit applications or challenges to denied permits need to have a sound basis for their decisions. The research underway by FHWA as this is written may begin to provide specific, directed answers to assist these officials in their work. In the interim, these governmental agencies and toll road operators, faced with the need to make such decisions now have, in our opinion, a sufficient and sound basis for doing so.

SECTION 10.

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