

## 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*.<sup>2</sup> 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

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<sup>2</sup>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°- 10°) 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° - 4°) 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. 75° 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. Maurant 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 85<sup>th</sup> 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 Lehtimäki 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 fatalities). 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 31°) 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 20° 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 33° x 27° 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 60° forward field of view (FOV) horizontal, and a 40° 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 60° horizontal and a 40° 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 Transport (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.<sup>3</sup>
- 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.<sup>4</sup>

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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<sup>3</sup> 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.

<sup>4</sup> 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.<sup>5</sup>
- 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.

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<sup>5</sup> 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 content as “not distracting” or “not 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 distracters.

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.