BUILDING CODE
BOARD OF APPEALS
SPECIAL MEETING AGENDA

500 W. Big Beaver
Troy, MI 48084
(248) 524-3344
www.troymi.gov
planning@troymi.gov

Theodore Dziurman, Chair; Gary Abitheira
Brian Kischnick, Michael Morris, Andrew Schuster

November 18, 2015 **10:00 AM** **COUNCIL BOARD ROOM**

1. ROLL CALL

2. HEARING OF CASES

A. **VARIANCE REQUEST, PATRICK DEPA FOR INTERNATIONAL OUTDOOR, INC., 1125 NAUGHTON** – The petitioner is requesting relief of the Sign Code to install a 70 foot tall, 1,608 square foot ground sign set back 0 feet from the property line adjacent to I-75 and 148 feet from the property line adjacent to Naughton, and less than 1,000 feet from any sign exceeding 100 square feet in area. The following variances are requested:

- A 200 foot variance to the required 200 foot setback from the adjacent I-75 property line.
- A 52 foot variance to the required 200 foot setback from the adjacent Naughton property line.
- A 1308 square foot variance from the requirement that the sign not exceed 300 square feet in area.
- A 45 foot variance from the requirement that the sign not exceed 25 feet in height.
- A 625 foot variance from the requirement that the sign be located at least 1,000 feet from any sign exceeding 100 square feet in area.

CHAPTER 85 - SECTION 85.02.05 C (5) IB ZONING DISTRICT

B. **VARIANCE REQUEST, PATRICK DEPA FOR INTERNATIONAL OUTDOOR, INC., PARCEL ON AUSTIN (88-20-26-401-056), ASSOCIATED WITH 1705 AND 1709 AUSTIN** – The petitioner is requesting relief of the Sign Code to install a 70 foot tall, 1,608 square foot ground sign set back 0 feet from the property line adjacent to I-75, and less than 1,000 feet from any sign exceeding 100 square feet in area. The following variances are requested:

- A 200 foot variance to the required 200 foot setback from the adjacent I-75 property line.
- A 1308 square foot variance from the requirement that the sign not exceed 300 square feet in area.
- A 45 foot variance from the requirement that the sign not exceed 25 feet in height.
- A 425 foot variance from the requirement that the sign be located at least 1,000 feet from any sign exceeding 100 square feet in area.

CHAPTER 85 - SECTION 85.02.05 C (5) IB ZONING DISTRICT

3. ADJOURNMENT

NOTICE: *People with disabilities needing accommodations for effective participation in this meeting should contact the City Clerk by e-mail at clerk@troymi.gov or by calling (248) 524-3317 at least two working days in advance of the meeting. An attempt will be made to make reasonable accommodations.*

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Impacts of Digital Advertising Billboards on Traffic Safety

Dr. Virginia P Sisiopiku (UAB)

Drs. A. Gan (FIU), D. Stavrinos (UAB), A. Sullivan (UAB)

UTC Conference for the Southeastern Region, Orlando, FL
April 4-5, 2013

SCOPE

- Investigate links between Advertising Billboards-Distraction-Traffic Safety Risk

- Synthesis of studies on billboard advertising and traffic safety
- On-going efforts to address issue at UAB and FIU

ROADSIDE ADVERTISING OPTIONS: Conventional Billboards

- Static billboards
  - the oldest form of mass media
  - 400,000 in US alone
- Advantages:
  - relatively low entry and operating costs
  - ability to appeal to the local market

ROADSIDE ADVERTISING OPTIONS: Digital billboards (DBB)

- Utilize light-emitting diode (LED) technology to provide vivid displays that can be updated every few seconds using computer input.
  - Fast growing market
  - 4,000 in US
- Advantages:
  - single board can advertise to far more clients than a traditional board
  - clients can update their advertisements frequently, and
  - targeted messaging

DBB UNIQUE FEATURES

- Brightness and contrast with surroundings
- Messages changing suddenly
- Large, imposing sizes
- Realistic imagery
- No driver acclimation with message
- Potential for message sequencing
- Potential for interactivity with driver

RESEARCH METHODS

- Meta-analysis studies
- Crash studies of historical trends
- Laboratory studies
- Naturalistic studies of driving behavior

NOTABLE RECENT META-ANALYSIS STUDIES AND FINDINGS

- Farbry et al., 2001
- Wallace, 2003
- Coetzee, 2003
- Birdsall, 2008
- Wachtel, 2009
- Molino et al., 2009 …

- **Meta-analysis studies** confirmed an association between crash rates and billboards at intersections

NOTABLE RECENT CRASH STUDIES AND FINDINGS

Examples include:

- Smiley et al., 2005
- Tantala and Tantala, 2010
- Yannis et al., 2012 …

- Most **crash studies** involving statistical analyses of historical data near DBB locations reported no statistically significant relationship with crash occurrence

NOTABLE RECENT LABORATORY STUDIES

Examples include:

- Young and Mahfoud, 2007
- Bendak and Al-Saleh, 2010
- Edquist et al., 2011
- Divekar et al., 2012
- Marciano and Yeshurun, 2012 …

LABORATORY STUDIES FINDINGS

- **Laboratory studies** confirmed that that the presence of DBBs decreased driver control, increased mental workload, and increased response time
  - Driver response to road signs delayed by 0.5-1 sec with advertising billboard presence
- DBBs caused drivers to be less observant of stopping cars ahead of them, and contributed to vehicle drifting into adjacent lanes.

NOTABLE RECENT NATURALISTIC STUDIES AND FINDINGS

Examples include:

- Akagi et al., 1996
- Kettwich et al., 2004
- Beijer et al., 2004
- VA Tech Transportation Institute, 2007
- Lee et al., 2007
- Ballidis, 2012 …

NATURALISTIC STUDIES FINDINGS

- **Naturalistic studies** reported mixed findings
  - Some concluded that that there was no substantial distraction caused by the advertising signs, and that gaze duration towards signs decreases as driving complexity increased
  - Other studies provided evidence of increased number of glances per sign and longer gazes in the presence of DDBs compared to static counterparts

LITERATURE REVIEW CONCLUSIONS

- Overall, the literature synthesis suggests that there is evidence of correlation between DDBs and increased driver distraction.
- However, local conditions, experimental settings, and other factors may play a role in the actual impact that advertising DBBs have on traffic safety
- Existing research is limited due to a lack of standardized methods and practices, data reliability, appropriate assumptions, relevant hypotheses, and objective intentions.

NEW RESEARCH ON THE WAY

DIGITAL ADVERTISING BILLBOARDS AND DRIVER DISTRACTION STUDY

- Project funded by the National Center for Transportation System Productivity and Management (NCTSPM, the Georgia Tech-led UTC)
- UAB and FIU Partnership with support from ALDOT and FDOT

APPROACH

Multi-state and multi-facet approach

- State-of-Practice-Synthesis
- Epidemiological Study
- Survey of Road Users
- Driving Simulator Study

STUDY TASKS

- Epidemiological Study:

  Analyze crash records from AL and FL and utilize appropriate statistical methods to examine the correlation between crash location occurrence and proximity to digital advertising billboards

- Survey of Road Users:

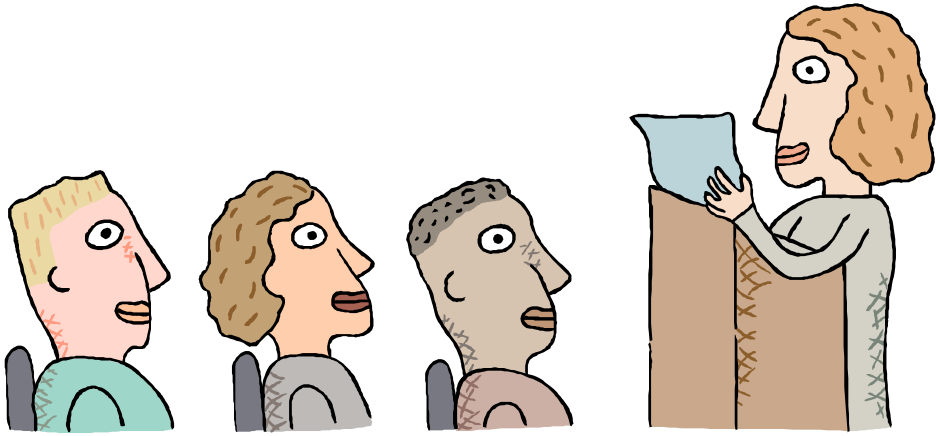
  Collect and analyze survey data on road users' perceptions and attitudes related to electronic and static billboards

- Driving Simulator Study:

  Study driving behaviors in various roadway settings with and without the presence of digital billboards in a driving simulator environment

ACCOMPLISHMENTS TO DATE

- Formed Project Advisory Committee
- Completed State of Practice Synthesis
  - Produced document summarizing findings
- Processed IRB approvals
- Developed and tested user survey instrument
- Constructed driving simulator scenarios
  - Produced document summarizing driving simulator protocol
- Funded 3 graduate students (2 in Civil Engineering; 1 Psychology)
- Technology Transfer



QUESTIONS AND COMMENTS

Driving Performance and Digital Billboards

FINAL REPORT

Prepared for:

Foundation for Outdoor Advertising Research and Education

By:

Suzanne E. Lee

Melinda J. McElheny

and

Ronald Gibbons

Virginia Tech
1872
TRANSPORTATION INSTITUTE

Center for Automotive Safety Research

March 22, 2007

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ABSTRACT

The results of a naturalistic study showed that several driving performance measures in the presence of digital billboards are on a par with those associated with everyday driving, such as the on-premises signs located at businesses. These performance measures included eyeglance performance, speed maintenance, and lane keeping. The current study was conducted in Cleveland, OH following the model of a previous study conducted in Charlotte, NC (which showed no measurable effects of conventional billboards on eyeglance patterns, speed maintenance, or lane keeping). Thirty-six drivers drove an instrumented vehicle on a 50-mile loop route in the daytime along some of the interstates and surface streets in Cleveland. Participants were not informed about the true purpose of the experiment, and were told that the purpose was to help understand the way people drive in a natural environment. Along the route, participants encountered five digital billboards, 15 conventional billboards, 12 comparison sites (similar to items you might encounter in everyday driving), and 12 baseline sites (sites with no signs). Twelve participants returned for a nighttime session to explore the potential effects of the digital billboards at night.

The eight seconds leading up to the events of interest were then analyzed in terms of eyeglance patterns, speed maintenance behavior, and lane keeping behavior. In a post-drive questionnaire, 42% of drivers mentioned billboards as one of the top five items that caught their attention (out of 18 choices). Eyeglance results showed that there were no differences in the overall glance patterns (percent eyes-on-road and overall number of glances) between event types. Drivers also did not glance more frequently in the direction of digital billboards than in the direction of other event types, but drivers did take longer glances in the direction of digital billboards and comparison sites than in the direction of conventional billboards and baseline sites. However, the mean glance length towards the digital billboards was less than one second. Various researchers have proposed that glance lengths of 1.6 seconds, 2.0 seconds, and longer may pose a safety hazard. An examination of longer individual glances showed no differences in distribution of longer glances between the four event types. There were only minor differences in speed maintenance or lane keeping performance for the four event types.

The overall conclusion, supported by both the eyeglance results and the questionnaire results, is that the digital billboards seem to attract more attention than the conventional billboards and baseline sites. Because of the lack of crash causation data, no conclusions can be drawn regarding the ultimate safety of digital billboards. Although there are measurable changes in driver performance in the presence of digital billboards, in many cases these differences are on a par with those associated with everyday driving, such as the on-premises signs located at businesses.

EXECUTIVE SUMMARY

The most notable findings from this study are as follows:

- Eyeglance results showed that there were no differences in the overall glance patterns between digital billboards, conventional billboards, comparison events, and baseline events during the daytime.
- Drivers did not glance more frequently in the direction of digital billboards than in the direction of other event types during the daytime.
- Drivers took longer glances in the direction of digital billboards and comparison sites than in the direction of conventional billboards and baseline sites during the daytime.
- An analysis of glances lasting longer than 1.6 seconds indicated that these longer glances were distributed evenly across the digital billboards, conventional billboards, comparison events, and baseline events during the daytime
- The nighttime results indicate that digital billboards and comparison events may be associated with more active glance patterns, as well as with more frequent and longer glances towards the digital billboards and comparison events.
- For the post-drive questionnaire, 42% of drivers mentioned billboards as one of the top five items that caught their attention; note that drivers did not know this was billboard study.
- In an open-ended question, three drivers mentioned billboards as the single most memorable item on the trip, and two referred specifically to the digital billboards as being memorable.

The motivation for the current study was to examine driver performance in the presence of digital billboards, as compared to other driving locations without them. There is a long history of studying billboards in the context of traffic safety but, although the research record covers many years (1951 until the present), it is lacking in volume and is primarily focused on conventional billboards. There were a few epidemiological studies performed in the early 1950's examining traffic accidents in the presence and absence of billboards; however, much of this early work was methodologically flawed. After a long gap in research, there were a few additional studies in the 1960's through the 1980's, none of which demonstrated that billboards are unsafe. More recent studies conducted in Canada have shown that there may be changes in driver behavior associated with video billboards (those with full motion), but those studies do not address the digital billboards of interest in the current study (with a static message that changes instantaneously without special effects).

Traffic accident analysis techniques have improved in recent years with the creation and maintenance of national crash databases. A careful examination of these databases shows that distraction caused by billboards fails to show up in any of the accident databases as an accident cause. Likewise, an examination of numerous driver distraction studies demonstrates that billboards fail to show up as a cause of driver distraction. The overall conclusion from all past research is that conventional billboards in general have not been shown to cause traffic accidents or change driver behavior. However, the question of whether digital billboards change driver behavior in some way cannot be answered by these previous studies; this is the motivation for the current study.

The current study was conducted in Cleveland, OH to assess the effects, if any, of digital billboards on driver behavior and performance. The study was conducted following the model of a previous study conducted in Charlotte, NC that showed no measurable effects of conventional billboards on eyeglance patterns, speed maintenance, or lane keeping. Thirty-six drivers were recruited with males and females equally represented; they were also equally divided by age (older: 50-75, younger: 18-35). Participants drove an instrumented vehicle on their own (without an experimenter in the vehicle) on a 50-mile loop route in the daytime along some of the interstates and surface streets in Cleveland. Participants were not informed about the true purpose of the experiment, and were told that the purpose was to help understand the way people drive in a natural environment. Along the route, participants encountered the following items:

- 5 digital billboards (all that were available on the route). The digital billboards were the standard bulletin size (14 ft x 48 ft) and the copy changed instantaneously every eight seconds (there were no special effects during the transition).
- 15 conventional billboards (similar to those studied in the Charlotte study).
- 12 comparison sites (similar to items you might encounter in everyday driving; comparable to digital billboards in terms of visual activity/attractiveness, including on-premises signs [some with digital elements], logo placards, landmark buildings, and murals).
- 12 baseline sites (sites with no signs).

After the drive, participants completed a questionnaire regarding which types of items and activities they had noticed along the route. Participants were paid a nominal amount for their participation. Twelve participants returned for a nighttime session to explore the potential effects of the digital billboards at night.

The eight seconds leading up to the events of interest were then analyzed in terms of eyeglance patterns, speed maintenance behavior, and lane keeping behavior. With 36 participants and 44 sites, there were 1,584 events available for analysis from approximately 63 hours of data collection. A small amount of data was lost due to cell phone use, sensor outages, sun angle, and vehicle stoppages, leaving 1,540 events for eyeglance analyses. Altogether, 124,740 video frames were analyzed and 10,073 individual glances were identified. The speed data were filtered to remove events as described above, and then further filtered to remove low speed events, leaving 1,494 events in this dataset, with 121,014 data points. The lane position dataset was further filtered to remove events indicating a possible lane change or lane position sensor failure (often due to poor lane markings). After filtering, there were 1,188 events remaining in the lane position dataset, with 96,228 data points.

In terms of demographics, the average age was 28 years for younger drivers and 59 years for older drivers. Most had completed high school, but few had attended college. All participants lived in the Cleveland area, and were familiar with at least some parts of the route. For the post-drive questionnaire, 42% of drivers mentioned billboards as one of the top five items that caught their attention (out of 18 choices). In a later open-ended question, three drivers mentioned billboards as the single most memorable item on the trip, and two referred specifically to the digital billboards as being memorable. By way of contrast, only 25% of drivers in the Charlotte study checked off billboards in their top five list (of 18 choices), and none mentioned billboards as being the most memorable aspect of the trip. Recall that drivers did not know that the purpose

of the study was to examine performance in the presence of billboards; in fact, they did not know that the study had anything to do with billboards.

Eyeglance results showed that there were no differences in the overall glance patterns (percent eyes-on-road and overall number of glances) between event types (digital billboard, conventional billboard, comparison events, and baseline events). Drivers also did not glance more frequently in the direction of digital billboards than in the direction of other event types. However, drivers did take longer glances in the direction of digital billboards and comparison sites than in the direction of conventional billboards and baseline sites. Given that three of the comparison sites had digital components, the similar eyeglance findings for these two event types are not surprising. An analysis of glances lasting longer than 1.6 seconds showed no obvious differences in the distribution of these longer glances across event types.

There were differences in speed maintenance, with conventional billboards showing greater variation in speed than digital billboards. However, this was thought to be the result of a road type interaction, given that all of the digital billboards were on interstates. When only interstate events were considered in the analysis, there were no significant differences in speed maintenance across event types. There was a trend towards poorer lane keeping performance for digital billboards and conventional billboards; however, this trend failed to reach significance.

A smaller exploratory study was also conducted at nighttime using a slightly shortened route. Given that the digital signs being studied were intrinsically illuminated, this was felt to be an important first step in determining whether there are driver performance differences in the presence of these signs under different levels of ambient illumination. Twelve drivers were used, again divided equally by age and gender. All of the nighttime drivers had previously driven the route during the daytime and were thus somewhat familiar with the route (so were unlikely to get lost or go off route). The nighttime study was exploratory in nature with fewer data points, so these data were examined descriptively rather than analyzed statistically (due to lack of statistical power).

Four eyeglance measures were examined for the nighttime data: eyes-on-road percent, overall glance frequency, mean glance duration in the direction of an event, and mean number of glances in the direction of an event. The eyes-on-road measure showed that digital billboards and comparison events tended to have less eyes-on-road time at nighttime than either baseline events or conventional billboards. The overall glance frequency was also higher in the presence of digital billboards and comparison events than in the presence of baseline events and conventional billboards. These two findings taken together show a more active glance pattern at nighttime in the presence of these two event types. The mean glance duration for glances in the direction of an event also showed higher values for digital billboards and comparison events. Finally, the mean number of glances in the direction of an event also showed digital billboards and comparison events as having higher values than either baseline events or conventional billboards. Taken together, these four findings indicate that digital billboards and comparison events *may* result in more active glance patterns overall, as well as more frequent and longer glances towards the digital billboards and comparison events at nighttime.

Two driving performance measures were examined for the nighttime data: standard deviation of speed and standard deviation of lane position. The standard deviation of speed appeared to be higher in the presence of both conventional and digital billboards than for baseline and comparison events. Lane keeping also showed a trend towards greater lane deviations in the presence of both digital billboards and conventional billboards.

The luminance values of many of the billboards, comparison events, and baseline events were also measured at nighttime. The digital billboards had noticeably higher luminance values than any of the other event types, even though their luminance was automatically reduced at night. This probably explains some of the driver performance findings in the presence of the digital billboards. The overall ranking of luminance by event (digital billboards were the highest, followed in order by comparison events, conventional billboards, and baseline events) closely mirrors the rankings of many of the performance measures for both daytime and nighttime, including eyeglance, speed maintenance, and lane keeping.

The overall conclusion, supported by both the eyeglance results and the questionnaire results, is that the digital billboards seem to attract more attention than the conventional billboards and baseline sites (as shown by a greater number of spontaneous comments regarding the digital billboards and by longer glances in the direction of the billboards). The comparison events, 25% of which included signs with digital components, showed very similar results to the digital billboards. Thus, there appears to be some aspect of the digital billboards and comparison events that holds the driver's attention, once the driver has glanced that way. This is most likely the result of the intrinsic lighting of these signs, which is noticeable even during the daytime. Drivers may also have maintained longer glances towards the digital billboards in the hopes of catching the next message (knowing that the message changes periodically). Although exploratory in nature, the nighttime results were very similar to the daytime results, with indications of degraded driving performance for digital billboards and comparison events.

These particular LED billboards were considered safety-neutral in their design and operation from a human factors perspective: they changed only once every eight seconds, they changed instantaneously with no special effects or video, they looked very much like conventional billboards, and their luminance was attenuated at night. It is thus quite likely that digital signs with video, movement, higher luminance, shorter on-message duration, longer transition times, and special effects would also be related to differences in driver behavior and performance. Because of the lack of crash causation data, no conclusions can be drawn regarding the ultimate safety of digital billboards. Although there are measurable changes in driver performance in the presence of digital billboards, in many cases these differences are on a par with those associated with everyday driving, such as the on-premises signs located at businesses. Conventional billboards were shown both in the current study and in the Charlotte study to be very similar to baseline and comparison events in terms of driver behavior and performance; thus, the design of digital billboards should be kept as similar as possible to conventional billboards.

INTRODUCTION

There is a long history of studying billboards in the context of traffic safety, but although the research record covers many years (1951 until the present), it is lacking in volume. There were a few epidemiological studies performed in the early 1950's examining traffic accidents in the presence and absence of billboards. As will be seen, much of this early work was methodologically flawed. After a long gap in research, there were a few additional studies in the 1960's through the 1980's, none of which demonstrated that billboards are unsafe. Traffic accident analysis techniques have improved in recent years with the creation and maintenance of national crash databases. A careful examination of these databases shows that distraction caused by billboards fails to show up in any of the accident databases as an accident cause. Likewise, an examination of numerous driver distraction studies demonstrates that billboards fail to show up as a cause of driver distraction. The lead author of this report recently participated on an expert panel charged with providing recommendations for a minimal data set to be included on police accident reports; billboards were never raised as a possible distraction or as an item that should be included on these accident reports.

As will be seen, there has been relatively little research on billboards and their effect on driver behavior, and little original research on digital billboards of the type discussed in this report. The current project was therefore undertaken to fill this research gap and to determine whether digital billboards do in fact cause a change in driver behavior as he/she passes a billboard location. Several measures of eyeglance location were used as primary measures of driver visual behavior. Additional measures of driver performance were included to provide further insight--these included speed variation and lane deviation. Drivers in this study used an instrumented vehicle, drove the route alone, and were uninformed as to the purpose of the study.

The report is organized as follows: a literature review, covering topics such as early accident analysis studies, sign conspicuity studies, and later safety and driver distraction studies; a methods section; a results section; conclusions; references; and supporting material contained in appendices.

REVIEW OF PREVIOUS RESEARCH

Early studies from the 1950's attempted to correlate the occurrence and frequency of accidents with the location of billboards or other roadway or roadside features. For example, a series of studies by the Minnesota Highway Department (Rykken, 1951) analyzed accident features in order to determine whether there was any direct relationship between accident frequency and type and several elements of roadway and roadside design, including advertising sign type and location. While a relationship between frequency of access points and accident occurrence was evident, no apparent relationship was found between accident occurrence and advertising sign type or location.

Rykken (1951) added that more accurate accident reports might reveal an unexpected relationship between signs and accidents: the absence of signs when no other roadside objects are present may increase the likelihood of accidents by decreasing the driver's sense of a need for caution. Immediately after 45 miles of highway with no billboards or advertising signs in viewable distance, a roadside interviewing station investigated driver response. Because drivers expressed a feeling of fatigue and unease after having driven the section, the author postulated that the combination of a small number of distracting features and the complete absence of billboards produced a feeling of security, which tends to result in higher average driving speed. Several severe accidents that occurred over that stretch were attributed to excessive speed.

McMonagle, a researcher with the Michigan State Highway Department, analyzed 2,675 accidents on a 70-mile strip of highway from 1947 to 1948 in order to measure the relationship between accidents and highway design and roadside features (McMonagle, 1951). The strip of road included a variety of roadside features and design characteristics, including the number of lanes and traffic volume. Findings showed that the highest incidence of crashes occurred near intersections, particularly when gas stations, restaurants and other establishments were clustered nearby. Only a slight association (correlation coefficient .11) existed between large advertising signs and accidents. While total advertising signs correlated with accident frequency to a greater degree (correlation coefficient .41), advertising signs still contributed less to accident frequency than did groupings of design features or roadside features such as gas stations.

In an attempt to correlate accident frequency with density of advertising and roadside business, Rusch (1951) analyzed crash reports originating in 1947 and 1948 that examined sections of highway distributed across Iowa. The accidents were assigned one of three causes: 1) roadside business, 2) inattention or misdirected attention, or 3) "other causes." Roadside business was listed as the cause of an accident only if the business was specifically named in the accident report, as in the case of a vehicle exiting a gas station and being struck by oncoming traffic. Results showed that twice as many collisions occurred on the portions of road in the high-density category than occurred on the other parts of the test stretches put together. More accidents were attributed to inattention than to any other cause in the high-density category. In the low-density category, more accidents were attributable to miscellaneous causes than to business and inattention combined. Sections of highway in the low-density category showed lower accident rates than those in the high-density category, even when traffic volume was held constant. In addition, accidents on low-density stretches occurred more sporadically with less of a tendency to recur in the same locations the following year. In reference to this study, Andreassen (1985)

later claimed that "the greatest number of inattention accidents occurred on the sections where business and advertising predominated as the roadside property usage, but this does not prove anything about the effect of advertising signs on accident occurrence."

Overall, these early studies provided some initial insight into accident causation, but did not demonstrate that billboards or other advertising signs were a possible cause of accidents. Intersections and high-density roadways combined with inattention were most commonly associated with an increased number of accidents. Interestingly, later analysts using modern statistical techniques critiqued these early studies as being methodologically flawed (e.g., Wachtel and Netherton, 1980; Andreassen, 1985).

A critical research review sponsored by the Federal Highway Administration (FHWA; Wachtel and Netherton, 1980) summarized knowledge concerning commercial electronic variable-message signage (CEVMS) in an effort to recommend national standards for their regulation. Because there was little research available in the area of CEVMS, their literature review focused on standard (conventional) billboards. Wachtel and Netherton (1980) opined that roadside advertising research based on accident studies has had limited value owing to either insufficient information concerning location and traffic or problems with statistical analysis and sampling error. While some studies have found positive relationships between outdoor advertising and accident frequency, others have arrived at the opposite conclusion.

According to Wachtel and Netherton (1980), human factors laboratory research techniques are capable of gathering much more precise, reliable, and valid data in the attempt to measure and explain the effect of outdoor advertising on driver behavior. Literature from several related fields indicated that outdoor advertising probably does not hurt driving performance noticeably when driving conditions are favorable (in terms of weather, traffic, road, vehicle, etc.). This is because the driver has sufficient spare processing capacity to pay attention to the signs without compromising the primary task. When stimulation is extremely low, as when there is very little traffic and very little to look at or to decide, unusual environmental features such as road signs may increase the driver's arousal and improve driving performance. When the driving task becomes highly demanding, the outdoor advertising must compete with more vital information sources such as traffic, weather, and official signage.

In a review of published literature relating accidents to advertising signs, Andreassen (1985) brought attention to weaknesses in the small amount of research that has been conducted in this area. Almost all studies have relied on correlations and/or subjectively assigned "inattention" factors, which can only produce very tenuous evidence for a causal link between advertising and accident frequency.

Garvey, Thompson-Kuhn, and Pietrucha (1995) reviewed the studies that attempted to evaluate directly the relationship between traffic accidents and advertising signs. The common problem with these studies is attributing accident causation; high-advertising and low-advertising sites may have different accident frequencies because of differing traffic densities, pedestrian activity, and roadway geometry. Although most evidence argues against a strong causative link, it is still not possible to ascertain the existence or nature of the relationship between advertising and accidents.

Recently, much attention has been focused on the causes and effects of distraction on driving, especially in the area of cellular phones and other in-vehicle technology. A review of the recent driver distraction literature failed to reveal any studies in which outdoor advertising was mentioned as a cause for driver distraction. As a matter of fact, this report's lead author recently served on the advisory panel for the revised Model Minimum Uniform Crash Criteria in which transportation safety experts recommended revisions to the minimum set of data to be collected as part of every crash report. There were lengthy discussions over which distraction variables should be recommended, and the words "billboard" or "advertising" were never mentioned.

The national crash databases do not mention billboards in their list of driver distractions. The two most prominent databases are the General Estimates System (GES), which estimates the number of all crashes based on a representative sample, and the Fatal Accident Reporting System (FARS), which is a true census of every fatal crash. The only mention of billboards in the 216 page user's manual for the GES database is in the Driver's Vision Obscured By variable, which has a category of Building, Billboard, or Other Design Features (GES, 2002). In other words, if an accident was caused by a driver's vision being obscured, billboards would be lumped together with buildings and other design features, both of which are much more common than billboards. The same holds true for the FARS user's manual of 458 pages – billboards are only mentioned in the Driver's Vision Obscured By variable, and are lumped together with buildings (Tessmer, 2002).

One recent study of driver distraction (Glaze and Ellis, 2003) reported one mention of the word "billboard" in the context of an accident caused by driver distraction. Glaze and Ellis performed a study to determine the nature of distraction/inattention crashes in the state of Virginia. A complex system of accident report sampling was administered via surveys sent to all seven Virginia state police divisions, four selected counties, and 14 independent cities. Roughly 2,800 crash scenes were reported, involving a total of almost 4,500 drivers. At least one distracted driver was involved in 98% of those crashes. Every accident report had a space to write an open-ended description of the main distracting factor in the accident, and over 1,400 responses were recorded. One response (out of 2,800 crashes) included a billboard being repaired as a causal factor for driver distraction leading to a crash. No mention of outdoor advertising was made in any other place in the study, despite the fact that 35% of distracters were outside of the vehicle in question (62% were in-vehicle and 3% were unknown). Typical in-vehicle distracters included passenger/children distraction (8.7%), adjusting radio/changing CD or tape (6.5%), eating or drinking (4.2%), and cell phone (3.9%). Typical out of vehicle distracters included looking at crash, other roadside incident, or traffic (13.1%), looking at scenery or landmarks (9.8%), and weather conditions (1.9%). There were also 25 cases of drivers being distracted by traffic signs or signals (<1%).

Tantala and Tantala (2005) have been the most recent researchers to attempt a rigorous examination of the relationship between advertising signs and traffic accidents. They used methods intended to control for the analytical issues noted with early studies of this type. They conducted two analyses for this research. In the first situation, a highway (New Jersey Turnpike) with advertising signs was selected and studied, including analysis of sign location, road conditions, and traffic-accident locations, to determine whether traffic accidents were more

prevalent at or near existing signs. More than four years of data and 23,000 accidents were used in this analysis. Statistical correlation coefficients showed that the correlation was statistically low for all analyses conducted, including accident density and sign density (with and without interchanges included), accident distance and viewer reaction distance (again with and without interchanges included), and accident density and proximity to the sign. They also found that these correlation values were consistent from year to year. This section of the analysis led them to conclude that there are no statistical or causal relationships between advertising signs and accidents.

In the second analysis by Tantala and Tantala (2005), the location of a recently installed sign was identified, and the incidence of traffic accidents near the sign was examined. Accidents before and after sign installation were examined to determine whether traffic accidents occurred more frequently in the presence of the sign. The sign was installed at a busy intersection near a mall in Pennsylvania. The intersection was controlled by a traffic signal. One year of pre-installation and one year of post-installation data were compared. There were no other changes to the intersection during the two year study period. After installation of the sign, the traffic volume increased, the accident rate decreased, the maximum number of accidents in any given day or week decreased, and the number of days without accidents increased. There were no statistically significant changes in accident occurrences after the installation of the advertising sign.

Researchers are beginning to conduct more studies of driver performance in the presence of various types of advertising signs. For example, Beijer, Smiley, and Eizenman (2004) studied video advertising signs (those with full motion displays) in Toronto using eyeglance analysis similar to that used in the Charlotte study. They compared the video signs to two other types of active signs (scrolling text and roller bar) and to conventional billboards. Significantly more glances, and even more importantly, significantly more glances that lasted $\geq$ 0.75 s were made to video signs than to scrolling text, roller bar, or conventional billboard signs. Taking all active signs together, these received significantly more glances and significantly more long glances per sign than the conventional billboards. However, there were no digital billboards of the type studied in the current research effort.

The most recent research paper in this area was conducted by Crundall, Van Loon, and Underwood (2006). They conducted a laboratory study to examine the differences between street level advertising (such as advertising on bus shelters) and raised level advertising (the same sorts of signs, but raised 10 ft above the ground). They concluded that street level advertisements attract and hold attention at inappropriate times as compared to raised level advertising. Since the billboards studied in the current report were never at ground level, this paper provided no new useful information.

It should be noted that the Virginia Tech Transportation Institute (VTTI) undertook another project for the Foundation for Outdoor Advertising Research and Education (FOARE) (Lee, Olsen, and DeHart, 2004). This project was undertaken in Charlotte, NC using methods similar to those used in the current study to determine whether there is any change in driving behavior in the presence or absence of conventional billboards. Several measures of eyeglance location were used as primary measures of driver visual performance. Additional measures were included to provide further insight into driving performance; these included speed variation and lane

deviation. The overall conclusion from this study was that there is no measurable evidence that billboards cause changes in driver behavior in terms of visual behavior, speed maintenance, and lane keeping. A rigorous examination of individual billboards that could be considered to be the most visually attention-getting demonstrated no measurable relationship between glance location and billboard location. Driving performance measures in the presence of these specific billboards generally showed less speed variation and lane deviation.

Participants in this study drove a vehicle equipped with cameras in order to capture the forward view and two views of the driver's face and eyes. The vehicle was also equipped with a data collection system that would capture vehicle information such as speed, lane deviation, Global Positioning System (GPS) location, and other measures of driving performance. Thirty-six drivers participated in the study, driving a 35-mile loop route in Charlotte, NC. A total of 30 billboard sites along the route were selected, along with six comparison sites and six baseline sites. Several measures were used to examine driving performance during the seven seconds preceding the billboard or other type of site. These included measures of driver visual performance (forward, left, and right glances) and measures of driving performance (lane deviation and speed variation).

With 36 participants and 42 sites, there were 1,512 events available for analysis. A small amount of data was lost due to sensor outages, sun angle, and lane changes, leaving 1,481 events for eyeglance analysis and 1,394 events for speed and lane position analysis. Altogether, 103,670 video frames were analyzed and 10,895 glances were identified. There were 97,580 data points in the speed and lane position data set.

The visual performance results indicate that billboards do not differ measurably from comparison sites such as logo boards, on-premises advertisements, and other roadside items. No measurable differences were found for visual behavior in terms of side of road, age, or familiarity, while there was one difference for gender. Not surprisingly, there were significant differences for road type, with surface streets showing a more active glance pattern than interstates. There were also no measurable differences in speed variability or lane deviation in the presence of billboards as compared to baseline or comparison sites. An analysis of specific, high attention-getting billboards showed that some sites show a more active glance pattern than other sites, but the glance locations did not necessarily correspond to the side of the road where the billboards were situated. Taken as a whole, the results of the previous research conducted for FOARE support the overall conclusion that driving performance does not change measurably in the presence or absence of billboards.

The only currently available research report related to electronic billboards is a literature review sponsored by the FHWA (Farbry, Wochinger, Shafer, Owens, and Nedzesky, 2001). The motivation for this report was to fill the knowledge gap in this area since the last attempt by Wachtel and Netherton in 1980. However, the material does not appear to address the instantaneously changing digital billboards of the type discussed in the current report. Examples shown pictorially in Farbry et al. (2001) are signs with changeable elements (such as time and temperature signs), tri-vision signs, and video digital billboards of the type studied by Beijer et al. (2004). Farbry et al. (2001) raised questions about safety implications with regard to driver distraction, summarized current knowledge in this research field, assessed areas needing

exploration, and developed a research plan to address them. While some electronic billboards (EBBs) display motion and color with fine detail, others just show a short sequence of words in which each letter is composed of a matrix of LEDs (Farbry et al., 2001). This type of display is also used by governmental agencies to present information to drivers and is known by several different acronyms: variable message sign (VMS); dynamic message sign (DMS); and changeable message sign (CMS). A tri-panel sign, also known as a tri-vision sign, is composed of triangular cylinders that rotate periodically, showing a different composite image in between each rotation. The only movement is that of the images in transition.

Studies attempting to draw causality from correlation between dynamic billboards and accident frequency run into the same difficulties found by studies investigating conventional billboards and accidents (Farbry et al., 2001). Common obstacles include consistently confounding traffic conditions in areas with heavy advertising, incomplete or inaccurate accident reports, and driver motivation to omit distraction when reporting crash causality. Even given these stumbling blocks, the correlation is still statistically clear: after a *dynamic*, illuminated billboard is installed, crash rates go up. A common trend was exemplified when a 35% increase in sideswipe and rear-end accidents on an interstate occurred after a variable message advertising sign was put up on the side of a sports stadium. The correlation, while rarely this dramatic, is a consistent one. However, even a correlation this strong is not sufficient evidence to assume causality. Enough other variables were held to be confounding the situation that the sports stadium sign was not deemed a traffic hazard in and of itself, and it remained in place for 16 years.

Farbry et al. (2001) caution that correlations alone provide little fodder for the development of countermeasures. Researchers hypothesize that a safety hazard is posed by dynamic advertising because it may cause greater distraction, which can be measured in several formal ways. One common method is to ask the driver to perform another task while driving, then to measure the degree to which the safe operation or control of the vehicle is affected. Lack of control is typically quantified by one of three measures: lateral deviation, maintenance of appropriate speed, and/or braking for emergencies. Lateral deviation is defined as either the degree to which the vehicle swerves away from the center of the appropriate lane or a measure of the variability in steering wheel position. Maintenance of appropriate speed refers to the headway between the vehicle and the vehicle ahead; if the lead vehicle slows down, the participant vehicle should also slow down and maintain an appropriate speed to keep the headway constant. Some experiments present an emergency and measure distraction by the amount of time it takes the participant to respond appropriately.

The literature review by Farbry et al. (2001) also revealed that the two demographic groups most susceptible to the dangers of distraction while driving are drivers over the age of 65 or under the age of 24. Older drivers' visual processing speed and attention degrade with age, resulting in little to no spare resources with which to encode and process anything but the most important information in the driving environment. Younger drivers usually have faster processing speeds, but they are less experienced and less efficient at resource allocation. Among other weaknesses, younger drivers take more risks, may not recognize hazards, and have poor focus on the driving task itself. Because of this, they may be more vulnerable to having their attention drawn by irrelevant but attention-getting stimuli.

Other than age, a variable that may influence the degree to which a sign distracts a driver is route familiarity (Farbry et al., 2001). A driver who is new to a road may be looking for navigational or service cues, and this task may be take longer in a more complex visual environment containing numerous advertising signs. On the same road, a familiar driver may not look around much since he already has all of the information that he needs. Familiar signs may be less likely to attract the attention of a driver who knows the roadway well and whose primary navigational interests may be traffic conditions and incidents. According to this theory, a visitor would be more likely to be distracted by an advertising sign than would a commuter.

Research regarding distraction, conspicuity, and legibility revealed that an increase in distraction, a decrease in conspicuity, or a decrease in the legibility of a sign may cause an increase in the crash rate (Farbry et al., 2001). The review shows that, at this point, there is no effective technique for evaluating safety effects of EBBs on driver attention or distraction. Crash studies may show a positive correlation between dynamic signs and crash rates, but driver age and route familiarity are examples of confounding variables whose interference may hide the fact that very little causality can be proven.

The final recommendation of the Farbry et al. (2001) report is for further research in this area. They recommend research using several methods, including crash analysis of the sort conducted by Tantala and Tantala (2005), simulator research, test track research, and field studies. Simulator and test track research both have limitations with regard to sign research, especially in regard to digital billboards. For example, it can be difficult to achieve the visual effect of an internally illuminated sign in a simulator. For test tracks, only a limited amount of driving performance data could be obtained, which would likely not be worth the expense of installing a digital billboard on the test track. However, both test track and simulator research are more appropriate for highly controlled experiments in which the goal is to obtain information about the design and content of the billboard copy, the timing of the change, and other design elements. If the goal is to evaluate driver performance and behavior in the presence of digital billboards that occur in the natural course of driving, then a field study is the appropriate technique, and this was the technique selected for the current study.

The overall conclusion from all past research is that conventional billboards in general have not been shown to cause traffic accidents or change driver behavior. However, the question of whether digital billboards change driver behavior in some way cannot be answered by these previous studies; this is the motivation for the current study.

METHOD

Selection of City

Both Pittsburgh, PA and Cleveland, OH were scouted as possible locations for conducting this study. The Pittsburgh streets where the digital billboards were located were generally very curvy and hilly, often with nearby intersections. The digital billboards were often situated at the bottom of a hill, at a curve, or just beyond an intersection. It would have thus been difficult to conduct meaningful eyeglance and speed analyses under these conditions (i.e., the signs were situated in most cases such that the driver had to look straight forward to see the signs). The Cleveland digital billboards, on the other hand, were located off to the side of the roadway in straight-away sections of interstate with no interference from hills, curves, or intersections. It was thus apparent that choice of Cleveland would allow for a more robust analysis with fewer dropped data points.

Digital Billboards

The item of interest in this study was digital Billboards. These billboards are illuminated from within via a matrix of LEDs. These devices are capable of displaying several messages in a rotation. The digital billboards are also capable of video and special transition effects (such as fades or wipes from one message to the next). However, the digital billboards used in this study simply transitioned from one message to the next in less than one second, using no transition special effects or video; in other words, there was no motion or apparent motion used in displaying the messages or transitioning between them. Messages changed once every eight seconds. The billboards appeared very similar to conventional billboards, except that the copy was crisper and easier to read from a distance even during the daytime, likely due to the intrinsic lighting. The lighting level was automatically dimmed at night to adjust to the ambient lighting level. Light measurements taken at night are presented in a different section of the report.

Experimental Design

This study was conducted as a mixed-factors research design (a 2 x 2 x 2 x 2 x 4 design, with four between-subjects cells). There were five independent variables: gender, age, route familiarity (determined post-hoc, so not balanced across subjects), event type, and road type. The between-subjects independent variables were gender (male or female) and age (younger or older). For the within-subjects variables, the levels were as follows: route familiarity (familiar or unfamiliar, defined later), event type (digital billboard, conventional billboard, baseline, and comparison, also defined later), and road type (interstate or surface roads). All of the participants drove each of the segments and were exposed to all of the billboards and comparison sites. A representation of the experimental design is included in Figure 1.

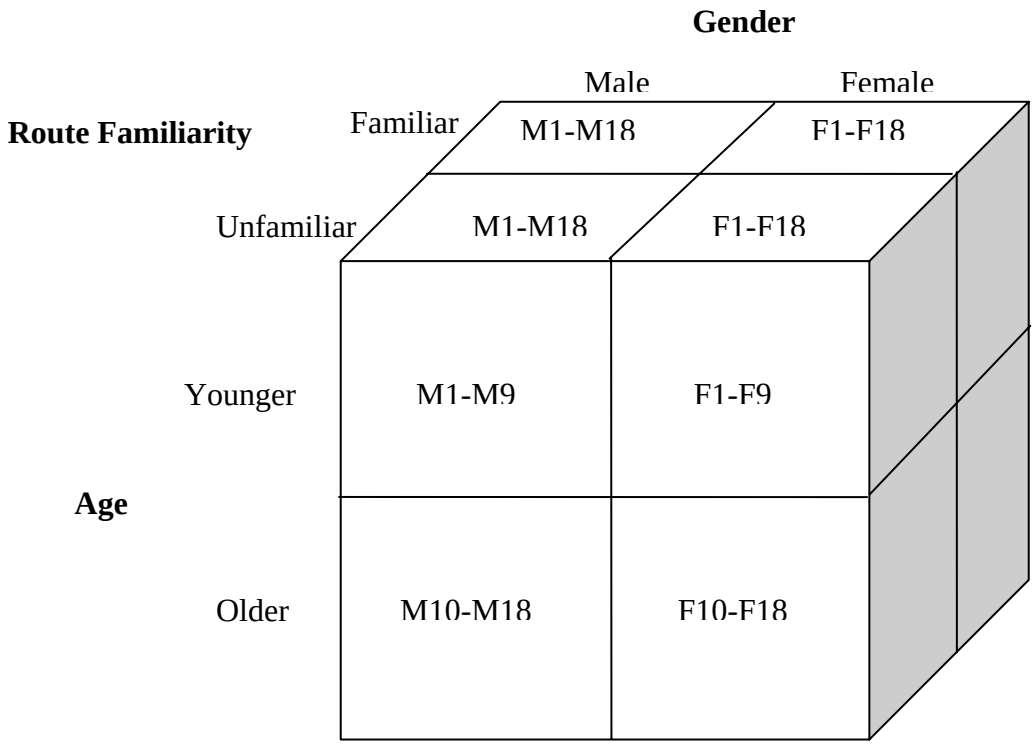

Figure 1. Assignment of Participants to Experimental Conditions.

Independent Variables

The five independent variables are listed in Table 1.

Table 1. Independent Variables.

Independent Variable	**Levels**
Age	Younger (18-35) or Older (50-75)
Gender	Male or Female
Route Familiarity	Unfamiliar or Familiar (familiarity with at least 4 segments determined for each subject)
Event Type	Digital Billboard, Conventional Billboard, Baseline (no billboards or other large signs) or Comparison (other signs or landmarks)
Road Type	Interstate or Surface Street

Age and Gender. Of the 36 participants, eighteen were younger drivers (18 to 35 years old) and eighteen were older drivers (50 to 75 years old). Eighteen of the participants were male and eighteen were female. Age was equally balanced across gender, as is illustrated by Figure 1 (e.g., of the 18 younger participants, 9 were male and 9 were female).

Route Familiarity. Route familiarity referred to how often a section was normally driven by the participant per week (unfamiliar = drove section less than once per week; familiar = drove

section at least once per week). Route familiarity was ascertained after the drive by asking participants how familiar they were with the various segments they had just driven. Thus, this variable was not balanced across the participant population.

Road Type. The two road types were interstates and surface roads. All of the participants were exposed to both road types. Approximately 85% of the route consisted of interstate segments, with the remainder being classified as surface streets.

Event Type. The four event types included digital Billboard, Conventional Billboard, Comparison, and Baseline. All of the participants were exposed to all four event types. Events were 8 seconds long (chosen because the digital billboards were programmed to change messages instantaneously once every 8 seconds; an event length of 8 seconds thus made it highly likely that a message change would be captured during the event). The end of an event was the point at which the experimental vehicle passed the object, and the start of the event was then defined as 8 seconds before the end point. All events on the route are listed and described in Table 2.

Digital Billboards. Five digital billboards were included along the driving route. Displays on the billboards changed instantaneously (i.e., no special effects such as fades, wipes, or shuttering occurred when the message changed) every 8 seconds; the signs followed standards for color, brightness, and placement. These five locations are shown in Figure 2 with the black dots (●).

Conventional Billboards. Conventional billboard events were defined as areas in which designated billboards were visible. These were identified by GPS coordinates (latitude and longitude) associated with their exact location near the roadway. Most of the billboards were the bulletin size, 14 ft (h) by 48 ft (w). Of the total set of billboards available on the route, a sample of 15 billboards was selected for efficiency of data reduction and to ensure a balanced sample. The sample was selected so that it was balanced in terms of side of the road, media type, road type, and (where possible) varying degrees of "visual clutter." None of the selected boards were located directly prior to or after a road exit or entry (preliminary review of the video indicated that drivers were likely to be changing lanes or monitoring items such as road signs during these times, which could confound the results of the analysis). Each side of the road was equally represented to the degree possible, and most of the digital and conventional billboards were 14 ft x 48 ft bulletins. The remaining few were smaller boards, including standard poster, junior paint, and 10'6" x 36' bulletins. Table 3 lists the selected billboards, while the locations of the selected billboards are indicated by red dots (●) in Figure 2.

Comparison Sites. Comparison events were areas with visual elements other than billboards. Examples include on-premise signs, logo placards, interesting landmark buildings, large wall murals, and variable message signs. Several events had digital components. The events were chosen before data collection began and were selected based on the experimenters' perception that these vents were comparable to the digital billboards in the visual attractiveness. These 12 sites are shown as aqua blue dots (●) in Figure 2.

Baseline events. The baseline event type referred to areas with no billboards or other large signs visible (except for perhaps speed limit and other small traffic control signs). These 12 areas

served as locations with which to compare velocity, lane position, and glance patterns and are indicated by blue dots (●) in Figure 2.

Table 2. Event Types Indicating Description, Side of the Road, Latitude, Longitude, and Specific Site Location Information.

	Event Type	Description	Side	Latitude	Longitude	Site	Road Type
1	4	Baseline	Both	41.41208267	-81.6701355	480 W, W/O Lancaster Dr.	I
2	2	Static Billboard	Left	41.42123795	-81.69820404	480 W, W/O Broadview Rd.	I
3	3	On Prem/Logo	Right	41.42151642	-81.70906067	480 W, E/O State Rd.	I
4	2	Static Billboard	Left	41.42173767	-81.71897125	480 W, E/O Pearl Rd.	I
5	4	Baseline	Both	41.42321014	-81.74341583	480 W, W/O Ridge Rd.	I
6	2	Static Billboard	Left	41.42559433	-81.76654053	480 W, W/O Tiedeman Rd.	I
7	2	Static Billboard	Right	41.42352295	-81.77274323	480 W, E/O W. 130th St.	I
8	1	LED Billboard	Left	41.42056274	-81.78245544	480 W, W/O W. 130th St.	I
9	3	On Prem/Logo	Left	41.42053986	-81.7904892	480 W, @ W. 139th St.	I
10	2	Static Billboard	Left	41.42324829	-81.80148315	4866 West 150th	S
11	4	Baseline	Both	41.4307785	-81.80125427	4545 West 150th	S
12	2	Static Billboard	Left	41.43348694	-81.79000854	13986 Puritas Ave	S
13	4	Baseline	Both	41.43657303	-81.78400421	13456 Bellaire Rd	S
14	3	On Prem/Logo	Left	41.43969727	-81.77674103	12686 Bellaire Rd	S
15	3	Tri-Vision Billboard	Right	41.44282913	-81.77227783	12071Bellaire Rd	S
16	4	Baseline	Both	41.45092773	-81.76893616	3757 West 117th	S
17	2	Static Billboard	Left	41.46089554	-81.76893616	3370 West 117th	S
18	4	Baseline	Both	41.46966553	-81.75019836	90 E, @ W. 97th St.	I
19	1	LED Billboard	Right	41.47394943	-81.72478485	90 E, @ W. 55th St.	I
20	2	Static Billboard	Left	41.47385406	-81.70856476	90 E, W/O Fulton Rd.	I
21	3	On Prem/Logo	Left	41.48424911	-81.69098663	90 E, S/O Abbey Ave.	I
22	1	LED Billboard	Right	41.4903717	-81.68776703	90 E, @ W. 3rd St.	I
23	3	On Prem LED Billboard	Left	41.49866867	-81.67558289	2071 Carnegie Ave.	S
24	3	On Prem/Logo	Left	41.49928284	-81.67251587	2351 Carnegie Ave.	S
25	3	On Prem LED Billboard	Left	41.52510452	-81.66101074	90 E, E/O E. 49th St.	I
26	3	Building	Right	41.53549194	-81.64455414	90 E, W/O E. 72nd St.	I
27	2	Static Billboard	Right	41.54089737	-81.62488556	90 E, W/O E. 99th St.	I
28	2	Static Billboard	Right	41.54464722	-81.61724854	90 E, W/O E. 105th St.	I
29	4	Baseline	Both	41.5479126	-81.60997009	90 E, @ E. 109th St.	I
30	3	On Prem/Logo	Right	41.55478668	-81.59642029	90 E, @ Coit Rd.	I
31	4	Baseline	Both	41.56173325	-81.59170532	90 E, W/O E. 140th St.	I
32	4	Baseline	Both	41.56638718	-81.57984161	90 E, W/O E. 152nd St.	I
33	2	Static Billboard	Right	41.57143021	-81.56455994	90 E, @ E. 167th St.	I
34	3	On Prem/Logo	Right	41.57068634	-81.56790924	90 W, @ E. 161st St.	I
35	4	Baseline	Both	41.56744385	-81.57712555	90 W, W/O E. 152nd St.	I
36	4	Baseline	Both	41.55927277	-81.59375763	90 W, W/O E. 140th St.	I
37	1	LED Billboard	Left	41.54701233	-81.61243439	90 W, W/O E. 105th St.	I
38	2	Static Billboard	Left	41.54128647	-81.62450409	90 W, W/O E. 99th St.	I
39	3	On Prem LED Billboard	Right	41.52567673	-81.66069031	90 W, W/O E. 55th St.	I
40	2	Static Billboard	Left	41.49006653	-81.66697693	77S, S/O Woodland Ave.	I
41	2	Static Billboard	Right	41.48295593	-81.66287231	77 S, @ I-490 Exit	I
42	1	LED Billboard	Right	41.46414566	-81.65770721	77 S, S/O Pershing Ave.	I
43	4	Baseline	Both	41.45179367	-81.65712738	77 S, N/O Harvard Ave. Exit	I
44	2	Static Billboard	Left	41.4439621	-81.65229797	77 S, N/O Grant Ave. Exit	I

Event Type: 1=LED Billboard, 2=Static Billboard, 3=Comparison, 4=Baseline

Road Type: I=Interstate, S=Surface Street

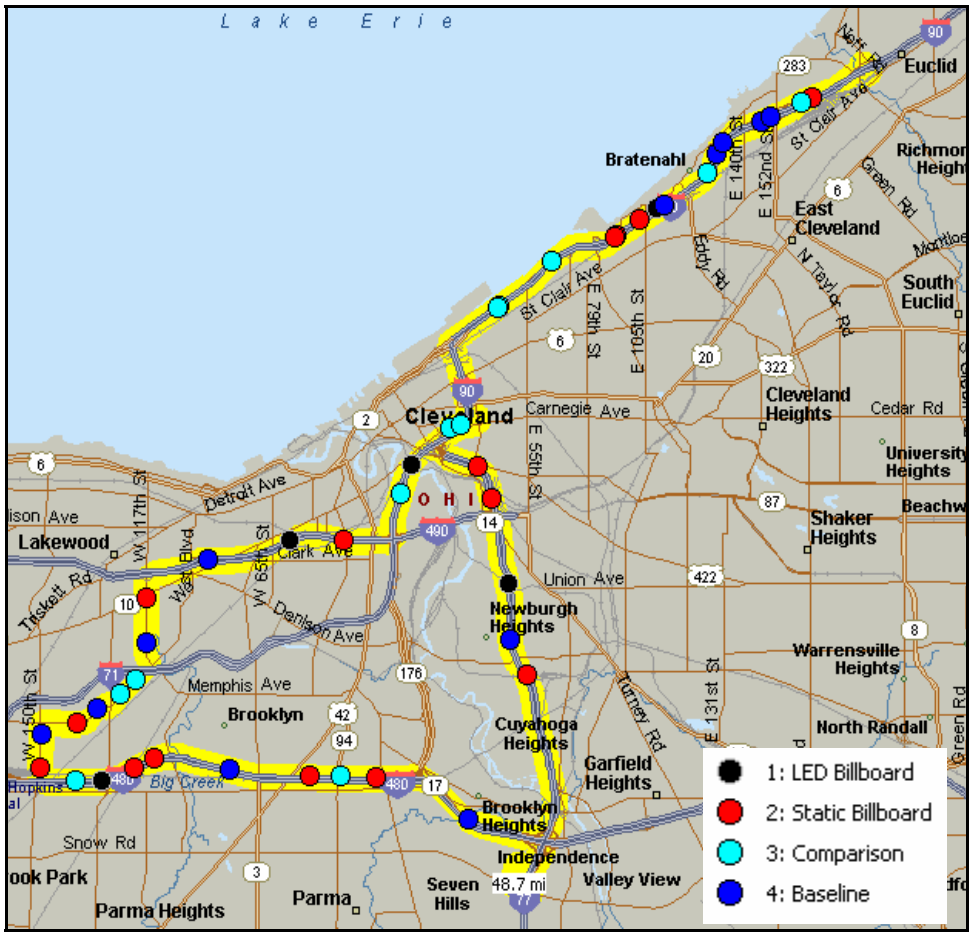

Figure 2. Map Illustrating Digital Billboards (black), Conventional Billboards (red), Comparison Sites (aqua blue), and Baseline Sites (blue).

Dependent Variables

The dependent variables are discussed in more detail in the results section, but they are reviewed briefly here. The purpose of the study was to determine if there are changes in driver behavior in the presence of billboards. Eleven dependent measures were used as indicators of driver behavior: nine eyeglance measures and two driving performance measures. The nine eyeglance measures included: total number of glances for center forward, left forward, and right forward; total glance duration for center forward, left forward, and right forward; and average glance duration for center forward, left forward, and right forward. Keep in mind that all glance locations reported here were out of the front windshield, but varied in location within the forward view. The two driving performance measures were speed deviation (standard deviation of speed over the 8 seconds of the event) and lane deviation (standard deviation of lane position over the 8 seconds of the event). Additional analyses examined driver glance behavior to certain other locations, including interior locations and exterior locations other than forward. The next section is a supplement to the literature review presented earlier, and lays the groundwork for the selection of these dependent variables, which are similar to those typically used in transportation safety research.

Selection of Dependent Variables Based on Previous Driving Studies

Measures of Visual Demand

According to Farber, Blanco, Foley, Curry, Greenburg, and Serafin (2000), typical measures of visual demand include: 1) glance frequency, 2) glance duration, 3) average duration per glance, and 4) total eyes-off-road time. Such measures are time-consuming to record and analyze but are typically used to measure visual attention. For example, previous research has reported on driver performance of in-car tasks such as adjusting the radio, viewing in-car displays (e.g., speedometer) or interacting with a navigation system (Wierwille, Antin, Dingus, & Hulse, 1988; Gellatly & Kleiss, 2000; Kurokawa & Wierwille, 1990; Tijerina, Palmer, & Goodman, 1999). Visual glance duration and the number of glances per task were investigated while performing conventional in-vehicle tasks and navigation tasks (Wierwille, Antin, Dingus, & Hulse, 1988). Findings indicated that glance frequency varied depending upon the task, and that glance duration for a single glance ranged from 0.62 s to 1.63 s. The mean number of glances across all tasks was between 1.26 and 6.52 glances. Zwahlen, Adams, and DeBald (1988) reported that "out of view" glance times (rear view mirror, speedometer, etc.) ranged from 0.5 s to 2.0 s during straight driving. Another example of such research is an experiment by Parkes, Ward, and Vaughan (2001) who measured glance frequency, glance duration, and average duration per glance to evaluate two in-vehicle audio systems, in terms of total "eyes off road" time.

Search and Scan Patterns

Early research included the investigation of visual search and scan patterns while driving (Mourant, Rockwell, & Rackoff, 1969; Mourant & Rockwell, 1970; 1972). It was found that as drivers became familiar with a route, they spent more time looking ahead, they confined their sampling to a smaller area ahead, and they were better able to detect potential traffic threats (e.g., movement in the periphery). Mourant and Rockwell (1970) found that peripheral vision was used to monitor other vehicles and lane line markers, that novice and experienced drivers differed in their visual acquisition process, and that novice drivers may be considered to drive less safely.

A recent field study investigated the influence of fatigue on critical incidents involving local short haul truck drivers (Hanowski et al., 2003). Fatigued drivers involved in critical incidents when making lane changes spent more time looking in irrelevant locations (i.e., locations other than out-the-windshield, out-the-windows, at the mirrors, or at the instrument panel). The mean proportion of time spent looking at irrelevant locations was 8%. However, during normal lane changes (not a critical event), the mean proportion of time that drivers spent looking at irrelevant locations was 3%, a significant difference. In terms of eye behavior, it appears that fatigued drivers involved in critical incidents pay less attention to relevant locations such as the road ahead and appropriate mirrors.

Mirror Glance Duration

Based on available literature discussed in this section, mirror glance times range from 0.8 s to 1.6 s (*M* = 1.1 s). Searches to the rear (blind spot) appeared to require a minimum value of 0.8 s. Nagata and Kuriyama (1985) investigated the influence of driver glance behavior in obtaining information through door and fender mirror systems. For door mirror systems, they reported that the average glance duration to the near-side (i.e., right side in this case) mirror was 0.69 s. Rockwell (1988) reported that the average glance duration to the left mirror was 1.10 s (*SD* = 0.33 s). This finding was consistent across different participants in three different experiments over a six-year period using the same data gathering and reduction technique. Taoka (1990) modeled the eyeglance distributions of Rockwell and found they could be well represented by means of a lognormal distribution. Taoka reported that the average time for viewing the left-side mirror was also 1.10s (*SD* = 0.3 s). The 5th percentile value was 0.68 s and the 95th percentile was 1.65 s. For right side mirror glances, Nagata and Kuriyama (1985) reported that average glance duration was 1.38 s (angle difference from the vertical axis of 70 degrees), while Rockwell reported an average glance duration of 1.21 s (10% larger than left glances), with an approximate standard deviation of 0.36 s. For the rear view mirror, Taoka (1990) reported that the average glance time was 0.75 s (*SD* = 0.36 s). The 5th percentile value was 0.32 s and the 95th percentile was 1.43 s.

Velocity

Velocity (traveling speed) has been used as a measure of driving performance for several decades. For example, Brown, Tickner, and Simmonds (1969) found that driving while telephoning had a 6.6% reduction in speed as compared to driving alone, in an early closed-circuit driving experiment. They also concluded that telephoning while driving may impair perception and decision-making skills. More recently, Alm and Nilsson (1994) concluded that a mobile telephone task while driving led to a reduction in speed level. In another effort, Tijerina, Kiger, Rockwell, and Tornow (1995) assessed driver workload for commercial vehicle operators in conjunction with using an in-vehicle device. Various measures were monitored including speed variance, which was highest for activities involving radio tuning and 10-digit cell-phone dialing tasks. Another study monitored speed for a driving study involving talking on a cell phone or talking to a passenger (Waugh, Glumm, Kilduff, Tauson, Smyth, & Pillalamarri, 2000). Results indicated that driving speeds were lower when talking on the phone as compared to talking to the passenger. It is generally recognized that tasks with high visual or cognitive demand can result in large deviations in speed.

Lateral Position

Lateral lane position or deviation is one of the most common measures of driver performance and distraction (Salvucci, 2002). Lane position can be measured in terms of lane exceedances (i.e., drift across the line between the current lane and the next lane) or, in the absence of actual lane crossings, lateral position in terms of distance from the center of the lane or the side lane line markings. Various researchers have used lateral position. For example, Serafin, Wen, Paelke, and Green (1993) conducted an experiment involving a driving simulator and car phone

tasks. Greater lane deviation was observed for dialing while driving as compared to tasks involving listening, talking, or mental processing. In another study, Alm and Nilsson (1994) reported that for difficult driving tasks, a mobile telephone task had an effect on the drivers' lateral position during various 500 m driving segments. Results indicated that the mobile-telephone task made drivers drive closer to the right lane line, especially for complex tracking tasks. In another study, Tijerina, Kiger, Rockwell, and Tornow (1995) evaluated various measures including lane position variance and lane exceedances. They concluded that lane keeping was degraded when performing message reading tasks. Again, multiple research findings indicate that high levels of visual and cognitive demand can result in a greater level of lane deviation.

Participants

Thirty-six participants who were familiar with the Cleveland, OH freeway system and downtown area were recruited. Participants were recruited via newspaper advertisement (Figure 3), flyers, and word of mouth. Participant selection was determined after a telephone screening and selection process. All participants were between the ages of 18 and 71, with equal gender representation (18 female, 18 male). The experimental protocol was approved by the Virginia Tech Institutional Review Board (IRB) prior to any contact with participants. Figure 4 illustrates an example of an experimenter seated in the experimental vehicle.

Driving Study
In Cleveland area, $20/hr for 2 hrs.
Must be 18-35 or 50-75 yrs old w/
driver's lic. Virginia Tech
Transportation Institute.
Call 866-454-4568 or email
drivers @vtti.vt.edu

Figure 3: Newspaper Advertisement that appeared in the Cleveland Plain Dealer.

Figure 4. Experimenter Seated in Experimental Vehicle.

Route and Equipment

Route

The pre-planned loop route was approximately 50 miles long and consisted of sections on Interstates 480, 90, and 77, as well as surface streets in downtown Cleveland, OH. Prior to collecting any data, experimenters from VTTI visited the area several times in order to determine the final route by verifying the presence of suitable billboards. A potential 65-mile route was originally recommended by associates from Clear Channel Outdoor Advertising, a local company located in Cleveland. After personal examination of the suggested route, the final 50-mile route was selected by the VTTI research team so that it could be completed in a timely manner, while still allowing participants to be exposed to a mixture of interstate, downtown, and residential road segments. This loop contained a variety of billboards and other outdoor advertisements (e.g., on-premise signs, logo placards) as well as standard department of transportation (DOT) roadway signs. Figure 5 illustrates the final route used for data collection, while Table 3 lists the driving directions used for the experiment. The directions were mounted on the dashboard as illustrated in Figure 6.

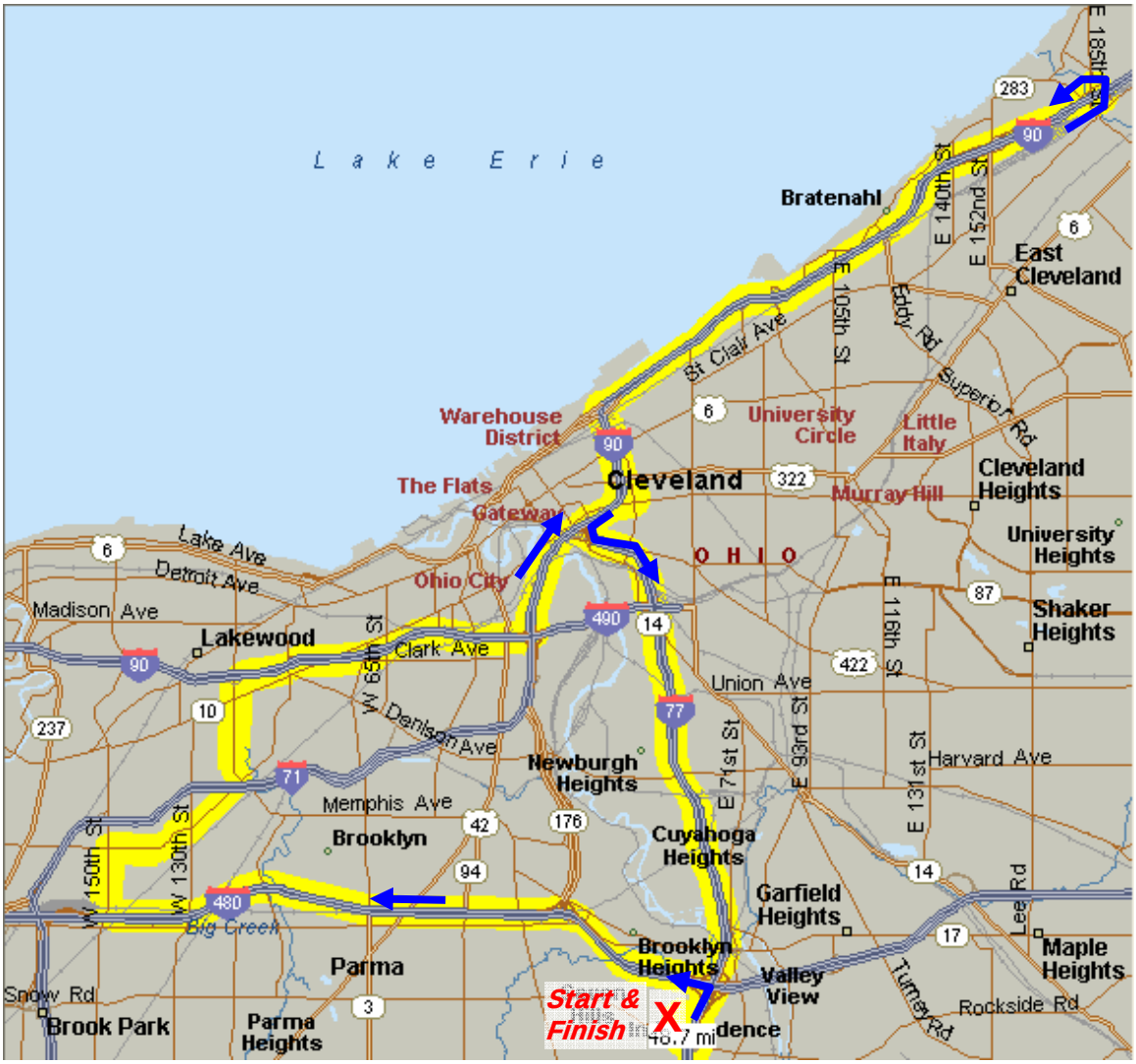

Figure 5. Map of 50-mile Daytime Loop Route in Cleveland, Ohio.

Table 3. Directions for 50-mile daytime route in Cleveland, OH.

	Directions	Trip Distance	Notes
←	Left out of Residence Inn onto **W. Creek Rd.**	0.0	
←	Left onto **Rockside Rd.**	0.3	
→	Right toward **I-77 North**	0.5	Go under overpass to I-77 N entrance
	Left lane onto **I-480 West** / Toledo	1.1	
EXIT 12A	Right Exit 12A, turn Right onto **W. 150th St.**	9.9	
→	Right onto **Puritas**	10.9	Curves to Left, becomes Bellaire
←	Left onto **W. 117th**	13.1	Just past entrance to I-71
→	Right onto **I-90 East** / Cleveland	14.4	
EXIT 172A	Right Exit 172-A, **East 9th St.**	20.1	Stay to Right
→	Right onto **Carnegie**	20.4	
←	Left onto **East 30th St.**	21.3	DODD Camera on far left corner
←	Go 1 block, Left onto **Prospect**	21.4	
←	Go 500 ft., Left onto **I-90 East**	21.5	
EXIT 182A	Right Exit 182A, Right onto **E. 185th St.**	30.9	
	Stay in Right Lane and get onto **I-90 West** to Downtown	31.2	Stay on 90 W when splits to left
EXIT 172A	Take Right Exit 172A to **I-77 South**	41.2	
	Follow I-77 South to **Rockside Road** exit	48.2	
EXIT 155	Take Exit 155 Rockside Road and Independence, turn Right onto **Rockside Rd.**	48.8	
→	Turn Right onto **W. Creek Rd.**	48.9	
→	Turn Right into **Residence Inn** parking lot	49.2	

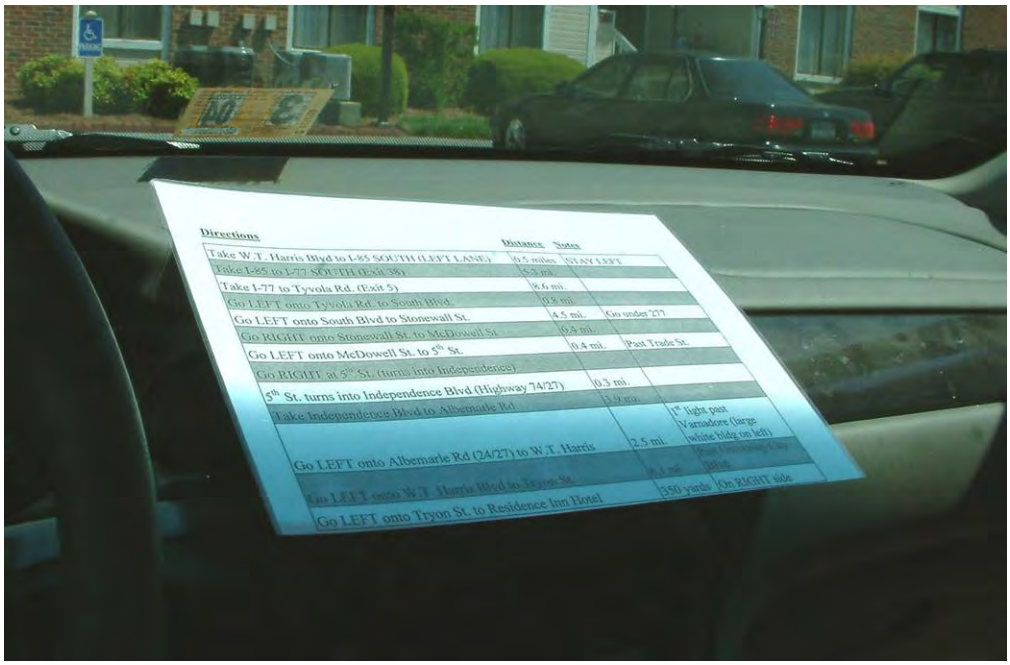

Figure 6. Directions mounted on dashboard of vehicle (this picture is from a previous experiment which used the same protocol and vehicle type).

Practice Route. A short, 1.5-mile practice route was also included. This route was driven prior to data collection on the 50-mile loop route. During the practice route, the experimenter rode as a passenger with the participant to make sure that the participant was familiar with the directions and the vehicle's displays and controls. Table 4 lists the directions for the practice route, which was conducted on local streets near the hotel where the study began and ended.

Table 4. Directions for 1.5-mile Practice Route in Independence, Ohio.

	Directions	Trip Distance	Notes
➡	Right out of Residence Inn onto W. Creek Rd.		
➡	Right onto Jefferson Dr.		
↩	Go around the traffic circle		
⬅	Left onto W. Creek Rd.		
➡	Right onto Patriot's Way		
	Straight at Stop		Past Applebee's
⬅	Left into Parking lots, loop back onto Patriot's Way		
	Straight at Stop		
⬅	Left onto West Creek Rd.		
➡	Right into Residence Inn parking lot	1.5 mi	

Vehicle

A 2002 Chevrolet Malibu was used in this study and is shown in Figure 7. The vehicle had an automatic transmission, an adjustable steering wheel, and other standard features.

Figure 7. Experimental Vehicle, 2002 Chevrolet Malibu.

Data Collection System

The vehicle was instrumented with a data collection system, including cameras, a computer, and sensors that continuously collected data. The system was activated approximately 2 min after the ignition was turned on and was deactivated when the driver turned it off. A video system with four cameras was used. Two cameras were mounted on the back side of the rear-view mirror--one facing forward left and the other facing forward right (Figure 8). This captured the forward views of the roadway as well as the sides where billboards and other objects were visible. The other two cameras captured the driver's face from two perspectives. One camera was mounted on the top left corner of the windshield near the A-pillar (Figure 9). The other camera was mounted just above the rear view mirror (Figure 10). Both faced the driver and captured head and eye movements. Since data reductionists needed to review all four video channels simultaneously, a quad-splitter was used to fuse the images. This produced a single, compartmentalized image such that each camera was presented in one of four locations (Figure 11). The quad splitter, computer, monitor, and keyboard were located in the trunk of the vehicle as shown in Figure 12. Finally, Figure 13 illustrates these components and shows how they interacted with sensors. Infrared illumination was used to provide adequate illumination for a smaller nighttime data collection effort, to be described later in the report.

Figure 8. Forward Facing Cameras Mounted Behind the Center Rear View Mirror.

Figure 9. Driver Face Camera, Mounted near the left A-Pillar.

Figure 10. Driver Face Camera Mounted Above Rear View Mirror.

Left Forward View	Right Forward View
Driver's Face, Left Side	Driver's Face, Right Side

Figure 11. Diagram of Simultaneous Presentation of Four Camera Views.

Figure 12. Data Acquisition System Located in Trunk of Vehicle.

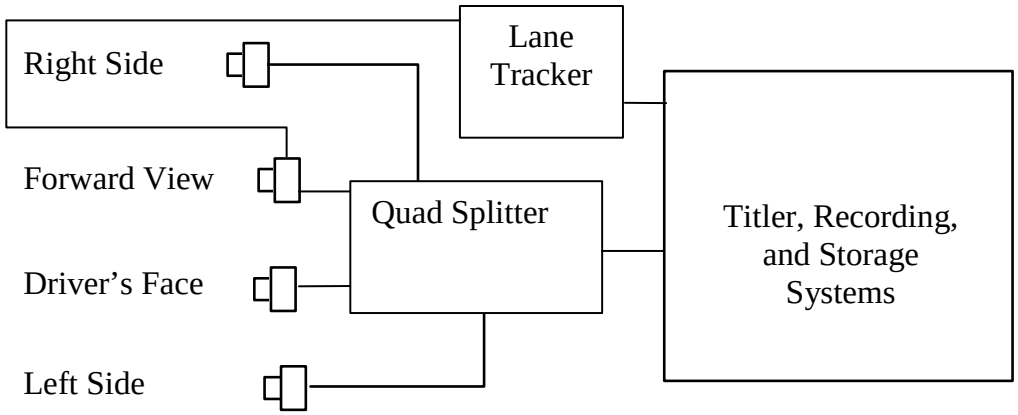

Figure 13. Components of the Data Collection System.

All video data were recorded at 30 Hz (30 frames per s), using MPEG 4 compression algorithms at a rate of 4 MB per minute. Driving performance data, including lane position and velocity, were collected at 10 Hz (10 times per s). The lane tracking system used fuzzy logic and statistical probabilities to detect lane edges in the forward camera view. Lane position was collected with a resolution of ±2 inches from the center of the lane. Raw performance data, including lane position, velocity, and video data, were saved on the hard drive of a laptop computer and then backed up onto individual DVDs for each participant. After each trial, the experimenter reviewed the data to assure that the data collection system performed to specification.

Procedure

Participant Recruitment and Screening

Straight-text newspaper advertisements were placed in the *Cleveland Plain Dealer* (Figure 3) and flyers were posted in strategic locations in Cleveland, OH to solicit volunteer participants for the study. Respondents were instructed to contact the experimenter via email or by telephone. A telephone/email screening form (Appendix A) was used to collect general information on age, gender, medical, and driving history, familiarity with the route(s), and use of corrective lenses or sunglasses. A list of potential participants was compiled as screenings were completed, and participants who met all of the required criteria were then contacted to set up an appointment for participation. The participant met the experimenter on the appropriate date and time in the hotel lobby of the Residence Inn on West Creek Road, in Independence, OH (just south of Cleveland).

Experimental Protocol

Upon arrival, each participant presented a valid driver's license for the experimenter's inspection. Each participant then completed an informed consent form (Appendix B) and a health screening questionnaire (Appendix C). Participants also completed a vision test using a Snellen eye chart. Only participants with vision of 20/40 or better were eligible to participate.

Participants received an orientation (including the practice route), drove the 50-mile experimental route, completed a post-drive questionnaire (Appendix D), and received $20/hr for their time. Most participants completed the experiment in less than two hours. All procedures for recruitment and data collection were approved by the Virginia Tech IRB, as required by federal and state law.

In all, 36 drivers were recruited for the full experiment. Another participant completed the experiment, but the data were not used because it rained during most of the session. Of the 36 drivers who completed the experiment, 3 repeated the experiment on a later date due to rain. That is, their initial data were not used and were replaced with the second driving session. The order in which participants were run in the experiment is shown in Table 5.

Table 5. Order of Participation (shown by Age and Gender).

Number	AgeGrp	Gender
1	O	M
2	O	M
3	Y	M
4	O	M
5	Y	F
6	Y	F
7	O	F
8	Y	F
9	O	F
10	Y	M
11	O	F
12	Y	M
13	O	M
14	O	M
15	Y	M
16	O	F
17	O	F
18	O	F
19	O	M
20	Y	F
21	Y	M
22	Y	F
23	Y	F
24	O	M
25	Y	F
26	O	F
27	O	M
28	Y	M
29	O	F
30	Y	F
31	Y	F
32	O	F
33	Y	M
34	Y	M
35	Y	M
36	Y	F

The informed consent form explained the general purpose of the experiment to the driver and obtained his/her permission to participate in the study. After the required paperwork was completed, the following script describing the experiment was read aloud to the participant:

> Today we will have you drive a pre-determined loop route along major freeways and highways. The vehicle that you will be operating is specially equipped with instruments that collect information about your driving habits. The purpose of this

> study is to collect information about the way people drive under normal circumstances, in order to improve driver safety. We want you to drive as you would if you were in your own vehicle and were driving, for example, to visit a friend, do an errand, or go to work. With this in mind, we will also want you to obey all typical traffic regulations as you normally would, including, but not limited to, posted speed limits, lane markings, and traffic control devices (such as stoplights).
>
> I will be riding in the passenger seat during a 5-minute orientation drive. You are welcome to ask questions if necessary, as this orientation will help you become familiar with the vehicle and its controls. As always, our first priority is your safety. If at any time you feel uncomfortable please inform me and we can make any necessary adjustments or end the study early.
>
> After the 5-minute orientation, I will exit the vehicle and have you drive the pre-determined route, which will bring you back to this location. This route will take about 1.5 hours. A map and written instructions will be provided for your reference, and I will also review the route with you before you depart. After the route is completed, I will debrief you and the session will be complete.
>
> Do you have any questions I can answer at this time?

The experimenter then reviewed the map (Figure 5) and directions (Table 4) in detail. A laminated copy of the map was stored in the glove compartment for easy reference. A laminated copy of the directions was prominently displayed on the dashboard (Figure 6). A cellular telephone was also stored in the glove compartment for emergency use only.

The experimenter then oriented the participant to the vehicle, including adjustment of the seat, seat belt, mirrors, and steering wheel. Displays and controls were also reviewed, including a review of the map, directions, and cell phone operation instructions. The participant then drove the 5-minute orientation route, with verbal reminders provided by the experimenter when required. After the orientation route was completed, the experimenter checked the data, reminded the participant to drive as he/she normally would, and then returned to the hotel. The participant drove the 50-mile loop route, which eventually brought him/her back to the hotel.

After the experiment, in-vehicle eyeglance calibration was completed in the hotel parking lot. With the vehicle parked, the experimenter sat in the passenger seat and provided verbal instructions. The protocol included having the participant sit as if driving, while alternating 3-second glances to various locations with a default forward glance location. The glances included left blind spot, left window, left mirror, left forward, forward, right forward, right mirror, right window, right blind spot, rear view mirror, instrument panel (speedometer), and climate and radio controls.

After the eyeglance calibration, the participant and the experimenter returned to the hotel lobby, where the post-drive questionnaire was completed (Appendix D). The experimenter then reviewed the questionnaire to make sure that all of the answers were legible. Item #3, “Please check the top five items that most caught your attention during your drive,” included a “Billboards” option (among a list of 18 possible items). If the experimenter noticed that

"Billboards" had been marked, she asked about every checked item in an attempt to discover the details as to what caught their attention. For the billboard item specifically, the experimenter noted what aspect of the billboard caught the participant's attention, without conveying the importance of that particular topic. Payment was then issued to the driver at a rate of $20 per hour, (2 hours in most cases, for a total of $40) and a payment log was signed to verify that funds were received. At no time was the participant made aware that this experiment was related to driving behavior regarding billboards or other roadside items.

Data for each participant were briefly reviewed to verify that all the cameras were operating correctly and that data had been recorded. Data and video files were then transferred from the data collection system's computer to a portable laptop computer. Each participant's data were copied onto a separate DVD as a second back-up measure. The results from the post-drive questionnaire were then entered into an Excel spreadsheet for later processing.

Data Reduction

Analyst Training

Two data analysts worked on this project under the supervision of the principal investigator. All analysts were experienced in video data reduction prior to this project. Training began with a 2-hour session in which the user manual was reviewed and the analysis software was demonstrated by the experimenter. Relevant functions were shown, and the process of how to load the map and associated GPS coordinates was explained. Prior to actual data analysis, each analyst spent an additional eight hours mastering eyeglance direction determination and spreadsheet use. This period included time with an experienced analyst present. A large part of that time was dedicated to establishing inter-analyst reliability by comparing judgments and modifying techniques until all analysts' independent determinations matched. Throughout the entire analysis effort, at least one experienced analyst was available at all times to answer any questions or review particular cases as needed. "Spot checks" were performed throughout the data reduction process, with input provided as needed to maintain a high level of consistency. Robust reliability was further assured by ascertaining that each analyst recorded a portion of the data from each participant (i.e., a portion of the data for each of the 36 participants was analyzed by each analyst). As events were completed, a written record was created with the analyst's initials and date of completion.

Software

This section outlines the data reduction software program developed to analyze digital billboard, conventional billboard, comparison, and baseline events. The software, currently called DART (Data Analysis and Reduction Tools), was originally developed by software engineers at VTTI for a large-scale naturalistic driving study known as the 100 Car Study (Dingus, Klauer, Neale, Petersen, Lee, et al., 2006). This program integrates Microsoft MapPoint 2003 using GPS data for billboard, comparison, and baseline site locations with the data obtained from the multiple sensors in the test vehicle via a graphical interface. A total of 36 files (representing the route driven for each participant) were analyzed. After a file was opened, the software presented the analyst with the relevant windows required for data identification and reduction. The MapPoint

application allowed the analyst to view a map of the Cleveland, OH area, showing the relationship between the site and the roads, so that video could be compared with GPS data during site identification and eyeglance analysis. The map illustrated the route and the location of the vehicle, which was represented by a green vehicle icon that moved as the event was played. This map served solely as a visual display and could not be manipulated.

Procedure

Data reduction was performed by the two analysts for each of the 36 data files. This occurred in three steps: software preparation, event identification, and eyeglance analysis. Analysts were blind as to which event type was being analyzed (in other words, they knew the event only by its number, and did not know what type of event was contained in that segment of data). This was done to insure impartiality in this aspect of the data reduction (event identification and eyeglance reduction were the only two aspects of data analysis which had a subjective component; this was compensated for by re-doing 10% of the events and calculating inter-rater reliability).

Event Identification

Analysts first used the DART software to identify the locations of interest. The GPS coordinates for each location were entered into a master map. Each file was then opened and the DART software suggested the correct point for each location of interest based on the master GPS list. The analyst compared the forward view shown in the video with a master file of forward views and adjusted the event timing slightly if necessary to make sure the forward views were the same for every participant (thus providing a common geographic point of reference for each event analyzed). The end of an event was defined as the sync number (time reference) at which the test vehicle passed the site, and the event's beginning was calculated to be eight seconds before the end point. Identification of the end point thus combined two methods: the GPS data was used to align the vehicle directly in conjunction with the site, and then the video was used to visually confirm accurate GPS positioning using comparison to a master file of forward views.

Eyeglance Analysis

Once all of the events were correctly identified and stored in the database, the analysts conducted the eyeglance analysis for each event. The first step in eyeglance analysis was familiarization with the participant's individual glance patterns by means of a glance location calibration video, during which participants looked at specific places according to a set script. Analysts referred often to the calibration file collected for each participant to make sure that the glance locations were being coded correctly.

As described in the procedures section, eye calibration was conducted *after* data collection was complete, in order to serve as a record of how a particular driver's glance to particular location is shown in video. Analysts reviewed these records in order to become familiar with the

participant's glance style. The analyst was thus able to conduct the glance analysis according to each participant's glance style. Glances were coded according to the following abbreviations:

F - Forward
RF - Right Forward
LF - Left Forward
RVM - Rear View Mirror
OX - Outer eXterior, including side mirrors, side windows, blind spot, etc.
DIR – glances toward the experimental route DIRections
OINT - Other INTerior, including speedometer, sun visor, cell phone, etc.

Analysts reviewed events from beginning to end, one tenth of a second at a time, determining the direction of glance for every tenth of a second for the eight-second duration of the event. New glances were recorded as the sync number at which the participant's glance *rested* in a new location. Transition time to the new location was included in the glance location the driver was moving *away* from. The DART program automatically calculated the duration of each glance. Summary information for each event included the number of glances, average glance duration, number of glances in each direction, and the average duration of glances in each direction. The final inter-rater reliability for the eyeglance reduction process was 96.5%, which is considered quite good. Approximately 5% of the daytime events were analyzed by both raters independently, resulting in 8,084 individual glance locations, each lasting 0.1 s. The agreement between raters for each location was compared; the 96.5% reliability means that the raters were in agreement for 7,804 glance locations.

Final Reduced Data Set

With 36 participants and 44 sites, there were 1,584 events available for analysis from approximately 63 hours of data collection. A small amount of data was lost due to cell phone use, sensor outages, sun angle, and vehicle stoppages, leaving 1,540 events for eyeglance analyses. Altogether, 124,740 video frames were analyzed (1,540 events x 81 frames/event) and 8,678 individual glances were identified. The speed data was filtered to remove events as described above, and then further filtered to remove events in which the maximum speed failed to read 20 mph or the minimum speed failed to reach 15 mph, leaving 1,494 events in this dataset, with 121,014 data points for speed. The lane position dataset was further filtered to remove events indicating a possible lane change or lane position sensor failure (often due to poor lane markings). After filtering, there were 1,188 events remaining in the lane position dataset, with 96,228 data points.

Statistical Analysis

Descriptive statistics were calculated using Excel. All other statistical analyses were conducted using SAS statistical software. The analysis of variance (ANOVA) statistical technique was used; in SAS this was accomplished by means of the general linear model (GLM) procedure. Where significant differences were found, and there were more than two levels of the independent variable, a post-hoc analysis was run using the Least Squares Difference procedure

in SAS to determine which levels were significantly different from which other levels. (For independent variables with just two levels that differ significantly, a simple examination of the means will demonstrate which level is significantly greater than the other.)

Nighttime Study

A smaller exploratory study was also conducted at nighttime using an abbreviated route that avoided some of the downtown streets. Given that the digital signs being studied were intrinsically illuminated, this was felt to be an important first step in determining whether there are driver performance differences in the presence of these signs under different levels of ambient illumination. All of the nighttime drivers had previously driven the route during the daytime and were thus somewhat familiar with the route (so were unlikely to get lost or go off route). The nighttime route directions are shown in Table 6, while the order of participation is shown in Table 7 (12 of the 36 drivers returned for the nighttime experiment). The nighttime route map is shown in Figure 14.

Table 6. Nighttime Driving Directions.

	Directions	Trip Distance	Notes
⬅	Left out of Residence Inn onto **W. Creek Rd.**	0.0	
⬅	Left onto **Rockside Rd.**	0.3	
➡	Right toward **I-77 North**	0.5	Go under overpass to I-77 N entrance
	Left lane onto **I-480 West /** Toledo	1.1	
EXIT 12A	Right Exit 12A, turn Right onto **W. 150th St.**	9.9	
➡	Right onto **Puritas**	10.9	Curves to Left, becomes Bellaire
⬅	Left onto **W. 117th**	13.1	Just past entrance to I-71
➡	Right onto **I-90 East** / Cleveland	14.4	
EXIT 182A	Right Exit 182A, Right onto **E. 185th St.**	30.1	
	Stay in Right Lane and get onto **I-90 West** to Downtown	30.4	Stay on 90 W when splits to left
EXIT 172A	Take Right Exit 172A to **I-77 South**	40.3	
	Follow I-77 South to **Rockside Road** exit	47.3	
EXIT 155	Take Exit 155 Rockside Road and Independence, turn Right onto **Rockside Rd.**	47.9	
➡	Turn Right onto **W. Creek Rd.**	48.0	
➡	Turn Right into **Residence Inn** parking lot	48.3	

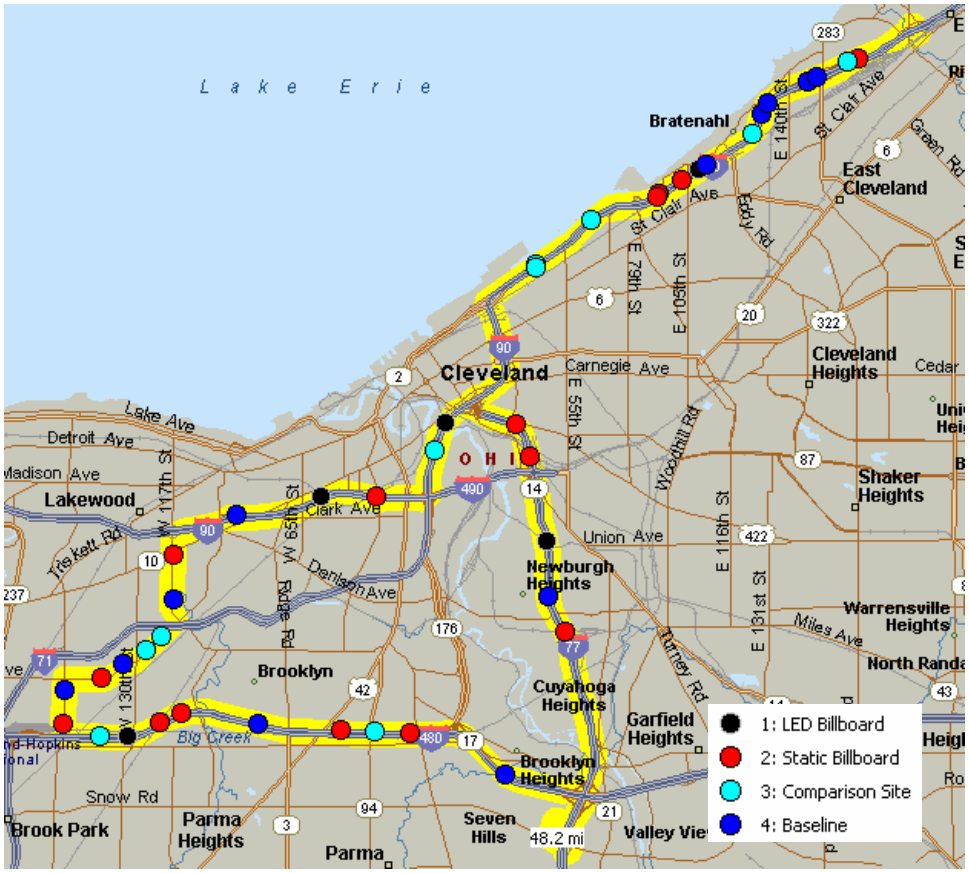

Figure 14. Map Illustrating Nighttime Route with Digital Billboards (black), Conventional Billboards (red), Comparison Sites (aqua blue), and Baseline Sites (blue).

Table 7. Nighttime order of participation.

Number	Age group	Gender
1	Younger	Female
2	Older	Male
3	Older	Female
4	Older	Female
5	Younger	Female
6	Older	Male
7	Younger	Male
8	Younger	Male
9	Older	Female
10	Older	Male
11	Younger	Male
12	Younger	Female

With 12 participants and 40 sites, there were 480 events available for analysis from approximately 42 hours of data collection. A small amount of data was lost due to cell phone use, sensor outages, and vehicle stoppages, leaving 470 events for eyeglance analyses. Altogether, 38,070 video frames were analyzed (470 events x 81 frames/event) and 2,335 individual glances were identified. The speed data was filtered to remove events as described above, and then further filtered to remove events in which the maximum speed failed to read 20 mph or the minimum speed failed to reach 15 mph, leaving 456 events in this dataset, with 36,936 data points for speed. The lane position dataset was further filtered to remove events indicating a possible lane change or lane position sensor failure (often due to poor lane markings). After filtering, there were 411 events remaining in the lane position dataset, with 33,291 data points. Because the nighttime study was exploratory in nature with fewer data points, these data are shown descriptively, but were not analyzed statistically (due to lack of statistical power).

RESULTS

Post-Drive Questionnaire – Daytime Results

Participants completed the post-drive questionnaire (Appendix D) after they returned from driving the daytime driving route as well as the nighttime route. The questionnaire gathered information such as route familiarity and items noticed while driving; it also collected demographic and personal information, including education level, marital status, ethnicity, and income. The questionnaire was the same one used by Lee et al. (2004) in the previous study using similar methods. The following sections summarize all questionnaire results for the daytime drivers, followed by a section describing the results for the nighttime drivers.

Demographics Overview

In terms of demographics, the average age was 28 years for younger drivers and 59 years for older drivers. The sample of drivers was quite diverse in terms of education level, marital status, and income. All drivers lived and worked in the Cleveland, OH area and were familiar with some or most of the route. The following sections provide details for relevant information about the sample of drivers. Table 8 presents these findings as well.

Age. The sample of 36 drivers ranged in age from 18 to 71 years old. The mean age of all participants was 43.3 years (SD = 16.7). The younger drivers ranged in age from 18 to 35 years old, with a mean of 27.9 years (SD = 6.0). The older drivers ranged in age from 50 to 71 years old, with a mean of 58.7 years (SD = 6.1).

Education Level. Participants were surveyed regarding the highest education level they had completed. The number of responses and equivalent number of years were used to calculate the product. This was used to calculate the mean education level for the sample by dividing the total number of years completed by the number of participants (482/36). The average was 13.4 years of education completed (equivalent to high school plus a year and a half of college). Most of the participants had finished high school, but few had attended college.

Marital Status. Half of the participants were married, while 28% reported that they were single and 17% were divorced. Two individuals (5.6%) indicated that they were separated.

Ethnicity. Most participants were European (Caucasian/White) with only one participant identifying herself as African American.

Income. The income level with the most participants was the group earning between $25,000 and $49,000 per year (16 participants or 44%).

Table 8. Summary of Demographic Results for All Daytime Participants.

CATEGORY	LEVELS			
Age (mean)	**Younger Drivers**	**Older Drivers**	**All Drivers**	
	27.9 years	58.7 years	43.3 years	
Education Level	**High Sch.**	**2-Yr Deg.**	**B.A./B.S.**	
	52.8%	25.0%	22.2%	
Marital Status	**Single**	**Married**	**Divorced**	**Separated**
	27.8%	50.0%	16.7%	5.6%
Ethnicity	**African American**	**European**		
	2.8%	97.2%		
Income Level	**$0-24K**	**$25-49K**	**$50-74K**	**>$100K**
	33.3%	44.4%	19.4%	2.8%

Route Familiarity

Route familiarity was assessed by three items in the questionnaire. Specific topics addressed were: location of work, location of home, and frequency of driving on roads in the experimental route (defined as familiarity). Table 9 presents the route familiarity findings.

Living and Working Location. All drivers reported that they were familiar with the Cleveland, OH area and had driven on the interstates and surface roads included in the route. All of the participants lived in the Cleveland area, and those who were employed also worked in the area. Cleveland proper, Parma, and Independence were the most common locations where participants lived and worked, with 39% of participants reporting that that they both lived and worked in one of these three areas (Independence and Parma are adjacent suburbs of Cleveland).

Familiarity. Route familiarity was also evaluated in terms of five route segments that represented various types of driving (i.e., various segments of interstate and downtown Cleveland). Drivers were asked to indicate if they were either “familiar” (driven at least once a week) or “not familiar” (driven less than one time a week) with each segment. In some cases, participants inquired about this question item, indicating (verbally) that, although they were quite familiar with certain areas, they may not drive on them every week. Nonetheless, the results indicated that overall, drivers were familiar with the route, particularly I-480 W between I-77 and W150th (83% were familiar with this segment as shown in Table 9).

Table 9. Route Segment Familiarity for All Daytime Participants.

	Route Segment				
% Familiar	I-480W between I-77 and W150th	W.130th - Bellaire - W.117th	I-90 between 9th and 185th	Carnegie Ave.	I-77 between I-90 and Rockside
	83%	42%	64%	67%	72%

Overview of What Drivers Noticed

Drivers primarily noticed items such as traffic and other drivers, road or highway signs, and road construction. Fifteen of 36 drivers (42%) marked "billboards" as one of the top 5 items (out of 18 items) that caught their attention during the drive. Participants engaged in a variety of activities while driving; listening to the radio or CD player and using the cell phone were the most prevalent. At no point was it apparent that any participant knew the specific purpose of the study; all responses indicated that drivers believed the study was related to observing drivers in a natural driving situation, which was also true. The following sub-sections describe findings in more detail, with tables illustrating drivers' responses.

Attention Getters. Participants were asked to indicate "the top five items that most caught your attention during your drive." Over 50% of drivers indicated that they paid attention to traffic, road signs, exit signs, and other drivers. The top 9 items (out of 18 listed) are shown in Figure 15. For those drivers who indicated "billboard" as one of the items that caught their attention, the experimenter asked them to verbally expand upon all items; however, none of these drivers made any additional comments about billboards except that they caught their attention. Three drivers (8%) mentioned billboard under a separate question regarding the single most memorable part of the drive. Their comments were "The lighted billboards," "Ridiculous billboards," and "The light up billboards." A fourth driver mentioned "Markers and signs" but did not elaborate further. Even in the daytime, the digital billboards appeared to have been noticeably different from conventional billboards and appeared to attract a certain amount of attention.

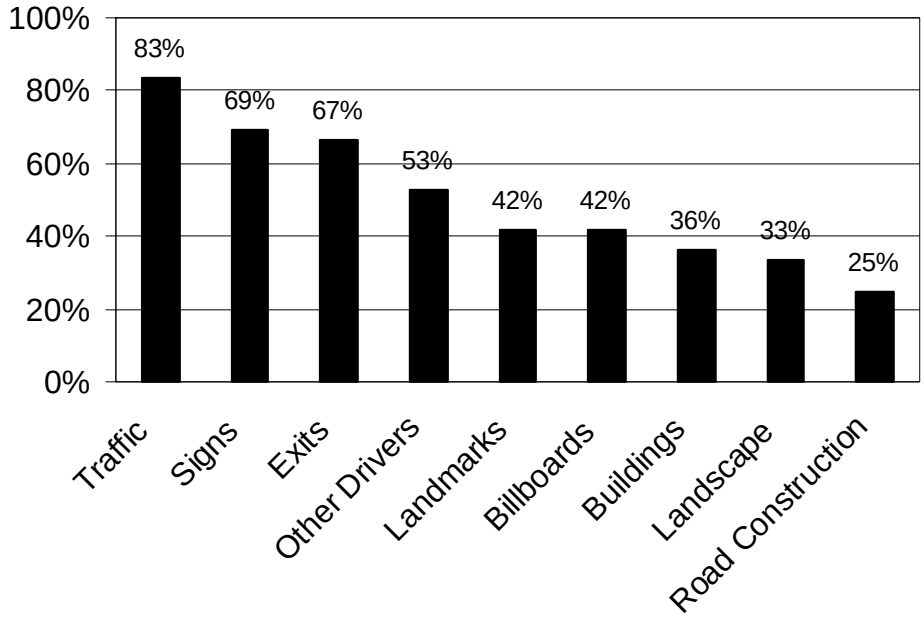

Figure 15. Top Daytime Attention Getters (top nine of eighteen possible).

Most Memorable. Participants were asked "What was most memorable about the drive?" This was an open-ended question, so the comments varied. For ease of categorization, similar comments were grouped where possible. There were 35 comments. Over 68% of the comments were related to construction, weather/view, the experimental vehicle, or traffic, as presented in Table 10.

Table 10. Number and Percent of Comments for Daytime Participants for the Question: "What was most memorable about the drive? For example, were there any objects that stood out?"

Comment Categories	Number of Comments	Percent of Comments
Other Vehicles/Traffic	7	17.5%
New Route/feature about route	6	15.0%
Lake	5	12.5%
Weather/View	4	10.0%
Test Vehicle	3	7.5%
Digital Billboards/Billboards/signs	3	7.5%
Neighborhoods	3	7.5%
Rough Road	3	7.5%
Relaxing/Positive trip	2	5.0%
Construction	1	2.5%
Near accident/Accident	1	2.5%
Sports Arena	1	2.5%

What Bothers You? Participants were asked, "What bothers you about other drivers?" This was an open-ended question, so the comments varied. For ease of categorization, similar comments were grouped where possible. A total of 30 comments were made. The large majority of the comments were related to aggressive maneuvers or questionable driving behavior such as tailgating, being cut off, not using turn signals, or driving slowly in the fast lane (Table 11).

Table 11. Number and Percent of Comments for Daytime Participants in Response to the Question: "Does anything about other drivers bother you? If so, please briefly describe."

Comment Category	Number of Comments	Percent of Comments
Tailgating	7	23.3%
Cut off	6	20.0%
No signal	5	16.7%
Speeding	3	10.0%
Aggressive	3	10.0%
Slow in fast lane	3	10.0%
Cell phone talking	1	3.3%
Drivers who don't pay attention	1	3.3%
Inability to adjust to conditions	1	3.3%

Other Activities. Participants were asked, "What other activities do you engage in while driving?" Again, this was open-ended and the comments varied, but similar comments were grouped where possible. There were 72 comments in all. Listening to the radio or CDs was the largest single activity, making up over 26% of the comments. Using the cell phone was also common (15%). Other activities included singing or talking, drinking, smoking cigarettes, and eating, as presented in Table 12.

Table 12. Number and Percent of Comments for Daytime Participants in Response to the Question: "What other activities do you typically engage in while driving?"

Comment Categories	Number of Comments	Percent of Comments
Listen to radio/CDs	21	38.9%
Cell phone	11	20.4%
Smoking	4	7.4%
Eating	4	7.4%
Drinking	3	5.6%
Talk w/others	3	5.6%
Adjust radio/CDs	2	3.7%
Driving/steering	2	3.7%
Adjust AC/windows	1	1.9%
Look for something	1	1.9%
Homework	1	1.9%
Read directions/map	1	1.9%

Other questions asked participants for additional input about the written directions and the purpose of the study. Substantively relevant participant responses included three separate suggestions relating to conducting a driving study with passengers or children, the effect of video cameras on driving behavior, and the statement that "driving in my own car would be more 'normal.' " While no one reported problems with the directions, three drivers did get off-route at one point during their trip; however, very few data points were missed. Drivers were also queried as to their recollection of the purpose of the study; all responses were within the scope of what they had been told verbally and in the informed consent form.

Post-Drive Questionnaire – Nighttime Results

Age

The sample of 12 nighttime drivers ranged in age from 25 to 62 years old and consisted of drivers who had recently performed the daytime portion of the experiment. As for the main experiment, the participant pool was balanced for age and gender. The mean age of the nighttime participants was 44.5 years (*SD* = 14.0). The younger drivers ranged in age from 25 to 35 years old, with a mean of 31.5 years (*SD* = 4.1). The older drivers ranged in age from 54 to 62 years old, with a mean of 57.5 years (*SD* = 3.3). The demographics for these 12 drivers are summarized in Table 13.

Table 13. Summary of Demographic Results for All Nighttime Participants.

CATEGORY	LEVELS		
Age (mean)	**Younger Drivers**	**Older Drivers**	**All Drivers**
	31.5 years	57.5 years	44.5 years
Education Level	**High Sch.**	**2-Yr Deg.**	**B.A./B.S.**
	58.3%	25.0%	16.7%
Marital Status	**Single**	**Married**	**Divorced**
	8.3%	66.7%	25.0%
Ethnicity	**European**		
	100.0%		
Income Level	**$0-24K**	**$25-49K**	**$50-74K**
	16.7%	41.7%	41.7%

Route Familiarity

Route familiarity was assessed by three items in the questionnaire. Specific topics addressed were: location of work, location of home, and frequency of driving on roads in the experimental route (defined as familiarity). As before, all nighttime drivers lived and worked in the Cleveland, OH area. Route familiarity was also evaluated in terms of five route segments that represented various types of driving (i.e., various segments of interstate). Drivers were asked to indicate if they were either "familiar" (driven at least once a week) or "not familiar" (driven less than one time a week) with each segment. Table 14 presents the route familiarity findings.

Table 14. Route Segment Familiarity for All Nighttime Participants.

	Route Segment				
	I-480W between I-77 and W150th	W.130th - Bellaire - W.117th	I-90 between 9th and 185th	Carnegie Ave.	I-77 between I-90 and Rockside
% Familiar	75%	42%	58%	58%	50%

Attention Getters

Participants were asked to indicate "the top five items that most caught your attention during your drive." Over 50% of drivers indicated that they paid attention to traffic, road signs, billboards, and exits. Figure 16 shows the top nine nighttime attention getters. For those drivers who indicated "billboard" as one of the items that caught their attention, the experimenter asked them to verbally expand upon all items, but no one made any remarks relevant to billboards. However, 3 of the 12 nighttime drivers (25%) noted billboards as being the single most memorable thing about the drive. One person just said "Billboards," another said "I saw a billboard that changed and I wished it hadn't because I wanted to read the previous message," and a third said "One billboard." This is much higher than the 8% who mentioned billboards as

being most memorable during the daytime, and may be a reflection of the nature of the digital billboards.

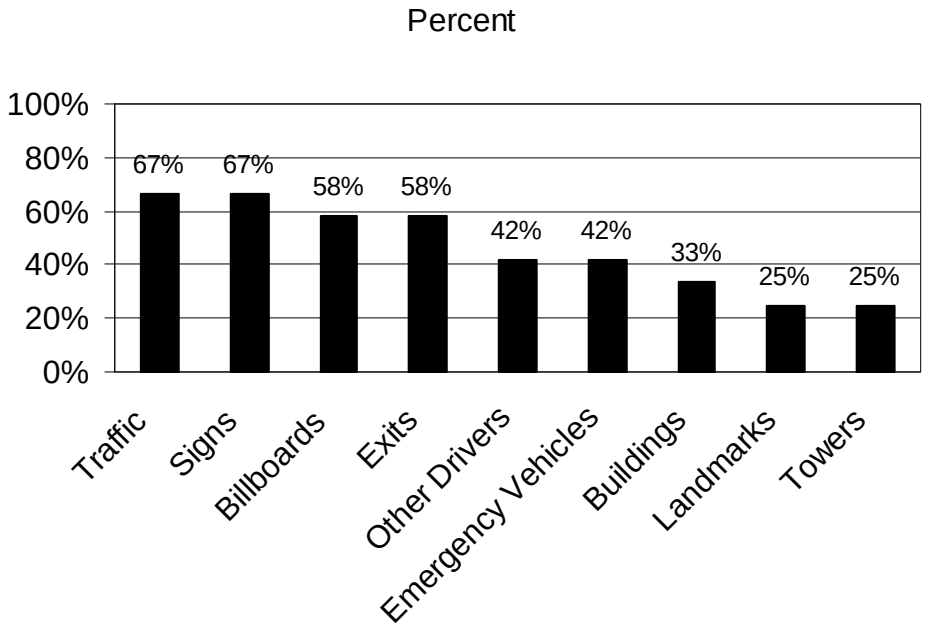

Figure 16. Top Nighttime Attention Getters (top nine of eighteen possible).

Most Memorable

Participants were asked "What was most memorable about the drive?" This was an open-ended question, so the comments varied. For ease of categorization, similar comments were grouped where possible. There were nine comments from the 12 nighttime drivers. As mentioned, three comments concerned billboards, while other common answers included the views and other vehicles and traffic, as presented in Table 15. The drivers had previously answered the general questions regarding "What bothers you about other drivers?" and "What other activities do you engage in while driving?" during their daytime session, so these were not asked again here. Likewise, the responses to "What is the purpose of this study?" were similar to what the same participants had said during the daytime session; all responses were within the scope of what they had been told verbally and in the informed consent form.

Table 15. Number and Percent of Comments for Nighttime Participants in Response to the Question: "What was most memorable about the drive? For example, were there any objects that stood out?"

Comment Categories	Frequency
Digital Billboards/Billboards	3
View	2
Other Vehicles/Traffic	2
Positive trip	1
Personal condition while driving	1

Driving Performance Results – Daytime

Event Type

Eyeglance Results. With regard to eyeglance behavior, there were six questions of interest, each of which will be discussed in turn:

1. Does eyes-on-road percent (looking straight forward) vary in the presence of different event types?
2. Is there a more active glance pattern in the presence of certain event types (as measured by the number of individual glances to any location during the eight seconds of the event)?
3. For events on the left side of the road, are there more glances in the left forward direction for certain event types?
4. For events on the right side of the road, are there more glances in the right forward direction for certain event types?
5. For events on the left side of the road, does the mean single glance time in the left forward direction vary according to event type?
6. For events on the right side of the road, does the mean single glance time in the right forward direction vary according to event type?
7. Are longer glances (longer than 1.6 s) associated more with any of the event types?

Question 1 (Does eyes-on-road percent (looking straight forward) vary in the presence of different event types?) was answered by examining the amount of time spend looking straight forward in the course of an event, and dividing it by 8 s to obtain the percentage of time the driver was looking forward. As shown in Figure 17, this ranged between 70% and 75% for the various event types, with baseline, digital billboard, and conventional billboard being close to equal. Statistical analysis showed that this measure did vary across event types ($F_{3,96} = 11.62$, $p < 0.0001$, using an α of 0.05 as a criterion, as is standard for studies of this type). The comparison events had significantly less eyes-on-road percent than did the other event types, which did not vary from one another.

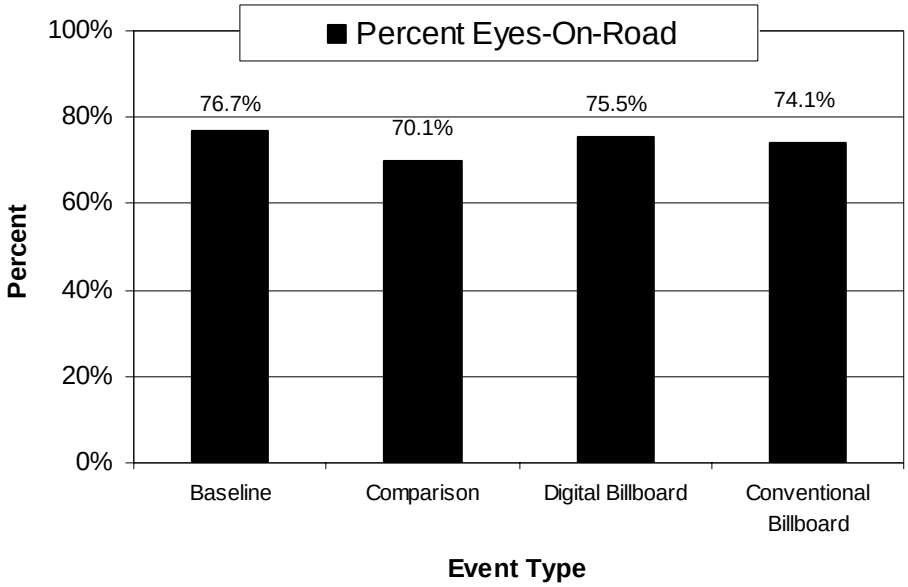

Figure 17. Percent Eyes-on-Road Time for the Four Event Types. (Comparison events were significantly lower than the other three event types, which did not differ from one another).

Question 2 (Is there a more active glance pattern in the presence of certain event types?) was measured by examining the number of individual glances to any location during the eight seconds of the event. A higher mean number of glances during the eight seconds indicated a more active scanning pattern. As shown in Figure 18, there were very few differences in the overall glance activity. The statistical analysis verified this observation, showing no significant differences between event types ($F_{3,96} = 1.78$, $p = 0.1564$).

Questions 1 and 2 were aimed at the larger question of whether overall driver eyeglance behavior changed in the presence of certain event types. In other words, did driver total time looking forward change in the presence of certain event types, and did drivers exhibit a more active glance pattern for certain event types? Except for lower eyes-on-road time for comparison events, there were no observed differences in overall eyeglance patterns. The next four questions are concerned with the specific eyeglance patterns that might be expected to occur if drivers were allocating more visual attention to specific objects located on the side of the road.

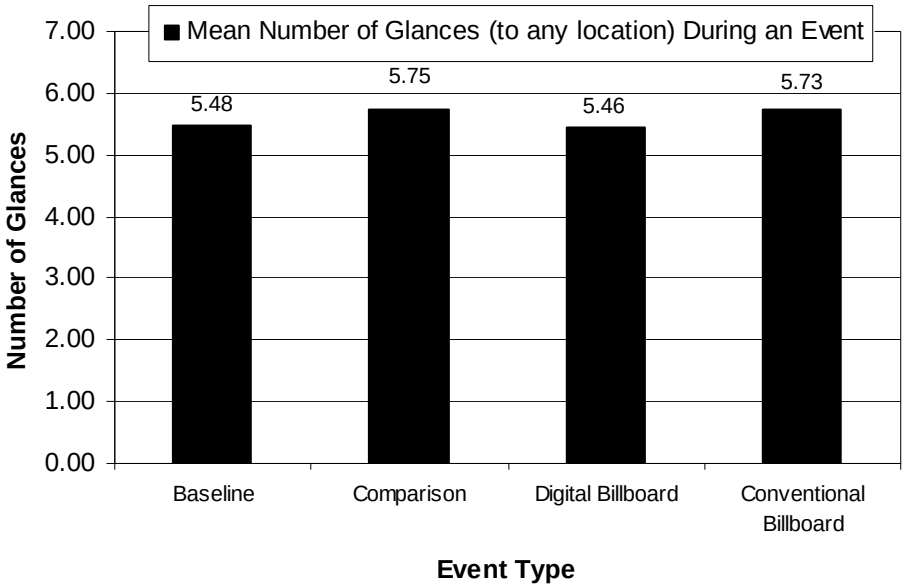

Figure 18. Mean Number of Glances to Any Location During an Event. (There were no significant differences between event types.)

Question 3 (For events on the left side of the road, are there more glances in the left forward direction for certain event types?) was aimed at the question of whether the presence of a site of interest on the side of the road was related to a greater number of glances in that direction. All baseline events were included in this analysis since these events were considered to have been located on both sides of the road. As can be seen in Figure 19, digital billboards to the left side of the road did garner a larger number of left forward glances during the eight seconds than did any of the other event types. However, statistical analysis showed that these differences were not significant ($F_{3, 73} = 1.49$, $p = 0.2244$).

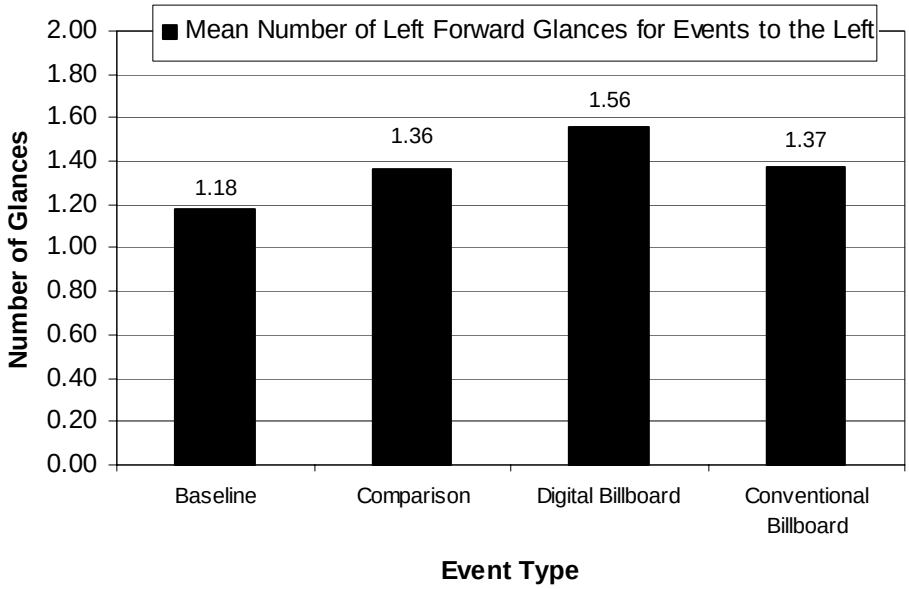

Figure 19. Mean Number of Left Forward Glances for Events on the Left Side of the Road. (There were no significant differences between event types.)

Question 4 (For events on the right side of the road, are there more glances in the right forward direction for certain event types?) was similar in intent, but used events on the right side of the road and right forward glances. Again, all baseline events were included in this analysis since these events were considered to have been located on both sides of the road. As can be seen in Figure 20, there appeared to be little difference in the number of right forward glances across event types. Statistical analysis showed that the observed differences were not significant ($F_{3,77} = 0.29$, $p = 0.8353$).

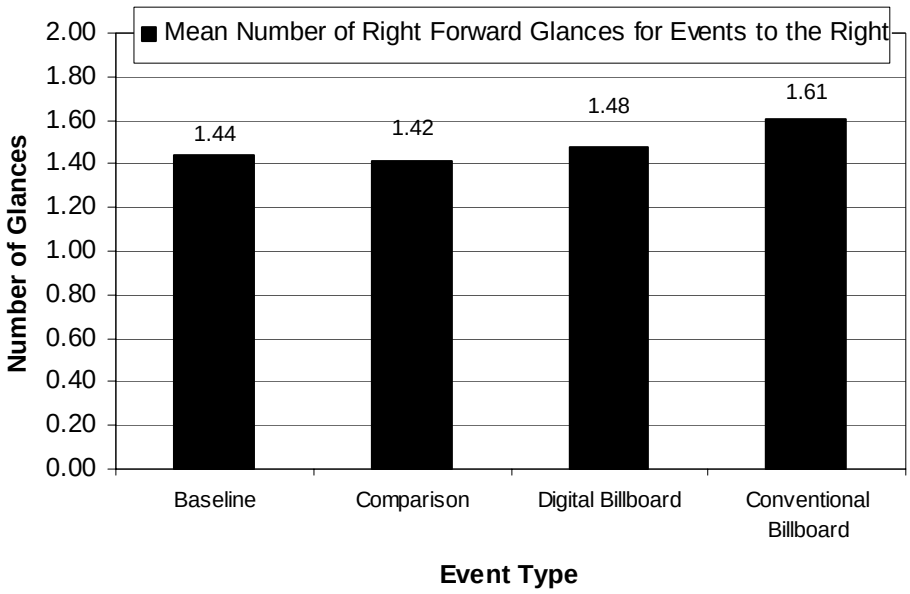

Figure 20. Mean Number of Right Forward Glances for Events on the Right Side of the Road. (None of the observed differences were significant.)

Question 5 (For events on the left side of the road, does the mean single glance time in the left forward direction vary according to event type?) was measured by examining the mean single glance time for left forward glances. Longer glances in the left forward direction for events to the left could indicate that the driver is paying greater visual attention to the event. Figure 21 shows that the digital billboard and comparison event types had longer mean single glance times than did baseline or conventional billboard events. Statistical analysis showed that these differences were significant ($F_{3,73} = 3.59$, $p = 0.0176$). Post hoc analysis showed that the digital billboards to the left had significantly longer left forward glances than did conventional billboards or baseline sites, but that they did not differ from comparison sites. Comparison sites differed from baseline sites, but not from conventional billboard sites, and conventional billboards and baseline sites did not differ from one another.

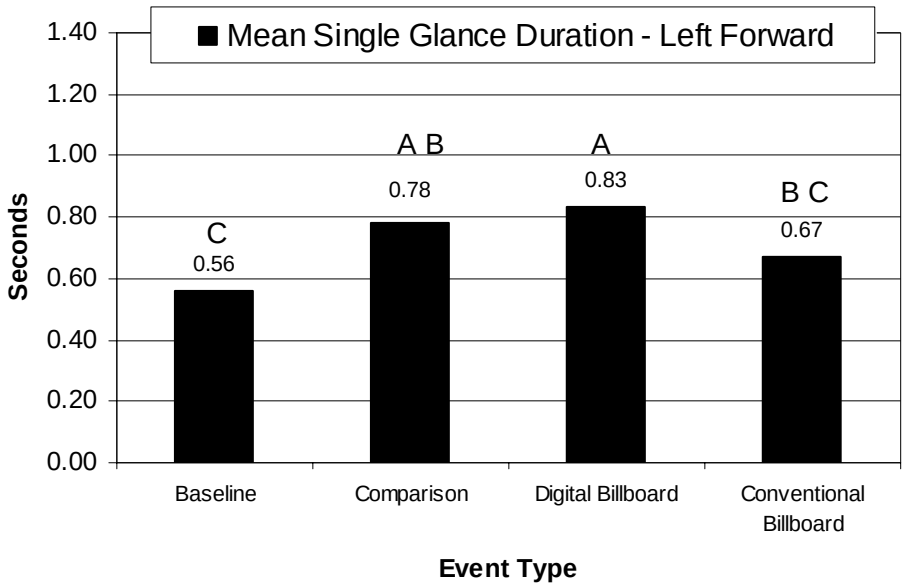

Figure 21. Mean Single Glance Time for Left Forward Glances for Events on the Left Side of the Road. (Data points with a shared letter do not differ significantly from one another.)

Question 6 (For events on the right side of the road, does the mean single glance time in the right forward direction vary according to event type?) was similar to Question 5 in approach, except that it examined right forward glances and events to the right. Statistical analysis showed that the observed differences were significant ($F_{3,77} = 3.73$, $p = 0.0147$). Post-hoc tests showed that digital billboards located on the right had significantly longer glance times to the right than did either baseline events or conventional billboards, but did not differ significantly from comparison events. Comparison events had longer glance times than did baseline events, but did not differ significantly from conventional billboards. Conventional billboards also had significantly longer glances than did baseline events.

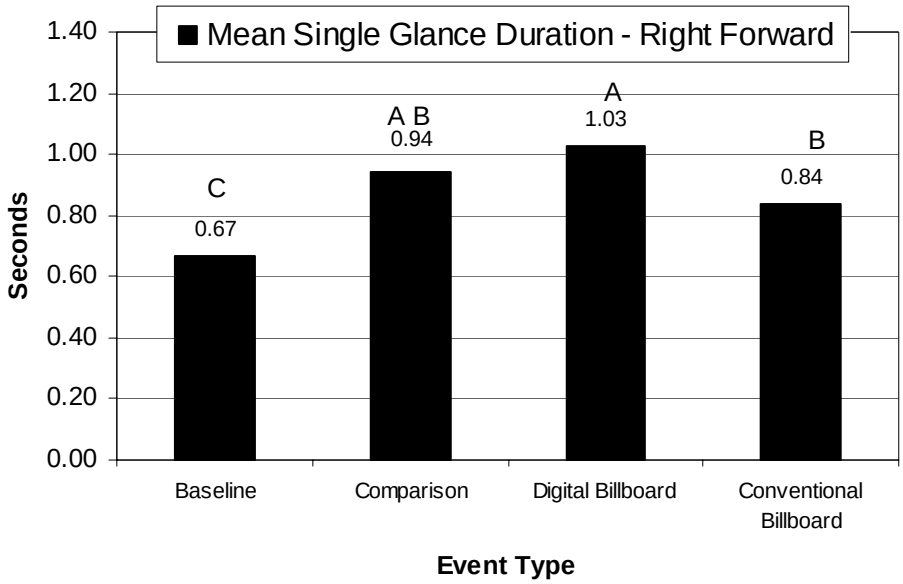

Figure 22. Mean Single Glance Time for Right Forward Glances for Events on the Right Side of the Road. (Data points with a shared letter do not differ significantly from one another.)

Question 7 (Are longer glances (longer than 1.6 s) associated more with any of the event types?) follows an approach provided by Horrey and Wickens (2007), who suggest analyzing the tails of the distributions whenever eyeglance analysis is performed. Various researchers have suggested that longer glances may be associated with poorer driving performance. For example, Wierwille (1993) suggests a 1.6 s criterion as representing a long glance away from the forward roadway. As shown in Figure 23, the distributions of glance duration were similar across all event types, and there was no obvious pattern of longer glances being associated with any of the event types.

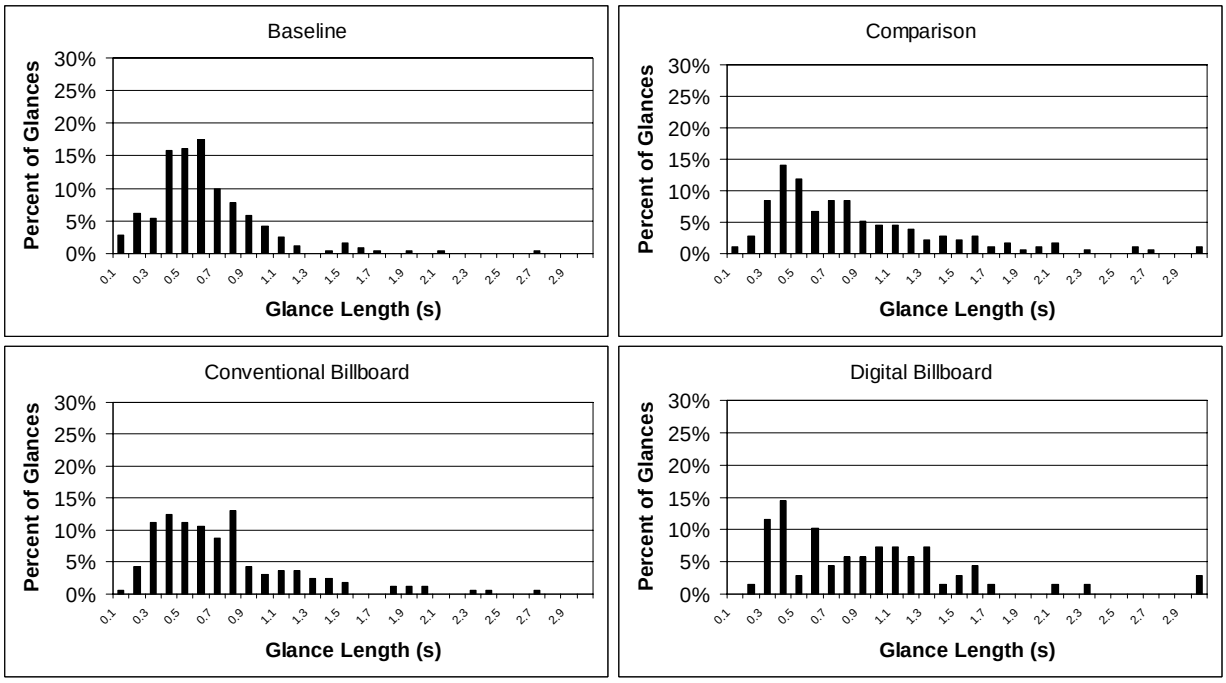

Figure 23. Tails analysis for the distribution of glance duration, (method described in Horrey and Wickens, 2007).

Discussion of Daytime Eyeglance Results. Results showed that digital billboards were not associated with changes in overall glance patterns (overall number of glances or percent eyes-on-road time). Likewise, digital billboards were not associated with more frequent glances towards the direction where the billboard was located. However, digital billboards in both the left and right directions were associated with longer glances in that direction.

There were only five digital billboards along the route (these were all that were available). This led to low statistical power for the digital comparisons, especially when the digital billboards were separated into left and right (two in one direction and three in the other). To increase power and verify the above findings, the data were next aggregated so that all glances in the direction where an event was located were included. For glance frequency, there were still no significant differences in the number of glances depending on event type ($F_{3, 91} = 1.22$, $p = 0.3065$). For glance duration, the findings from above were also confirmed with this combined analysis ($F_{3, 91} = 4.98$, $p = 0.0030$). Digital billboards and comparison sites did not differ from one another, but each differed from conventional billboards and baseline events. Conventional billboards and baseline events did not differ from one another; these results are shown in Figure 24.

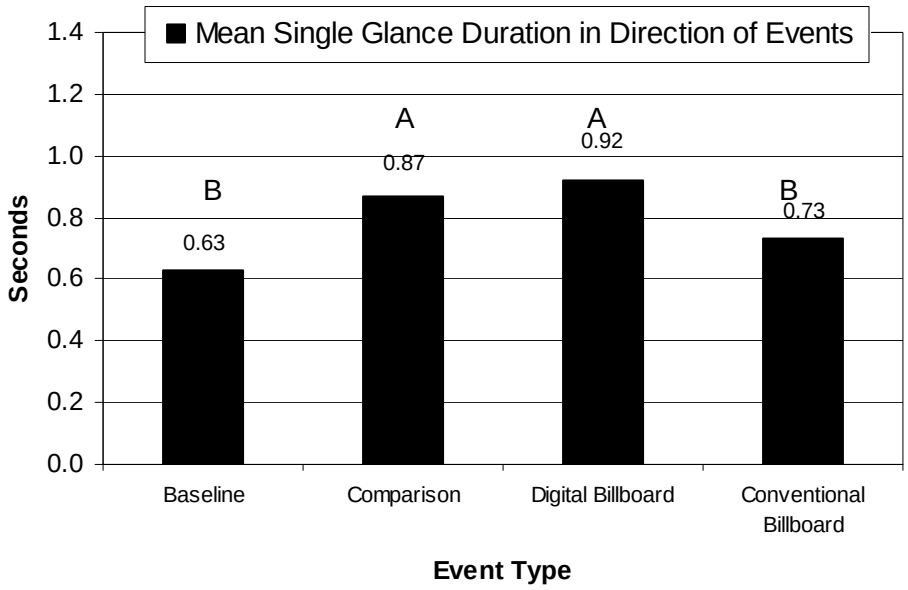

Figure 24. Mean Single Glance Time for Glances in the Direction of Events. (Data points with a shared letter do not differ significantly from one another.)

It should also be noted that digital billboards did not differ in glance duration from comparison events for left side, right side, or the combined comparison. Several of the comparison events had a digital component, but in the form of on-premises signing rather than as billboards. One comparison event used full motion video at times. Thus, it is not surprising that these event types revealed similar glance duration patterns. Finally, it should be noted that the results for conventional billboards were similar to those found in the Charlotte study, with very few differences between conventional billboards and either comparison events or baseline events.

Speed maintenance. As shown in Figure 25, there were differences in the standard deviation of speed for the different event types. These differences were statistically significant ($F_{3, 96} = 5.33$, $p = 0.0019$), with conventional billboards showing a higher speed deviation than baseline and digital billboards, but not different from comparison sites. Baseline events, comparison events, and digital billboards did not differ from one another. Much of this difference may be because there is typically greater speed deviation on surface streets than on interstates, and all of the digital billboards were on interstates. To account for this in the research design, the same analysis was conducted, but using only events occurring on interstates. In this analysis, there were no significant differences in standard deviation of speed ($F_{3, 96} = 1.66$, $p = 0.1819$), as shown in Figure 26.

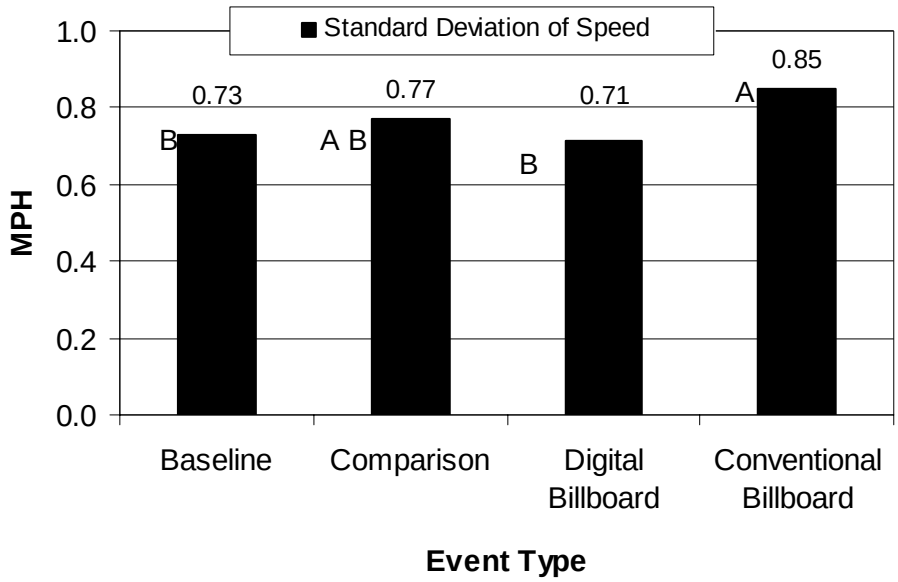

Figure 25. Standard Deviation of Speed by Event, in miles per hour. (Data points with a shared letter do not differ significantly from one another.)

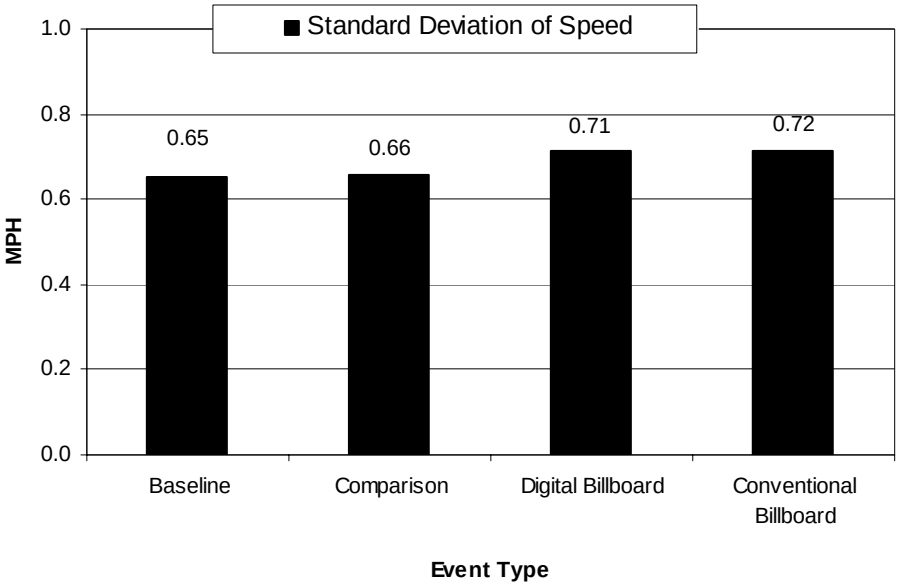

Figure 26. Standard Deviation of Speed by Event for Events Occurring on Interstates, in miles per hour. (None of the observed differences was significant.)

Lane keeping. The standard deviation of lane position was calculated for each event. Standard deviation was used instead of average lane position, because average lane position can be to the right or left, and thus an average would tend to wash out true differences, while standard deviation takes overall deviation into account, regardless of left or right. While there appeared to be differences in lane keeping for the different event types as shown in Figure 27, these differences did not quite reach significance ($F_{3, 91} = 2.46$, $p = 0.0673$). Nevertheless, the trend is that digital billboards and conventional billboards seem to be related to poorer lane keeping, and it is likely that a larger sample would have shown significance for this measure.

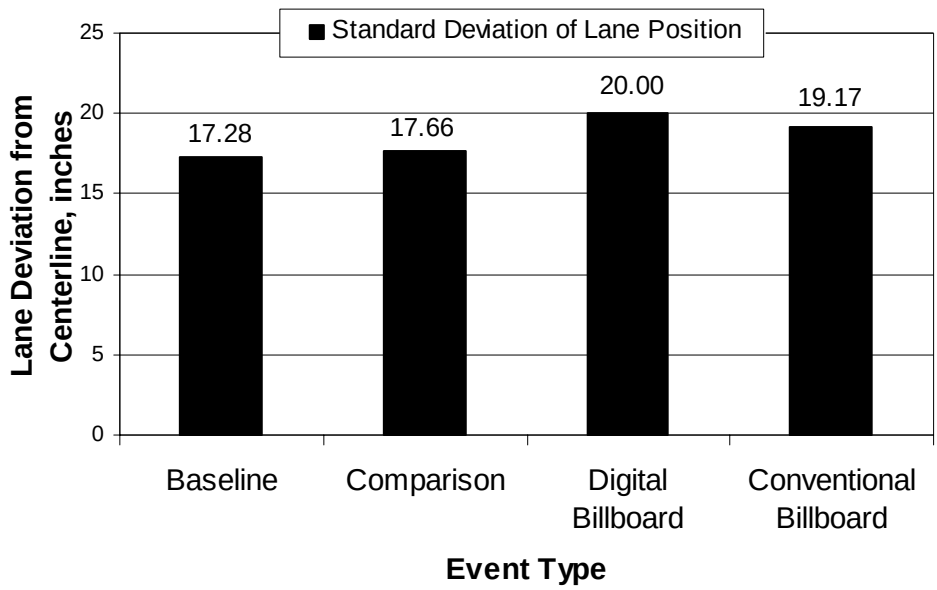

Figure 27. Standard Deviation of Lane Position by Event, in inches. (None of the observed differences was significant.)

Other findings

Road Type. There were significant differences in the two overall eyeglance measures, both of which indicated a more active glance pattern on surface streets. The eyes-on-road percentage was higher for interstate events than for surface street events (71% for interstate vs. 64% for surface streets; $F_{1, 32} = 30.29$, $p < 0.0001$). There were also more total glances during an event on surface streets as opposed to on the interstates (6.3 glances for interstate vs. 7.2 glances for surface streets; $F_{1, 32} = 10.51$, $p < 0.0028$). There were no significant differences for the eyeglance measures associated with the left or right side of the road. These findings are consistent with the findings of the Charlotte study, in that eyeglance patterns tend to be more active while driving on surface streets due to driver monitoring of driveways, intersections, and on-coming traffic.

Familiarity. Drivers spent significantly more time with their eyes on the road while driving on unfamiliar roads (73% for familiar roads and 75% for unfamiliar roads; $F_{1, 22} = 4.81$, $p = 0.0392$). However, this small significant difference likely has no practical implications, especially given that the overall glance frequency was not significant ($F_{1, 22} = 1.38$, $p = 0.2530$).

There were no significant differences for speed maintenance or lane keeping depending on familiarity with the route segment. These results are likely confounded by the fact that most of the road segments that drivers classified as familiar were the interstate portions of the route, while the unfamiliar roads tended to be the surface street sections.

Age. There were two age findings in the eyeglance measures. Older drivers had higher eyes-on-road percentage than did younger drivers (73% for older and 67% for younger; $F_{1, 32} = 4.46$, $p = 0.0426$). Younger drivers also had more frequent right forward glances for events to the right than did older drivers (younger = 1.55 right forward glances per event; older = 1.34 right forward glances per event; $F_{1, 32} = 4.42$, $p = 0.0436$). Younger drivers thus seemed to have a slightly more active glance pattern than older drivers, but this did not show up in very many of the eyeglance measures examined. There were no age differences for speed keeping or lane maintenance.

Gender. There were no significant findings for gender for eyeglance, speed maintenance, or lane keeping measures.

Driving Performance Results – Nighttime

Event Type

Eyeglance results. As mentioned previously, there were about one-third fewer data points for the nighttime portion of the study, which was considered an exploratory study. Thus, the results in this section are presented descriptively, without statistical analysis. Where the differences shown are strong, it is likely that a larger study would show statistical significance, while weak differences may or may not hold up with a larger study. Four eyeglance measures were examined for the nighttime data: eyes-on-road percent, overall glance frequency, mean glance duration in the direction of an event, and mean number of glances in the direction of an event. Eyes-on-road percent is presented in Figure 28, which shows that digital billboards and comparison events tended to have less eyes-on-road time at nighttime than either baseline events or conventional billboards. The overall glance frequency was also higher in the presence of digital billboards and comparison events at nighttime, as shown in Figure 29. These two findings taken together show a more active glance pattern at nighttime in the presence of these two event types, which mirrors some of the daytime findings.

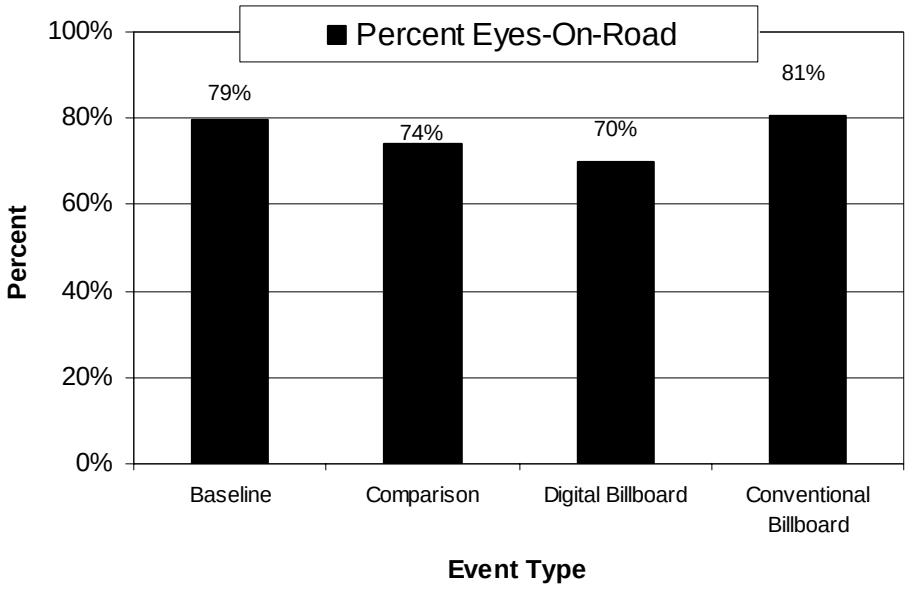

Figure 28. Eyes-on-Road Percent by Event Type for the Nighttime Exploratory Study.

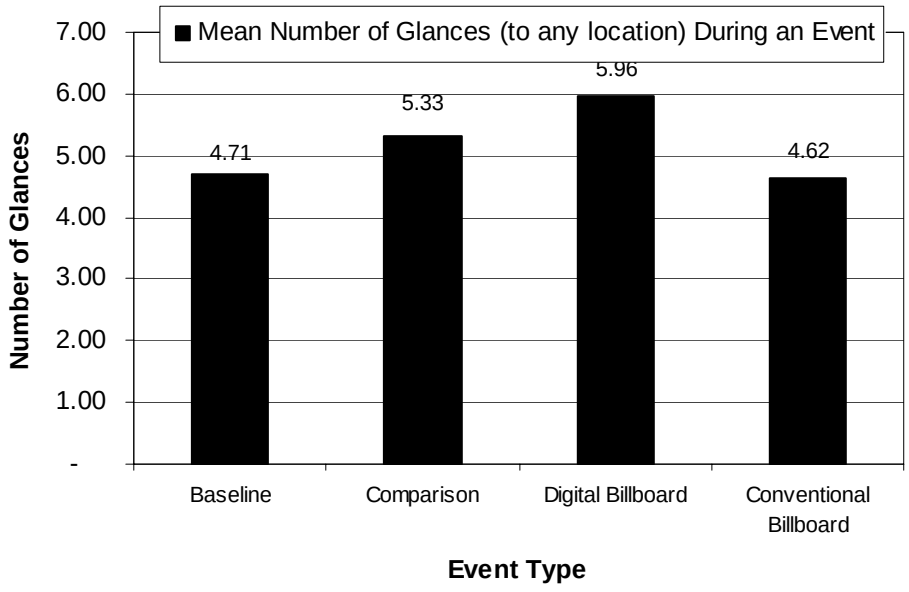

Figure 29. Overall Glance Frequency by Event Type for the Nighttime Exploratory Study.

The mean glance duration for glances in the direction of an event also showed higher values for digital billboards and comparison events; however, in this case, the comparison sites appeared to have longer glance times than did the digital billboards (Figure 30). The mean number of glances in the direction of an event again showed digital billboards and comparison events as having higher values than either baseline events or conventional billboards, as shown in Figure 31. Taken together, these four findings indicate that digital billboards and comparison events

may result in more active glance patterns overall, as well as more frequent and longer glances towards the digital billboards and comparison events.

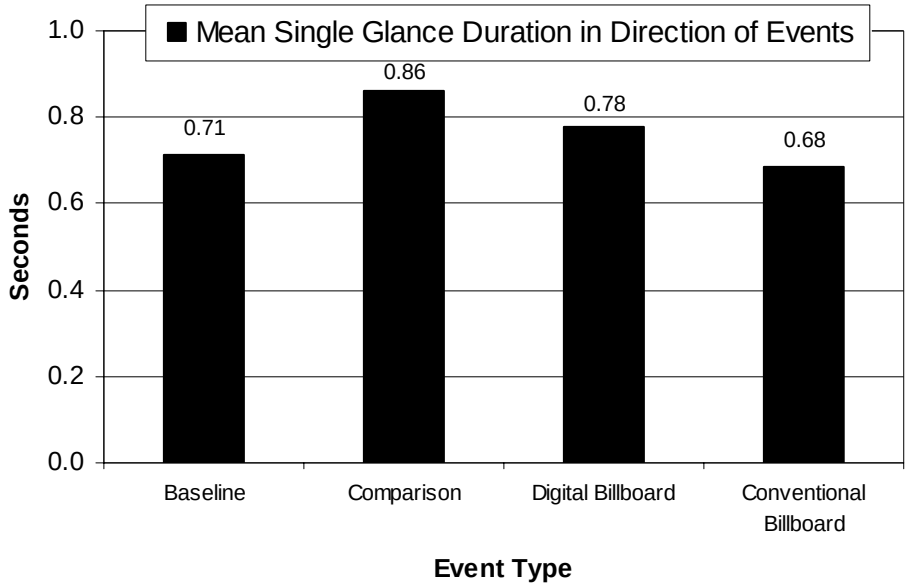

Figure 30. Mean Glance Time for Glances in the Direction of an Event for the Nighttime Exploratory Study.

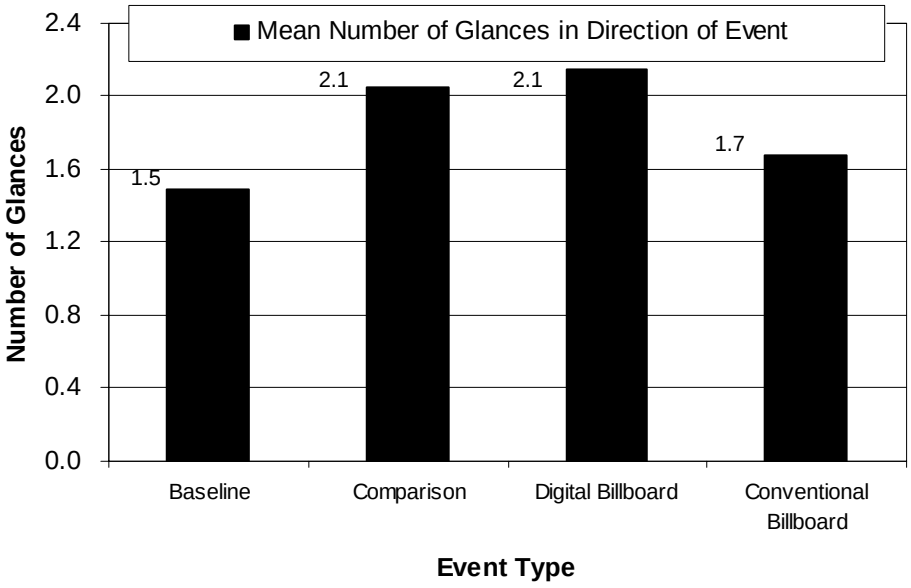

Figure 31. Mean Number of Glances in the Direction of an Event for the Nighttime Exploratory Study.

Speed maintenance. Figure 32 shows that the standard deviation of speed appeared to be higher in the presence of both conventional and digital billboards than for baseline and comparison events. If this effect is related to the event type, it may be due to the attempt to read the copy of these signs at night while driving. If this is true, the higher value shown for conventional billboards may indicate that these signs are more difficult to read at night than are the digital billboards.

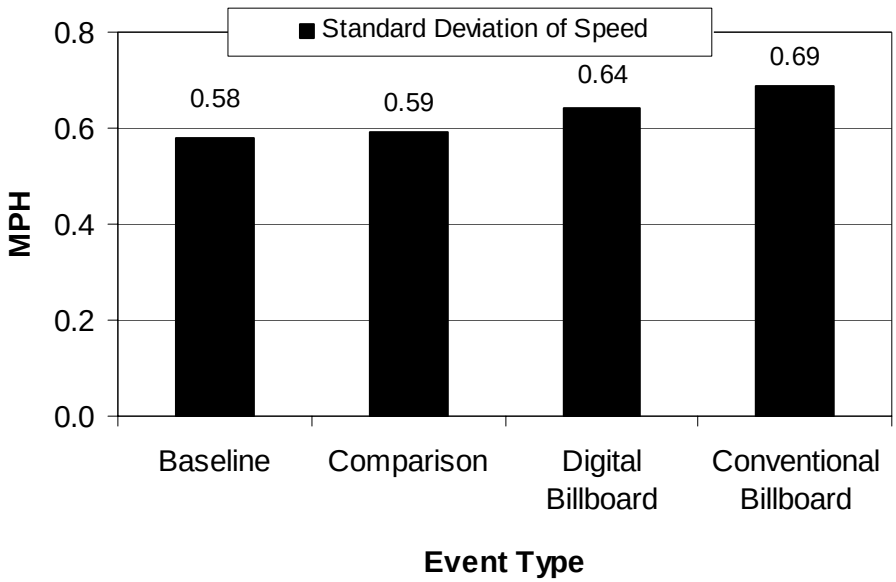

Figure 32. Speed Maintenance as Measured by the Standard Deviation of Speed by Event for the Nighttime Exploratory Study.

Lane keeping. Lane keeping also showed a trend towards greater lane deviations in the presence of both digital billboards and conventional billboards as shown in Figure 33. As was true for speed maintenance, conventional billboards showed higher values than did digital billboards. Again, this may be an indication of the difficulty of reading these signs at night.

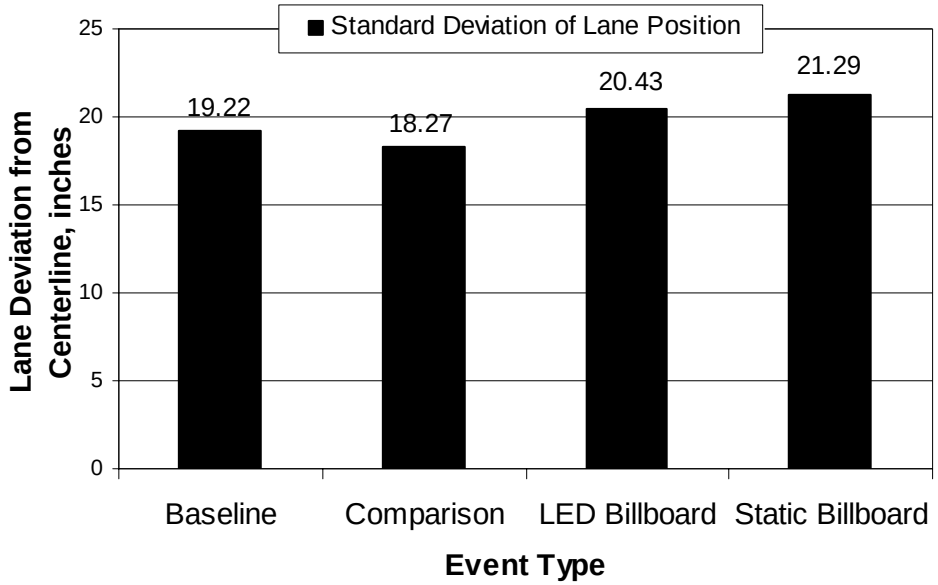

Figure 33. Lane Keeping as Measured by the Standard Deviation of Lane Position by Event for the Nighttime Exploratory Study.

Nighttime Luminance Measures

The luminance was measured with a Radiant Imaging Charge-Coupled Device (CCD) photometer with a 300 mm lens. The CCD photometer provided a method of capturing the luminance of an entire scene at one time. Luminance represents the amount of light that is projected off a surface in a given direction. For this investigation, the direction of interest was towards the driver. Luminance is measured in candelas per meter squared.

The photometer was located in the experimental vehicle as close to the driver's position as possible (Figures 34 and 35). The experimental vehicle was then driven to the sign location and stopped on the side of the road. Images of the sign were then acquired. For multiple face signs such as the digital and the tri-visions signs, each of the presented messages was imaged. Using the software provided with the system, the average luminance of the sign and each message was measured. The photometer was connected to a laptop computer in the back seat that stored the data as the images were acquired. All measurements were taken at night. Figure 36 shows the average luminance measures for each of the four event types measured in candelas per meter squared. Note that the digital billboards had noticeably higher luminance values than any of the other event types, even though their luminance was automatically reduced at night. This probably explains some of the driver performance findings in the presence of the digital billboards. The overall ranking of luminance by event (digital billboards were the highest, followed in order by comparison events, conventional billboards, and baseline events) closely mirrors the rankings of many of the performance measures for both daytime and nighttime, including eyeglance, speed maintenance, and lane keeping. Altogether, there were 74 measurements (17 for comparison events, 36 for digital billboards, 6 for conventional billboards, and 15 for baseline events). More readings were taken for the digital billboards because each message was measured individually.

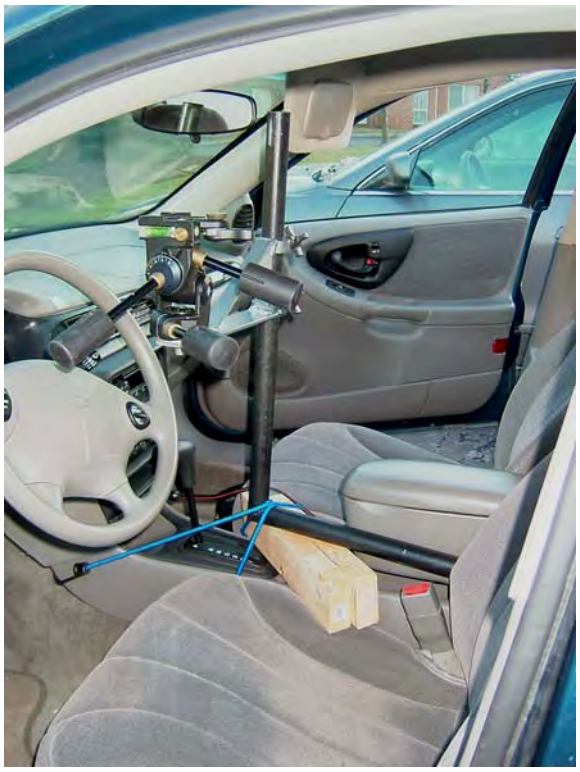

Figure 34. Bracket for Radiant Imaging CCD Photometer.

Figure 35. Radiant Imaging CCD Photometer in Position for Measurements, with Experimenter Making Final Adjustments.

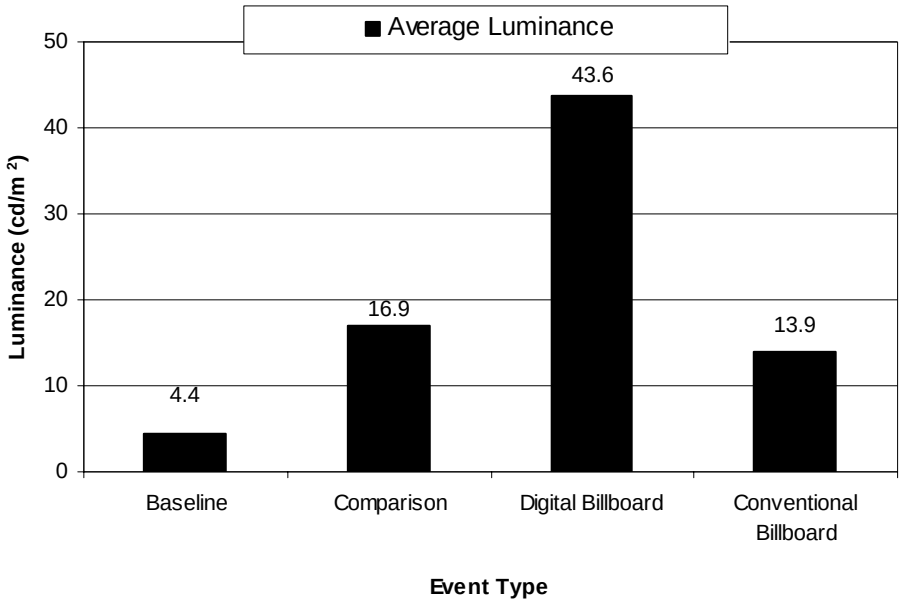

Figure 36. Average Luminance of the Four Event Types, in Candelas per Meter Squared.

COMPARISONS TO THE CHARLOTTE STUDY

There were several similarities and several differences between this study and the study conducted in Charlotte, NC. The original intent was to make the studies as similar as possible, and this was achieved to the degree possible, as demonstrated by the following items:

- Both were conducted in mid-sized cities (Charlotte population: 540,828; Cleveland population: 478,403; both figures taken from US Census 2000).
- Both were conducted in areas with similar terrain (fairly flat, with a few rolling hills; Charlotte elevation: 650 feet; Cleveland elevation: 581 feet).
- Both studies included conventional billboards, comparison events, and baseline events.
- Both studies showed similar results when conventional billboards were compared to baseline and comparison sites (very few differences in eyeglance measures, speed maintenance, or lane keeping for conventional billboards as compared to baseline events and comparison events).
- Both studies used 36 participants who performed the experiment in the daytime, equally divided into four age by gender cells (nine older males, nine older females, nine younger males, and nine younger females).
- Both included participants who lived and worked in the area and were familiar with at least some parts of the route.
- Both studies were conducted during similar times of day (between rush hours, from about 9 a.m. to 4 p.m.).
- Both studies included surface streets and interstates.
- Both studies used the same make and model of vehicle, and similar instrumentation.
- Both studies used the same basic protocols and questionnaires.
- The data were reduced and analyzed in a similar fashion using the same software tools.
- Both studies were sponsored by a foundation with strong ties to the outdoor advertising industry. Thus, in each study every effort was made to remove sources of potential bias. These efforts included:
    - Final selection of route and events were made by VTTI project staff;
    - Data collection and reduction was as automated as possible (speed and lane keeping data were totally automated, and involved no human intervention or interpretation); and
    - In the case of eyeglance data reduction, where human intervention and interpretation were necessary, data reductionists knew very little about the project, its focus, or its sponsor. They evaluated each event according to a number code, with no knowledge about whether the number represented a digital billboard, conventional billboard, comparison event, or baseline event.
    - In addition, the participants themselves did not know the true purpose of the study.

Differences between the two studies included the following items; these were motivated primarily by the difference in focus between the two studies:

- The focus of the Charlotte study was driver performance in relation to conventional billboards, while the focus of the Cleveland study was driver performance in relation to digital billboards.
- The comparison events in each study were chosen to be comparable to the events of interest. In the Charlotte study, the comparison events were chosen prior to data collection and were considered by the experimenters to be visually similar to conventional billboards. In the Cleveland study, the comparison events were again chosen prior to data collection and were considered by the experimenters to be visually similar to digital billboards.
- The Cleveland route was longer (50 miles, versus 35 miles for the Charlotte study; this was due to the need to include as many digital billboards as possible).
- The Cleveland subject pool was not as representative of the demographics of Cleveland as was the Charlotte subject pool (in terms of race and ethnicity). For example, Cleveland is approximately 41% Caucasian, while 97% of the participants were Caucasian. Charlotte is 58% Caucasian and 61% of the participants in that study were Caucasian.
- The Charlotte study examined the 7 seconds preceding each event, while the Cleveland study used 8 seconds (to increase the chances of capturing data for a message change for the digital billboards).
- The Cleveland study included digital billboards, which were not present in the Charlotte study.
- The Cleveland study included an exploratory nighttime study using 12 of the daytime participants.
- Luminance measures were obtained for the Cleveland study as part of the nighttime exploratory study.
- The Charlotte study included some US highway type roads that were not available in the Cleveland study.
- Because the digital billboards were all located on the interstate segments of the route, the road type and event type were confounded, unlike in the Charlotte study. To get around this, some of the analyses examined only events occurring on interstates.
- Because most of the drivers were more familiar with the interstate segments than with the surface streets, road type and familiarity were also confounded to a greater degree than in the Charlotte study. However, this interaction was not a primary focus of the current study.
- The Cleveland study was conducted in late fall and early winter, while the Charlotte study was conducted in late spring.

CONCLUSIONS

As with all studies, especially those conducted in real-world environments, the research design demonstrated both limitations and strengths. The study was designed to be as similar as possible to the study previously conducted in Charlotte, NC, with the major exception of the focus of the study (conventional billboards for Charlotte and digital billboards for Cleveland). The studies were similar in many important aspects with the exception of the location of the digital billboards. In the Charlotte study, billboards were present on all road types, while in Cleveland, all of the digital billboards were located along interstate highways. Thus, no conclusions can be made regarding the potential impact of digital billboards located on surface streets on driver behavior or performance. Despite this one flaw, necessitated by the real-world constraints of the digital billboard locations, the overall findings of this study were consistent and compelling.

The overall conclusion, supported by both the eyeglance results and the questionnaire results, is that the digital billboards seem to attract more attention than the conventional billboards and baseline sites (as shown by a greater number of spontaneous comments regarding the digital billboards and by longer glances in the direction of the billboards). The comparison events, 25% of which included signs with digital components, showed very similar results to the digital billboards. Thus, there appears to be some aspect of the digital billboards and on-premises signs that holds the driver's attention once the driver has glanced in that direction. This is most likely the result of the intrinsic lighting of these signs, which is noticeable even during the daytime. Drivers may also have maintained longer glances towards the digital billboards in the hopes of catching the next message (knowing that the message changed periodically), although an analysis of longer glances did not bear this out.

Although exploratory in nature, the nighttime results were very similar to the daytime results, with degraded eyeglance performance for digital billboards and comparison events. The digital billboards were also found to have much higher luminance at nighttime than any of the other event types.

These particular LED billboards were considered safety-neutral in their design and operation from a human factors perspective: they changed only once every eight seconds, they changed instantaneously with no special effects or video, they looked very much like conventional billboards, and their luminance was attenuated at night. It is thus quite likely that digital signs with video, movement, higher luminance, shorter on-message duration, longer transition times, and special effects would also be related to differences in driver behavior and performance. Because of the lack of crash causation data, no conclusions can be drawn regarding the ultimate safety of digital billboards. Although there are measurable changes in driver performance in the presence of digital billboards, in many cases these differences are on a par with those associated with everyday driving, such as the on-premises signs located at businesses. Conventional billboards were shown both in the current study and in the Charlotte study to be very similar to baseline and comparison events in terms of driver behavior and performance; thus, the design of digital billboards should be kept as similar as possible to conventional billboards.

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APPENDICES

Appendix A: Initial Participant Telephone Screening Form

FOARE Cleveland Participant Screening Script

Note to Researcher:
Initial contact between participants and researchers may take place over the phone. If this is the case, read the following Introductory Statement, followed by the questionnaire. Regardless of how contact is made, this questionnaire must be administered verbally before a decision is made regarding suitability for this study.

Introductory Statement:
After prospective participant calls or you call him/her, use the following script as a guideline in the screening interview.

Hello. My name is Melinda McElheny and I'm a researcher with the Virginia Tech Transportation Institute in Blacksburg, Virginia. The project involves participation in a driving study to help researchers understand how people drive.

This study involves coming to a meeting room at the Residence Inn by Marriott in Independence, OH, just south of Cleveland on I-77 one time for approximately 2 hours. During this session you would help us by driving one of our vehicles along a pre-selected route for about 50 miles. The vehicle will be equipped with data collection equipment. Does this sound interesting to you?

Next, I would like to ask you several questions to see if you are eligible to participate.

Questions

1. Do you have a valid driver's license?

   Yes _____ No _____

2. How often do you drive each week?

   Every day ____ At least 2 times a week___ Less than 2 times a week_____

3. How old are you? _____ (stop if not 18-35 years old or 50-75 years old.)

4. What type of vehicle do you usually drive?_____

5. Have you previously participated in any experiments at the Virginia Tech Transportation Institute? If so, can you briefly describe the study?

   Yes _____ _____
   No _____

6. How long have you held your drivers' license? _____

7. Are you able to drive an automatic transmission without assistive devices or special equipment? Yes _____ No _____

8. Do you have a history of any of the following? If yes, please explain.

Stroke	No____	Yes___
Brain tumor	No____	Yes___
Head injury	No____	Yes___
Epileptic seizures	No____	Yes___
Respiratory disorders	No____	Yes___
Motion sickness	No____	Yes___
Inner ear problems	No____	Yes___
Dizziness, vertigo, or other balance problems	No____	Yes___
Diabetes	No____	Yes___
Migraine, tension headaches	No____	Yes___

9. (Females only, of course) Are you currently pregnant?

Yes _____ No _____ (If "yes" then read the following statement to the participant: *"It is not recommended that pregnant women participate in this study. However, female participants who are pregnant and wish to participate must first consult with their personal physician for advice and guidance regarding participation in a study where risks, although minimal, include the possibility of collision and airbag deployment."*)

10. Are you currently taking any medications on a regular basis? If yes, please list them.

Yes _____ _____
No _____

11. Do you have normal or corrected to normal hearing and vision? If no, please explain.
Yes _____
No _____ _____

12. Have you ever had radial keratotomy, LASIK, or other eye surgeries? If yes, please specify.
Yes _____ _____
No _____

I would like to take your name, phone number or phone numbers, and/or email where you can be reached and hours/days when it's best to reach you.

Name _____ Male/Female

Phone Numbers _____ Age: _____

Best Time to Call _____

Email _____

When contacting participants for scheduling purposes, the following statement must be included in the conversation. "*We ask that all participants refrain from drinking alcohol and taking any substances that will impair their ability to drive prior to participating in our study*."

Criteria for Participation:

1. ***Must hold a valid driver's license.***
2. ***Must be 18-35 or 50-75 years of age.***
3. ***Must drive at least 2 times a week.***
4. ***Must have normal (or corrected to normal) hearing and vision.***
5. ***Must be able to drive an automatic transmission without special equipment.***
6. ***Cannot have lingering effects of brain damage from stroke, tumor, head injury, recent concussion, or infection. Cannot have had epileptic seizures within 12 months, respiratory disorders, motion sickness, inner ear problems, dizziness, vertigo, balance problems, diabetes for which insulin is required, chronic migraine or tension headaches.***
7. ***Cannot currently be taking any substances that may interfere with driving ability (cause drowsiness or impair motor abilities).***
8. ***No history of radial keratotomy, LASIK eye surgery, or any other ophthalmic surgery.***
9. ***Must be willing to drive without sunglasses or tinted lenses.***
10. ***Must live or work in the Cleveland area.***

A total of 2 hours of time will be needed. What days and times would you be able to participate?

Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
9:30	9:30	9:30	9:30	9:30	9:30	9:30
11:45	11:45	11:45	11:45	11:45	11:45	11:45
2:00	2:00	2:00	2:00	2:00	2:00	2:00

Thank you for your time. I will contact you to schedule a session if you are selected as a participant.

Appendix B: Informed Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants of Investigative Projects

Title of Project: Influence of driver characteristics on driving performance

Investigators: Dr. Suzanne E. Lee, Research Scientist, Virginia Tech Transportation Institute.

Dr. Ronald B. Gibbons, Research Scientist, Virginia Tech Transportation Institute.

Melinda J. McElheny, Senior Research Specialist, Virginia Tech Transportation Institute.

I. The Purpose of this Research Project

This study will collect driver performance data to help understand the way people drive in a natural environment (with no experimenter present). The goal of this study is improve the understanding of how people drive.

II. Procedures

For this study you will be asked to drive on a loop-route on freeways and highways in Cleveland, Ohio. We want you to drive as you normally would on any roadway, following the typical laws and regulations of the road. The session is expected to last about two hours, including this orientation. You will then be paid for your participation.

This vehicle contains sensors and data processing equipment that will capture aspects of your driving behavior. Small video cameras are also mounted in the vehicle. One of these cameras will be directed toward your face while you are driving. The equipment has been installed in such a way that you will hardly be able to notice its presence. It will not interfere with your driving, and there is nothing special that you will need to do in regard to the equipment.

This experiment will consist of five experimental stages:

1. Introductory stage

This stage consists of preliminaries. You will be asked to read the informed consent form. Once you have signed this form, we will also ask to see your driver's license, and an eye exam will be administered. Finally, we will have you complete a medical questionnaire. Once you have completed this stage we will go on to stage 2.

2. Familiarization with the test vehicle

While the instrumented vehicle is parked you will be shown how to operate the vehicle (for example, lights, mirror adjustments, windshield wipers, etc.) as this may be different from your

personal vehicle. You will then be asked to set each control to the best level for your comfort and driving performance. You will then take a short drive with the experimenter riding along in the passenger's seat to become familiar with the vehicle. This stage should take approximately 15 minutes.

3. Preparation for loop route
The experimenter will then review the loop-route with you. You will be given a map and written directions that the experimenter will review with you.

4. Driving the loop route
You will then drive the instrumented vehicle for approximately 1.5 hours over the pre-planned loop route of approximately 50 miles. You are expected to follow the posted speed limit and to wear your seatbelt. Also, please stay in the right-hand lane to the extent possible during the drive. The loop route is to be completed in one session if possible.

5. Debriefing and Payment
After completing the experiment, you will return here for a short debriefing session. You will then be paid for your participation. It is expected that the complete session will last approximately 2 hours, including orientation, loop-route, and debriefing.

III. Risks

<u>The experiment is believed to be minimal risk.</u> There are risks or discomforts to which you are exposed in volunteering for this research. The risks in this study are the same as the risks normally associated with driving on public roadways. The risks involved include the following:

1) The risks normally associated with driving on commonly encountered roadway segments at freeway speeds, and if you are participating in the nighttime driving study, the risks include those normally associated with driving on similar roadway segments at night.
2) Possible fatigue due to the length of the experiment. However, the route will be selected to minimize the amount of driving required. You will be instructed to exit the roadway to take a break if you feel the need to do so at any time during the experimental session.
3) Cameras will videotape you as you drive the vehicle; therefore, we will ask you not to wear sunglasses. However, you should feel free to put on your sunglasses if this request at any time impairs your ability to drive the vehicle safely.

The following precautions will be taken to ensure minimal risk to you:

1) The experimenter will monitor you during the orientation drive and help you become familiar with the experimental vehicle. However, as long as the you are driving the research vehicle, it remains your responsibility to drive in a safe, legal manner.
2) You will be required to wear the lap and shoulder belt restraint system while in the car. The vehicle is also equipped with a driver's side airbag supplemental restraint system.
3) If an accident does occur, you will be instructed to call appropriate emergency services via a cell phone in the glove compartment, and then to call the experimenter. If a visit to a medical facility is required, you would be required to undergo examination by medical personnel.

4) A cell phone (stored in the glove compartment) will be made available for you to call the experimenter for any reason. You will be instructed to call only while the vehicle is in a safe location, and while the vehicle is not in motion.
5) All data collection equipment will be mounted such that, to the greatest extent possible, it does not pose a hazard to you in any foreseeable case.
6) None of the data collection equipment or the display technology interferes with any part of your normal field of view present in the automobile.

IV. Benefits of this Research Project

The information collected from this project will provide new information on how people tend to drive in a natural setting. This information will be used to improve roadway and vehicle design, so that roadside and in-vehicle devices can be better designed to fit in with what people expect. While there are no direct benefits of participating in this study, you may find the experiment interesting. No guarantee of benefits has been made to encourage you to participate. However, to avoid biasing other potential participants, you are requested not to discuss this study with anyone for at least 8 months after participation.

V. Extent of Anonymity and Confidentiality

The results obtained from this study will be kept completely anonymous. Your name will not appear on data derived from your session. Only a number will differentiate your data from others who take part in the study. This number, and not your name, will also be used in subsequent data analyses and reports.

As indicated, video will be recorded while you are driving. The video includes an image of your face, so that we can determine where you are normally looking. The video will be treated with confidentiality and kept secure. It will be shared only with other qualified researchers, and not published except as noted in the following paragraph.

If at a later time we wish to use the video information for other than research purposes, say, for public education, or if we wish to publish (for research or for other purposes) your likeness or other information from the study that identifies you either directly or indirectly, we will only do so after we have contacted you again and obtained your explicit permission.

VI. Compensation

You will be paid $20 per hour for the time you actually spend in the experiment. It is estimated that the entire session, including orientation, driving, and debriefing will be 2 hours. Payment will be made in cash immediately after you have finished your participation.

VII. Freedom to Withdraw

You are free to withdraw at any time without penalty. If you choose to withdraw from this study you will be compensated for your time up until that point.

VIII. Medical Treatment and Insurance

If you should become injured in an accident, the medical treatment available to you would be that provided to any driver or passenger by emergency medical services in the vicinity where the accident occurs. The vehicle you will be driving is insured for automobile liability and

collision/comprehensive through Virginia Tech and the Commonwealth of Virginia. There is medical coverage for you under this policy. The total policy amount per occurrence is $2,000,000. This coverage would apply in case of an accident, except as noted below.

Under certain circumstances, you may be deemed to be driving in the course of your employment, and your employer's worker's compensation provisions may apply in lieu of the Virginia Tech and Commonwealth of Virginia insurance provisions, in case of an accident. The particular circumstances under which worker's compensation would apply are specified in Virginia law. If worker's compensation provisions do not apply in a particular situation, the Virginia Tech and Commonwealth of Virginia insurance provisions will provide coverage.

Briefly, worker's compensation would apply if your driving for this research can be considered as part of the duties you perform in your regular job. If it is not considered as part of your regular job, then the insurance policy would apply.

IX. Approval of Research

You should know that this research project has been approved, as required by the Institutional Review Board for Research Involving Human Participants at Virginia Polytechnic Institute and State University, and the Virginia Tech Transportation Institution.

X. Participant's Responsibilities

I voluntarily agree to participate in this study. I have the following responsibilities:

1) I should not participate in this study if I do not have a valid driver's license or if I am not in good health.

2) I should notify the experimenter if at any time I do not want to continue my participation.

3) I should operate the instrumented vehicle in a safe and responsible manner.

4) I should answer all questions truthfully.

XI. Participant's Permission

Check one of the following:

- ☐ I have **not** had an eye injury/eye surgery (including, but not limited to, LASIK, Radial Keratotomy, and cataract surgery.)
- ☐ I **have** had an eye injury/eye surgery and I've have been informed of the possible risks to participants who have had eye surgery. I choose to accept this possible risk to participate in this study.

Participant #_____

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.

_____

Signature **Date**

Should I have any questions about this research project or its conduct, I may contact:

Dr. Suzanne E. Lee, Principal Investigator (540) 231-1511
Melinda J. McElheny, Senior Research Specialist (540) 231-1557
David Moore, Chair of the Virginia Tech Institutional Review Board (540) 231-4991

Participants must be given a complete copy (or duplicate original) of the signed Informed Consent.

Appendix C: Health Screening Questionnaire

Health Screening Questionnaire

1. Are you in good general health? Yes No

   If no, list any health-related conditions you are experiencing or have experienced in the recent past.

   _____
   _____
   _____

2. Have you, in the last 24 hours, experienced any of the following conditions?

Inadequate sleep	Yes	No
Hangover	Yes	No
Headache	Yes	No
Cold symptoms	Yes	No
Depression	Yes	No
Allergies	Yes	No
Emotional upset	Yes	No

3. Do you have a history of any of the following?

   Visual Impairment Yes No

   (If yes, please describe.)

   _____
   _____
   _____

   Seizures or other lapses of consciousness Yes No

   (If yes, please describe.)

   _____
   _____
   _____

   Any disorders similar to the above or that would impair your driving ability Yes No

   (If yes, please describe.)

   _____

_____
_____

4. List any prescription or non-prescription drugs you are currently taking or have taken in the last 24 hours.

_____
_____

5. List the approximate amount of alcohol (beer, wine, fortified wine, or liquor) you have consumed in the last 24 hours.

_____
_____

6. Are you taking any drugs of any kind other than those listed in 4 or 5 above?

Yes No

_____ _____
Signature Date

Participant #_____

Appendix D: Post Drive-Questionnaire

Thank you for participating in this driving study. We appreciate your responses to the following items. All information will remain confidential.

1. Please check either "Familiar" (driven at least once a week) or "Not Familiar" (driven less than one time a week) for the following roadway sections:

I-480between I-77 and 150th	_____Familiar	_____Not Familiar
W.130th –Bellaire–W.117th	_____Familiar	_____Not Familiar
I-90 between 9th and 185th	_____Familiar	_____Not Familiar
Carnegie St.	_____Familiar	_____Not Familiar
I-77 between I-90 and Rockside	_____Familiar	_____Not Familiar

---

2. For the following systems, please check what you liked or disliked:

Seating	_____like	_____neutral	_____dislike
Air conditioning	_____like	_____neutral	_____dislike
Engine power	_____like	_____neutral	_____dislike
Visibility	_____like	_____neutral	_____dislike
Steering	_____like	_____neutral	_____dislike

---

3. Please check the top five items that most caught your attention during your drive:

_____Surrounding traffic
_____Other drivers
_____Construction areas
_____Road/street signs
_____Emergency vehicles
_____Buildings
_____Landmarks
_____Walls
_____Landscaping/scenery
_____Gas Stations
_____Restaurants
_____Motels/Hotels
_____Billboards
_____Towers
_____Highway/Exit Signs
_____Smoke Stacks
_____Apartments/housing
_____Other_____

---

4. Did you experience any problems while following the written directions? ___Yes ___No
   If yes, please describe:

---

5. What was most memorable about the drive? For example, where there any objects that stood out?

---

6. What other activities do you typically engage in while driving?

---

7. Does anything about other drivers bother you? If so, please briefly describe:

---

8. Please provide any other input about this study:

---

9. In what city do you live?

---

10. In what city do you work?

---

11. What level of education have you completed?

    _____Elementary/Secondary
    _____Junior High School
    _____High School degree
    _____2-yr Associate degree
    _____Bachelor's degree
    _____Master's degree
    _____Doctoral/Professional degree

---

12. Please indicate your marital status:

    _____single _____married _____widowed _____divorced _____separated

---

13. Which of the following groups best represent your ethnicity?
    _____African American
    _____Hispanic (Latino)
    _____Asian

_____Native American (American Indian)
_____European (Caucasian, White)
_____Multi-racial

---

14. Which of the following best represents your annual household income?
_____$0-$24,999
_____$25,000-$49,999
_____$50,000-$74,999
_____$75,000-$99,999
_____ > $100,000

---

15. What was the purpose of this study?

An Exploratory Study of the Impact of an Electronic Billboard on Freeway Traffic and Safety

Mahesh Pandey & Kevan Shafizadeh, Ph.D., P.E., PTOE

Abstract. This paper summarizes the results of an evaluation of traffic and safety impacts of a new electronic billboard on Highway 50 near the campus of California State University, Sacramento ("Sacramento State") using an analysis of the fundamental traffic flow parameters on the eastbound and westbound portions of the freeway before and after the new electronic billboard was activated in August 2008. Crash and collision records from the California Highway Patrol (CHP) were also analyzed before and after the billboard's activation. Finally, a survey was conducted to evaluate perceptions of safety toward the billboard by campus community stakeholders. The results indicate that the presence of an electronic billboard does not appear to have a negative impact in traffic performance (flow, speed, and lane occupancy) nor on the crash rate in the study section of the freeway based on the data analyzed. Finally, more than two-thirds of the individuals randomly surveyed on campus who drive past this electronic billboard regularly did not believe that the billboard posed a traffic safety risk.

Introduction

This project involves an analysis of traffic flow parameters and crash data on upstream portions of electronic billboard on Highway 50 near Sacramento State before and after the installation of the new electronic billboard in August 2008 (Pandey, 2010). In the project study area, U.S. Highway 50 near Sacramento State is an eight-lane freeway that serves an important transportation corridor, linking downtown Sacramento with suburban areas to the east. Data from the California Freeway Performance Measurement System (PeMS) database were analyzed for changes in common traffic flow parameters: speed, flow rate, and lane occupancy over a two-month period before and after the installation of the electronic billboard. Crash and collision data were also analyzed for changes in non-injury, injury, and fatal crashes (if any) over a year period before (August 2007- July 2008) and a year period after (August 2008- July 2009) the installation of the electronic billboard. Finally, a campus transportation intercept survey was conducted in May 2010, as a part of an annual evaluation of the campus transportation system and contained questions to evaluate the public's perception of safety of this electronic billboard adjacent to Highway 50. This project contributes to similar ongoing research studies and helps road authorities (e.g., State Departments of Transportation) to identify the potential traffic and safety impacts of the electronic billboards adjacent to freeways.

Background

The Sacramento State electronic billboard, which is 48 feet by 14 feet in dimension, uses light-emitting diode (LED) technology and displays eight messages every 64 seconds to motorists on Highway 50 (University Enterprises, 2008). This section of freeway serves as a major access point to Sacramento State, as well as a major corridor for commuters and general road users to downtown Sacramento. While there is some concern that drivers can become distracted, it is essential to find out if there is any negative impact on the performance of traffic or safety due to the presence of this electronic billboard adjacent to the freeway.

Any distraction (internal or external to vehicle) is a frequently cited factor in increasing crashes (Farbry, et al., 2001). Mobile phones, music devices, and global positioning system (GPS) devices are some examples of internal factors. External factors can include other vehicle on the road, construction or other activities on or adjacent to the road, billboards, shop fronts, and even public art installations adjacent to road. Roadside advertising on electronic billboards is one external source designed to attract the attention of drivers and road users. Further, the electronic billboards were cited as a cause of driver distraction during a national safety summit hosted by U.S. Transportation Secretary Ray LaHood in Washington, D.C. (Scenic America, 2010).

Meanwhile, electronic billboards are becoming a popular means of advertising and providing public information alongside highways. With application of LED technology and computer controls, electronic billboards today are programmable to change the images as required, typically every six to eight seconds (OAAA, 2009a). They can display high quality images and have the capability of updating and designing new images frequently. Electronic billboards on the side of highways have been useful for federal, state, and local law enforcement to display time-sensitive information like traffic conditions, directions/instructions during emergency evacuations, and Amber Alert child abduction bulletins (OAAA, 2009b). Law enforcement and other public safety officials can use electronic billboards to reach mass audiences quickly.

There are approximately 450,000 billboards installed across the United States and about 1,800 of them are electronic billboards (Copeland, 2010). There were approximately 400 electronic billboards in 2007 (Story, 2007), and electronic media is a fast-growing sector of the outdoor advertising market. Even though the billboard industry claims that the electronic billboards are not dangerous, little research has been done in this field to conclude that they have no impact on the traffic flow and road safety. Most states have adopted laws or regulations to allow electronic billboards that display multiple images. Some states prohibit all billboards including Alaska, Hawaii, Maine, and Vermont. Similarly, some states and local governments limit electronic billboards along public roadways, as shown in Figure 1. Nationwide, about 1,500 cities and communities prohibit the construction of electronic billboards (Scenic America, 2010). Therefore, it is important to understand the trade-offs between the billboard advertiser's need to grab driver's attention and the significance of its impact on the traffic stream and safety.

Figure 1: States and Local Governments Limiting Billboards (Source: Copeland, 2010)

While the demand for electronic billboards is increasing, electronic and conventional billboards remain heavily regulated. The federal Highway Beautification Act of 1965 and its amendments and regulations of state and local bodies are in place to provide effective control of outdoor advertising. Electronic billboards fall under these regulations. Local laws and ordinances must fulfill these overriding federal and state guidelines. In 2007, the Federal Highway Administration (FHWA) relaxed a rule against electronic billboards. To keep pace with technology, FHWA has said that roadside billboards could use "changeable message" technologies as long as these signs do not scroll or flash (Sheppard, 2007). The computer-controlled display allows advertisers to change the advertisement slowly at the intervals that claim to prevent driver distraction.

Electronic billboards are attracting state and local governments as a way to generate revenue. In October 2008, California Department of Transportation (Caltrans) asked FHWA to allow the conversion of the state's 692 traffic alert and message signs to state-of-the-art electronic billboards so that they can be leased for business advertisements when not in use for traffic information (Solof, 2009). Former Governor Arnold Schwarzenegger also proposed an idea of expanding the presence of electronic billboards throughout the state by converting overhead freeway changeable message signs (CMS) into electronic billboards. The former governor saw the plan as a way to generate revenue and improve the technology of warning signs, but critics feared the new signs would distract drivers and lead to more collisions (Yamamura, 2010).

Massachusetts Bay Transportation Agency (MBTA) is auctioning off space for sixty new electronic billboards along highways in eastern Massachusetts to raise revenue (about $6 million per year) to support the Boston-area bus and train network (Solof, 2009). The MBTA already has more than 200 electronic billboards in place. Some communities and the Massachusetts state legislature are challenging the sign, however many communities and state officials are looking for guidance from the federal government.

Data

California Freeway Performance Measurement System (PeMS) has been set up to collect real-time data from freeways in the State of California to compute freeway performance measurements and to facilitate other traffic related studies. This system can be accessed through the Internet at http://pems.dot.ca.gov. PeMS collects the raw flow and lane occupancy data that comes from more than 30,000 individual lane detectors every 30 seconds in California (PeMS, 2010). Flow is expressed as the number of vehicles that crosses over a detector during a given time period. It is measured in terms of vehicles per hour (vph) or vehicles per hour per lane (vphpl). Lane occupancy is the percentage of time that a detector is occupied in a given time of period and is a percentage that ranges from 0% to 100%. The lane occupancy is commonly used as a surrogate for the density of the traffic over a road segment. PeMS aggregates the lane-by-lane 30 second data into a single number that represents the five-minute total of vehicle flow over all lanes at that location. The five-minute data sample for flow is computed by summing the individual 30 second data samples. For lane occupancy, the five-minute data sample represents the weighted average over the 30-second data samples received, based on the number of vehicles observed.

The majority of loop detectors in the state of California are single loop detectors (Chen, et al., 2001). Speed is measured directly from radar detectors, but single loop detectors cannot measure speed. PeMS has ability to compute speed for sensors that do not report speed, such as single loop detectors. Double loop detectors are installed in specific spacing, which have the capability of measuring vehicle speed but PeMS does not use the speed measurements from the double loops. PeMS research has shown that their speed calculation algorithm based solely on the flow and lane occupancy are better than speed measured from double loops (PeMS, 2010).

Flow, lane occupancy, and speed data were obtained from the PeMS website then exported into an Excel spreadsheet. The detectors on the study section were identified as sensor 313684 for eastbound direction and sensor 312205 for the westbound direction (as shown in Figure 2). At this location, data were obtained in five-minute intervals for the study period (October through November 2007 and October through November 2008) in each direction for all lanes located on the study segment (four lanes on each side).

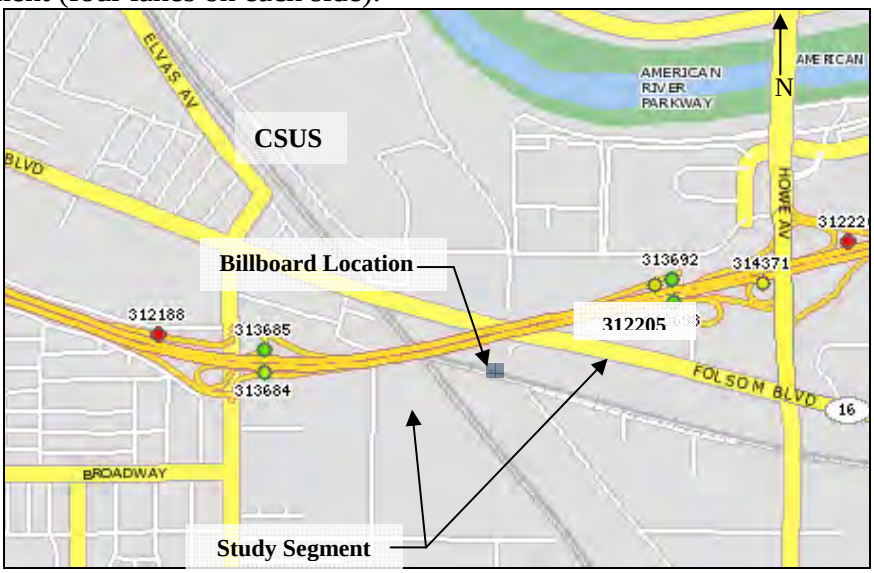

Figure 2: Location of Detectors on Highway 50 Study Section

It should be noted that varying detector health, varying traffic characteristics, and the presence of incidents can affect the data obtained from PeMS, and these sources of error could effect on the result of the freeway performance analysis:

- Detector Health: The greatest potential for error comes from the detection itself. Detector health involves whether the detector actually measures data and sends it to the controller. The detection problems can occur with failures at the sensors or anywhere in the data transmission process. In absence of real time traffic detector data, PeMS generates the imputed data to fill missing data, which may be different from actual data from the working detector. The imputed data may not be as accurate as data from working sensor. In this study, data reported by detectors were generally 75% - 100%. There were few periods when detectors did not report any data, and those data-holes were filled by imputed data. When detectors reported 0% data, the imputed data available in the PeMS database were excluded in the analysis of before and after period traffic measures in this report.

- Traffic Type: The traffic volume consists mostly of short passenger cars (average length 16 feet) and long trucks (average length 60 feet). The truck volumes estimated from the PeMS algorithms were not measured. Truck volumes were estimated from five-minute aggregated volume and lane occupancy data.
- Incidents: For example, an incident or just downstream of the study segment can cause congestion on the study segment on upstream of traffic flow, which affects the end result. On the other hand, an incident upstream of the study segment causes low flow for certain time followed by a surge in flow after a lane is reopened.

California Highway Patrol (CHP) has a well-maintained database and a website to record and access incidents on state highways. PeMS has maintained a system to interface with the CHP database and obtain the incident data to store in its database. The incident data contains vehicle incidents information reported by CHP: the time, the location, and the detail of the incident. PeMS also receives incident data from Caltrans Traffic Accident Surveillance and Analysis System (TASAS), which contains data on incidents (but not breakdowns) and the verified locations.

Sacramento State's electronic billboard is located near absolute postmile 8.76 (distance from the beginning of the route). One half-mile (2,640 feet) before the electronic billboard in each direction was considered for evaluation in this study. Crash data available on the PeMS website for Highway 50 were downloaded from postmile 8.3 to postmile 8.9 in eastbound direction and postmile 8.6 to postmile 9.2 in westbound direction of the posted billboard for the period of one year before (August 2007 to July 2008) and one year after (August 2008 to July 2009) the installation of the electronic billboard.

Public opinion data was collected as part of the Sacramento State Campus Transportation Intercept Survey. The survey is conducted annual by students in a transportation engineering course in the Department of Civil Engineering (CE 147). Students in this course randomly sample individuals entering the campus at major access points to ask questions about their trip into campus and their general opinion of transportation services and facilities. Surveys were conducted on May 4-6, 2010. Four questions directly related to the electronic billboard. There were a total 484 respondents to this survey.

Methodology

In the report "Traffic Safety Evaluation of Video Advertising Signs," Smiley et al., provided the basic methodology to study the impacts of Sacramento State's electronic billboard on traffic and safety. Traffic flow, lane occupancy, speed, crash data, and public opinion were used in both studies.

In this study, the safety and traffic performance were analyzed from available traffic data before and after the installation of the electronic billboard near Sacramento State. Speed, flow, and lane occupancy data at the approach of the billboard on Highway 50 in each direction was obtained from the PeMS database. Because all the traffic data were primarily collected through the detectors on the freeway, it was important to identify the location of detectors on the main traffic stream at or nearest to the study segment. Detector locations (detector number) were identified on Highway 50 on eastbound and westbound directions near the billboard. Once the

detector numbers were known, the five-minute interval speed, flow, and lane occupancy data were downloaded into Excel from the PeMS database for a period of two months before and after the installation of the sign in the month of October to November 2007 and October to November 2008. The billboard was commissioned on August 2008.

There were four lanes in each direction of the study segment. Speed, flow, and lane occupancy were downloaded for each lane. The individual lane data was averaged to compute the mean operating speed, flow per lane, and lane occupancy per lane. PeMS records the hourly flow in five minutes increments. Therefore, the five-minute average flows were converted to hourly flows multiplying by 12. Plots of flow, speed, and lane occupancy were prepared to visualize the traffic performance over the study period in each direction. (See Pandey, 2010.)

The data recorded on weekends and holidays were removed from the dataset because the traffic operations are not similar on weekdays and weekends. On weekdays, there exists more traffic, which is more sensitive to changes in driver behavior. During the study period, there were four holidays observed. They were Columbus Day, Veterans Day, and Thanksgiving (two days). The data from all individual weekdays were combined into a single, "average weekday," which contained speed, flow, and lane occupancy in five-minute intervals. Average weekday data were plotted as speed versus flow, speed versus lane occupancy and flow versus lane occupancy to find out any changes in travel pattern before and after the electronic billboard was installed.

It was assumed that the low traffic volume and lane occupancy during the off peak periods would be least affected by the electronic billboard. Only peak-hour weekday conditions were analyzed. The study segment was analyzed for any change in performance between 6:30 am to 8:30 am and between 3:30 pm to 5:30 pm. The mean value of speed, flow, and lane occupancy and their standard deviations were computed. Then the speed, flow, and lane occupancy and their standard deviations were compared between the before and after periods to conclude if changes were observed.

In this case, the study segment was analyzed for any change in performance during the morning peak period (6:30 am to 8:30 am) and the afternoon peak period (3:30 pm to 5:30 pm) during a typical weekday (Wednesday). Wednesday was chosen arbitrarily, as it was the middle of the week and there were no holidays during the study period. Moreover, traffic studies are generally conducted on Tuesdays, Wednesdays, or Thursdays (Caltrans, 2002). The times were chosen to best capture the peak travel period, even though the time of the peak hour can vary from day to day. This peak travel period is most important to a large number of users. Therefore, the mean value of speed, flow, and lane occupancy, and their standard deviations were computed during the morning and afternoon peak periods. Then the speed, flow, and lane occupancy and their standard deviation, were analyzed and compared before and after the electronic billboard was installed to conclude if any changes occurred. For comparison of change in flow, speed, lane occupancy, and their standard deviation, the percent change was calculated using the following equation:

$$\text{Percent Change, } \%\Delta = \frac{(Final - Initial)}{Initial} \times 100$$

In the study of the Sacramento State electronic billboard, a post-hoc crash analysis was also considered where incident data was collected for one year prior to and one year after the operation of the electronic billboard. Vehicle incident data was analyzed to compute the crash rate in each direction during the study period, and the crash rates before and after the installation of the electronic billboard were compared to conclude if changes had occurred. The average daily traffic (ADT) was computed for both direction during the study period for both direction and the duration of study. The crash data downloaded from the PeMS website was sorted to identify the number of incidents on the study segment in each direction during the study period. The weekend and holidays were also included in the analysis. The study segment was considered 2,640 feet (0.5 miles) to make the evaluation more conservative and inclusive. Analysis was done for a segment of 0.5 miles before the electronic billboard in each direction. The crash rates, which quantifies in the number of crashes per million vehicle miles (MVM), for the study segment were calculated using the following equation:

$$\text{Rate per MVM, } R = \frac{a \times 1{,}000{,}000}{ADT \times l \times d}$$

where a is the number of collision per year, l is the roadway segment length, d is the number of days during study period, and ADT is the average daily traffic (Fricker & Whitford, 2004).

Finally, a public opinion survey data obtained from the Department of Civil Engineering was a part of on-going evaluation of campus transportation system. Only the electronic billboard related responses were included in this report for analysis of opinions of the respondents. The responses were imported into a spreadsheet and analyzed.

Analysis and Results

The PeMS database provided information for speed, lane occupancy (surrogate for lane density), and flow for every five-minute interval throughout the day. There are 288 intervals per day and 17,856 intervals over the course of two months. To analyze these data, Excel spreadsheets were prepared. The mean and standard deviation were calculated. The data analysis was carried out as outlined below.

Flow, speed and lane occupancy against time were plotted to obtain a general overview traffic operation during the study period in the study section. The plots were real representations of the total data (flow, speed and lane occupancy) obtained from PeMS database in both directions. From the plots, some data gaps were identified on November 22, 2008 in eastbound traffic. From these figures, the westbound traffic was observed to have more fluctuation in speed compared to eastbound traffic before and after the installation of the electronic billboard. Further, on the same segment the detectors did not report any data after November 22. So, the imputed data available on the PeMS database was excluded from analysis.

The five-minute data granularity of the weekdays were averaged to obtain five-minute average values over the 24-hour for the study sections of the study periods. Here the mean values (flow, speed, and lane occupancy) were determined at the increment of five-minutes for a 24-hour period. These data were used to prepare plots of speed versus lane occupancy, speed versus flow, and flow versus lane occupancy in five-minute interval on an average “average weekday” for both directions before and after. These plots provided an overview of flow, speed, and lane

occupancy with each other. Further, each plot of the basic parameters in each direction before and after the installation of the electronic billboard were observed to be similar. Based on these plots, traffic operation in the study segment before and after the installation of the billboard were not significantly changed in the same direction. However, in westbound direction, for higher flow values, fluctuations in speed were higher than in the eastbound direction.

Traffic parameters (flow, speed, and lane occupancy) were analyzed for a two month period before (October - November 2007) and after (October - November 2008) the installation of the electronic billboard. An analysis of a typical weekday was done, and Wednesdays were chosen so that day-of-week variability was not introduced. The five-minute data points of all Wednesdays were averaged to obtain five-minute average values over the 24-hour period. These five-minute average values of Wednesday data were used to prepare plots of flow versus time, speed versus time, and lane occupancy versus time for the eastbound direction and westbound direction. These plots provided comparison of flow, speed, and lane occupancy in each direction before and after the installation of the electronic billboard during a typical weekday (Wednesday) during the months of October and November. The change in traffic operation parameters (flow, speed, and lane occupancy) before and after the construction of the billboard could be visualized from these plots. The plots provided an idea of the morning and afternoon peak periods and variations of traffic throughout the day.

The mean and standard deviation of flow, speed, and lane occupancy over the peak two hours in morning and in afternoon were computed and compared by calculating the change in percentage of the after-period measured to the before-period measure. A decrease in variance of speed may be anticipated to improve safety; however, an increase in mean lane occupancy (i.e. decreased headway) and increased speed variance would likely decrease safety (Smiley, et al., 2005). When drivers get distracted they may slow down, resulting in greater speed variability, or they may allow unsafe headways or densities (lane occupancies) to develop when they fail to react quickly to detect the slowing of the vehicle in front of them. When lower headways develop, there will be less reaction time, and the probability of collision increases.

Further, a typical analysis of flow, speed, and lane occupancy were done to observe the variation in performance measures during morning and afternoon peak periods in each direction before and after the installation of electronic billboard. In the eastbound direction, the standard deviations (SD) of speed and lane occupancy decreased with the increase in operating mean speed. The increase in speed (25%) during afternoon, and increase in standard deviation (more than 75 %) during morning and afternoon, as shown in Table 1 were unusual and could be the effect of weather (rain), lane closures, or some event in the nearby area particularly on November 2007. Even though the flow variation during morning was higher after the installation of the electronic billboard, the speed and lane occupancies were not impacted adversely. In the eastbound direction, vehicle speeds, and lane occupancies, through the months of October and November on the Wednesday peak periods after the installation of the electronic billboard, were not found to be impacted (see Table 1).

Table 1: Eastbound Traffic Measures: Wednesdays Oct to Nov 2007 and 2008

	AM (6:30 - 8:30)			PM (3:30 - 5:30)		
	2007	2008	% Change	2007	2008	% Change
Mean Flow, vphpl	1,526	1,582	3.72	1,539	1,672	8.62
Flow SD, vphpl	145	159	9.78	154	119	-22.75
Mean Speed, mph	53.4	62.9	17.76	46.1	57.7	25.09
Speed SD, mph	15.7	1.8	-88.26	19.2	4.5	-76.38
Mean Lane Occ., %	11.82	11.74	-0.63	13.71	13.40	-2.28
Lane Occ. SD	2.06	1.33	-35.23	3.37	1.77	-47.47

Similarly, in the westbound direction vehicle speed, and lane occupancy, through the months of November and December during the Wednesday morning peak period after the installation of the electronic billboard, were found to be better than the year before the installation of the electronic billboard during the same period of time (Table 2). The standard deviations of flow, speed, and lane occupancy decreased with the increase in the operation speed. However, standard deviations of flow, speed, and lane occupancy increased during the afternoon peak period, compared to before period measures. On the other hand, mean speed was higher with the decrease in lane occupancy during the afternoon peak period. The increase in flow variation was observed to have no significant adverse effect on operating speed and lane occupancy.

Table 2: Westbound Traffic Measures: Wednesdays Oct to Nov 2007 and 2008

	AM (6:30 - 8:30)			PM (3:30 - 5:30)		
	2007	2008	% Change	2007	2008	% Change
Mean Flow, vphpl	1,887	1,887	0.00	1,599	1,608	0.56
Flow SD, vphpl	212	192	-9.44	172	206	19.97
Mean Speed, mph	51.6	54.3	5.29	43.5	46.8	7.67
Speed SD, mph	9.9	9.5	-4.46	16.2	17.2	6.00
Mean Lane Occ., %	17.55	16.17	-7.85	19.47	18.03	-7.40
Lane Occ. SD	4.37	3.88	-11.26	7.53	8.11	7.76

The total number of injury and non-injury incidents and the crash rates in one year after the installation of the electronic billboard were found to be lower than in the year before the installation of the electronic billboard in both directions. The results show that the study segment 2,640 feet upstream from the electronic billboard did not exhibit any increase in the crash rate compared to the year before the installation of the electronic billboard in both directions, as seen in Table 3 below. Crash rates are expressed in terms of crashes per million vehicle miles (MVM).

Table 3: Crash Analysis

	Eastbound		Westbound	
	Aug 07 – July 08	Aug 08 – July 09	Aug 07 – July 08	Aug 08 – July 09
AADT	88,424	77,806	94,338	93,543
Incidents	10	7	12	11
Crash Rate	0.62	0.49	0.70	0.64

The on-campus survey indicated that a majority (69.2%) of the respondents (333 out of 481) drove through the study segment. Among the survey respondents, 24.9% indicated they drove past the electronic billboard daily, while 26.6% indicated they drove past the electronic billboard a few days a week. Another 11.0% and 6.7% indicated that they drove past the electronic billboard weekly or monthly, respectively. A total of 333 respondents indicated that they drove through the study segment at least monthly, among which 85.6% (285) noticed the electronic billboard while driving through the study segment. The number of respondents who noticed the electronic billboard was high. The results indicated drivers using the study segment have high awareness of electronic billboard.

Moreover, 285 participants in the survey responded to a question about the potential distraction and safety risk of the electronic billboard. Among this number, 34.7% (99) had expressed that the electronic billboard is distracting to drivers, and 31.6 % (90) expressed that the electronic billboard poses a safety risk to traffic. The result indicated that the majority of respondents did not have negative perception towards the electronic billboard regarding distraction and traffic safety. At the same time, these results indicated that a large portion of the driving public (one-third) may find this electronic billboard to be a safety concern.

Conclusions

The presence of the electronic billboard does not appear to have a significant negative impact in traffic performance (flow, speed, and lane occupancy) or incidents in the study section of the freeway. Since the majority of the road users at this segment are commuters, they seem to be familiar with the electronic billboard, and it does not appear to affect their driving. Even though electronic billboards are capable of displaying multiple messages/commercials at the same location, the advertisements are not a major distraction to drivers. The study could not conclude any changes in measurable impact on road safety after the installation of the electronic billboard. In the meantime, the public opinion survey indicated that more than two-thirds of the drivers surveyed believed that electronic billboard does not pose a safety risk to traffic.

Limitations

It is recognized that this study has many limitations. The period of two months before and after the installation of electronic billboard were considered in the study of traffic performance (flow, speed, and lane occupancy). Analysis of longer periods of time before and after the electronic billboard was installed could yield more reliable results. The impact of gasoline prices, economic downturn, weather, and ban on cell-phone use during driving may have some effect on traffic volumes and on traffic performance. Also, drivers involved in incidents may not have indicated whether the incident occurred, in part, due to the electronic billboard. The PeMS

database only provides information based on injury or non-injury incidents, and the types of collision (rear end, sideswipe, overtaking, erratic etc.) were not provided. From the number of incidents at one location, it can be difficult to generalize about the safety of all electronic billboards. Different locations may have different travel patterns, and drivers may react differently in other locations. Similar studies in different locations would be helpful to generalize about the safety impact of electronic billboard on roadways. Finally, the data from the campus opinion survey was limited only to the campus population, which may be a different demographic group (gender, age, employment status, and income) of the study segment travelers. Including a more representative sample of the segment population could give more reliable results.

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Authors:

Mahesh Pandey is a former graduate student in the Department of Civil Engineering at California State University, Sacramento who is currently working for the County of Sacramento.

Kevan Shafizadeh, Ph.D., P.E., PTOE is an associate professor of Civil Engineering at California State University, Sacramento and faculty advisor for the Sacramento State ITE Student Chapter.

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

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Research, Development, and Technology
Turner-Fairbank Highway Research Center
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FOREWORD

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

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

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

Michael F. Trentacoste
Director, Office of Safety
Research and Development

Gerald Solomon
Director, Office of Real Estate
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16. Abstract

The present report reviews research concerning the possible effects of Commercial Electronic Variable Message Signs (CEVMS) used for outdoor advertising on driver safety. Such CEVMS displays are alternatively known as Electronic Billboards (EBB) and Digital Billboards (DBB). The report consists of an update of earlier published work, a review of applicable research methods and techniques, recommendations for future research, and an extensive bibliography. The literature review update covers recent post-hoc crash studies, field investigations, laboratory investigations, previous literature reviews, and reviews of practice.

The present report also examines the key factors or independent variables that might affect a driver's response to CEVMS, as well as the key measures or dependent variables which may serve as indicators of driver safety, especially those that might reflect attention or distraction. These key factors and measures were selected, combined, and integrated into a set of alternative research strategies. Based on these strategies, as well as on the review of the literature, a proposed three stage program of research has been developed to address the problem.

The present report also addresses CEVMS programmatic and research study approaches. In terms of an initial research study, three candidate methodologies are discussed and compared. These are: (1) an on-road instrumented vehicle study, (2) a naturalistic driving study, and (3) an unobtrusive observation study. An analysis of the relative advantages and disadvantages of each study approach indicated that the on-road instrumented vehicle approach was the best choice for answering the research question at the first stage.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSIONS FROM SI UNITS

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

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

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1.0 INTRODUCTION

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

1.1 BASIC RESEARCH QUESTION

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

There is another approach to determining the possible safety impact of CEVMS. This approach is based upon the abstract psychological constructs of driver attention and distraction. A driver must devote a certain amount of attention to the driving task at hand, and sufficient distraction from that driving task could be associated with the higher risk of a crash. The measurement of driver eye glance behavior is often taken as an indirect indicator of attention. Thus, the driver's eye glances should be concentrated in the region of the roadway ahead, and any frequent or long eye glances away from this region toward other objects, including CEVMS, could be regarded as an indication of possible driver distraction. If the eye glances toward a certain object and away from the roadway ahead are sufficiently frequent or sufficiently long to exceed criteria established for safe driving, this outcome can be taken as an indication of a possible safety impact. The validity of using eye glance behavior measures in this manner rests on two

assumptions: that eye glances are related to attention and/or distraction and that there are generally accepted safety criteria for excessive eye glances away from the roadway ahead. These assumptions are not universally accepted.

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

1.2 SCOPE

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

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

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

technical information is developed. The present report does not provide guidance to States on the control of CEVMS.

2.0 LITERATURE REVIEW UPDATE

2.1 BACKGROUND

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

2.2 POST-HOC CRASH STUDIES

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

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

Stutts et al. conducted an analysis of several crash data reporting systems to identify major sources of driver distraction and the relative importance of different types of distraction as contributing factors in motor vehicle crashes.[5] Distraction was described as one form of inattention, and it has been implicated as a factor in more than half of the police reported inattention crashes identified by the National Highway Transportation Safety Administration.[6] In this study, 8.3 percent of drivers involved in police-reported crashes were identified as distracted, but 35.9 percent of these crashes were coded as “unknown.” For this and other

reasons, it is believed that the reported percentage of distraction-related crashes substantially under-represents the true statistics.[5] Among the types of distractions coded in the database, the largest contributor (29.4 percent) was “outside person, object, or event,” and the second largest (25.6 percent) was “other.”

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

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

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

2.3 FIELD INVESTIGATIONS

The spectrum of field investigations related to roadway safety is broad. It includes unobtrusive observation, naturalistic driving studies, on-road instrumented vehicle investigations, test track experiments, driver interviews, surveys, and questionnaires. Klauer et al., in one of several papers to emerge from a National Highway Traffic Safety Administration (NHTSA) project known as the “100-Car Naturalistic Driving Study,” provides preliminary information about the role of driver inattention in crashes and near-crashes.[10] Although the study did not specifically address CEVMS, it represents an important methodology for investigating driver distraction. Their results show that 78 percent of crashes and 65 percent of near-crashes included driver

inattention and/or distraction as a contributing factor. This contribution from inattention and distraction is larger, by a factor of three, than previous research has indicated. The authors believe that the "100-Car Naturalistic Driving Study" provides the first direct link (i.e., without reliance on crash surrogate measures) showing distraction/inattention as a contributing factor to motor vehicle crashes. In another variant of the "100-Car Naturalistic Driving Study," Klauer et al. identifies four specific unsafe behaviors that contributed to crashes and near-crashes.[11] One of these, inattention and/or distraction, is of direct relevance to the present project. This term is operationally defined by Klauer et al. as a driver looking away from the forward roadway for greater than 2.0 s. Under these conditions, the odds of a crash or near-crash are nearly twice those than when the driver attends to the forward roadway. The study stresses the importance of including near-crashes in the database for two reasons. First, the kinematics of crashes and near-crashes are similar, meaning they involved comparable levels of driver emergency actions, such as swerving and hard braking. Second, 83 percent of the crashes in this study were not reported to the police. Thus, the study indicates that relying on crash statistics alone will substantially underreport crashes due to inattention and/or distraction.

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

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

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

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

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

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

Three of the field investigations of CEVMS effects mentioned earlier employ indirect measures of driver attention (eye glances) in the context of an on-road instrumented vehicle experimental approach. Although CEVMS stimuli are real, the experimental approach suffers from a degree of artificiality in its implementation. The research participants usually drive in an experimental

vehicle along a route which is contrived for experimental purposes, and the route does not serve a useful purpose in their daily lives. The research participants sometimes drive with an experimenter present in the instrumented vehicle, and they sometimes wear a head-mounted eye-tracking device. Two of the three studies cited used a somewhat intrusive but more accurate head-mounted eye-tracking device. One study used a less obtrusive but also less accurate vehicle-mounted eye-tracking device, where cameras were mounted in the vehicle cab. Although the research participants were not told the purpose of the investigation, the participants were definitely aware that they were participating in a driving experiment of some kind, and they may not have exhibited entirely natural behaviors as a result. Furthermore, eye glance behavior is difficult to measure, and it is not easy to relate directly to attention and distraction. For a more specific analysis of some further design and methodological concerns with the Lee et al. study cited above, see Wachtel.[12,9]

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

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

2.4 LABORATORY INVESTIGATIONS

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

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

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

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

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

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

Chan et al. were primarily interested in the longest glances away from the forward roadway since these have been implicated in prior studies (e.g., Horrey and Wickens[20]) as major contributors to crashes. Thus, they used as their dependent measure the maximum time that drivers spent continuously looking away from the forward roadway during a specific distraction task. In terms of in-vehicle distractors, as hypothesized, inexperienced drivers showed a consistent pattern of looking away from the roadway for longer periods of time than experienced drivers. However, the findings about external distractions were quite different and unexpected in two key ways. There was very little difference in the duration of distraction episodes between the experienced and inexperienced drivers, and the maximum distraction durations were significantly longer for the out-of-vehicle tasks than for the in-vehicle tasks. The two experience groups showed little differences in the percentage of distraction episodes longer than 2.0 s, 2.5 s, and 3.0 s, in all cases longer for the external than for the in-vehicle distractors. The study also demonstrated that, "drivers are more willing to make extended glances external to the vehicle than internal to the

vehicle" (p. 17).[19] Chan et al. conclude that, "it is likely that our out-of-vehicle tasks (which not only engage attention but also draw the eyes and visual attention away from in front of the vehicle) would have quite significant detrimental effects on processing the roadway in front of the vehicle" (p. 22).[19]

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

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

2.5 PREVIOUS LITERATURE REVIEWS

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

Cairney and Gunatillake, working on behalf of the Government of Victoria, Australia, undertook a review of the literature with the goal of generating recommendations for guidelines for the control of outdoor advertising in that State.[22] They cited two prior reviews by Wachtel and Netherton in the United States and by Andreassen in Australia as the basis of their review.[2,23] Since these earlier studies, the technology used for the display of roadside advertising and the addition of in-vehicle distractors has changed. Cairney and Gunatillake conclude that the principal concern remains the effects that a sign may have on a driver's visibility of other road users, the roadway, and traffic control devices, particularly at high-demand locations, such as interchanges. They suggest several research approaches, including case studies, site

investigations, and laboratory simulations to address these newer technologies. They conclude that the best of the studies conducted to date demonstrate that when all confounding variables are controlled statistically, sites with advertising signs have higher crash rates than sites without them. However, large, well-controlled studies will be required to detect significant effects because the effect size is small. They further conclude that changeable message signs may have a more direct bearing on crash rate than static signs. The findings of the study suggest that unregulated roadside advertising has the capability of creating a significant safety problem. The conclusions from their review run counter to Andreassen's conclusion that, "there is no current evidence to say that advertising signs, in general, are causing accidents" (p. 4).[23]

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

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

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

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

2.6 REVIEWS OF PRACTICE

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

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

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

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

As a result of his work cited immediately above, Coetzee reviewed literature, performed a regulatory analysis, and recommended changes to regulations for outdoor advertising control in South Africa.[30] Although superficially similar to regulations in the United States, billboard control in South Africa goes much further, regulating the design and amount of information (in bits) that can be displayed on a given sign, as well as the proximity of two or more advertising

signs to one another and to road features, such as official signs and interchanges. In South Africa, message sequencing, visual clutter, and sign size are restricted for different display technologies. This document includes a description of the terms *critical event* and *critical zone*, and it demonstrates how regulations would control advertising signs in these applications. Coetzee finds support from the earlier work of Ogden and the experiments of Johnston and Cole, concluding that, whereas drivers may be able to ignore advertisements when the driving task requires attention, it is possible that an attention-getting sign can assume primary importance and interfere with not only any spare capacity that a driver might have but also the information processing capacity reserved for primary task performance.[31,32] The danger arises, according to Coetzee, when processing the information on the advertisement interferes with the driver's principal vehicle control task in situations that demand attention and rapid reactions.[30] The Coetzee report is the only work in the present review of the literature that has attempted to establish the parameters of billboard location and content based on theories of information processing and cognitive demand.

2.7 CONCLUSIONS FROM LITERATURE REVIEW

2.7.1 Basic Research Question

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

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

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

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

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

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

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

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

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

easy to identify the champion study and give that study a strong weighting, it is more difficult to evaluate the weaker studies at the middle and bottom of the list.

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

2.7.2 Methodological Implications

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

When scanning for hazards, drivers' eye movements tend to fall within a horizontal window centered on the focus of expansion in the forward view. This focus of expansion is related to the visual flow of the moving scene where points and objects all emerge from a single point. Because an attention-getting billboard may be able to attract a driver's glance even unintentionally, a CEVMS that falls within this scanning pattern can interrupt the pattern and

cause a distraction at an inopportune time. Furthermore, research suggests that the distraction from a roadside billboard may be unconscious. Consequently, drivers may not be aware that they are being distracted, and they are unable to verbalize that any distraction occurred. Although where someone's eyes look may not be the same as where his or her attention is focused, a theoretical connection may be implied. Through this connection, measurements of eye glance behavior permit the researcher to gain potential entrance into this realm of unconscious allocation of attention. This allocation of attention should play an important role in an effective program for future research.

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

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

3.0 KEY FACTORS AND MEASURES

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

3.1 KEY FACTORS (INDEPENDENT VARIABLES)

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

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

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

The following are the key factors relating to the billboard:

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

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

The following are the key factors relating to the roadway:

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

The following are the key factors relating to the driver:

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

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

The following are the key factors relating to the environment:

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

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

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

The key independent variables were selected from the expanded list represented in table 1 by three senior research psychologists, all coauthors of the present report and familiar with CEVMS research. The criterion for selection was the importance of that factor in conducting research on CEVMS effects. Thus, the list of key factors indicates critical independent variables which need to be considered in any proposed program of research. The brightness and crispness, or photo realism, of the CEVMS images are extremely important. Any image changes, apparent motion or video motion in the CEVMS, and location parameters are also critical factors. The next level of importance relates to environmental factors. Two distinct classes of variables must be taken into account: general visual clutter and the presence of other off-premise commercial CEVMS

(nearby billboards). In particular, compelling information from CEVMS used for advertising may conflict with important roadway safety information conveyed by nearby traffic control devices (official signs). The question should also be raised concerning possible enhanced distraction caused by the urgency of Amber Alerts and other public safety messages displayed on CEVMS. Any contextual links among the messages from several sequential CEVMS, as well as any specific user interactions with the CEVMS must be taken into account. Factors to consider for drivers include their familiarity with the driving route and the expected presence or absence of CEVMS. Lastly, the complexity of the roadway geometry and the volume of traffic are likely to play significant roles.

3.2 KEY MEASURES (DEPENDENT VARIABLES)

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

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

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

Key measures relating to vehicle behavior are as follows:

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

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

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

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

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

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

4.0 RESEARCH STRATEGIES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

be considered in developing any future research program on CEVMS effects. They provide the basis for selecting a recommended first stage study in such a program.

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

5.0 FUTURE RESEARCH PROGRAM

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

5.1 STAGES

The proposed research program would have the following three stages:

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

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

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

The above stages of the proposed research program are to be pursued sequentially. The initial stage is directed at determining whether or not a potentially harmful CEVMS distraction effect exists. To demonstrate such a distraction effect, an independent and objective threshold criterion of excessive distraction must be employed. If no potentially harmful distraction is shown, at least as far as driving safety is concerned, there would be little need to pursue the second stage of developing a basis for regulating CEVMS or the third stage of relating CEVMS distraction to more direct measures of safety (crashes). If potentially harmful distraction is shown in the first stage, the second and third stages would be implemented in order. The order of the last two stages may appear to be reversed. Normally, it would seem desirable to establish a relationship

between CEVMS distraction and crashes before developing a basis for regulation. However, in this instance, the LED-based digital CEVMS technology is so new that it will not be possible to reliably measure crashes for some time. Meanwhile, if possible distraction is shown, the community of practitioners engaged in outdoor advertising control will need near-term technical information on the luminance, contrast, change rates, and spacing of CEVMS to minimize that distraction. For this reason, the stages have been proposed in the order given above.

5.2 APPROACH

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

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

5.3 STRUCTURE

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

5.3.1 Stage 1—Determination of Distraction

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

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

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

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

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

5.3.2 Stage 2—Basis for Regulation

If the results of the first stage reveal a CEVMS driver distraction effect sufficient for public concern, then the second stage of the proposed research program would be implemented to provide an initial technical basis for possible regulation. This stage would consist of a series of eye glance and safety surrogate evaluations in the field and in the laboratory designed to investigate the various parameters of CEVMS which contribute to driver distraction. Although field methods can capture the realism of the CEVMS stimulus, they do not allow the researcher

to independently vary a variety of CEVMS parameters one at a time so as to isolate the effect of that variable, as some of the laboratory techniques would. For example, this second stage might begin with attempts to estimate the gross effects of certain salient CEVMS parameters in the field. Throughout this section, the brightness of the CEVMS will be used as an example, but the approach can be adapted to many other relevant CEVMS characteristics. For example, many current CEVMS displays adjust their brightness for day and night. If the outdoor advertising industry would agree to adjust the brightness of several installations both during the day and at night for the purposes of experimentation, partial estimates of the effects of brightness on eye glance behavior might be elaborated for selected luminance levels.

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

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

5.3.3 Stage 3—Relationship to Crashes

The third stage of the proposed research program relates changes in potentially harmful distraction effects due to various CEVMS parameters to changes in actual roadway safety (crashes and their consequent fatalities, injuries, and property damage). This stage is directed at validating the earlier findings with regard to CEVMS distraction based on eye glance and safety surrogate measures in the context of retrospective crash data. This stage of the program would likely employ the Empirical Bayes, or Bayesian, method of analyzing crash statistics. The Bayesian approach formally incorporates prior knowledge into the process of current research, and it translates probabilistic calculations into statements of belief concerning statistical hypotheses in place of the classical confidence interval concept employed in parametric

statistics. The Empirical Bayes method also incorporates the crash history of other control sites with similar traits to account for extraneous factors which may be influencing the crash data at the site of interest. In short, the Empirical Bayes method possesses distinct statistical advantages over the naïve before/after technique and even the before/after technique with a simple control. The Empirical Bayes method is well suited for the task of estimating vehicle crash rates along different stretches of roadway, including those stretches with CEVMS. The prediction of baseline crash rates, and their potential increase or decrease with the introduction of CEVMS, is essential to this final stage of the proposed research program. This final stage should also be designed to answer, to whatever degree possible based on crash statistics, some of the practical questions of interest to the community concerned with outdoor advertising control. Because of the low numbers of crashes and their susceptibility to multiple determining causes, considerable effort, time, and expense will likely have to be expended on this final stage.

6.0 RECOMMENDED FIRST STAGE STUDY

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

6.1 SUMMARY OF STUDY APPROACHES

6.1.1 On-Road Instrumented Vehicle

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

deviation, and traffic conflicts. A rough budgetary estimate for conducting such an on-road instrumented vehicle study is between $400,000 and $800,000 (see appendix B for more details).

6.1.2 Naturalistic Driving

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

6.1.3 Unobtrusive Observation

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

Some secondary independent variables might include the time of day (day/night) and traffic conditions (peak, nonpeak). This study method depends completely on safety surrogate measures

associated with driver errors and other measures of driver performance (headway, lane deviation, and erratic maneuvers), and it requires a large camera array over a long distance recording for extended periods, as well as extensive data analysis. A rough budgetary estimate for conducting such an unobtrusive observation study is between $1 million and $3 million (see appendix B for more details).

6.2 COMPARISON OF STUDY ALTERNATIVES

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

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

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

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

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

7.0 CONCLUSIONS

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

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

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

APPENDIX A—EXPANDED TABLES

A.1 KEY FACTORS (INDEPENDENT VARIABLES)

Table 1. Expanded key factors (independent variables).

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

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

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

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

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

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

A.2 KEY MEASURES (DEPENDENT VARIABLES)

Table 2. Expanded key measures (dependent variables).

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

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

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

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

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

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

A.3 KEY RESEARCH STRATEGIES

Table 3. Expanded key research strategies.

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

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

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

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

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

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

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

APPENDIX B—DETAILED DESCRIPTION OF STUDIES

B.1 ON-ROAD INSTRUMENTED VEHICLE APPROACH

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

B.1.1 Method

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

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

B.1.2 Factors and Measures

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

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

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

B.1.3 Advantages/Disadvantages

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

Another advantage of this method is the ability to structure driving scenarios to have an appropriate number of CEVMS, standard billboard, and other visual stimuli all located on a controlled course, which all research participants drive in a consistent manner. The ability to choose and structure the test drive assures adequate and uniform exposure to CEVMS and other relevant visual stimuli. The ability to exert experimental control is a valuable asset to this method. It facilitates a clean and robust statistical analysis of the data because all of the

participants are exposed to all of the experimental conditions the same number of times in a relatively controlled manner. Experimental control ensures a high level of CEVMS exposure, thereby contributing to the productivity and cost effectiveness of this technique.

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

B.1.4 Budgetary Cost

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

B.2 NATURALISTIC DRIVING APPROACH

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

B.2.1 Method

The naturalistic driving method employs a standardized instrument package which is installed in the participant's own private vehicle or in a vehicle loaned to the participant. The installation is made as unobtrusive as possible so that the participant's vehicle appears and performs as it normally would. The instrument package is capable of measuring many of the same variables as the on-road instrumented vehicle, such as speed, lane position, acceleration, GPS time and position, driver eye glance frequency, direction, and duration. The instrument package is also

connected to the vehicle data bus so that additional vehicle-related measures of engine, braking, and steering performance are also recorded. However, because of the unobtrusive nature of the experimental technique, this method cannot support the use of extremely accurate head-mounted or vehicle-mounted eye-tracking equipment. In the present state of technology, these accurate eye movement instruments involve careful calibration procedures with the driver. With this method, the eye-tracking system is mounted in the dashboard in a manner which involves little or no driver interaction. Once the participant's vehicle has been instrumented, data are collected by means of automatic wireless downloads without participant awareness or involvement. The instrumentation is left in the vehicle for a period of 3 to 6 months, during which time the participant drives the vehicle for normal personal or business use.

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

B.2.2 Factors and Measures

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

As in the on-road instrumented vehicle study, the primary measure or dependent variable is the frequency, direction, and duration of driver eye glances. The fundamental hypothesis of self-regulated attention which needs to be concentrated on the roadway scene ahead remains the same. As before, if the frequency and duration of eye glances away from the roadway ahead exceed accepted norms or criteria, then driver safety is assumed be compromised. Thus, eye glance behavior is the primary dependent variable in this study, as well. However, the particular unobtrusive and disengaged dashboard-mounted eye-tracking device may not be capable of making as accurate measurements of eye-movements as can other more delicate vehicle-mounted or head-mounted devices which require periodic participant calibration. Consequently, this study

method depends more heavily on secondary dependent variables. Safety surrogate measures associated with driver errors and other measures of driver performance (headway, lane deviation, conflicts, and erratic maneuvers) become increasingly important in this method. Since the participants will be driving according to their own personal schedules, additional dependent variables may include the time of day (day/night), traffic conditions (peak and nonpeak), in-vehicle distractions (eating and/or cell phone use), and state of fatigue.

B.2.3 Advantages/Disadvantages

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

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

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

B.2.4 Budgetary Cost

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

B.3 UNOBTRUSIVE OBSERVATION APPROACH

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

B.3.1 Method

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

B.3.2 Factors and Measures

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

In contrast to the on-road instrumented vehicle and naturalistic driving studies, the primary dependent variable is not driver eye glance behavior. Instead, this study method depends completely on safety surrogate measures associated with driver errors and other measures of driver performance (headway, lane deviation, and erratic maneuvers). These are subtle driving behaviors to measure by means of distal cameras mounted along the roadway. Unless the

cameras are mounted very high, multiple vehicle images may occlude each other. For a long stretch of roadway, such as might required for CEVMS exposure, a relatively large array of cameras may be needed. Thus, a large amount of data needs to be collected and analyzed in such a study. Automatic machine vision video analysis algorithms can help in the data analysis process, but such algorithms are not yet sufficiently sensitive and robust to reliably identify all of the subtle indicators of driver errors, conflicts, or maladaptive performance which might accompany CEVMS exposure. The use of other sensors instead of or in addition to cameras may mitigate some of these data analysis problems to a certain extent.

B.3.3 Advantages/Disadvantages

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

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

B.3.4 Budgetary Cost

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

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HRDS-07/02-09(WEB)E

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

FINAL REPORT

Submitted Under NCHRP Project 20-7 (256)

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

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

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

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

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

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

Reviewer #5 proposed an interesting thought experiment that addressed the difference between the question: “What is the statistical relationship between digital billboards and traffic safety?” and the question: “Are accidents more, less, or equally likely to occur near digital billboards compared to conventional billboards?” The reviewer suggests that these two questions are not necessarily incongruent, as we stated in the report, and that the second question is both technically correct (as is the first), and more *useful* because it addresses the safety issue in a manner closer to real-world driving; i.e. with the recognition that conventional billboards are a given part of the landscape. While we do not disagree with the reviewer’s position, we question the underlying assumption that the presence of conventional billboards is the accepted and acceptable norm. Most of the research reviewed for this report studied driver distraction and other safety-related measures with real-world or simulated conventional billboards, and many of these studies (as have studies going back decades) identified safety concerns; the fact that control and enforcement may be lax should not de facto make the presence of these billboards the accepted baseline. As well, there are several States and local jurisdictions that ban all

billboards, so this baseline is not universal, even in the US. But our greatest concern is with the industry's efforts to raise the bar that research must be meet before, in their view, digital billboards could be found to have adverse traffic safety impacts. The study by Lee, et al., discussed at length in our report, compared digital billboards, not only to conventional billboards, but to "comparison" sites. When the research demonstrated that driver eye movements and vehicle control issues were similar between the DBBs and these comparison sites, the authors proclaimed the digital signs "safety neutral" because, as they defined them, the comparison sites contained "items you might encounter in everyday driving." But a careful reading of the report shows that these sites included digital on-premise signs, tri-vision signs and video boards. In other words, they were rather the same as DBBs, except that they included on-premise signs. In our opinion, this subtle "criterion creep" is unprofessional and inappropriate.

EXECUTIVE SUMMARY

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

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

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

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

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

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

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

SECTION 1.

INTRODUCTION AND BACKGROUND

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

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

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

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

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

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

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

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

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

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

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

SECTION 2.

REVIEW OF THE LITERATURE.

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

Perception Research Services, 1983.

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

Cole and Hughes, 1984

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

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

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

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

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

Young, E. 1984.

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

Pottier, A. 1988.

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

Pottier evaluated the abilities of twelve participants to detect the shape and location of a number of official traffic signs, as quickly as possible, under four different test conditions. These conditions included: (a) a simple or complex visual environment; (b)

different shapes (three) and sizes (three) of the signs; (c) different degrees (three) of eccentricity from the central point of fixation; and (d) different time periods (three) in which the signs were visible. Eye movements were recorded as well. Some of the findings of this study were as expected – specifically, that longer observation time improves detection performance, larger signs are more easily detected than smaller ones, and certain shapes (circle and triangle) are more easily detected than others (rectangle).

For our present purposes, the most relevant findings were related to the visual angle from which road signs were most easily detected. Pottier found that, when there was no visual noise in the (simulated) environment, the optimal detection zone was located between zero and ten degrees (0°- 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. 75º at 65 km/h, the speed limit on the road they studied. Their target sign was a typical national highway route marker, and they instructed their nine subjects (5 male, 4 female, and age range 21–66) merely to report as soon as they were able to confirm the route number. Eye movements were recorded from a point 400 meters upstream of each of six

signs that appeared along the route, within predefined sections. The visual noise ratio was measured at intervals of 20 m throughout each section. The authors found a statistically significant decrease in the detection distance of the sign as the visual noise level increased along the 400m approach to that sign. They further found that older drivers were significantly more adversely affected by the visual noise, and that males were more adversely affected than females. The authors conclude that visual noise along highways can be dangerous because it reduces the detection distance of important roadside information. While this study provides a unique approach to assessing the impact on driver performance of roadside distracters, and visual clutter, it suffers from several limitations. First, the number of subjects was quite small, and the distinction between older drivers and others is not defined. (There were only two subjects above the age of 60, for example). The definition of visual noise was somewhat vague, and the methodology used for measuring eye glances was unclear. Nonetheless, this is a novel, real-world approach to measuring the impact of roadside visual clutter, with a dependent measure (identifying the route number as early as possible) that is natural and reasonable.

Bergeron, J. 1996a

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

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

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

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

- Attentional resources needed for the driving task are diverted by the irrelevant information presented on advertising signs. This is an impact attributable to the "nature of the information" that is conveyed on such signs. This distraction leads to degradation in oculomotor performance that adversely affects reaction time and vehicle control capability.

- When the driving task imposes substantial attentional demands such as might occur on a heavily traveled, high speed urban freeway, billboards can create an attentional overload that can have an impact on micro- and macro-performance requirements of the driving task. In other words, the impact of the distraction varies according to the complexity of the driving task. The greater the driving task demands, the more obvious are the adverse effects of the distraction on driving performance.

- The difficulty of the driving task can vary in several ways. Those that relate to the physical environment (e.g. weather, roadway geometry, road conditions) are unavoidable, and drivers must adjust to them (unless they take an alternate route or wait for better conditions). Necessary sensory information adds to the workload of the driving task, but is, of course, needed to perform safely. In addition, road signs and signals that communicate complex but necessary information contribute to the overall workload of driving. In this case, however, years of study have been directed toward making this information as clear and as easily accessible as possible.

- To some extent, the level of mental workload that impacts driving occurs at a pre-processing level. Bergeron cites, as an example, a complex or cluttered visual environment. In this case, the attentional effort that drivers expend in searching for target objects (e.g. signs and signals) will be more laborious, demand more resources, and lead to declines in performance levels.

- The presence of a billboard increases the confusion of the visual (back)ground and may lead to conflict with road signs and signals.

- Situational factors that are likely to create a heavy mental workload include: complex geometry, heavy traffic, high speeds, areas of merging and diverging traffic, areas with road signs where drivers must make decisions, roadways in poor repair, areas of reduced visibility, and adverse weather conditions.

- The very characteristics of billboards that their designers employ to enable them to draw attention are those that have the greatest impact on what Bergeron calls attentional diversion.

- Drivers must constantly carry out the work of recognizing stimuli that may not be immediately meaningful to them. This task requires time and mental resources, both of which are in limited supply.

- Attention directs perception, and vice versa. In other words, when we are looking for something, our sensory system places itself at the service of our attention. But it is also possible for a sensation to attract the attention of drivers because it may represent something that is of potential importance. For example, authorities put flashing lights on emergency vehicles because they want drivers to attend to them.

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

Bergeron, 1996b

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

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

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

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

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

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

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

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

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

Schieber and Goodspeed IV, 1997

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

better. Our concern is that an excessively bright DBB in a visually complex, typically urban environment will succeed in drawing attention to itself and away from other signs in the environment, including official signs. Third, as this study, and others, have demonstrated, older drivers have a particularly difficult time detecting official highway signs in complex environments. Unfortunately, the trend in the U.S. is to increasingly more complex environments, which does not augur well for our aging society.

Theeuwes, et al., 1998, 1999

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

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

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

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

The results showed that, when no new object was added to the display (the control condition), the participants were able to move their eyes directly to the target; however, in those trials where the new object was introduced (the experimental condition), participants' eyes often went toward the new object, stopped briefly, and then went on to

the target. In other words, with the new target present, two different eye movements were made, the first to the new, irrelevant target, and the second to the target that was the object of the task. Reaction time to the task (the identification of the letter inside the gray circle) was significantly slowed when the new, irrelevant target was present. The authors note that the task irrelevant stimulus attracted this initial eye glance even when it appeared in the direction opposite the target. At the end of the experiment, the researchers explicitly asked the participants whether they were aware that the new object affected their eye movements. The answers were that they were sure that their eye movements were not affected by the onset object. Their conclusion from this first experiment was: "Both the goal directed allocation of attention and the movement of the eyes to a clearly defined target can be disrupted by the appearance of a new but task-irrelevant object in the visual field, even when this object appears quite distant from the target" (Theeuwes, et al., 1998, p. 381).

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

Cairney and Gunatillake, 2000

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

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

The authors identify, and briefly describe, six different types of signs, and suggest that different guidance or regulation is needed for each. Only two of the sign-types, the variable message and tri-vision signs, are relevant to our current study. They further discuss illuminated signs, and the types of motion or apparent motion that can be achieved by such signs, including: flashing, chasing, scintillating, etc., and they discuss

the appropriateness of restrictions on dazzling or glare impacts on motorists, and on maximum luminance (brightness) levels that should be appropriate for the ambient roadside environment. Finally, they suggest that the lighting color displayed on such signs should never mimic that of official traffic control devices, although they say nothing about the shape of images displayed. For all signs, Cairney and Gunatillake concluded that the common concern is the effect that a sign may have on a driver's visibility of other road users, the roadway, and traffic control devices, and that appropriate regulations generally prohibit signage in areas near where the demand for driver concentration is high, "such as intersections, interchanges, and level crossings" (p.3).

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

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

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

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

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

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

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

Farbry, et al., 2001

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

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

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

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

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

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

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

The authors identified relevant research in other aspects of road safety that might not, at first, seem to relate to the possible safety implications of roadside electronic billboards. Areas of research interest such as older and younger drivers, distraction due to in-vehicle

technology, and display and lighting characteristics of changeable message signs used for official purposes, are all discussed. Clearly, these areas of research *are* relevant to DBBs, as will be discussed below.

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

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

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

One of the principal purposes of this project was to identify needed research and propose approaches to conduct such studies. The authors describe the goal of such research as determining whether there are conditions under which EBBs are a safety concern as

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

Beijer, 2002

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

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

demand, Beijer suggests that, in heavy traffic, “glances at (advertising) signs may be inappropriate (p.3), and the measurement of such glances was one of the key objectives of this project.

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

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

Beijer tested two basic hypotheses:

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

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

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

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

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

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

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

above the travel lanes vs. older signs that were typically mounted on the right. Of course, it is also possible that the signs on the left were simply more distracting, and more capable of attracting the drivers' attention than those on the right.

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

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

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

Young and Regan, 2003

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

new technologies are brought to market. Although they are addressing in-vehicle distractions, their statements can apply to external distraction, including DBBs, as well.

Wallace, B., 2003a, b

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

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

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

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

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

might have caused these drivers to experience phototaxis (also called the “fascination phenomenon”) in which the large, bright billboard captured their attention to such an extent after a long, monotonous stretch of road, that drivers became “absorbed” in the sign, and simply failed to notice or respond to the curve in the road where the sign was located.

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

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

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

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

In summary, his major conclusions are:

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

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

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

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

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

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

CTC & Associates, 2003

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

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

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

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

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

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

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

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

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

billboards, may add additional demand to driver workload in high-volume intersections" (p.6)."

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

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

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

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

Lansdown, 2004

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

Finnish Road Administration, 2004

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

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

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

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

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

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

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

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

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

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

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

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

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

From their review of earlier work in this field the authors suggest research strategies that might be most successful in the future. They believe that accident studies, driver interviews and questionnaires are not sufficiently sensitive to measure the possible effects

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

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

Smiley, Smahel, and Eizenman, 2004

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

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

bicyclists, and no evidence that the glances at the video signs reduced the proportion of glances at traffic signs or signals.

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

Beijer, Smiley, & Eizenman, M., 2004

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

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

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

The active (all but billboard) signs consistently received longer glance durations and a greater than average percentage of total and long glances, whereas the billboard signs received fewer than average such glances. And, although there were no significant differences in either average glance duration or maximum glance duration for the different sign types, the billboards received significantly fewer glances than any of the

other three sign types. This suggests that drivers attended to the active signs longer, possibly in anticipation of the next message to be presented. With a fixed billboard, of course, the message will not change as a driver approaches it.

When only long-duration glances were considered (those longer than 0.75 second), the authors found that 22% of the total glances were in this category. Of these 194 cases, five (20%) lasted for longer than two seconds. The authors express concern that long glances can pose a serious hazard in close following situations. Since 22 of the 25 subjects made at least one long glance at an advertising sign, the authors conclude that "distraction … was not just an isolated incidence."

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

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

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

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

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

might relate to the number and duration of glances made to it, further explanation would be needed.

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

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

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

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

1. Drivers' eye movements were recorded as they drove past video advertising signs at three downtown intersections and along an urban expressway. Several questions were addressed, including: Do drivers look at video advertising signs; if so how often and for how long? Do these glances come at the expense of glances at traffic related targets?

2. Traffic conflicts were analyzed at two of the intersections, comparing the approach where video signs were visible to the approach where they were not. The question addressed was: Is there an increase in conflicts (that might indicate a lower level of safety) on approaches where video signs were visible?

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

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

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

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

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

The authors discuss the one intersection video sign that was the most distracting as measured both by the percentage of subjects who looked at it and the total number of glances made to it. Surprisingly, this sign was visible for less time than the others studied, was smaller than the other intersection signs, was mounted lower (closer to the driver's line of sight), and was in a less cluttered environment, making it more conspicuous. It was also farther from the driver's line of sight than the other intersection signs. The authors describe it as having "less entertaining" content, although they do not discuss any of the characteristics of its imagery such as its brightness, resolution or contrast. One possible explanation for this seeming inconsistency can best be explained by a comparison of the distracting effects of in-vehicle devices (e.g. entertainment systems) to external-to-vehicle sources (such as the DBBs of interest in this paper). As discussed

elsewhere in the present report, one key difference between these two types of distracters is that, to a large extent, a driver may choose when to divert his attention from the roadside to engage with in-vehicle devices, but can attend to the external distracters only when these are visible to him. In other words, if the momentary task demands on a driver are high, that driver may postpone (or cease, if already begun) his interaction with the non-essential in-vehicle technology. But a billboard, electronic or not, is in a fixed position and, like a call to a driver's mobile phone, the distraction occurs independent of the momentary degree of demand on the driver as the sign is approached. If that billboard is highly attention getting or highly salient to a driver, that driver does not have the luxury of postponing his gaze at the sign; the window of opportunity to view the sign is, in essence, "now or never." And, as reported by Smiley and her colleagues (2004), some drivers will divert their attention from the road for long periods of time *despite* the task demands that they may be facing. Applying this analogy to the unexpected results found for this particular video sign, it is possible that drivers paid more attention to this sign precisely because it was visible to them for less time than the other video signs studied, and therefore provided approaching drivers with a shorter window of opportunity to attend to it once it had captured their attention.

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

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

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

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

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

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

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

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

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

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

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

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

The authors, during a brief discussion of the results of an earlier study conducted with a different video sign on a different Toronto area highway, highlight the difficulties facing researchers' abilities to conduct definitive studies of this subject. They state: "Clearly,

some video signs are more distracting than others." While this would appear obvious, it carries with it the concern that there can be no "one size fits all" solution with regard to sign design or operation or with the regulation and control of such signs. It does remind us, however, that there are certain characteristics of sign design, operation, and placement that can be generally understood to contribute to greater distraction and inattention, and that sign operators as well as highway authorities should concentrate on these factors in their efforts to ensure the highest levels of traffic safety in the presence of roadside advertising signs.

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

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

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

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

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

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

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

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

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

This is one report of several that have been presented and/or published from the "100 car naturalistic driving study." This seminal study, and the data that it has

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

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

Among the principal findings were that driving while drowsy increased a driver's near-crash/crash risk by four to six times over the baseline, and engaging in secondary tasks increased this risk by two times for "moderate" secondary tasks, and by three times for "complex" secondary tasks. These findings, of course, are not directly relevant to a study of distraction from roadside billboards, but are reported here because they are representative of behaviors often associated with driver distraction. The study further found that "driving-related inattention to the forward roadway" was *safer* than normal driving – but when this behavior is defined, this finding becomes more plausible. This behavior was characterized by the experimenters as including actions such as checking the rear-view mirror, side view mirrors, vehicle instruments, and other traffic through the

vehicle's side windows or the sides of the windshield. As the authors state: "drivers who are checking their rear-view mirrors are generally alert and engaging in environmental scanning behavior" (p.x). Thus, it is somewhat puzzling that the authors chose to include these behaviors together with other distracters.

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

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

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

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

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

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

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

SWOV Institute for Road Safety Research, 2006

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

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

The report reviews the work of several recent authors, including Wallace (2003), Smiley and her colleagues (2005), and Tantala & Tantala (2005). They summarize these studies by saying that the first two studies found a negative effect of advertising signs at busy intersections and at places where advertising signs might have a similar design or color to traffic control devices; the latter two studies found no *causal* relationship between the signs studied and crashes. Their review of a study by Crundall, et al. (2006) indicated that billboards at eye level captured the attention of drivers both longer and more frequently than billboards elevated three meters above the road surface, particularly for drivers who were given the task of identifying dangerous situations. The SWOV conclusion was: "Precisely in a dangerous situation it is important for the driver to have his attention on the road; an advertising billboard can slow the driver's reaction time, which increases the chance of a crash" (p.2).

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

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

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

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

They suggest, based upon the strongest findings from past research, that it is better not to place billboards at busy traffic spots, and that billboards should not resemble traffic signs or other traffic indicators. Further, blinking and moving objects have proven to be

difficult to ignore, and thus dynamic billboards are ill-advised. In the past, different levels of government have employed their own guidelines for the placement of billboards along the roadside; unambiguous guidelines are advisable.

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

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

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

Road Safety Committee, 2006

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

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

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

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

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

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

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

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

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

Klauer, Sudweeks, Hickman, & Neale, 2006b

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

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

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

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

Crundall, Van Loon, and Underwood, 2006

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

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

The authors suggest that, because it is possible to identify fixed roadside "hazards" (such as dangerous curves, complex interchanges, etc.), it is therefore possible to ensure that roadside advertisements are not located in such areas. Their greater concern, however, is

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

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

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

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

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

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

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

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

Another finding from Crundall, et al. also raises concern. The authors cite a study by Boersma (1989) that suggests that visual clutter in the observed environment tends to

increase the visual search time for a target of interest, and studies by Eriksen and Eriksen (1974) and Logan (1996) that demonstrated that the proximity of distracters to a target increases the amount of time required to respond to the target. Crundall, et al. conclude that the embedded nature of SLAs within a complex scene may produce the same result, i.e. increasing the time required for a driver engaged in proper scanning behavior to locate and respond to a real hazard that may be present.

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

Horrey and Wickens, 2007

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

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

In this study, the authors collected data in a driving simulator to study glance durations to an in-vehicle display. They then set out to show how an analysis of the average or mean glance duration could produce results, and therefore lead to conclusions and recommendations, that were quite different than using the same experimental data but analyzing the tails or extremes of the data. Their results showed that analysis of the mean glance duration did not clearly distinguish between tasks of varying difficulty. When

analyzing the tails of the distribution for the same experimental data, however, the authors found very large differences, and these differences had implications for hazard response time and, therefore, crash potential. As a result of their findings, the authors revised a crash risk model that they had previously proposed. The revised model has not yet been validated due to a lack of data, but the results from this study demonstrate its viability.

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

Clark and Davies, 2007

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

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

We had a number of concerns with the design and execution of this study, most of which are acknowledged by the authors. One concern that was not addressed is that the road sign stimuli could appear in any one of 10 different positions on the display screen, a far different case than exists in the real world. A second concern is that each stimulus (both road sign and distracter) appeared suddenly on the screen and remained visible for exactly two seconds. In the real world, signs appear in the distance, often before they can be read, and become clearer and larger as they are approached. In this study, the sudden "on" and "off" appearance of signs of interest might well have influenced participant behavior in ways that would not occur on the road. Further, in the four "load" conditions

(no load featuring no distracters, low load with three, high load with six, and "overload" with ten), all of the distracter signs, as well as the target official sign, were presented at the same time, around the perimeter of the display. Responses to this rather unrealistic display might not translate very well to the real world in which signs appear in fairly limited and well defined locations, and in which they appear at different times and for different intervals. Nonetheless, the study produced some interesting findings; findings which are quite consistent with the results of other studies employing very different methodological approaches, and discussed elsewhere in the present report. Whereas driving expertise had no influence on response (reaction time to the simulated road stimuli), the number of distracters did. Specifically, a significant increase in reaction time was found between the no distracter condition and the two highest distracter conditions, although there was no significant difference between the no-load and low-load conditions. There was, however, a consistent increase in reaction time to the road signs as load from distracting stimuli increased, suggesting that the higher loading driving tasks (as represented by the number of advertisements visible) were "detrimental to road safety." The implications of this study are that advertisements should be kept to a minimum at busy junctions and areas where drivers need to concentrate" (unpaginated).

Lee, McElheny, & Gibbons (2007).

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

Perception Research Services (2007)

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

Shinar, 2007

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

The author poses a paradox that has confronted researchers in this field for many years. Because roadside commercial billboards, particularly the latest digital billboards, are specifically designed to attract a driver's attention (and billboard owners and operators tout their success at doing so in their promotions to potential customers), we would expect them to be a significant source of distraction. Indeed, as discussed elsewhere in the present report, numerous studies have shown that drivers do direct their gaze to billboards as they drive. Yet several studies have demonstrated that despite drivers' glances toward billboards, there has been little observed adverse impact on driving performance. In an effort to better understand this paradox, Shinar and his colleagues conducted an on-road study using 16 experienced drivers and an instrumented vehicle. The route took the participants past a large, attention-getting billboard in one direction and then followed the same roads in the opposite direction from which the billboard was not visible. A camera hidden below the vehicle's rear-view mirror recorded the participants' direction of gaze. Results showed that drivers looked to the right (in the general direction of the billboard) 23% of the time when the billboard could be seen, but

only 10% of the time when the billboard was not visible to them. Drivers' time spent looking forward at the road and traffic was effectively the same regardless of whether or not the billboard was visible. Shinar believes that the billboard attracted the drivers' spare attentional capacity that might otherwise have been spent looking at other objects equally irrelevant to the driving task. He concludes: "Thus, drivers were able to allocate a significant amount of their attention to the sign but they did not do that at the expense of the attention that they allocated to monitoring the road and traffic" (p. 528).

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

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

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

younger cohort at quickly shifting attention, may be particularly at risk under such circumstances.

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

Tantala & Tantala (2007).

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

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

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

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

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

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

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

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

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

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

The study examined only traditional, fixed, billboards; electronic or digital billboards were not analyzed. Thus, the direct relevance of its findings to DBBs cannot be assessed. As suggested above, we believe that simulation may not be the ideal methodology to

study EBBs because it is difficult, if not impossible, to faithfully reproduce the visual characteristics of such signs (brightness, depth and fidelity of the graphic image) in the simulation environment due to limitations on the graphics processing capability of most simulation systems. Indeed, even in today's most sophisticated driving simulators, it is necessary to design signs that are oversized in order to realistically represent sight distances at which the messages on such signs can be read in the real world, and the complexity of the real world visual environments in which DBBs are most likely to be found remains a challenging task to recreate in simulation.

Chan, Pradhan, Knodler, Pollatsek and Fisher, 2008

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

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

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

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

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

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

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

In discussing their results, Chan and her colleagues compare their findings to those of Wikman et al. who performed their analysis on-road. The data from the two studies is in

strong agreement, and provides evidence to support the viability of using a driving simulator to study driver viewing behavior. In reviewing their data on external distraction and relating it to the earlier work of Klauer et al. (2006a), Muttart et al. (2007), and others, these authors express concern that "it is likely that our out-of-vehicle tasks (which not only engage attention but also draw the eyes and visual attention away from in front of the vehicle) would have quite significant detrimental effects on processing the roadway in front of the vehicle (p. 22)."

Lazarus, 2008

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

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

Speirs, Winmill & Kazi, 2008

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

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

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

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

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

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

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

Within a brief discussion of internal- and external-to-the-vehicle distraction, the authors discuss the growing concern with cognitive overload – which Wallace (2003b) suggests can occur when too much information is presented in certain situations, leaving the driver with insufficient time to process the available information and make time-critical decisions. Such decisions, which may involve maneuvering for exits, merges, or lane drops, also include what Crundall, et al. (2005) have called "transient hazards" such as a

pedestrian or bicyclist suddenly entering the road, or a vehicle failing to yield the right of way. Wallace believes that visual clutter, which contributes to cognitive overload, is growing worse, with an increasing number of billboards, on-premise signs, and, as well, official highway signs.

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

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

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

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

The Circular is apparently based, in part, on findings from a study conducted by the Privilege Insurance Company, which found that 83% of drivers responding to a survey had admitted being distracted by roadside advertisements, with 23% of those reporting

that they had veered out of their lane as a result of the distraction. (Privilege Insurance, 2005).

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

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

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

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

- There could be other unknown variables that could have led to the reported accidents.
- There are many opportunities for error or omission in data entry in police accident reporting forms.
- In minor accidents, the involved vehicles may move away from the POR to clear traffic lanes, thus further degrading the potential accuracy of identifying the true location.

- The point of rest (POR) of the involved vehicle(s) (which is what is commonly identified in police reports) may have little relationship to the point of distraction that was the proximal cause of the crash.[3]
- Accidents, particularly minor accidents, are underreported.
- Accident data considers only those incidents that result in an actual collision. But there are likely many more incidences of distraction that result in driver error (such as late braking, lane exceedances) without consequence, and others that result in "near misses" that might have resulted in a crash but for the evasive actions of another driver. "As no data on 'near misses" is available, it is not possible to quantify the full effect of distraction" (p. 35).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

At the outset of the survey, respondents were given a list of 14 possible sources of distraction (both within and outside the vehicle) and asked to select those which they considered to be most distracting. The top five identified sources, and the percentages of respondents who provided those answers were: Rubbernecking at accidents (75%), child passengers in their vehicle (68%), hands-free mobile phone use (67%), roadside billboards 61%), and roadwork (50%). When asked about the single greatest source of

distraction, 24% said mobile phones, 18% reported other passengers, 13% said rubbernecking at accidents, and 9% selected roadside billboards. No other distracters were considered the most important by more than 5% of the respondents (in-car navigation systems and actions by other vehicles).

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

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

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

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

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

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

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

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

> "Changing signs draw attention to themselves; they are not part of the traffic and amount to a serious distraction. I cannot understand why they are allowed!"

> "Those with images that change over a period of time tend to attract a longer spell of attention whilst waiting for the next image. If one's vehicle is actually moving at the time this has the effect of driving blind while watching the particular sign."

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

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

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

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

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

For those 913 respondents who stated that their driving performance had been affected by roadside advertising, they were presented with a series of seven statements and asked to

indicate whether they felt each was true or false. The statements, and the level of truth assigned to them, were as follows:

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

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

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

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

Among their principal conclusions, Speirs and her colleagues suggest that current guidance and policy is insufficiently detailed to address the different types and characteristics of outdoor advertising devices, particularly DBBs. As a result, further research is needed to quantify the level and significance of the risk. They believe that post-hoc accident studies would not be useful to pursue unless the researchers had direct access to the involved drivers in near-real time. They point to the most recent research studies that they reviewed, those by Young and Mahfoud (2007) and Clark and Davies (2007) as producing "statistically significant results which suggest that the level of distraction caused by advertising does present a genuine road safety concern" (p. 117). These studies, however, have been criticized by some stakeholders as being "unrealistic"

in that they were simulator based and thus their applicability to the real world may be compromised. Nonetheless, the authors recommend that further research build on Young and Mahfoud's work "to explore and quantify the effect of different characteristics of advertisements on levels of driver distraction" (p. 122). They argue that a future study, if properly funded and conducted on an advanced driving simulator, should be able to overcome some of the limitations of this earlier work – small sample size, limited number of variables, stimulus material not fully representative of actual billboards, and a simulator of somewhat limited flexibility and fidelity. The authors review three UK-based driving simulators, and recommend that future work be undertaken at the University of Leeds Driving Simulator (UoLDS). In their discussion of the strengths and weakness of a driving simulator study, the authors argue that simulators permit the different types and sizes of billboards of interest to be studied to examine the effects on drivers, a task that would be more complex in a test track or on-road study. Finally, the authors present a suggested approach for the conduct of a driving simulator study.

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

Dudek, C., 2008

Dudek (2008) reviewed the state-of-the-practice for the use of official, permanently mounted changeable message signs (CMSs) during "non-incident, non-

roadwork" periods. Practices relating to the display of AMBER (America's Missing: Broadcast Emergency Response) alert messages were included, The report was based on a review of the literature and a survey of State DOT traffic management centers (TMCs) and agencies that operate toll roads. Overall, responses were received from 40 States and six toll road agencies with a total of 100 TMCs operating 3,023 urban and 821 rural CMSs.

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

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

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

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

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

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

Although traditionally left blank when not in use for their intended purpose, there has been an increase in the use of these signs by transportation agencies over the past 10 years to display messages when the signs are not otherwise needed. Such messages have

been predominantly those that indicate travel time, and these are recommended by FHWA. However, other, non-essential messages have seen growing use, including information about congestion, speed, traffic ordinances, safety campaigns, and public service announcements (PSAs).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

notice a sign whose message has changed from something irrelevant to something of importance to them. And there is considerable concern about the loss of credibility of official CMSs when they display messages that the public believes are not timely and not related to traffic safety and flow.

Edquist, J., 2009a, 2009b

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

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

In a simulator-based driving study performed to try to confirm or refute an earlier study using still photographs, Edquist found that, when billboards were present, participants drove more slowly, took longer to change lanes in response to direction to do so by road signs, made more errors when changing lanes, and spent more time looking at the roadside and less at the road ahead of them. Older drivers in particular made more errors when changing lanes when billboards were present. The author notes that, due to

limitations in the simulator platform, her scenarios depicted relatively low complexity environments. In addition, there was not enough traffic in the simulated road scenes to create elevated levels of driver workload, and the billboards depicted were simpler than those typically found on actual roads. Thus, she concludes, her experiment likely underestimated the adverse effects of billboards on driver response to traffic conditions. The author notes that there are often questions about the extent to which simulator results can be generalized to the real world; however, in this case, since both the visual and cognitive workloads in the simulator were lower than they would be in the real world, she believes that the real effects of these distracters are probably larger than what she observed. Edquist summarizes her study by stating that visual clutter adversely affects where drivers look, what they see and how quickly they see it, and negatively impacts their driving performance in terms of speed maintenance and response to traffic signs.

Fisher, D., 2009

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

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

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

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

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

These findings suggests, of course, that older drivers are less likely to be distracted by inside the vehicle sources than are younger drivers, but, when the distracter is a billboard, older drivers are just as likely to be distracted as younger drivers, and the percentage of drivers who engage in excessively long glances to such billboards is substantially higher for external than for inside-the-vehicle distracters. Fisher hypothesizes that drivers

looking inside their vehicle at a navigation system, entertainment device, etc., are aware that their eyes are off the road, but when the distracter is outside the vehicle, along the roadside, drivers may be able to observe the forward view including traffic in their peripheral vision and therefore believe that they are attentive to the driving task. This will be a subject for future research.

Martens, M., 2009

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

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

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

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

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

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

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

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

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

10. In driving, "bottom up" distracters should be avoided.

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

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

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

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

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

SECTION 3.

RESEARCH UNDERTAKEN OR PUBLISHED BY THE OUTDOOR ADVERTISING INDUSTRY

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

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

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

A series of studies conducted by Perception Research Services (1983), and separately reported by its President (Young, 1984) was intended to "observe the attention-getting ability of outdoor boards from the perspective of the individual in an automobile (Young, 1984, p. 19). This work measured the eyegaze behavior of 200 licensed drivers who viewed a 27 minute video of a drive through three metropolitan areas to "observe the stopping power of outdoor" (p. 19). Although insufficient detail was presented in the published reports to independently review the research, the results are illuminating. First, the author suggests that recall scores (based on questioning of the participants immediately after the simulated drive) "grossly (understates) the true impact of outdoor advertising … that outdoor is generating approximately two and one-half times as much attention as recall scores would ever indicate" (Young, p. 20). Second, the research found that "outdoor advertising located near highway signage tends to generate *greater* attention. We hypothesize that the highway signage tends to wake up the driver; his state of alertness increases and his attention to advertising and signage in the immediate area tends to get enhanced" (Young, p. 21). Finally, the research found that outdoor advertising attracts attention regardless of whether the displayed message is of interest/relevance to the driver or not. These findings, and particularly the last, obviously intended for an audience within the billboard industry, provide a useful comparison to the findings of several of the studies discussed in Section 2 of this report. In particular,

Young's finding that billboards attract a driver's attention whether or not the message is of interest or relevance, is quite similar to the findings of Crundall, et al. (1999), and Theeuwes, et al. (1998, 1999), both of whom showed that drivers do not, and cannot, ignore such irrelevant stimulation, even during the performance of a high priority task. Interestingly, Young's findings run directly counter to arguments routinely made by industry representatives in discussions with regulators – that there is no adverse safety consequence of billboards because, when a driver is engaged in a demanding task, he simply ignores the advertisement. An updated version of this report was issued in 2000, but has not been made public.

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

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

Tantala & Tantala (2007)

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

Limitations of Post-Hoc Accident Analysis.

Any post-hoc accident study, in which researchers review statistical summaries of traffic collision reports (TCRs) is limited, not only by the detail and accuracy of the original reports, but also by the inherent simplifications imposed by the coding system used to summarize the data in the first place. When a third party excerpts this summary

data for inclusion in a statistical data base, as is the case here, the level of detail and specificity that may have originally been present is further compromised. When such summary data are used to relate crashes to driver distraction that may or may not have been caused by the location and operation of DBBs, the interpretation of crash data is subject to further limitations, discussed below.

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

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

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

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

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

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

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

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

Erroneous Underlying Assumptions.

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

Assumptions about the Visibility Distance to DBBs.

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

It is imperative, therefore, that the researchers identify, in advance of data collection, those roadway sections which were, and those which were not, within the visibility and legibility ranges of the seven DBBs that they studied. To support their determination of these locations, the authors provide the reader with five different terms, none of which are clearly defined in the report. These terms are: "visible range from route," "viewer reaction zone," "viewer reaction distance (VRD)," "viewer reaction distance zone", and "viewer reaction time (VRT)." The only one of these terms that is given a definition is this tautological and confusing description of VRD: "… Viewer Reaction Distance (is) how far from a billboard that the driver is potentially within the 'influence' of the

billboard" (p. 45, 79). In other words, viewer reaction distance is the distance in which the viewer can react to the DBB. Instead of providing a meaningful or operational definition of this key term, the authors explain that "reasonable values for VRD were previously determined in previous studies, and are a function of the driver's speed." But no such previous studies are cited, and no other basis for the VRD formula is offered. Regardless of the basis for the determination of VRD, however, the researchers' statement that it is a function of speed is simply wrong. Clearly, the *distance* at which a driver can first see, and then read, any sign (DBBs included) is independent of speed; it is only viewer reaction *time* that would be affected by speed. This is a critical error, because this false assumption led the authors to identify those road sections upstream of each DBB for which they would collect and review the accident summary data. If these roadway sections were inappropriately truncated, and we will show below that this was the case, potential billboard-related crashes would be missed, and the identified correlation coefficients would be artificially and incorrectly reduced.

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

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

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

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

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

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

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

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

"Data Bias" And "Intersection Bias"

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

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

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

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

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

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

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

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

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

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

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

Decades of research into driver distraction has shown that alert, experienced drivers can tolerate some distraction when their task demands are not high, but that all drivers have upper limits on their cognitive capacities, and that there are certain road, traffic, and environmental conditions that may increase cognitive demands to the extent that additional sources of distraction should be avoided. Thus, the exclusion from analysis of some of the very types of crashes that might be *expected* to occur in the vicinity of DBBs is troubling, and, as with the decision to artificially truncate the data collection in road

sections upstream of DBBs, results in a likely substantial understatement of the actual crash statistics that took place in road sections where drivers were able to observe these DBBs. Taken together, the choice of crash types to exclude is a serious weakness of this study, given that some of the very kinds of crashes excluded are those that would be of direct relevance to the potential for distraction caused by billboards.

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

Inappropriate Statistical Methods, Assumptions, Analyses.

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

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

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

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

In a section of the report titled "Accident Density and Billboard Density," it is clear that the researchers have inappropriately commingled DBBs with traditional billboards along

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

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

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

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

assumption, the research methodology did not include true comparison sites where billboards were absent, and thus any assessment of the contribution to crashes from DBBs against a true baseline were impossible.

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

Oversights, Omissions, and Evidence of Bias.

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

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

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

Bias is evident throughout the report. For example, the authors' state that their numbering system for the billboards studied was "arbitrary" (p. 10), but a review of the website of the billboard owner, ClearChannelOutdoor, shows that this information was supplied by them. Several figures and tables in the report are taken directly from the ClearChannel

website, and a ClearChannel executive was quoted as saying that his company had "hired" the researchers to perform the study (Slobodzian, 2007).

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

Author Response.

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

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

The second point made in the Wachtel review with which Tantala takes issue is that "the review opines that our analyses should not exclude 'bias' factors because accidents are often multi-causal and those are the very factors that increase the likelihood of accidents" (p. 2). Tantala expresses his agreement with Wachtel's opinion, and states "we did include this in part of our study. In fact, we performed an analysis that included <u>all</u> data collected and compiled by the State of Ohio…. This robust, comprehensive and all-inclusive data-set includes the very multi-causal accidents that the review references" (p. 2)." But the Tantala letter provides no link or reference to any pages, tables, or figures in the report where a reader might find these all-inclusive analyses (those in which the stated biases were included in the analyses). Indeed, our re-review of the paper, undertaken as a result of the Tantala letter, finds no such analyses. In fact, only Table 4-5 (p. 54) addresses the all-inclusive vs. bias-adjusted accidents, and it merely presents the

summary statistics of raw accident counts and accident rates with no accompanying analysis. In contrast, after stating: "A more fair and unbiased comparison of accident data would exclude accidents from known causes" (p. 63), the report presents a series of four tables (4-7 through 4-10) and seven figures (4-11 through 4-17) that present "the number of accidents with statistical bias events excluded within the visible range" (p. 63). If there was any comparable presentation of the all-inclusive data within the report, this reviewer could not find it.

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

Lee, McElheny, & Gibbons (2007).

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

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

Study Overview.

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

Methodological Concerns.

Eye Glance Recording.

Eye movement recording and analysis is a time-proven method for determining where drivers are looking as they drive. Until recently, however, it has not been possible to obtain precise eye glance data (with a precision of 1 deg or better) without the use of

highly intrusive, head mounted equipment. The trade-off is to use recording equipment that is mounted on the dashboard or other interior vehicle structure, but the weakness of this less intrusive system is that eye glance information can then be obtained only for more gross directions of gaze. In other words, while it is possible to record the general direction in which a person is looking, it is not possible to know with confidence the exact object (no less an image within that object) being viewed, or the distance from the eye at which that object is located. Because this study employed such vehicle-mounted equipment, the researchers could report only on the general direction of gaze and could not identify if, or when, a participant was looking at a specific object (such as a DBB) in the visual field.

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

Lack of control over site variables

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

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

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

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

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

Confounding of data collection sites.

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

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

The choice of an 8-second data recording interval.

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

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

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

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

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

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

Measurement of nighttime luminance levels.

The authors measured the luminance levels of different sites at night. They took these measurements from the participant-driver's eye position, a decision which masked and minimized the actual brightness differences between the DBBs and the other sites. A more appropriate comparison would have been from measurements taken directly in front of each of the signs of interest (as recommended in, for example, TERS, 2002; NYDOT 2008a) so that the authors could be sure that they were comparing sign against sign without the contribution of the general ambient environment. Several other weaknesses affected this measurement approach. First, taking measurements from the driver's position would have yielded non-comparable readings even if every sign had the same luminance, merely because the signs were positioned at different angles to the driver, and

were located at different horizontal and vertical distances from the driver's eye. Second, the authors do not state whether some of the (non-DBB) sites measured at night were those on surface streets and whether there were fixed luminaires within the range of the luminance meter at such sites. The presence of fixed lighting would also have reduced the actual luminance differences between DBBs and other sign sites. Third, since the DBB displays changed every 8 sec, the luminance levels on these signs changed accordingly. Thus, unless the researchers measured each DBB with the identical display (highly unlikely), they would have no way to compare the light output of the different DBBs. They would not know, for example, whether measured differences between DBBs were due to actual sign output, different brightness settings, or differences between displayed messages. Despite these limitations in measurement strategy, however, and despite the fact that the digital billboards were automatically dimmed at night, the authors recorded nighttime luminance levels at the driver's eye position that were, on average, 10 times greater for the DBBs than for baseline sites, approximately 3 times brighter than sites with conventional billboards, and approximately 2.5 times brighter than comparison sites. The authors' state: "this probably explains some of the driver performance findings in the presence of the digital billboards" (p. 68).

Inappropriate and Inconsistent Statistical Treatment.

Eye glance recording and long duration eye glances.

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

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

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

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

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

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

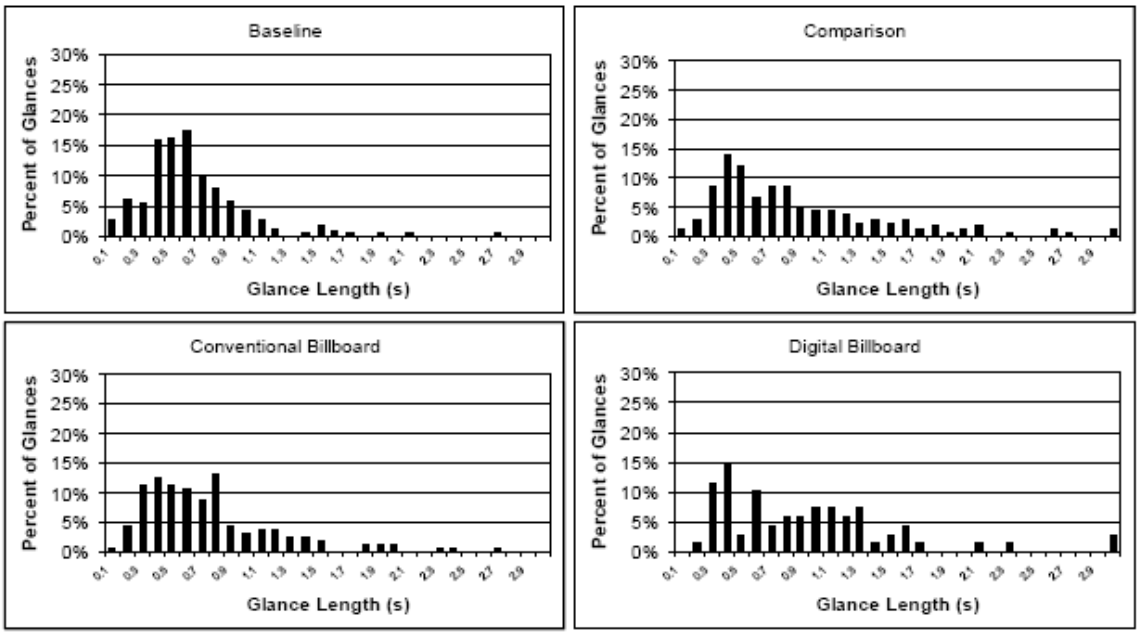

Figure 23. Tails analysis for the distribution of glance duration, (method described in Horrey and Wickens, 2007).

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

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

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

In summary, this visual inspection of the researchers' data suggests that long glances occur two-to-three times more often with DBBs and comparison sites than they do with baseline or conventional sites, and that the longest glances (3.0 sec or longer) occur *only* with these sites. These results suggest important differences for the longest glances, the

ones that highway safety experts are most concerned with. One must ask why the authors chose not to perform a statistical analysis of this data, particularly when they did so for every other set of eyeglance data, and why they reported that their visual inspection of these data suggested that there was "no obvious pattern of longer glances being associated with any of the event types" (p. 59). The report offers no explanation.

Misleading and Inconsistent Reporting and Evidence of Bias.

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

Was this a "naturalistic" study?

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

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

Literature Review.

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

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

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

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

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

Obfuscation of Study Purpose and Intentional Confounding of Study Sites

The stated purpose of this study was to "assess the effects, if any, of digital billboards on driver behavior and performance" (p. 8), *not*, as suggested in the Abstract, to ascertain whether driving performance in the presence of digital billboards was similar to performance in the presence of other, primarily on-premise, digital signs. As discussed

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

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

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

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

The authors provide voluminous data for irrelevant issues (e.g. 124,740 video frames analyzed, 96,228 data points collected, 8,678 eye glances identified, etc.) but offer no information useful to readers who might want to know what was actually studied. For example, there are no images of any of the billboards or other sites studied, there is no

indication of the precision with which eye gaze was captured, etc.). It appears as if the researchers intended to overwhelm the reader with useless information in an attempt to avoid questions about the real issues.

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

> "The lead author of this report recently participated on an expert panel charged with providing recommendations for a minimal data set to be included on police accident reports; billboard were never raised as a possible distraction…" (p. 11).
>
> "After a long gap in research, there were a few additional studies in the 1960's through the 1980's, none of which demonstrated that billboards were unsafe." (p. 11)
>
> "The national crash databases do not mention billboards in their list of driver distractions." (p. 14)

Findings that DBBs are "Safety Neutral."

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

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

As expected, the researchers found quite similar driver performance and behaviors at these two types of sites, and these performance and behavior variables differed, in the critical area of eyeglance behaviors, from the two other types of sites studied (conventional billboards and baseline sites). The clear lesson, had the researchers chosen

to accept it, was that sites containing digital imagery with changing messages (whether on- or off-premise) were more demanding and more distracting than sites devoid of such sign characteristics. Yet, the authors took this obvious conclusion and twisted it in favor of their biases by reporting that DBBs were "safety neutral" because the adverse, and potentially unsafe, driver behaviors that they observed at such sites were generally similar to the behaviors that they observed at the comparison sites. This conclusion, accompanied by the authors' contrived term "safety neutral" seems to reflect obvious bias, and flies in the face of efforts to promote highway safety by reducing, not increasing, the number of irrelevant, distracting, roadside stimuli.

Correlation and causation.

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

Nighttime data collection.

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

SECTION 4.

HUMAN FACTORS ISSUES

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

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

- *Distraction and inattention*. It is important to distinguish between these two terms, which are often confused. Inattention involves the failure of a driver to concentrate on the driving task for any reason, or for no known reason at all. It is distinguished from distraction in that it may have no known cause, and possibly no remediation. Conversely, distraction is a failure of concentration on the driving task that is a direct result of some activity or stimulus that triggers this failure to concentrate. Distraction may be due factors internal to the driver, such as fatigue, medication, illness, alcohol, or a focus on unrelated issues. It may be external to the driver but internal to the vehicle, such as mobile telephone use, adjusting the vehicle's controls or non-safety-related equipment (e.g. radio, navigation system, heating or air conditioning), conversations with passengers, or other non-driving related behaviors such as reading, grooming, or singing. Finally, distraction may be due to factors that are external to the vehicle, including vehicular, pedestrian or bicycle traffic, buildings, scenic vistas, roadside businesses, or advertising signs, including billboards. Whereas it may be impossible to control for the inattention that affects all drivers from time to time, many of the causes of distraction can be controlled.

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

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

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

- The *Zeigarnik Effect*. In 1927, Russian psychologist Bluma Zeigarnik demonstrated that tasks that have been initiated by humans but, for whatever

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

- *Brightness and glare*. Brightness is the subjective impression of the luminance of a sign, and glare is a physiological response. The majority of public complaints about DBBs concern their excessive brightness, particularly at night, to the extent that they become the most conspicuous item in the visual field, and draw the eye away from other objects that need to be seen. The photograph shown in Figure 5 was taken by the author of a DBB from a distance of six miles. The photograph was taken at 7:52 AM, and has not been altered in any way.

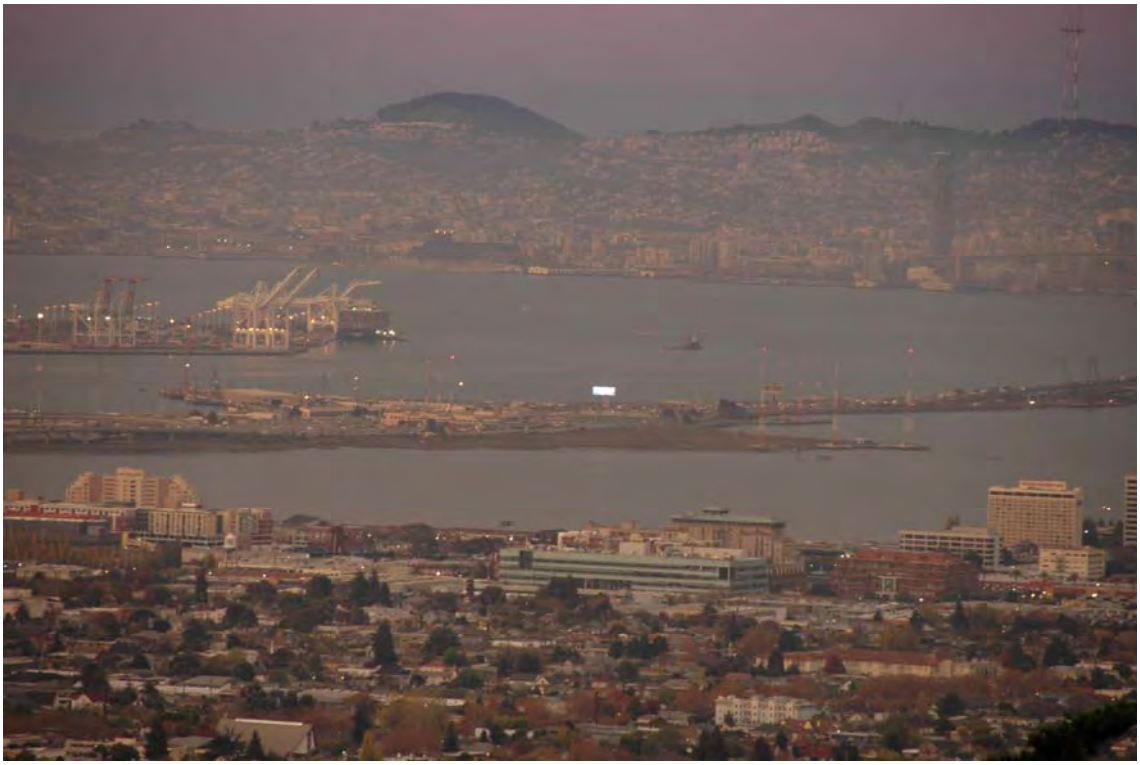

Figure 5. Unaltered photograph of a DBB from a distance of six miles

- *Legibility and readability*. Signs, to efficiently communicate a message, must be legible and readable. Specific design characteristics of official traffic signs such as font, letter size, color and contrast between figure and background, etc., have been specifically selected and mandated after years of empirical

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

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

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

- *Visual attention*. Our attention may be drawn to, or captured by, an object such as a billboard either because we make a conscious effort to attend to it ("top down") or because some characteristic of the object (e.g. size, placement, brightness, etc.) captures our attention without volitional intent ("bottom up"). The first type of visual attention is also referred to as "search conspicuity," whereas the second is known as "attention conspicuity." Road

and traffic safety experts take advantage of bottom up visual attention capture by: employing unique colors for traffic control devices when challenging conditions are present (e.g. the use of orange for construction and work zones), outfitting emergency response vehicles with flashing lights and sirens, and by using flashing beacons and/or flashing messages on road signs when urgent safety warnings must be communicated. DBBs, more than any previous technology used for roadside advertising, are capable of commanding drivers' attention by employing extremely high luminance levels, bright, rich colors, and a pattern of message display that may appear to flash.[12]

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

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

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

SECTION 5.

CURRENT AND PROPOSED GUIDELINES AND REGULATIONS

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

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

International Guidelines and Regulations

Queensland, Australia

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

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

Other key definitions include:

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

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

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

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

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

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

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

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

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

These maximum permitted luminance levels are

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

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

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

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

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

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

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

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

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

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

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

- The complete screen display should change instantaneously.
- In a text-only display, the background color should be uniform and non-conspicuous.

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

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

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

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

In light of recent proposals from the States of California (Kempton, 2008) and Nevada (Martinovich, 2008) to consider public-private partnerships that might result in advertising on State-controlled roads, the TERS report provides useful guidance for "advertising devices provided as part of sponsorship arrangements" (Appendix A). The report describes a program in which "the Department may permit the erection of Advertising Devices for a defined period in exchange for … private sector sponsorship of road infrastructure and/or works (p. A-2). Examples of such projects include construction of a pedestrian footbridge over the roadway, roadside landscaping and tree planting, and

rubbish removal including removal of illegal Advertising Devices. Project sponsorship must be based on full and open competition, and the project must be warranted in its own right. For sponsorship of "major infrastructure such as pedestrian overpasses," the Department may permit: "third party advertising on the sponsored structure, on free standing advertising devices, or on existing overhead transport structures within the vicinity of the sponsored infrastructure;" in the case of roadside cleaning and/or landscaping, the Department may permit: "the erection of signs, which contain the sponsor's corporate logo, designating the start and end of the sponsored section of road" (p. A-3). Graphic examples are provided which depict a fixed sign displaying a corporate name on a pedestrian overpass, and four examples of signs depicting sponsorship of cleaning or landscaping projects, which are quite similar to FHWA's "acknowledgement signs" (D-14-1, 2 and 3) proposed for the next edition of the MUTCD (Capka, 2005).

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

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

South Africa.

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

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

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

Part B of the regulations contains provisions that are applicable to all advertisements. Section 6, Subsection 1 of this Part (excerpted below) identifies outright prohibitions on the grounds of “road safety and traffic considerations” by stating that no advertisement may:

- Be so placed as to distract, or contain an element that distracts, the attention of drivers of vehicles in a manner likely to lead to unsafe driving conditions
- Be illuminated to the extent that it causes discomfort to or inhibits the vision of approaching pedestrians or drivers of vehicles
- Be attached to traffic signs, combined with traffic signs, … obscure traffic signs, create confusion with traffic signs, interfere with the functioning of traffic signs, or create road safety hazards
- Obscure the view of pedestrians or drivers, or obscure road or rail vehicles and road, railway or sidewalk features such as junctions, bends, and changes in width
- Be erected in the vicinity of signalized intersections which display the colours red, yellow or green if such colours will constitute a road safety hazard
- Have light sources that are visible to vehicles traveling in either direction (p. 12).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Victoria, Australia.

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

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

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

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

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

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

New South Wales (NSW), Australia.

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

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

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

Four lighting zones were classified, generally as follows:

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

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

The Netherlands.

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

The initial work has led to the following recommendations:

- There should be no information that actively attracts attention; this includes no moving objects, no LCD or LED screens, and no moving or changing pictures or images.

- Non-driving related information should not appear within the driver's central field-of-view (less than 10 deg from straight ahead). Based upon an assumption of 300m sight distance, traversed at +/- 9 sec, this results in a prohibition of such signs within 50m of the road edge. Any sign within that boundary must be "extremely simple" and no billboards are permitted.

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

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

- No distractions should be permitted at merges, exits and entrances, close to road signs or in curves (specific constraints will follow)

- No telephone numbers will be permitted

- No fluorescent colors are permitted

- No ambiguity is permitted

- No controversial information is permitted; examples include sex, violence, religion, nudity

- No mixture of real and fake words is permitted.

- Commercial signs must be 90 deg to the road to minimize head turning

- No signs will be permitted that mimic road signs in color or layout

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

Brazil.

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

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

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

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

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

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

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

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

- Advertising signs should be located at a tangent to approaching drivers
- Advertising signs should be no closer than 1000 m from one another on the same side of the road, and no closer than 500 m from the nearest advertising sign on the opposite side of the road.
- The display time of each image on a variable message sign should be long enough to appear static to 95% of drivers approaching it at highway speed
- The message change interval should not exceed 2 s
- The displayed image should remain static from the moment it first appears until the moment it is changed
- No animation, flashing or moving lights should be allowed.
- No message or image that could be mistaken for a traffic control signal should be displayed.
- Messages should be simple and concise.

United States.

New York State.

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

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

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

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

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

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

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

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

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

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

Within 1,100 feet of:

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

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

- A signed curve
- A lane merge/weave area

Within 5,000 feet of:
- Another CEVMS
- An official traffic device that has changeable messages

Primary Highways

Within 1,100 feet of:
- An entrance to or exit from a controlled access highway
- A signed curve
- A lane merge/weave area

Within 5,000 feet of:
- Another CEVMS
- An official traffic device that has changeable messages

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

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

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

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

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

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

City of San Antonio, Texas.

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

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

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

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

City of Flowery Branch, Georgia.

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

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

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

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

Duration of Message – "Each multiple message shall remain fixed for at least the amount of time that would result in one (1) message per mile at the highest speed limit posted

within the 5000 feet approaching the sign for the road from which the sign is to be viewed."

Transition Time – "When a message is changed, it shall be accomplished in less than one-tenth (1/10th) of a second and shall not use fading, swiping, or other animated transition methods."

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

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

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

City of Oakdale, Minnesota.

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

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

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

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

To address concerns of excessive brightness, the ordinance sets a limit of 2,500 Nits during daylight ("between the hours of civil sunrise and civil sunset"), and 500 Nits at nighttime ("between the hours of civil sunset and civil sunrise"), measured from the face of the sign. In addition, signs must have installed ambient light monitors which adjust the

brightness of the sign based on (ambient) light conditions. Further, the sign must have a system that automatically shuts the sign off when the display "deteriorates, in any fashion, 5% or greater until the … sign has been repaired to its fully functional factory specifications." At the time of permit application, the sign owner is required to specify the lamp wattage and luminance level in Nits, and state that the sign will be operated in accordance with City Codes at all times.

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

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

St. Croix County, Wisconsin.

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

Under the ordinance at §17.65 (C)(3)(f), signs with "external and uncolored" illumination are permitted. In addition to typical prohibitions against flashing, moving, traveling, or animated signs or sign elements, the following prohibitions apply to all signs with internal illumination:

- No illuminated off-premises sign which changes in color or intensity of artificial light at any time while the sign is illuminated shall be permitted.

- No illuminated on-premise sign which changes in color or intensity of artificial light at any time when the sign is illuminated shall be permitted, except one for which the changes are necessary for the purpose of correcting hour-and-minute, date, or temperature information.

- A sign that regularly or automatically ceases illumination for the purpose of causing the color or intensity to have changed when illumination resumes (are

prohibited)

- The scope of 3.f's prohibitions include, but are not limited to, any sign face that includes a video display, LED lights that change in color or intensity, 'digital ink,' and any other method or technology that causes the sign face to present a series of two or more images or displays.

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

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

St. Johns County, Florida.

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

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

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

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

Second, the ordinance places specific prohibitions on vehicle mounted advertising. "Signs on vehicles" are prohibited (Section XIV, Subsection 10, p. 26-27) with specific

exceptions such as those for parked vehicles not visible from the street, licensed or certified common carrier vehicles such as buses and taxicabs, vehicles temporarily traveling through the county, or vehicles on which signs are placed that identify the business or its principal product(s) if said vehicle is used during the operating hours of the business, provided that the vehicle is not repeatedly parked in a location where it serves as additional signage.

City of Tucson, Arizona.

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

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

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

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

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

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

Outdoor Advertising Industry

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

- A displayed message appears for no less than four seconds

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

Others

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

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

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

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

Key provisions of the stated criteria are:

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

SECTION 6.

RECOMMENDATONS FOR GUIDELINES

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

MINIMUM MESSAGE DISPLAY DURATION (MESSAGE ON-TIME).

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

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

discussed below, good human factors practice would suggest that minimum display duration should differ with sight distance, prevailing speeds, and other factors.

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

Recommendation.

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

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

INTERVAL BETWEEN SUCCESSIVE DISPLAYS.

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

Recommendation:

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

VISUAL EFFECTS BETWEEN SUCCESSIVE DISPLAYS.

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

Recommendation.

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

MESSAGE SEQUENCING.

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

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

Recommendation.

Message sequencing should be prohibited.

AMOUNT OF INFORMATION DISPLAYED.

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

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

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

There remains, however, a clear distinction between the efforts of highway and traffic safety experts on the one hand and the creators of outdoor advertising sign content on the

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

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

Recommendations.

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

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

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

INFORMATION PRESENTATION.

As discussed immediately above, considerable research in both the US and abroad has produced clear and consistent recommendations for display presentation characteristics that facilitate speed and ease of reading and rapid, unambiguous message interpretation. These recommendations, through years of development and constant refinement have resulted in uniform standards for official signs. The lessons learned from this research, and the adoption of the spirit of such standards by the outdoor advertising industry could produce DBBs that facilitate rapid, error-free reading of roadside advertisements with lower levels of driver attentional demand and distraction. Typeface, font, color and contrast of figure and background, character size, etc., all play a role in the legibility and readability of a display. Figure 6, above, shows the potential difficulty of reading a message presented on a DBB with several display features that are less than optimum for readability by approaching drivers.

Recommendations.

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

DBB Size.

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

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

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

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

Recommendations.

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

BRIGHTNESS, LUMINANCE AND ILLUMINANCE.

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

Brightness is a measure of the *perceived* intensity of a source of light. As described by Halsted (1993), "brightness is a subjective attribute of light to which humans assign a label between very dim and very bright (brilliant). Brightness is perceived, not measured… The response is non-linear and complex. The sensitivity of the eye decreases as the magnitude of the light increases" (p. 2). A DBB is constructed of thousands of Light Emitting Diodes (LEDs) that operate together to produce the myriad colors and levels of light that we see when we view such a sign. Thus, we may consider a DBB to be a source of light, although, in actuality, it is built of many individual sources. If we were to set a DBB to its maximum output and observe the sign in full sunlight, it would appear less bright to the human observer than it would if we viewed the same sign, at the same setting, at night. Similarly, if we viewed the sign at the same setting at night in a bright urban landscape it would appear less bright than if we viewed it in a dark rural environment. Accordingly, when trying to develop guidelines or requirements for the "brightness" of DBBs, what we really mean is that we need to establish objective, measurable limits on the amount of light that such billboards actually emit, and set different upper bounds for different environmental and ambient conditions. Such

conditions might include daylight in sun or clouds, dusk and dawn, adverse weather such as rain or fog, and nighttime conditions in urban, suburban, or rural settings. In short, "brightness" cannot be used as a criterion to regulate or provide guidance for the output of DBBs.

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

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

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

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

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

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

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

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

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

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

The report describes the IESNA recommendations (Rea, 2000) for "illuminated billboard signs and other large advertising panels" (i.e. the dedicated, fixed lighting shining on the billboard to illuminate it at night) and identifies two factors that must be considered when applying these values. The first is the degree of reflectivity of the billboard itself – a dark-colored sign will reflect less light than will a light-colored sign (assuming that the lighting sources are equal). The second is the surrounding location – whether the billboard is located in a bright, typically urban, setting, or in a dark, typically rural setting. The IESNA values for billboards in bright surroundings is 1000 lux (abbreviated lx), and for dark surroundings, 500 lx. Assuming that a billboard had a white sign face

with a reflectance of 0.8, the luminance (L) of such a billboard (the amount of light reflected back from the sign) would be 250 candela per square meter (cd/m^2) in the bright environment, and 130 cd/m^2 in the dark setting. The authors then reviewed product information supplied by two billboard manufacturers and concluded that industry recommendations were in close accord with those recommended by the IESNA.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

TERS describes its luminance measurement methodology as summarized below:

- Allow the billboard to "burn in" for at least 100 hours.

- Use a luminance meter with a field of view of 2 degrees.

- Ensure that no ambient background area or spurious light source beyond the billboard is included in the field of view of the luminance meter.

- Take the measurement with the operator standing at the edge of the traveled way, in a direct line, and at a longitudinal distance from the billboard determined by a formula shown as:

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

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

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

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

Recommendations.

The measurement of luminance is reasonably straightforward, and, although there are some technical disagreements on how this measurement should be made, these differences are minor. Both New York State (Bullough and Skinner, 2008) and the Queensland (Australia) government (TERS, 2002) use equivalent methods, which are similar to the approach recommended by an FHWA expert in this field (Andersen, 2008b).

These methods can be adopted for use by any jurisdiction, with two caveats. First, although Queensland has explicitly recognized the need for different maximum billboard luminance levels depending upon different roadway environments, such ambient lighting conditions in the U.S. may differ from those in Australia, and State and local jurisdictions may wish to define their environmental surroundings to be in closer accord with local conditions “on the ground.” Second, given that luminance standards must establish maximum acceptable levels, it is important that the any measurement of DBBs in the field be done with the signs set to their maximum output, i.e. displaying a completely white screen. Because digital billboards can display an essentially infinite variety of colors and patterns, it is not appropriate to take field measurements of signs displaying actual messages, since, at any given time, such messages may not represent the maximum luminance values of which the sign is capable. (Figure 6 shows a DBB which, because of its color, may be representative of a low luminance level).

The OAAA, in its “Code of Principles on Digital Billboards” (OAAA, 2008) makes the following statement with regard to DBB luminance:

> We are committed to ensuring that the ambient light conditions associates with standard-size digital billboards are monitored by a light sensing device at all times and that display brightness will be appropriately adjusted as ambient light levels change.

Although not included within its code of principles, the OAAA (2008) states:

> The outdoor advertising industry has established guidelines after commissioning research by Dr. Ian Lewin, a former chairman of the Illuminating Engineering Society of North America (IESNA). Digital billboards, according to the standards, should have lighting levels no more than 0.3 foot candles (fc) above the level of surrounding ambient light conditions."

Unfortunately, this research study is not available on the OAAA website, and OAAA officials refused our request for access to Dr. Levin's research. The language reported by the organization on its website, however, suggests two problems with their approach. First, they used illuminance as their measurement technique, whereas other organizations used luminance. Second, the OAAA expert apparently recommended that DBBs be controlled such that their maximum display output is capped at a fixed amount (0.3 fc) greater than the surrounding environment. This specification may be inappropriate because illumination levels do not increase in linear fashion. Thus, a DBB with an output that is 0.3 fc higher than the ambient illumination in an urban environment (where the majority of DBBs are likely to be located) will appear to the driver to be much brighter than official TCDs and other traffic, whereas a DBB with an output that is 0.3 fc higher than that of a suburban or rural environment may not appear to be so extremely bright, and may be less likely to overwhelm important safety targets and signals of lower luminance.

There is one ambient lighting/weather condition that suggests a need for an exception to the recommendations that DBB luminance controls are unnecessary in daylight. This exception occurs during daytime fog. In daytime fog, the ambient lighting conditions may be described as high brightness and low contrast. The water vapor in the atmosphere scatters light sources and may cause glare. In dense fog, drivers may have difficulty seeing vehicles ahead of them, even when these vehicles have their lights on. Multi-vehicle crashes are not infrequent in dense fog, and this is often attributed to drivers being unable to see vehicles ahead of them in sufficient time and distance to stop. The very high luminance levels of which modern DBBs are capable, and to which they are typically set during daylight so as to be visible in full sunlight, may have a potentially deleterious effect in fog, especially if the DBB is placed so that it is close to the center of the driver's focal vision upon approach, such as might be the case on a horizontal curve

As recommended by the OAAA, DBBs should be equipped with sensors that measure ambient brightness, and dimmers that can control the sign output to predetermined levels. Although necessary, this is not sufficient. These predetermined levels should be established by the means suggested above. Further, if the onboard sensors cannot detect daylight fog and adjust the sign's output accordingly, jurisdictions should develop their own output limitations for these conditions.

The good news is that regulatory bodies and billboard companies seem to reach similar conclusions about the maximum luminance values that billboards should not exceed under defined conditions. If these two stakeholder groups can agree upon measurement

methods, environmental descriptors, and means for ensuring that limits are not exceeded, one of the key concerns about the distraction potential of DBBs could be close to resolution.

DISPLAY LUMINANCE IN THE EVENT OF FAILURE.

There are a number of failure modes that can affect the luminance of a DBB, and there have been reported cases of failures in which the display luminance defaulted to a level far higher than intended or permitted.

Although, as discussed above, the OAAA provides guidance on its website and in periodic reports about suggested upper limits on display luminance (which it calls brightness, and suggests that DBBs include a device to automatically control the sign brightness relative to the ambient environment, the organization is silent on the issue of luminance control in the event of system or subsystem failure.

Recommendations.

Roadway authorities should incorporate into their guidelines verifiable requirements that, in the event of any failure or combination of failures that affect DBB luminance, the display will default to an output level no higher than that which has been independently determined to be the acceptable maximum under normal operation. If this cannot be achieved, then the display should be required to default to an "off" position until the problem can be resolved.

LONGITUDINAL SPACING BETWEEN DIGITAL BILLBOARDS.

As noted by the OAAA, different States have widely varying longitudinal spacing requirements for billboards in general and DBBs in particular. These requirements are typically described by the distance in feet that the nearest billboards must be spaced from one another. Often there is a different spacing requirement for billboards on opposite sides of the road. From the perspective of potential driver distraction, however, longitudinal billboard spacing should not be based on absolute distance, but upon whether two or more such billboards are within the driver's field of view at the same time, and, consequently, whether the unsynchronized changing messages on such billboards can distract by conveying the appearance of flashing. Accordingly, longitudinal spacing minima may vary depending upon prevailing travel speeds, sight distance, and topography, and thus may vary considerably from one location to another, even within the same jurisdiction.

Recommendations.

Governments or roadway operating authorities should establish minimum longitudinal spacing requirements for DBBs such that an approaching driver is not faced with two or more DBB displays within his field of view at the same time. This minimizes the risk of distraction and ensures that a flashing effect (that may be caused by two [or

more] different signs cycling through messages on different programs) will not occur. Any such longitudinal spacing requirements should address signs on both sides of the roadway. If a consistent spacing requirement is appropriate or necessary within any particular jurisdiction, then the most conservative spacing consistent with the above requirements should be established.

DBB PLACEMENT WITH RELATION TO TRAFFIC CONTROL DEVICES AND DRIVER DECISION AND ACTION POINTS.

Beyond the design and operational characteristics of DBBs themselves (brightness, display duration, etc.) perhaps the most important DBB characteristic with impact on traffic safety is the placement of such signs in relation to driver decision and action points, and to the traffic control devices (signs, signals and markings) that aid drivers in these decisions and guide them in these actions. Specifically, it is understood that the cognitive demands on drivers is greatest (other factors held constant) when they must position themselves to take an exit, enter a freeway, reduce or drop lanes, merge with other traffic, change route, etc..

The independent research reviewed for this report recognizes the importance of such constraints almost without exception, and the many jurisdictions, in the U.S. and abroad, that have published guidance and/or regulations nearly all address these concerns. And although these guidelines and restrictions are not fully consistent across regulatory agencies, they are remarkably similar. Although some published guidance and regulation is too vague to be useful in terms of enforcement potential or proven safety benefits. Others may well serve as a model that State and local governments, and other roadway authorities might adopt.

We believe that the adoption of objective constraints for DBB placement in relation to official TCDs, to intersections and interchanges, and to decision and action points is firmly justified because, to a great extent, the design and placement of TCDs themselves is the result of empirical research that has led to nationwide standards. Similarly, the design of intersections and interchanges, and of roadway design for safe and efficient traffic movements, is based on long-standing, well-researched, thoroughly documented principles. Accordingly, we believe that prohibitions against the placement of distracting irrelevant stimuli in roadway settings where drivers must make decisions and take actions should be imposed.

Recommendations.

The guidance provided by the government of Queensland, Australia is particularly well researched and documented, and might serve as a basis for US highway agencies. Similarly, the recommendations promulgated in New South Wales, Australia, are relevant, as is the guidance developed in South Africa, with specific regard to the placement of DBBs relative to official traffic signs.

ANNUAL OPERATING PERMITS.

There are several reasons why a Government agency or toll road or other roadway operating agency might want to rescind the operating permit for a DBB after initial approval. For example, traffic delays, crashes, or other operational difficulties may increase and the authority may attribute such difficulties to the presence or operation of the sign. New technologies may become available and used on the sign that the authorities find inappropriate. The sign may experience frequent failures or misoperation. The road abutting the sign may need to handle increasing traffic, or may need to be upgraded with additional lanes, interchanges, or signage, placing the DBB, after the fact, in a location that the authorities believe to be unsafe.

The City of Oakdale, Minnesota, as discussed in Section 5, grants annual permits to operate DBBs; the permits must be renewed each year. This allows the City to maintain oversight of sign operation, and facilitates updates to controlling legislation should new technologies emerge or should new operational data or research findings suggest needed changes to sign location or operation. Without such a process, a permitted sign may continue to operate unchecked, regardless of whether new information would suggest modifications to placement or operation.

Recommendation.

Government agencies and roadway operating authorities might consider the practice adopted in Oakdale, Minnesota, whereby owners of DBBs are granted a permit to operate a sign for a year, and must renew the permit annually.

SECTION 7.

DIGITAL BILLBOARDS ON-PREMISE AND ON THE RIGHT-OF-WAY

Digital Billboards as On-Premise Signs.

On-premise signs, those that advertise products or services that are available on the property on which the sign is located, have been a mainstay in the US for generations. The objectives of the current project were to "develop guidance for state DOTs and other highway operating agencies with respect to the safety implications of the digital display technology for outdoor advertising signs." Traditionally, outdoor advertising signs refer to billboards, also known as off-premise signs. As such, on-premise signs are outside the scope of this report. However, to the average motorist, the difference between billboards and on-premise signs is transparent. In addition, as the cost of LED display technology comes down, and as the power of this technology grows, it becomes more likely that roadside businesses, particularly those with multiple users such as shopping centers, auto malls, sports complexes, and entertainment venues, will increasingly install large digital advertising signs on their property.

Generally, despite the fact that such displays may use the same technologies as billboards, the owners/operators of these signs are represented by different organizations, and they have been regulated quite differently than have roadside billboards. On-premise sign regulation is typically accomplished through local zoning codes, and may, in general, be far more variable and likely less stringent with regard to the means of the display, display characteristics, or the size of the sign than comparable controls on billboards. Many such codes have changed little in recent years, despite the growth of digital technology for on-premise displays.

From the traffic safety perspective, it is possible that the risk of driver inattention and distraction is higher for some on-premise signs than for some DBBs, because on-premise signs may be larger and closer to the road, mounted at elevations closer to the approaching driver's eye level, and placed at angles that may require excessive head movements, In addition, many such signs may display animation, full motion video, sound, and other stimuli.

To our knowledge, the largest digital advertising sign in the world is an on-premise sign, mounted on the roof of a grocery warehouse and store in New York City. This sign, shown in Figure 7, is 90 ft tall by 65 ft wide[15], and is mounted on a 165 ft tall steel post on the roof of the warehouse, adjacent to a major interstate highway. The sign, claimed to be visible for over two miles, was recently used during a five-month period to present a rotating series of 19 animated spots for a local magazine. The animation took advantage of the "billboard's ability to display high-impact full motion video and graphics." The

[15] The face of this sign measures 5,850 sq ft, nearly nine times the size of a typical roadside DBB.

president of the company that created the commercials said: “It’s really a blast to be driving around the city and suddenly see your work looming over all of this traffic entering and leaving the city” (Black Hammer, Undated).

Figure 7. The world’s largest LED sign; an on-premise sign in New York City. The sign measures 90 ft tall by 65 ft wide and is mounted on a 165 ft tall steel post on the roof of building.

For transportation agencies and traffic safety organizations concerned about the risks of driver distraction, digital on-premise signs should not be overlooked as a potentially important near-term concern.

Strictly from the perspective of driver safety, agencies might want to consider restrictions for on-premise sign operations at least as rigorous as those for billboards, as well as restrictions on size, height, proximity to the right-of-way, and angular placement with regard to the oncoming driver’s line of sight. Of all of the guidelines proposed in this report for DBBs, there may well be an equal or greater need to consider similar controls for on-premise signs. In addition, consideration must also be given to such signs’ capacity for animation, flashing lights or other special effects, and full motion video.

DIGITAL BILLBOARDS WITHIN THE RIGHT-OF-WAY

On October 10, 2008, Nevada Director of Transportation, Susan Martinovich, transmitted an SEP-15 project application to FHWA’s Nevada Division Administrator, Susan Klekar, titled: “Auctioning Rights to Construct Enhancements on and within Roadway Interchanges” (Martinovich, 2008).

The heart of the proposed program is the "enhancement" of selected interchanges by private partners that have submitted the highest or best value bids to the State. The application suggests that these enhancements may include landscaping, "architectural facades such as archways, public art or other aesthetic features" (p. 2). In exchange for developing and constructing these enhancements (and, it is suggested, removing them at the end of the lease term) the winning bidder "would be allowed to advertise within the interchange right of way limits" (p. 2). Although the application places no restrictions on the type of advertising that might be considered, the State suggests that this advertising might likely take the form of "incorporating the private partner's trade name, trademark, logo or other similar device into the design of the proposed enhancements" (p. 2).

The application States: "No design or enhancement would be accepted that would create a safety issue for motorists or pedestrians" (p. 2), and "safety will be foremost. No design will be allowed that will compromise safety" (p. 5). Given that the State proposes no *a priori* assessment of potential safety impacts, that the installations will be in place for 10 or more years, and that the only suggested safety analysis would be an undefined comparison of accidents; it is difficult to understand how this commitment to safety could be fulfilled.

Further, although the State's application does not mention that any of the potential enhancements will involve electronic signage, neither are such displays foreclosed. In fact, the final paragraph of the application states: "The tourism based economy of Nevada relies on spectacular displays, be they man-made or natural. Such exceptions (sic) of grandeur make this program an ideal match" (p. 9). When the recognition of man-made spectacular displays is associated, as this proposal is, with "context sensitive design," the potential for the types of enhancements that are associated with Las Vegas and Reno cannot be discounted.

On August 27, 2008, the Director of the California Department of Transportation (Caltrans) wrote to the Secretary of the US Department of Transportation seeking support for the expansion of its efforts "to integrate private sector participation in the provision of infrastructure, service, and ongoing maintenance of the State's transportation system" (Kempton, 2008). One of the "potential opportunities" for such partnership was described as follows:

> The Department's system of changeable message signs could be enhanced through private sector participation. In exchange for use of the space on the signs for commercial purposes, businesses could enhance the level of graphics, provide a steady income source, and use state-of-the-art technology to increase the quality of transportation and safety-related messages that are relayed to the signs.

At the time of the Caltrans request, the popular press (see, for example, McGreevy, 2008, Miranda, 2008) reported that the initiative was proposed by Clear Channel Outdoor, one of the country's largest providers of DBBs. The Caltrans proposal has raised numerous concerns within the highway safety community. A significant concern is that this

initiative, if it went forward, would be in direct violation of several key sections of the Manual of Uniform Traffic Control Devices (MUTCD, 2003). Examples include:

> Traffic control devices or their supports shall not bear any advertising message or any other message that is not related to traffic control" (p. 1A-1).[16]
>
> Changeable message signs shall display pertinent traffic operational and guidance information, not advertising" (p. 2E-20).
>
> When a changeable message sign is used to display a safety or transportation related message, the display format shall not be of a type that could be considered similar to advertising displays. The display format shall not include animation, rapid flashing, or other dynamic elements that are characteristic of sports scoreboards or advertising displays (p. 2A-3).

Other sections of the MUTCD, including those that address signage that might be considered closer to messages that are commercial in nature, nonetheless prohibit advertising. For example:

> The content of the legend on each panel (of a Tourist-Oriented Directional Sign) shall be limited to the business identification and directional information for not more than one eligible business, service or activity facility. The legends shall not include promotional advertising" (p. 2G-1).

Indeed, in official interpretations of the MUTCD and its purposes over the years, the FHWA has consistently taken a strong position in opposition to advertising within the right-of-way, and has supported its views with the legal opinion of its chief counsel.

For example, in 2001, in a policy memorandum addressing the purpose of "Adopt-a-Highway" signs and their treatment in the MUTCD, then FHWA Deputy Executive Director Vincent F. Schimmoller stated, in part:

> Recently, it has come to our attention that there are a significant number of Adopt-a-Highway signs throughout the country displaying commercial trade logos, slogans, telephone numbers, Internet addresses, and similar forms of commercial promotion… These signs are clearly intended for advertising to the passing motorists rather than acknowledging the litter pickup service of an organization for which the program was intended…These actions concern us and we would like to clarify Federal Highway Administration's (FHWA) position on this subject.
>
> Adopt-A-Highway signs displaying commercial trade logos, slogans, telephone numbers, Internet addresses, and similar forms of commercial promotion are not in conformance with the 2000 MUTCD.

[16] Note that this "Standard" is the very first requirement specified in the MUTCD and is included in Section 1A.01, titled: "Purpose of Traffic Control Devices."

> Further, the placement of commercial advertisement within the roadway rights-of-way is a violation of Federal law and regulation…. Allowing the use of commercial advertising signs along the roadway is a disservice to the traveling motorist who is relying on roadside signs for regulatory, warning, and guiding information. The Specific Sign Logo program and the Tourist Oriented Destination Sign programs, which are in compliance with the MUTCD, have been developed to provide guidance information to the traveling motorist.

This memorandum was supported by an attached legal opinion from the FHWA Chief Counsel (Malone, 1996). This document stated, in part:

> Signs erected solely as advertising signs do not fit any of the accepted categories of the MUTCD. They certainly do not regulate or warn motorists. Nor do they "give such information as will help them [motorists] along their way in the most simple, direct manner possible"… They are not concerned with promoting "the safe and efficient utilization of the highways"…Advertising signs on the right-of-way therefore are not approved signs under the MUTCD.
>
> It would be ludicrous to suggest that Congress, while mandating the States to control advertising along thousands of miles of Interstate and Federal-aid primary highways, would also allow the States to erect billboards on the rights-of-way of those same thousands of miles of highway.

In closing, the Chief Counsel expressed his belief that "FHWA clearly has the authority to withhold funds from a State that allows the erection of billboards on the rights-of-way, an act which constitutes a failure to comply with Title 23 requirements."

More recently, Federal Highway Administrator Peters (2003) issued in interim policy on Acknowledgment Signs on rights-of-way. She said, in part:

> The FHWA recognizes a distinction between signing intended as advertising and signing intended as an acknowledgment for services provided.
>
> With regards to advertising signs within the highway right-of-way, the FHWA reaffirms its long held position that advertising is not permitted on highway rights-of-way.
>
> Generally speaking, an advertisement has little if any relationship to a highway service provided. The advertiser wants to get its recognizable company emblem or logo before the motoring public, and, if possible, information on how or where to purchase the company products or service. If the acknowledgment sign goes beyond recognizing the company's contribution to a particular part of the highway and includes phone numbers or Internet addresses, the sign would more properly be termed an advertising sign.

Even in her recognition of the acceptable role of acknowledgment signs in specific applications, Peters stated that "a compelling responsibility for public safety" leads the FHWA to find certain locations inappropriate for such signs, including "on the front, back or around the perimeter of any traffic control devices, including but not limited to:

- Traffic signal heads and supports,
- Any regulatory, guide or warning sign,
- Changeable message sign,
- Traffic control device posts or structures
- Bridge piers
- At any site where the acknowledgement sign would obscure the ability of a driver to detect and understand existing traffic control devices."

Further, she stated that such signs would be "inappropriate and not allowed on public highways…at key decision points where a driver's attention is more appropriately focused on traffic control devices or traffic conditions. These locations include, but are not limited to:

- Exit and entrance ramps and other lane-weaving areas
- Highway-rail grade crossings
- Work zones
- Areas of limited sight distance

In short, FHWA's ongoing policy, and its interpretation of the MUTCD and the legislation at 23 U.S.C. § 402(a) and § 109(d) under which the MUTCD was promulgated, have clearly expressed opposition to advertising of any kind within the right-of-way. Regardless of any benefits from the public-private partnerships that California and Nevada have suggested, and regardless of any State budgetary difficulties that might be eased by revenue from such partnerships, FHWA's position against advertising on the right-of-way has been consistently and, we believe, appropriately, based on its interpretation of the Federal Highway Administrator's authority to decide which signs "promote the safe and efficient utilization of the highways" (Malone, 1996).

Other highway and toll road operating authorities have been approached by advertising companies (see, for example, Dudek, 2008, p. 35), or have independently considered the use of outdoor advertising on new or existing signage within their rights-of-way (see, for example, The Port Authority of New York and New Jersey (PANY, 2006). There can be

little doubt that an official acceptance by FHWA of the ideas promulgated by California or Nevada in their recent SEP-15 initiatives would have important ramifications nationwide. Indeed, there is concern that some roadway operating authorities may not wait for FHWA action and may consider taking steps to approve advertising on their rights-of-way regardless of FHWA's position. The FHWA legal opinion discussed above (Malone, 1996) came in response to "a decision by the New Jersey Turnpike Authority to erect 12 double-sided billboards in the right-of-way of the New Jersey Turnpike…" And the PANY Request for Proposal advised proposers that "for the purpose of this analysis, the Consultant shall assume that the Authority is exempt from local, State, and Federal regulations, including FHWA policy" (Attachment A, Page 1).

Whether the placement and operation of DBBs within the right-of-way is a safety concern is an issue that is central to the present report. In addition, the precedent that would be set by the installation of such signs has important ramifications for the nation's highway system, and for the continued role of the MUTCD as the national standard for the design and use of official traffic control devices on streets and highways. Although a discussion of the history, development, and impact of the MUTCD is beyond the scope of this report, it bears comment that the document is unambiguous when it comes to the potential for commercial messages to be displayed on official signs.

It is the opinion of this author that permitting California to study its proposed exceptions to the requirements of the MUTCD and existing Federal law would bring about several adverse consequences:

- It would undermine decades of human factors research and application that ensures that information important to the driving task is conveyed to the motorist in the most clear, concise, succinct and unambiguous manner possible.

- It would set a dangerous precedent that would lead to similar actions by State and local governments, toll roads, and other private road operators nationwide.

- It would open to challenge the entire basis of the MUTCD, and erode confidence in and respect for the country's only standard for the proper use of traffic control devices on streets and highways.

And, most significantly, it would likely diminish safety and traffic flow on our streets and highways through a direct and immediate increase in driver inattention and distraction.

SECTION 8.

NEW TECHNOLOGY, NEW APPLICATIONS, NEW CHALLENGES.

This project has been focused on the impact of commercial electronic (digital) roadside signs on traffic flow and safety. Such signs, known as billboards in some jurisdictions and off-premise signs in others, are typically located outside the right-of-way, on private property, and they advertise products that are not sold, or services that are not performed on the property on which the sign is located. Billboards, regardless of the technology used to present and change the display, differ from on-premise signs in that the latter must be, generally, located on the premises at which the advertised service is performed, or product sold.

During the course of our research for this project, we learned of the growing use of new applications that increase the power and/or functionality of these digital, predominantly LED signs. These new applications have begun to appear on billboards in the US and abroad, on mobile (vehicle-mounted) displays, and on on-premise signs. Although some of these applications fall outside the charter of this project, this report would be incomplete without mention of them.

In most cases these new technologies and new applications are not addressed in Federal or local regulations and guidance; in some, regulations have already been imposed to address them. In a third category, some new developments appear to be in direct conflict with existing regulations or guidance. This chapter, although not contemplated when this project was initiated, will provide a brief overview of these new technologies and applications.

Billboard Audio and Other Stimuli.

Digital outdoor advertisements are already in use in some US locations that broadcast audio along with their visual messages. It is not unreasonable to assume that audio, and perhaps other attention-getting stimuli, may appear in the future. Internationally, we are aware that the SANRAL (2000) regulations recognize this potential, and prohibit it. Part B, Subsection 4 states: “No advertisement will be allowed that emits a noise, sound, smoke, smell or odours” (p. 13). In the U.S., both St. Croix County, Wisconsin, and the city of Tucson, Arizona, have similar requirements.

Digital Billboards on Moving Vehicles.

Vehicles in the traffic stream, primarily commercial trucks, have long borne advertisements for the truck owner or for the products being carried. One might think of these as mobile “on-premise” signs. In some cases, “supergraphics” (although, not, to our

knowledge, digital) have been demonstrated that can convert trucks or large, over-the-road trailers into dramatic mobile visual images. One example is shown in Figure 8.

Figure 8. An over-the-road trailer featuring “supergraphic” imagery.

Urban and suburban taxicabs, buses, and rail transit vehicles may also display advertisements, and increasingly, these advertisements feature LED signage. These are the equivalent of mobile “off-premise” ads in that they advertise a product or service that has nothing to do with the vehicle displaying the ad.

For example, as part of its “Prepare Bay Area,” earthquake preparedness campaign, the (San Francisco) Bay Area Chapter of the American Red Cross faced a truck with a two-sided artist’s rendering of what downtown San Francisco might look like after the next earthquake. The truck drove around the city to attract attention, then parked at a location where the billboard lined up perfectly with the existing streetscape, as shown in Figures 9a and 9b.

Figure 9a. A mobile billboard from the (San Francisco) Bay Area Chapter of the American Red Cross parked in front of a building, depicting what might happen to that building after an earthquake.

Figure 9b. The same mobile billboard shown in Figure 8a looking in the opposite direction.

In the past few years, a number of products have become available that take advantage of the latest technologies to incorporate LED billboards onto the sides and rear of commercial trucks. In many cases, the sole purpose of such vehicles is to serve as a rolling advertisement; in others, the truck may display advertising while in transit, then park at a specific location to use its large-screen display in support of a concert, sporting event, parade, or other special function. In the latest advances, these signs can be raised electrically or hydraulically above the roof level of the truck; in some cases they can also rotate 360º. One company, named GoVision, advertises that its vehicles can display full

motion video while in moving traffic. Indeed, news reports indicate that this occurred recently in Boston. On its website (www.govision.com) the company describes two products, a 40 ft trailer with a 9 ft high by 16 ft wide LED screen, and a 48 ft trailer equipped with a 627 sq ft, high definition video (720p resolution) wide LED screen.[17] The smaller vehicle, with its LED screen blank, is shown in Figure 10.

Describing this "moving television" product, the company suggests these uses:

- Get stuck in morning traffic playing a breakfast products commercial
- Drive around a sporting event's traffic promoting the new high powered SUV
- Add GoBig to your Xmas parade playing the latest holiday movie clips

Figure 10. A 40 ft trailer with an integral LED video screen measuring 9x16 ft. The screen shows full motion video while the truck is moving in traffic, and can be raised to a height of 25 ft for viewing while parked.

In other, less dramatic examples, several urban and suburban commuter bus and rail systems have begun to integrate digital billboards onto the sides of their vehicles. Figure 11 shows an urban transit bus displaying a digital advertisement.

[17] A standard size highway billboard, conventional or digital, measures 672 sq ft.

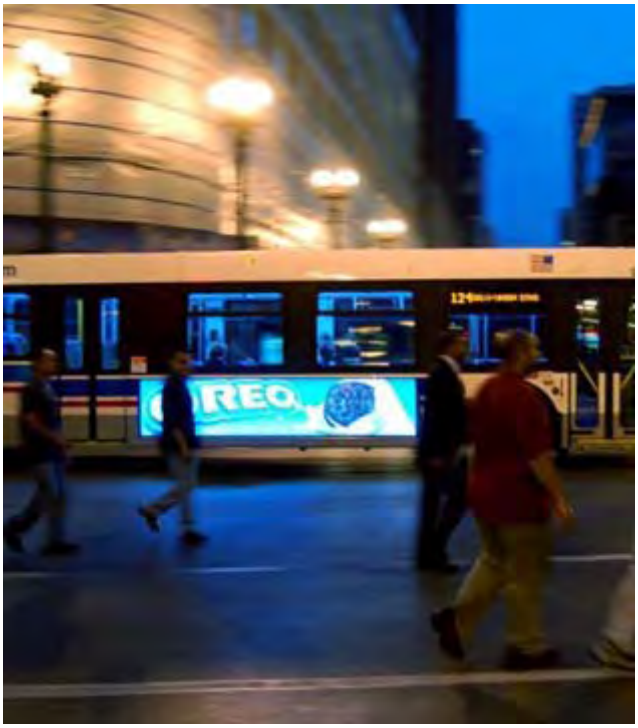

Figure 11. An urban transit bus displaying an LED billboard in traffic.

Although we are unaware of any research that has been conducted to evaluate these mobile display units, it would seem that the potential for driver distraction from the use of this technology within the traffic stream is quite high, not only because the changeable (and video) signs are in physical motion, but also because the presence of the advertising signage at extremely close lateral distances may require an extreme eye and/or head movement for the sign to be seen.[18]

As discussed earlier in this report, several jurisdictions have recognized or anticipated the risk of vehicle-based advertising, and have imposed restrictions on its use. In some cases, these controls are also directed at such vehicles when they are in operation while parked adjacent to roads visible to passing drivers within the jurisdiction's control. See, for example, the ordinances of St. Johns County, Florida, and Tucson, Arizona, discussed in Section 5.

[18] It is noted that digital display technology using LEDs is also being marketed to the general public as a mechanism both for "personalizing" a vehicle, or for "marketing," "while providing automobile owners with an opportunity to profit from driving their vehicle." (See, for example, LED Wheels, 2004). Although there is clear potential for driver distraction from such vehicle-mounted digital imagery, it is beyond the scope of this project to determine whether such applications would constitute commercial advertising and thus be subject to the controls in place in certain jurisdictions and which may be considered for adoption in others.

“Personalized” And Interactive Billboards.

Interactive billboards, those that permit, support, or encourage personalized communications with the driver *in real-time*, have begun to appear on US roads, although this technology seems to be more progressing more quickly in Europe. Made possible by newer and ever more sophisticated technologies include cellular phones, text messaging, RFID, infra-red cameras, and others, these DBBs may take several different forms. These are briefly discussed below.

a. Signs that convey a personal greeting to the driver.

The popular Mini Cooper automobile, owned by BMW Corporation, has introduced a series of billboards in major US cities that display a static image of the automobile, along with a one line digital display that is normally blank. However, if the owner of a Mini Cooper has “opted in” by expressing an interest in the program, the sign’s digital display will present a “personal greeting” to the approaching driver. Figure 12 illustrates one of these billboards in use in New York City.

Figure 12. Personalized Mini Cooper billboard.

b. Signs that interact with the driver in real time.

In Paris, a trial has begun in which cell phone users who have agreed to participate will receive phone calls from billboards (Christensen, 2006; Crampton, 2006). These calls will offer additional product information, promotions, etc., that are keyed to the users’ location-enabled cell phones. The enabling technology was originally developed by the French National Institute for Research in Computer Science and Control to provide assistance to disabled people. According to the outdoor advertising

company that is running the project: “With this project, we are really starting to create the personalized digital city… We eventually will see a rich dialogue running between mobile phone and what are now uncommunicative objects.”

In Belgium, as a driver approaches the digital billboard shown in Figure 13 the sign displays a series of codes. The driver chooses one, and sends a text message to an indicated number. The billboard responds by sending a return message containing a question. The driver then texts his answer to the question. The answer, in turn, triggers the DBB to respond like a pinball machine. A correct answer causes the sign to light up, and the driver is entered into a drawing (in this case, for the pictured car); a wrong answer causes the sign to “tilt”

Figure 13. Interactive billboard in Belgium. See text for details of the sign’s operation.

c. Signs that unobtrusively obtain information from drivers and vehicles.

Adjacent to an exit ramp along US 99 in Turlock, California, a “smart” 20 ft by 30 ft high-definition DBB (Figure 14) monitors the passive “local oscillator” signals emitted by the FM radios of passing vehicles. These signals reflect the frequencies to which the radios are tuned. The system compiles the statistical data, merges it with a media audit database that contains detailed consumer demographic and purchasing pattern information coded by radio station format, and enables the sign to post ads targeted to that demographic. “Smart Signs could inform passing motorists about special offers to shoppers as they approach stores or malls. A Smart Sign could entice consumers to respond via text message to a question posed by the sign. Information can even be pulled off the internet and displayed” (Christensen, 2007).

Figure 14. A “smart” DBB in Turlock, California

Many digital billboards have been equipped with video cameras that can record approaching traffic. A recent service aimed at the outdoor advertising industry permits an inconspicuous billboard-mounted camera, supplemented with an infra-red surround lighting device, to record the eye-movements of drivers approaching the sign (Skeen, 2007). Although this service is currently offered as a means to demonstrate to sign owners the amount of driver attention being given to their sign and its specific messages, it is a small technological step to combine these eye movement recordings with other demographic or personal information to target personalized messages or provide other “services.”

DBB Hacking.

One concern about DBBs, unlike any other in this report, is the potential for computer “hackers” to break into the control or communications system for these displays and change the messages and images displayed. For many years, loosely organized groups like the Billboard Liberation Front have made commercial billboards their targets for mischief. The type of technology that wirelessly controls DBBs has proven vulnerable to such vandalism, although reports of such hacking have been disputed.

Related technologies, such as those used for official portable changeable message signs (PCMS) have been successfully hacked in different jurisdictions on several occasions. Just before this report was finalized, the popular news media reported on a series of such hacks at a construction zone in Austin, Texas (Miller, 2009). Figure 15 shows one PCMS that was affected by this activity. At the same time, several websites published detailed instructions on how to perform such hacks (see, for example, Wojdyla, 2009). Although this latest example of vandals hacking into digital signs was quickly fixed by the sign manufacturer, the fact remains that roadside digital control technology is susceptible to being taken over by criminals or pranksters intent on changing the messages and images

displayed on the signs for their own amusement, political or social purposes, or for other reasons. DBB owners and operators should be alert to these challenges, and should design, develop and implement corrective actions. Government agencies responsible for the regulation and oversight of such signs should ensure that any potential vulnerabilities are protected against.

Figure 15. A portable changeable message sign (PCMS) that was “hacked.”

SECTION 9.

SUMMARY AND CONCLUSIONS

This project has focused on three overlapping pillars of support in its effort to develop suggested guidelines for the control of DBBs: (a) human factors practices and principles; (b) guidelines and regulations currently in place in the US and abroad; and (c) the research literature.

Human factors principles have been developed over many years through empirical research, and have seen applications in practice regarding road safety throughout the developed world. Such principles and practices are codified in standards such as the MUTCD and SARTSM, to name but two, which were reviewed for this report. The wisdom of such human factors practices and principles is tested daily on streets and highways, and they are constantly being modified or supplemented when a "better mousetrap" is developed through research (recent examples include the development and implementation of the Clearview font for road signs, and the growing use of wider pavement markings to accommodate our ageing driver population).

And, in the guidelines and regulations that we reviewed, it was rewarding to learn that many of them, too, come from a solid research base. Examples of these empirically grounded guidelines include those in South Africa, Queensland, Australia, and The Netherlands (currently under development). Of course, some guidelines and regulations, even though based on sound research, either don't get enforced, or don't make it out of the draft stage. Thus, one of our goals has been to seek out the best supported and most practical guidelines that have been promulgated, review them based on their grounding in research and/or sound human factors practice, and hold them out as candidates that might serve as models for others to consider.

Our comprehensive and critical review of the literature focused on studies undertaken since the FHWA report of 2001, with the addition of several earlier studies that were included because of their relevance and because they were not previously given in-depth consideration in this context. As required by the program Statement of Work, we also separately reviewed research undertaken by or on behalf of the outdoor advertising industry.

Unfortunately, this issue is enormously difficult to study. This is because every billboard, road, and driver is different. A study evaluating a four-second message display interval might obtain quite different results from one using eight-seconds. A study in daylight will almost certainly find different driver responses than the identical study conducted at night. And a study conducted with free-flowing traffic may have a different outcome than one that examines the same road and the same billboard when traffic demands are greater. In addition, the key selling point of DBBs is that they can change messages every

few seconds, and it is technically possible for them not to repeat the same message during a several hour cycle. Thus, studying such billboards *in situ* confronts the researcher with the added problem that it may be difficult to compare the experiences of any two (or more) drivers as they pass the DBBs under study for the simple reason that these drivers will, in all likelihood, experience signs with different content, different brightness levels, different graphics, and different font styles and sizes. This suggests that laboratory studies, despite what we believe to be important limitations, may permit better control over these inherent sign design and operational variables. Another alternative, not yet attempted with DBBs to our knowledge, involves a cooperative effort between researcher and sign operator in a field setting, so that the many relevant variables can be controlled and systematically presented to drivers, thus maintaining the validity of the field setting with some of the experimental control more commonly available only in the laboratory. Nonetheless, it is difficult if not impossible to design and conduct a research study whose results can be applied with confidence to DBBs as a whole.

In the recently published FHWA study, Molino and his colleagues (2009) comprehensively assessed the strengths and weaknesses of different research methods that might be applied to this challenge. When combined with the daunting number of DBB-related factors[19] (and levels within each factor), as well as the many measures that might be addressed to provide a complete answer to this research question, we believe that it is unlikely that any agency, private organization, or public-private partnership will have the resources available in the foreseeable future to undertake such a study. At best, future studies may be able to answer questions such as:

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[19] A subset of the number of DBB-related factors that must be studied to fully answer questions about DBBs and traffic safety.

Message change interval
Duration of message change
Sign luminance at night
Sign dimensions
Distance of DBB to traveled lanes
Angle of sign orientation to the approaching driver
Proximity of DBB to official signs, or on-premise advertising signs
Number and width of lanes of travel
Roadway geometry – vertical and horizontal curvature
Speed limits and prevailing speeds
Traffic volume
Traffic mix (e.g. percentage of large trucks, buses)
Proximity of DBB to exit or entrance ramps, gores, lane drops, route divides
Familiarity of the motorist with the roadway
Weather conditions
Environment in which DBB is located (e.g. urban, suburban, rural)
Amount of information presented on a DBB
Information presentation (color, contrast, font, etc.).

- Is a DBB that changes its message every eight seconds more distracting than one whose message is fixed for 60 seconds or longer?
- Is a sign of night luminance X more distracting than one of luminance Y?
- Do DBBs within certain defined distances of entrance or exit ramps contribute to more erratic or delayed vehicle movements than DBBs at greater distances?

In short, the issue of the role of DBBs in traffic safety is extremely complex, and there is no single research study approach that can provide answers to all of the many questions that must be raised in looking at this issue. When we recognize that not every study is designed well or conducted rigorously, or where inappropriate assumptions are made or questions asked, there should be little wonder why research has not yet been able to fully "resolve" this issue.

Adding to the challenges of developing empirical answers that will satisfy the criteria for the development of guidelines or regulations is the fact that DBB technology and applications are evolving quickly. As costs come down and capabilities increase, new applications will be found for this technology. What will be the benefit of research that addresses the distracting effects of DBBs when on-premise LED signs will soon be proliferating – signs that may be larger, brighter, closer to the road, and displaying animation and full-motion video? Regulations promulgated for off-premise DBBs may seem quaint almost as soon as they are written. Potential research, even now, is years behind the implementation of the types of signs that are the subject of the research. How will we address the questions posed by roadside digital advertising that interact with the driver in real time by sending personalized messages to mobile phones, and requesting real-time responses by text messaging? And how will (or should) we address issues raised by digital signs that record potentially personal information about drivers passing such signs?

These are not questions that can be resolved in this report. There is hopeful news, however, about progress that has been made in forming and responding to key research questions. Almost without exception, the research studies discussed in this report have made dramatic advances in methodological sophistication, statistical power, and control of extraneous variables compared to those studies discussed in earlier research reviews. As a result, these more recent studies (primarily those completed within the past ten years) typically produce results and conclusions that are more reliable and valid than those of which their predecessors were capable. And, tellingly, the results of the most recent research are remarkably consistent.

A small number of important research studies, all published (or to be published) within the past several years, may have opened the door to a solution to the long-standing question of whether unsafe levels of driver distraction can occur from roadside billboards. The first, by Horrey and Wickens (2007) demonstrated that when making decisions that may result in road safety guidelines or regulations, we should be concerned, not with mean performance but rather with the poorest performances, those in the "tails" of the distribution. Of course, in many ways highway, traffic, and human factors engineers have been designing our vehicles and roadways in this manner for many

years. Human factors professionals speak of designing systems to accommodate the 95th percentile operator, (e.g. FHWA, 1998), roadway geometric design is often established based upon 85th percentile speeds (e.g. Schurr, et al., 2005), the size of letters on highway signs and the width of pavement markings are being increased to accommodate the older driver's deteriorating visual acuity, and even the duration of push-button actuations for pedestrian crossing signals is now based on research that focuses on the tails of the distribution (Noyce & Bentzen, 2005). Horrey's and Wickens' arguments were made in the context of a study that evaluated eyes-off-road time for interacting with in-vehicle technology, but the implications should be the same for external distracters such as DBBs, and have been so demonstrated by Chan et al. (2008).

The second study, a breakthrough known as the 100 car naturalistic driving study, has produced a number of separate reports (for example, Klauer, et al., 2005, Klauer, et al., 2006a, Klauer, et al., 2006b). Although "naturalistic" driving studies had been conducted on a small scale previously, Klauer and her colleagues at Virginia Tech Transportation Institute (VTTI) were the first to employ this methodology on a large scale. As discussed earlier in the present paper, these researchers placed 100 highly (but unobtrusively) instrumented cars in the hands of 100 people and allowed them full use of these vehicles for 18 months. There were no experimenters present in the vehicles, data was collected without any interference to the driver and was downloaded remotely, and the participants were free to drive these vehicles in any way they wished, as if they were their own. One finding from this work that is of particular interest in our discussion of DBBs is that a driver's eyes-off-road time due to external-to-the-vehicle distraction or inattention was estimated to cause more than 23% of all crashes and near crashes that occurred.

The third study of relevance here (Chan, et al., 2008), also discussed earlier in the present report, used a driving simulator to study the tails of the distribution when participants drove a five mile route while performing a series of in-vehicle and external-to-the-vehicle distracting tasks. The authors found, as they expected, that younger drivers, when dealing with the in-vehicle task, took their eyes off the road for a significantly longer time than did the older drivers (2.76 seconds vs. 1.63 seconds, respectively, when the measure was the mean length of the maximum episode of continuous inattention). Quite to the researchers' surprise however, were their findings that: (a) the maximum episode durations were much longer for the out-of-vehicle tasks than for the in-vehicle tasks, and (b) that the difference between the older and younger drivers in the out-of-vehicle tasks was small (pp. 16-17). Specifically, they found that the average maximum duration for the out-of-vehicle tasks (for all participants) was 3.54 seconds, vs. that for the in-vehicle tasks of 1.35 seconds, a highly significant difference. The difference in average maximum duration for out-of-vehicle tasks between the older and younger drivers, however, was 3.41 vs. 3.67 seconds, an insignificant difference. The authors' conclusion is that younger and older drivers are "equally bad" in being distracted by external stimuli, in that neither age/experience group has "learned to limit the durations of their glances off to the side of the vehicle" (p.22). Finally, even a study sponsored by the outdoor advertising industry (Lee, McElheny, & Gibbons, 2007), despite an experimental design that sought to minimize the differences between DBBs and other roadside stimuli, has produced results showing significantly longer average glance durations to roadside digital

signs than to "baseline" sites and to traditional (fixed) billboards, and, the researchers suggest, *all* measures of visual glances indicative of driver distraction would prove to be significantly worse in the presence of digital signs if a full study was to be conducted at night.

In short, we have made substantial progress in our understanding of the impacts on driver distraction from external-to-vehicle sources since the late 1990s. We now know that extended episodes (two seconds or longer) in which a driver's eyes are not attending to the driving task greatly increases (by 3.7 times) the likelihood of a crash (Klauer, et al., 2006a). Other researchers have suggested that the upper limit for an acceptable distraction episode may be 0.75 second (Beijer, et al., 2004, Smiley, et al., 2005) or 1.6 seconds (Wierwille and Tijerina, 1998). And, as shown both by Beijer (2002) in an on-road study, and by Chan and her colleagues (2008), in a simulator study, there is growing evidence that billboards can attract and hold a driver's attention for the extended periods of time that we now know to be unsafe. As stated succinctly by Beijer, his findings seem to show that "drivers are comfortable turning their attention away from the road for a set period of time, regardless of the demands of the driving task" (p. 76). And, as Chan, et al., describe it: "These data … indicate that it is likely that our out-of-vehicle tasks (which not only engage attention but also draw the eyes and visual attention away from in front of the vehicle) would have quite significant detrimental effects on processing the roadway in front of the vehicle" (p.22).

We also have data to show, despite a lack of analysis by the researchers, that an on-road study (Lee, et al., 2007) using an instrumented vehicle found many more such long glances made to DBBs and similar "comparison sites" consisting of (among other things) on-premise digital signs, than there were to sites containing traditional, static billboards, or sites with no obvious visual elements. Indeed, the mean values for these long glance durations proved to be significantly greater for the sites with digital signs than for the others. From the same study, we have evidence expressed by the researchers that if we were to conduct our research at night we would find that *all* measures of eye glance behavior would demonstrate significantly greater amounts of distraction to digital advertisements than to fixed billboards or to the natural roadside environment, and that driver vehicle control behaviors such as lane-keeping and speed maintenance would also suffer in the presence of these digital signs. Because the design of this study minimized the differences between the characteristics of DBB sites and the others, and did not report all of the pertinent data collected, it seems reasonable to believe that the differences found might be more pronounced in a more rigorous experiment.

When we add the results of these recent, applied research studies, to the earlier theoretical work by Theeuwes and his colleagues (1998, 1999), in which they demonstrated that our attention and our eye gaze is reflexively drawn to an object of different luminance in the visual field, that this occurs even when we are engaged in a primary task, and regardless of whether we have any interest in this irrelevant stimulus, and that we may have no recollection of having been attracted to it, we have a growing, and consistent picture of the adverse impact of irrelevant, outside-the-vehicle distracters such as DBBs on driver performance.

Beyond the issues of research, however, we also face what we might call a "criterion problem." States and local jurisdictions must ask themselves this question: What level of knowledge and what degree of certainty must we have before we can be confident in the issuance of guidelines or regulations about DBBs? For example, must we have demonstrable proof that DBBs *cause* crashes? This is the argument raised by the outdoor advertising industry whenever it challenges a local code or ordinance, or goes to court to overturn a permit denial. If crash causation is the standard that must be met, we may never get there. This is not necessarily because DBBs are not a causative factor in crashes; it is, as most researchers believe, more likely that our research methods are not sufficiently sensitive to identify this linkage. This, in turn, is a result of the substantial difficulties involved in conducting post-hoc statistical analyses of crash summaries for an issue that is so profoundly complex. When we know that more than 80% of accidents are not reported to the police, that drivers would not likely admit crashing as a result of such distraction, and that research has clearly shown that our attention as well as our eyes are reflexively drawn to objects such as DBBs even when we have no interest in them and have a more important task to perform, and that we may well be unaware of attending to them at all, it is little wonder that such epidemiological studies may simply be incapable of adding to our knowledge of the traffic safety impacts of DBBs.

Then again, we have rarely required proof of actual crash causation prior to setting speed limits, restricting in-vehicle mobile telephone use, or even developing current billboard operational and location restrictions. The argument against the control of DBBs because studies to date have not proven a cause and effect relationship between DBBs and crashes is simply spurious. It would seem sufficient to initiate action based on a level of consistency achieved in research. And such consistency is now being achieved.

It is likely that those who feel that no guidance or regulations can be promulgated until we have clear proof of causality will continue to argue that there is insufficient information to take any action in this regard regarding roadside DBBs. But those who think that their job is to do what they can to enhance safety for the traveling public based upon the best available information, now have, in our opinion, access to a strong and growing body of evidence, including evidence from industry supported research, that roadside digital advertising, attract drivers' eyes away from the road for extended, demonstrably unsafe periods of time.

States and local jurisdictions faced with permit applications or challenges to denied permits need to have a sound basis for their decisions. The research underway by FHWA as this is written may begin to provide specific, directed answers to assist these officials in their work. In the interim, these governmental agencies and toll road operators, faced with the need to make such decisions now have, in our opinion, a sufficient and sound basis for doing so.

SECTION 10.

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Background

Motorists can be distracted by a variety of factors -- in and out of vehicles. Critics of outdoor advertising -- without providing supportive data – claim that billboards cause traffic accidents.

Position

Years of studies, expert testimony, as well as state and federal court decisions, point to no correlation between outdoor advertising and traffic accidents. Common sense also leads to this conclusion.

Meaningful improvements to traffic safety are derived from proper road design and repair, and removal of hazards from the road.

MESSAGE POINTS

- ❒ **No evidence exists that billboards cause traffic accidents.**

*Traffic safety experts have studied the relationship between outdoor advertising and traffic accidents since the 1950's, finding no scientific or authoritative evidence that billboards are linked to traffic accidents.

A 2004 study conducted by the Center for Crash Causation and Human Factors at Virginia Tech's Transportation Institute (VTTI) found billboards do not measurably affect driving performance. The study concluded that a driver's performance, speed maintenance, and lane keeping were not measurably impaired in any way along highways and other roads with billboards.

Another major independent study commissioned by the American Automobile Association (AAA) Foundation for Traffic Safety (Phase I, released in 2001) concluded that "some items -- such as CB radios, billboards, and temperature controls -- are not significant distractions."

In Phase II of the study (released in 2003), billboards were not mentioned at all as a distraction. Phase I and II of the study were based on monitoring eye movements along with selected "contextual" and "outcome" variables, including: presence of passengers in the vehicle, light conditions, weather conditions, roadway type, traffic level, vehicle position, hand position, and driver performance. Phase I and II of the study were based on monitoring eye movements.

* With advances in technology, billboard messages can move. These signs are known as tri-visions. The Federal Highway Administration says changeable message billboards are safe. On April 2, 2002, the Federal Highway Administration published its' decision in the Federal Register to amend the Oregon Federal/State Agreement allowing tri-vision signs adjacent to controlled routes. This decision culminates three years of bureaucratic gamesmanship and resolves a long-sought advance for the outdoor advertising industry. The FHWA states that even though the agency is concerned with the safety of the motoring public, that "Tri-vision signs do not appear to compromise the safety of the motoring public," (Federal Register, April 2, 2002, Volume 67, Number 63, pages 15661-15662; U.S. DOT/FHWA Notice of Amended Federal/State agreement, FHWA Docket No. FHWA - 2001 - 9706).

* The U.S. Department of Transportation, state transportation agencies and property/casualty insurance statistics indicate no correlation between billboards and traffic accidents.

* A sampling of local law enforcement agencies has found no evidence that drivers' accidents were caused by billboards.

* Government -- via state transportation agencies -- routinely uses roadside signs and

message boards to provide information to motorists, including information intended to enhance safety.

❒ **Real gains in traffic safety come from proper design and maintenance of roads, and reduction of roadway hazards.**

A comprehensive study released in December 2001 by The Road Information Program (TRIP) said urban fatalities are typically caused by poor road conditions and mistakes by drivers.

The TRIP report identified these steps to improve safety:

- Provide medians or median barriers to separate traffic, when practical.
- Build or widen lanes on major routes to 12 feet.
- Repair potholes and improve pavement conditions to reduce sudden swerving.
- Improve intersection safety by building turn lanes, clearly marking lanes, improving signalization, improving lighting and using larger lettering on street signs and directional signs.
- Reduce road-side hazards such as trees and utility poles.
- De-ice roads in bad weather.

❒ **Studies show that billboards can improve safety conditions along highways.**

*Safety experts indicate that advertising signs in rural areas can reduce driver boredom, which many believe contributes to highway safety.

*Surveys of drivers and road users show that the lighting provided by billboards provide security and visibility to many motorists.

TRAFFIC SAFETY RESEARCH & ANALYSIS

Citations:

* Virginia Tech Transportation Institute, Center for Crash Causation and Human Factors, “Driving Performance in the Presence and Absences of Billboards, “ prepared by Suzanne E. Lee, Erik C.B. Olsen, and Maryanne C. DeHart, (2004); prepared for the Foundation for Outdoor Advertising Research and Education.

* AAA Foundation for Traffic Safety, "The Role of Driver Distraction in Traffic Crashes," prepared by Jane C. Stutts, Ph.D., Donald W. Reinfurt, Ph.D., Loren Staplin, Ph.D., and Eric A. Rodgman, B.S., University of North Carolina Highway Safety Research Center, Chapel Hill, NC., 2003 (Phase II).

(Available by visiting the OAAA website, Members only section, click Research and Studies link/Traffic Safety)

* AAA Foundation for Traffic Safety, "The Role of Driver Distraction in Traffic Crashes," prepared by Jane C. Stutts, Ph.D., Donald W. Reinfurt, Ph.D., Loren Staplin, Ph.D., and Eric A. Rodgman, B.S., University of North Carolina Highway Safety Research Center, Chapel Hill, NC., 2001 (Phase I).

(Available by visiting the AAA Foundation website, http://aaafoundation.org)

* Anderson, Pamela K., “An Independent Analysis of the Impact of Outdoor Advertising (Billboards) Upon Traffic Safety,” December 12, 2001.

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* Blanche, E.E. "The Roadside Distraction," Traffic Safety 65(11), pp. 24-25, 36-37; 1965.

* Burbaris Traffic Associates letter to Barrett Outdoor: A traffic engineer review stating that there is no substantial evidence of a correlation between billboards and traffic accidents, April 13, 1993.

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* Morrison, Bruce J. and Dainoff, Marvin J. "Factors Determining Selective Attention Among Competing Stimuli During Varying Workload, Research Proposal," Miami University Psychology Department.

* New South Wales Planning and Environment Commission, Report of the Outdoor Advertising Policy Committee, New South Wales, Australia, October 1977.

* North Carolina Highway Safety Research Center, "Do Billboards Cause Accidents?" The Accident Reporter, February 1974.

* United States Congress, Outdoor Advertising and Traffic Safety, Congressional Record, 88th Congress; 9 May 1963, 109, Part 6-House. Washington D.C. (Comments on Madigan-Hyland Report by Blanche, E.E.)

BILLBOARDS DON'T CAUSE TRAFFIC ACCIDENTS

Statistics from the Department of Transportation indicate no correlation between billboards and traffic accidents.

Two separate DOT/FHWA research studies over twenty years apart (1980 and 2001) performed literature reviews of the safety impacts of electronic billboards and variable message signs. Neither research report offered any conclusion that billboards are linked to traffic accidents. Likewise, both reports recommended that more research is needed.

Further, an article in "Policy Watch," published in the *Journal of Public Policy and Marketing* concluded that because there are no credible studies demonstrating that changeable message technology poses a threat to motorist safety, that attempts to consider new regulations on billboards is unnecessary.

Fatality Statistics

Consider the four states that have banned billboards altogether: Alaska, Hawaii, Maine, and Vermont. The automobile fatality rate in these states is higher than other more populous states.

California had virtually the same number of fatalities per 100,000 drivers in 1987 as Vermont, and that rate is greater than Massachusetts. Alaska's fatality rate was greater than New York's, and Maine's greater than Pennsylvania. Hawaii had a fatal accident rate higher than Connecticut, Rhode Island, or New Jersey.

This information, provided by DOT's Fatal Accident Reporting System 1987, reinforces an earlier study conducted in California. The Dr. Slade Hulbert Report, researched in conjunction with UCLA, determined that

there is no "evidence that urban billboards are distracting motorists and thereby creating a traffic hazard."

Most fatal crashes (77 percent) occur on two-lane roads, while only 14 percent of fatal crashes occur on roads with four or more lanes, according to analysis published in 2002 by the American Association of State Highway Transportation Officials (AASHTO).

TRAFFIC SAFETY REPORTS AND EXPERT WITNESS LETTERS

A compendium of traffic safety reports and expert witness letters is noted below:

* "Safety and Environmental Design Considerations in the Use of Commercial

Electronic Variable-Message Signage," June, 1980, Federal Highway Administration, Report No. FHWA/RD-80/51, 96 pages.

* "Electronic Advertising Along Highways-Concern for Traffic Safety," by Jerry Wachtel, FHWA, Public Roads, Vol. 45, No. 1 June 1981.

* "Traffic Accidents and Advertising Signs," Australian Road Research Board, Report No. AIR 000-213, by D. C. Andreassend, July, 1984.

* "The Highway Safety Issue Revisited," Outdoor Advertising Association of America, June, 1970.

* "The Motorist and Outdoor Advertising," and "How Standardized Poster Panels and Painted Bulletins Help the Driver," by Dr. A.R. Lauer, September, 1954.

* Review of U.S. Department of Transportation Fatality Rates per Licensed

Drivers by State, 1987 statistics, by OAAA, 1990.

* Letter summarizing the "Relationship Between Roadside Signs and Traffic Accidents: A Field Investigation," January, 1978, by Charles Holahan, Univ. of Texas, Council for Advanced Transportation Studies.

* Minnesota DOT research approving a 5-year experimental program for changeable-message signs, 1994.

OAAA Issue Brief

Traffic Safety

- ☐ No evidence exists that billboards cause traffic accidents
- ☐ Traffic safety experts say that digital billboards are not linked with accidents
- ☐ FHWA agrees with the Nevada DOT that billboards do not compromise traffic safety
- ☐ Statistics from the Department of Transportation indicate no correlation between billboards and traffic accidents

Background: Motorists can be distracted by a variety of factors -- in and out of vehicles. Critics of outdoor advertising -- without providing supportive data – claim that billboards cause traffic accidents.

Position: Years of studies, expert testimony, as well as state and federal court decisions, point to no correlation between outdoor advertising and traffic accidents. Common sense also leads to this conclusion.

Meaningful improvements to traffic safety are derived from proper road design and repair, and removal of hazards from the road.

Message Points: Traffic safety experts have studied the relationship between outdoor advertising and traffic accidents since the 1950's, finding no scientific or authoritative evidence that billboards are linked to traffic accidents.

- A study from South Carolina shows that digital billboards are not associated with traffic accidents. The South Carolina Department of Transportation reviewed accident data for six months after installation of three digital billboards in 2006 compared to the same timeframe during the prior year.

  "The study based on the period of review does not highlight a problem with the digital billboards. Also, as of August 28, 2007, the South Carolina Department of Transportation (SCDOT) has not received any complaints in regard to the digital billboards," said Deputy State Highway Engineer Dipak M. Patel, on September 6, 2007.

- The Foundation for Outdoor Advertising Research & Education (FOARE)* sponsored these studies because of the need for an empirical assessment of digital billboards and traffic safety. The test market was Cleveland, OH. Award winning researchers with decades of experience working for government and private sector clients conducted this comprehensive research.
- The first study was conducted by one of the nation's leading research institutes on transportation and driving performance: the Virginia Tech Transportation Institute (VTTI).
- The VTTI study found that digital billboards were considered safety-neutral in design and operations from a human factors perspective.
- The driver's mean glance in the direction of a digital billboard is less than one second.
- The VTTI study pointed to the need for analysis of accident data.
- To complement VTTI's human factors research, FOARE commissioned Tantala Associates, consulting engineers based in Philadelphia. These engineers conducted both a temporal and spatial analysis of the traffic and accident data near seven digital billboards on Interstate routes in

Cuyahoga County, OH, for the periods 18 months before and 18 months after these billboards were converted from conventional to digital.

- Digital billboards have no statistical relationship with the occurrence of accidents.
- Accidents occur with or without billboards.

The 2003 study (in Charlotte, NC) conducted by the Virginia Tech's Transportation Institute found billboards do not measurably affect driving performance. The study concluded that a driver's performance, speed maintenance, and lane keeping were not measurably impaired in any way along highways and other roads with billboards. The study identified ten contributing factors in driver behavior, with no mention of billboards.

Leading contributing factors in drivers' behavior

- 22.16% Drowsiness
- 3.58% Dialing hand held-device
- 3.56% Talking/listening to hand-held Device
- 2.85% Reading
- 2.15% Eating
- 1.41% Applying makeup
- 1.23% Reaching for an object
- 1.11% Reaching for a moving object
- 0.91% Looking at external object
- 0.35% Insect in vehicle

With advances in technology, billboard messages can move. These signs are known as tri-visions. The Federal Highway Administration says changeable message billboards are safe. On April 2, 2002, the Federal Highway Administration published its' decision in the Federal Register to amend the Oregon Federal/State Agreement allowing tri-vision signs adjacent to controlled routes. This decision culminates three years of bureaucratic gamesmanship and resolves a long-sought advance for the outdoor advertising industry. The FHWA states that even though the agency is concerned with the safety of the motoring public, that "Tri-vision signs do not appear to compromise the safety of the motoring public."

The U.S. Department of Transportation, state transportation agencies and property/casualty insurance statistics indicate no correlation between billboards and traffic accidents.

A sampling of local law enforcement agencies has found no evidence that drivers' accidents were caused by billboards.

- Government -- via state transportation agencies -- routinely uses roadside signs and message boards to provide information to motorists, including information intended to enhance safety.

Logo Signs

Installing more Logo signs on Interstate right-of-way does not cause more traffic accidents, according to research based on wreck reports.

The federal government has authorized blue signs on the right-of-way near Interstate exits featuring Logos of service companies providing food, gas, lodging, and camping. Demand is heaviest for space on Logo signs for food.

In 2000, Virginia started a pilot program at certain interchanges to add full service food logos onto camping signs (see photo). Virginia's DOT commissioned a study to analyze:

- traffic safety
- potential public confusion

"There was nothing in the crash data results to suggest that the additional signs caused an increase in crashes," said the study, conducted by the Virginia Tech Transportation Institute (VTTI).

Researchers examined crash data from 1999 through 2003 for areas near the test sites.

Meanwhile, a telephone survey of 804 Virginians concluded that people reported low levels of confusion regarding more than one service sharing Logo sign space.

Real gains in traffic safety come from proper design and maintenance of roads, and reduction of roadway hazards

A comprehensive study released in December 2001 by The Road Information Program (TRIP) said urban fatalities are typically caused by poor road conditions and mistakes by drivers.

The TRIP report identified these steps to improve safety:

- Provide medians or median barriers to separate traffic, when practical.
- Build or widen lanes on major routes to 12 feet.
- Repair potholes and improve pavement conditions to reduce sudden swerving.
- Improve intersection safety by building turn lanes, clearly marking lanes, improving signalization, improving lighting and using larger lettering on street signs and directional signs.

- Reduce road-side hazards such as trees and utility poles.
- De-ice roads in bad weather.

FHWA agrees with the Nevada DOT that billboards do not compromise traffic safety

A notice of amended agreement between FHWA and the Nevada DOT changed the state's zoning terminology to allow for the effective control of billboards in Clark County (Las Vegas), Nevada. That change allowed for Las Vegas to be recognized as an "urban area boundary" rather than an "incorporated villages and city." This clarification could have paved the way for an increase number of billboards because urban areas are generally more intensely developed. Thus, FHWA distributed guidance stating that the change in zoning designation would not compromise traffic safety even though the change may cause an increase number of billboards.

Department of Transportation
Federal Highway Administration

Outdoor Advertising Council

Agency: Federal Highway Administration
(FHWA), DOT
Action: Notice of Amended agreement

Summary: The Federal Highway Administration agrees with the Nevada Department of Transportation (NVDOT) that one of the definitions in the Highway Beautification Federal/State Agreement between the United States of America and the State of Nevada should be amended by deleting "incorporated villages and cities" and substituting urbanized area boundaries, as defined by 23 U.S.C. 101 (a).

Dates: The amended agreement is effective as of March 5, 1999.

Supplementary Information: The change in the agreement is aimed primarily at effective control of billboards in Clark County (Las Vegas), Nevada, where a vast part of the effective control of outdoor advertising signs as described in section 131(c) in urban areas outside of incorporated villages and cities. Las Vegas is reportedly the fastest growing urban areas in the United States. The State of Nevada believes that the change to the term "urbanized area boundaries" in the agreement could allow between 20 and 24 new billboard sites primarily in the Las Vegas urbanized area but would still prohibit the erection of signs in incorporated cities, towns, or villages outside of urbanized areas as required by section 131 (c). The state maintains that the amendment would result in minimal aesthetic

impact because urban areas are generally intensely developed and contain numerous on-premise signs.

The FHWA believes that traffic safety within the Las Vegas urbanized area is not compromised by the amended language. Certainly the State of Nevada, which is legally responsible for the safety of its highways, would not have proposed the amendment if it would lead to an increase in accidents

Statistics from the Department of Transportation indicate no correlation between billboards and traffic accidents.

Two separate DOT/FHWA research studies over twenty years apart (1980 and 2001) performed literature reviews of the safety impacts of electronic billboards and variable message signs. Neither research report offered any conclusion that billboards are linked to traffic accidents. Likewise, both reports recommended that more research is needed.

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"Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction," Final Report, Human Centered Systems Team, Office of Safety Research and Development, Federal Highway Administration, September 11, 2001, 47 pages

Safety and Environmental Design Considerations in the Use of Commercial Electronic Variable-Message Signage," June, 1980, Federal Highway Administration, Report No., FHWA/RD-80/51, 96 pages

Report to County of San Diego
Board of Supervisors

Exploring the Use of Digital LED Billboards

Advance Planning Division

Planning & Development Services

January 31, 2013

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I. Introduction

Outdoor advertising displays, including billboards, have been in existence for decades. There are an estimated 450,000 billboards faces in the United States. Outdoor advertising displays are currently regulated by federal, state and local acts, codes and ordinances. In the early years, billboards were installed without regulation. The resulting concern over safety/driver distraction and visual blight caused the public to demand controls. The first State Outdoor Advertising Act was enacted in 1933.

In 1965, the Federal Highway Beautification Act (HBA) was passed. The HBA declares that "outdoor advertising displays in areas adjacent to the freeway should be controlled in order to protect the public investment, to promote the safety and recreational value of public travel, and to preserve natural beauty." It also states, "Federal Aid Funds for any State which has not made provision for effective control of outdoor advertising shall be reduced by 10% …"

The California Department of Transportation (Caltrans) controls outdoor advertising displays (billboards) which are visible from our highways. Caltrans is required to control these advertising displays pursuant to the following regulations:

- **1965: Federal Highway Beautification Act**
  - Required states to control billboards or risk losing 10% Federal Funds
- **1967: CA Outdoor Advertising Act**
  - Included landscape restriction not required by the Highway Beautification Act. California is the only state with landscaped freeway restrictions.
- **1978: CA Outdoor Advertising Regulations**
  - Business and Professions Code, Division 3, Chapter 2, Sections 2500-2513 apply to landscaped freeways.

(source: Caltrans http://dot.ca.gov/hq/oda/)

The County of San Diego began regulating "Off-Premise Signs" (including billboards) in the Zoning Ordinance in 1973. The intent of the ordinance is that the "regulations impose reasonable standards on the number, size, height and location of off-premise signs, and sign structures and facilitate the removal or replacement of nonessential off-premise signing, in order to prevent and relieve needless distraction and aesthetic clutter resulting from excessive and confusing sign displays; to promote traffic safety; to safeguard and enhance property values; and to promote the public safety and general welfare. It is further intended that these regulations provide one of the tools essential to the preservation and enhancement of the environment, thereby protecting an important aspect of the economy of the county which is instrumental in attracting those who come to visit, vacation and trade. In communities subject to community design review, scenic and/or historic preservation programs, these sign regulations are intended to enhance such programs. The provisions contained within these sections have been determined to be the least burdensome that will satisfy the intended purposes of the Off-Premise Sign Regulations." In addition, lighting of Off-Premise Signs is regulated by the County's Light Pollution Code. The purpose of this code is "to minimize light pollution to allow citizens of

the county to view and enjoy the night environment and to protect the Palomar and Mount Laguna observatories from the detrimental effect that light pollution has on astronomical research."

Unlike traditional billboards, digital billboards (which are also known as Commercial Electronic Variable Message Signs (CEVMS) and Off–Premise Message Center Displays) do not use paper or vinyl printed advertisements mounted on a billboard face. Instead, "digital technology produces static images which are changed via computer (typically every six or eight seconds), providing a non-manual way to change billboard "copy." Digital billboards do not scroll, flash, or feature motion pictures. Advertisers can change their messages quickly, including multiple times in one day… Print and broadcast news media use digital billboards to deliver headlines, weather updates, and programming information. Law enforcement and other public safety officials use digital billboards to reach mass audiences quickly. The image of a missing person or emergency information can be displayed in minutes." (source: Outdoor Advertising Association of America (OAAA))

Staff has been directed to explore the use of digital LED billboards in the unincorporated county. As directed, staff has worked with local billboard operators, local community planning/sponsor groups and other interested parties to investigate options that would change the County's sign ordinance to allow the conversion of traditional billboards to digital LED billboards throughout the unincorporated areas of San Diego County. Any revised options were required to include the prohibition of animation and not allow an increase in the number of billboards that already exist; to include an appropriate conversion ratio of existing traditional billboards with digital billboard and to address impacts such as light pollution and driver safety. Proposed options are contained in section VI below.

II. Current Codes and Regulations

Within the unincorporated area of the county, billboards are considered "Off-Premise Signs". These signs are regulated by the Zoning Ordinance and all lighting that may be associated with these signs is regulated by the Light Pollution Code. The following is a summary of those regulations:

Zoning Ordinance: Sec. 6200, Off-Premise Signs

An Administrative Permit is currently required to permit any off-premise sign.

- Permitted Zones- Currently, Off-Premise Signs (including billboards) are only allowed in C37, C38, M54 & M58 zones, in areas not subject to Community Design Review Area, Scenic Area, or Historic/Archaeological Landmark and District Area Regulations. They must also be 300 feet from any residential zone with frontage on the same street.

- Sign Area- Current ordinance limits signs to 300 square feet.

- Sign Height- Current ordinance limits signs and sign structures to 25 feet.

- Spacing- Current ordinance requires a minimum of 500 feet between signs.

- Lighting- Current ordinance does not allow any light bulb, tube, filament or similar source of illumination to be visible beyond the property line. It also prohibits intermittent or variable intensity lighting.

- Maintenance of Nonconforming Signs- Current code limits maintenance to very minor repairs. No expansion or reconstruction of signs is permitted.

County Code: Title 5, Division 1, Chapter 2- Light Pollution

- Zone A-Lamps above 4050 Lumens prohibited.

- Zone B-Lamps must be fully shielded.

- Hours of Operation- Current code requires lighting on billboards to be turned off between midnight and sunrise.

Caltrans Outdoor Advertising Permit Requirements

In addition to local permit requirements, a permit is also required from Caltrans for any outdoor advertising display which is visible from an Interstate or primary highway. In order for an outdoor advertising display application to be considered for a permit adjacent to an Interstate or primary highway the following criteria must be met:

Display Location

- Must be outside the right of way of any highway.
- Must be outside of any stream, or drainage channel.
- There must be an existing business activity within 1000 feet of proposed display location on either side of the highway.
- Location of property where display is to be placed must be zoned industrial or commercial.
- Must have current property owner consent, in writing, to place the display at desired location.
- Must have written permission (building permit) from the local government having jurisdiction where the display is to be located.
- Location may not be adjacent to a landscaped section of a freeway. *
- Location may not be adjacent to a scenic highway. **
  (San Diego: Hwy 78 from west boundary of Anza Borrego Desert State Park to east boundary; Hwy 125 from State Route 94 near Spring Valley to Interstate 8 near La Mesa)

- If adjacent to a Bonus*** segment of an Interstate freeway, copy, size, and spacing is more restrictive.

Display

- Display must be 500 feet from any other permitted display on same side of any highway that is a freeway.
- Display must be 300 feet from any other permitted display on same side of any primary highway that is not a freeway in an unincorporated area.
- Display must be 100 feet from any other permitted display on same side of any primary highway that is not a freeway and is within the limits of an incorporated city.
- Display must be 500 feet from an interchange; intersection at grade or safety roadside rest if the highway is a freeway and the location is outside the limits of an incorporated city and outside the limits of an urban area.
- An electronic changeable message center display must meet the above spacing requirements and be 1000 feet from another electronic message center display.
- Maximum height for the advertising display area is, 25 feet in height and 60 feet in length, not to exceed an overall maximum of 1200 square feet.

* Landscaped freeway is a section of a freeway which is now, or hereafter may be, improved by the planting at least on one side of the freeway right-of-way of lawns, trees, shrubs, flowers or other ornamental vegetation which shall require reasonable maintenance.

** Scenic highway is a section of a highway that has been officially designated and maintained scenic pursuant Section 260, 261, 262, and 262.5 of the Streets and Highways Code or as referred to in Section 131(s) of Title 23 of United States Code.

*** Bonus segment is any portion of an Interstate freeway which is constructed upon any part of right of way, the entire width of which was acquired for right of way subsequent to July 1, 1956, except those segments of the Interstate system that traverse commercial or industrial zones within the boundaries of incorporated municipalities, as such boundaries existed on September 21, 1959, or other areas where the land use, as of September 21, 1959 was clearly established by State law as industrial or commercial.

Note: There may be existing advertising displays (billboards) which do not comply with these regulations. A "Nonconforming advertising display" is allowed to remain pursuant to the regulations contained in Business and Professions Code, Section 5200 et seq.
http://www.dot.ca.gov/hq/oda/download/ODA_Act_&_Regulations.pdf

Constitutional Constraints

With few exceptions, the County cannot regulate the content of speech on authorized sign types. The County can, however, regulate the time, place and manner (size, height, etc.) in which signs are allowed.

Permitted Locations for Billboards under Current Ordinance

Based on the existing zoning of properties within the unincorporated county, staff has determined that there are approximately 153 parcels that may allow for Off-Premise Signs under the current ordinance.

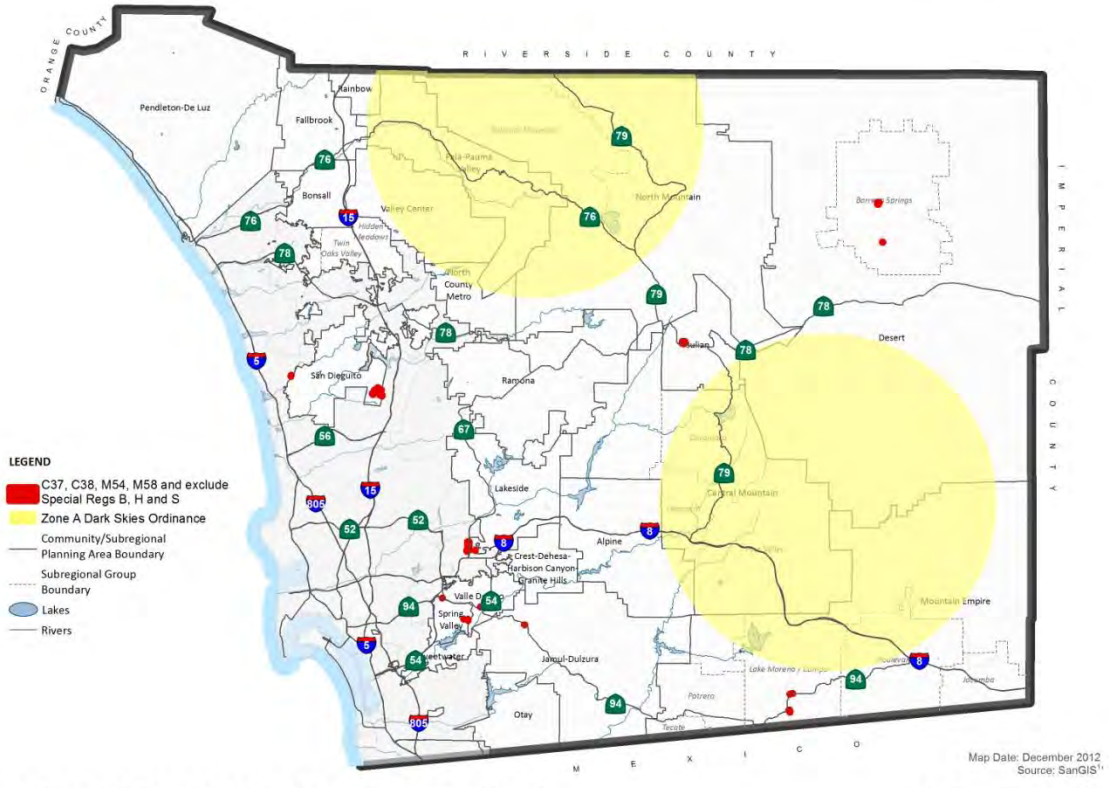


Figure 1

These locations are in the Borrego Springs, Jamul-Dulzura, Julian, Lake Morena-Campo, Lakeside, San Dieguito, Spring Valley and Valle de Oro Community Planning/Sponsor Group Areas. None of the parcels are located in Zone A of the Dark Skies area.

Existing Billboard Inventory

Staff requested information from the three large billboard companies in San Diego County regarding the location of existing billboards within the unincorporated area. In addition, staff reviewed the Caltrans Outdoor Advertising Permit information to determine additional billboard locations owned by other companies or individuals. It is likely some existing billboards within the unincorporated county have not been accounted for in this inventory.

Existing Billboard Inventory by Community

	Lamar	Clear Channel	CBS	Other*	Total
Alpine	1		2		3
Bonsall	2			1	3
Borrego				11	11
Boulevard	1			1	2
Fallbrook	2	6			8
Jacumba	6				6
Julian				1	1
Lakeside	15	16	4		35
NC Metro				1	1
Rainbow	5				5
Ramona			7		7
San Dieguito	2			2	4
Spring Valley			2		2
Valle de Oro	3	8	6		17
Valley Center	1				1
CP Area Unknown	2				2
	40	30	21	17	108

* There may be additional billboards not counted

It is estimated that there are at least 108 billboards in the unincorporated area of the county. The billboard companies have indicated that they would be interested in converting 13 of the existing billboards to digital technology.

Lamar: 8 of 40 billboards
Clear Channel: 3 of 30 billboards
CBS: 2 of 21 billboards

Staff conducted a "windshield survey" of existing billboards along numerous highways within the county. A number of billboards are in the outermost areas of the county approaching the Imperial and Riverside County lines; however the likely candidates for conversion to digital billboards would be along the busier stretches of highway or highway interchanges with higher traffic volumes.

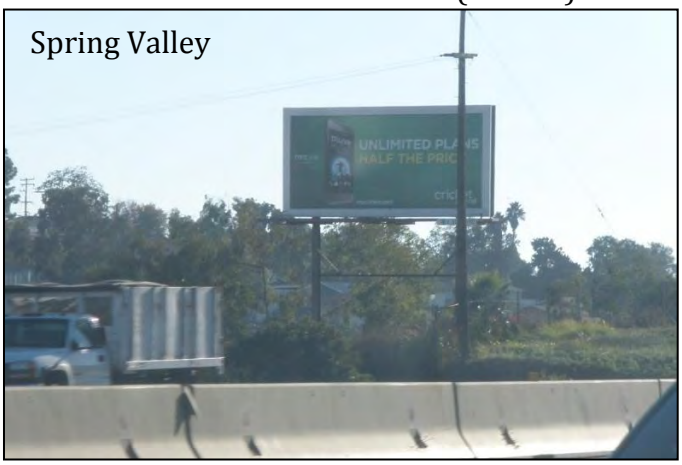
Traditional Billboards

Bulletin: 14 ft. H x 48 ft. W (672 s.f.)

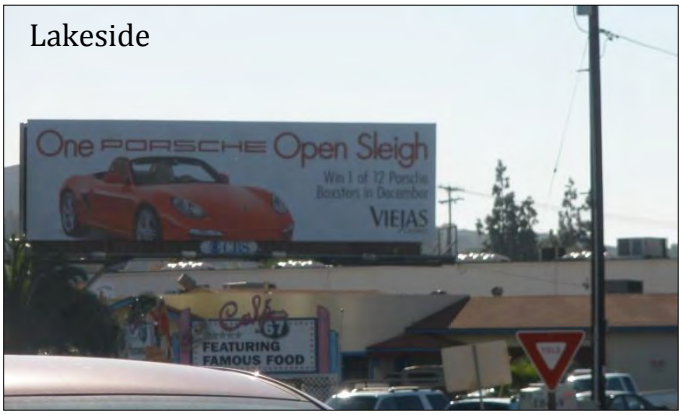
Poster: 12 ft. H x 24 ft. W (288 s.f.)

Valle de Oro

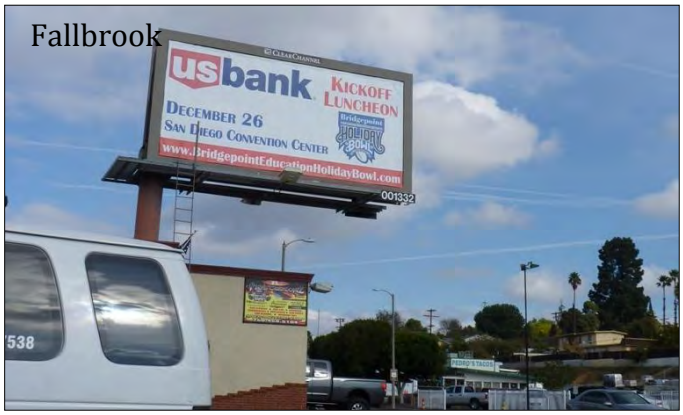
Spring Valley



Lakeside



Fallbrook

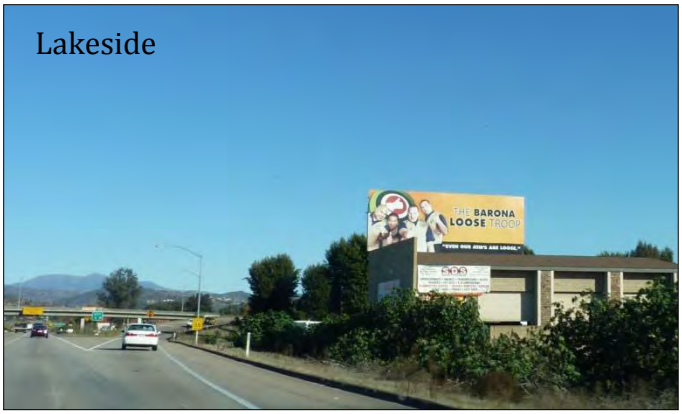


Lakeside

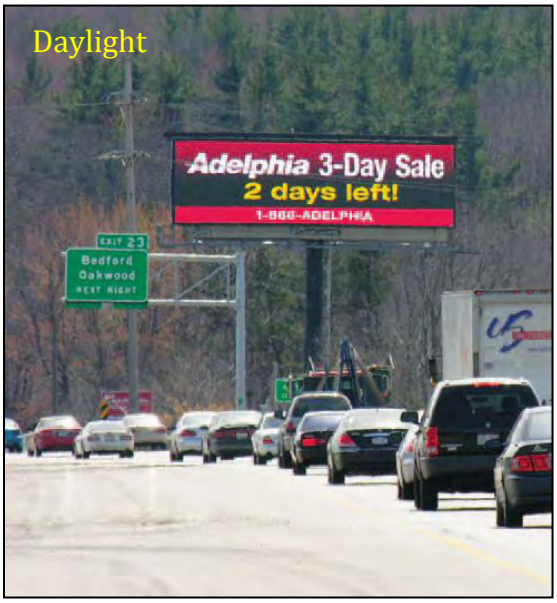
Alpine

Lakeside

Ramona



Digital Billboards



III. What other jurisdictions are doing

Staff has reviewed ordinances and spoken to staff from other jurisdictions within California and across the US (see Table 1). Although many jurisdictions have not amended their ordinances to allow digital billboards, there are jurisdictions which allow conversion of traditional billboards to digital billboards, usually with a requirement that a specified number of billboards be removed in exchange for allowing one digital billboard. Some jurisdictions which did not have regulations prohibiting digital billboards have amended their ordinances to limit or prohibit the installation of any additional digital billboards within their communities.

Table 1: DIGITAL BILLBOARDS IN OTHER JURISDICTIONS

County	Digital Allowed?	Exception	Criteria
Alameda	NO		
Imperial	NO		
Los Angeles	YES		CUP required, only allowed in certain Manufacturing zones
Orange	NO		
Riverside	NO		
San Bernardino	NO	Have allowed some with a Variance	
Santa Clara	NO		
City			
Fontana	YES	Requires Relocation Agreement	Requires removal of 6 billboards (or 3 double sided) structures to allow replacement of 1 digital billboard
Hesperia	YES	Billboards or digital advertising displays may only be constructed, relocated, or upgraded upon the approval of a relocation agreement and site plan review by the city council	New billboards are prohibited, and the erection, alteration, construction, replacement, use, installation or conversion of any billboard within the city is prohibited.
Los Angeles	NO	Existing digital billboards were allowed per a Settlement Agreement in 2006. Not allowed under current ordinances.	
San Bernardino	YES		Conditional Use Permit required, Subject to Outdoor Advertising Act
Vallejo	YES	No new signs, conversion only. Conversion requires execution of an agreement between the applicant and the city	Use Permit application and requirement to remove at least four existing legal conforming and/or legal nonconforming off-site sign structures regardless of the number of existing sign faces on the structures, in exchange for approval to construct one new off-site digital/electronic sign structure with a maximum of two sign faces
Victorville	YES		To convert an existing billboard to digital requires removal of 3 existing legal nonconforming billboards (Site Plan approved by ZA). To relocate and convert a billboard to digital, requires removal of 2 legal nonconforming billboards and a relocation agreement (approved by PC and City Council)
State			
Arizona	YES		Digital billboards within a 75 mile radius of specified observatories must conform to specified levels of brightness from sunset to 11pm and must be extinguished from 11pm until sunrise. Exceptions only for amber alerts and other gov't emergencies.

Staff has concluded that a majority of surrounding counties in Southern California do not allow traditional billboards to be converted to digital technology. There are numerous smaller jurisdictions which do allow digital billboards within their cities. Some jurisdictions that did not have restrictions are now adopting ordinances to prevent additional billboards from converting to digital technology. The jurisdictions that do allow digital billboard conversions require removal of anywhere from 2 to 6 existing traditional billboards to allow one digital billboard.

Although there are benefits to having the digital billboards, such as alerting travelers to emergencies or providing notification of Amber Alerts, these benefits may not outweigh the impacts to local communities.

IV. Community and Industry Outreach

Staff met with representatives from the 3 major billboard companies and with representatives from numerous Community Planning/Sponsor Groups to explore the use of digital LED billboards as follows:

Industry representatives - October 19, 2012
CPG/CSG representatives - November 14 & 16, 2012
Industry representatives - December 19, 2012
Joint meeting - CPG/CSG/Industry representatives - January 24, 2013

Industry

During the first meeting with industry representatives, staff reviewed the direction given by the Board of Supervisors and explained the existing County regulations pertaining to billboards. Industry representatives provided information regarding digital technology and the conversion of traditional billboards to digital billboards in other jurisdictions. They explained the benefits of digital billboards.

Benefits can include:

- Rehabilitation of older billboards,
- Potential reduction in number of existing nonconforming billboards (existing billboards can remain indefinitely)
- Community alerts and public safety announcements including coordination with County Emergency Services to provide timely updates
- Automatic control of light levels based on ambient light
- No animation is allowed pursuant to federal and state controls

Staff also requested that the representatives provide information regarding the location of their existing billboards within the unincorporated county.

At the second meeting with industry representatives, staff provided an overview of progress made and provided a summary of the concerns raised by the Community Planning/Sponsor Group representatives. Staff presented the draft options for amending the ordinance and discussion resulted in revisions to some of the proposals.

Community Planning/Sponsor Groups

Staff held meetings with representatives from seven of the County's Community Planning/Sponsor Groups to discuss the idea of amending County ordinances and codes to allow digital billboards. Staff explained the Board of Supervisors direction, the existing state and County regulations applicable to billboards and provided the information from industry regarding digital billboards. None of the communities present felt that digital billboards would be in keeping with their community character and felt that the increase in light would be detrimental to the rural character. There were many concerns raised regarding safety and potential distraction to motorists along the highways. In addition, questions were raised regarding the unfair advantage of billboard companies over local businesses which are not allowed to have digital signs for their businesses. Although there were not representatives from all CPG/CSG available for the meeting, staff has been in communication with additional groups to keep them informed of this project and obtain feedback. See Table 2 for a summary of the CPG/CSG input.

It should be noted that the existing Zoning Ordinance provisions prohibit billboards on properties with Community Design Review Area Regulations and areas with Scenic Area or Historic/Archaeological Landmark and District area designations. Although the various Community Design Guidelines do not address Off-Premise Signs specifically (since billboards are not allowed in these areas), the provisions relating to On-Premise Signs allow illumination only by light projected on the sign; internally illuminated signs are not permitted. If the existing ordinance and codes are amended to allow digital billboards in these areas, the Design Review Guidelines for the various communities may need to be updated as well as the Scenic Area regulations, to address these Off-Premise Signs. The Scenic Preservation Guidelines for the I-15 Corridor Design Review Board specifically prohibit off-premise signs except for Temporary Real Estate Development signs, Community Identification Signs and directional signs. Any amendment to the Zoning Ordinance to allow digital billboards should not conflict with adopted Community Plans or Community Design Review Guidelines.

Table 2:

Group	Are existing billboards located in their community?	Community position re: digital billboards
Alpine	YES	No comments received
Bonsall	YES	Oppose in their community. Digital billboards conflict with goals and policies in Bonsall Community Plan and Design Review Guidelines and with the dark sky policy
Boulevard	YES	No comments received
Fallbrook	YES	Dec 17, 2012: Voted to oppose digital billboards Jan 21, 2013: Digital billboards would be contrary to community character,

		concerns regarding public safety and may be detrimental to local businesses.
Jacumba	YES	No comments received
Julian	YES	Dec. 10, 2012: Voted to oppose digital billboards
Lakeside	YES	No comments received
Pala-Pauma	(UNKNOWN)	Dec. 22, 2012: Supportive of proposed options
Ramona	YES	Jan. 10, 2013: Voted 9-5-0-0-1 to support Option 6 (Specific Locations) with removal of 3 traditional billboard to allow conversion of 1 digital billboard
Rainbow	YES	Oppose amending the ordinance to allow digital billboards
San Dieguito	YES	No comments received
Spring Valley	YES	Jan 8, 2013: Comments provided on all proposed options. Added that the ordinance should include ability of local planning group to give input to the County on appropriateness of a billboard within their Planning/ Sponsor area
Valle de Oro	YES	Jan 15, 2013: Voted 10-0 to oppose any change to the County's Sign Ordinances that would allow the introduction of digital billboards. Valle de Oro Community Plan Policy prohibits development of new billboards or the modification of existing billboards.
Valley Center	YES	Jan 14, 2013: Voted 14-0-0 to oppose digital billboards in Valley Center. They do not support the proposed options and feel that allowing these billboards would conflict with Dark Skies Ordinance, the Community Plan and Design Guidelines.

The International Dark Sky Association has also expressed concerns regarding the light pollution created by digital billboards and its potential adverse effects on the local observatories.

A joint meeting was held between representatives from Community Planning/Sponsor Groups, the billboard industry and County staff. At this meeting staff provided an overview of the progress made on the project and discussed the direction of the report to the Board of Supervisors. Community Planning Group representatives asked questions regarding digital billboard technology and the options proposed for ordinance amendments. A billboard industry representative showed a video of an actual digital billboard with time lapse to show the billboard operation during the day and evening. The video also demonstrated the change in copy at an 8 second interval. There was also discussion regarding lighting technology and coordination of emergency messages with the County Office of Emergency Services.

Comment letters and emails were received from various Community Planning Groups and from other organizations and individuals. Copies are attached at the end of this report.

V. Changes to Codes and Regulations

Safety & Operations

The safety of travelers along the highways and public roads must be considered as part of any amendment to ordinances or codes related to billboards and other signs. Driver distraction by advertising displays which may have changeable electronic messages would need to be considered and restrictions included ensuring that information is presented safely and effectively.

California Department of Transportation (Caltrans) regulates the placement of outdoor advertising displays (including billboards) which are visible from California Highways. Permits from Caltrans are required and these billboards must conform to the California Business and Professions Code (Outdoor Advertising Act) Section 5200 et seq. and Section 21466.5 of the Vehicle Code. These codes contain regulations for all billboards and specific regulations pertaining to "changeable electronic messages" (digital signs) regarding allowed location, proximity to other billboards (digital and traditional), frequency of message changes, illumination and prohibition of animation.
http://www.dot.ca.gov/hq/oda/download/ODA_Act_&_Regulations.pdf

In addition, the state code specifies that a governing body of any city, county, or city and county may enact ordinances, including, but not limited to, land use or zoning ordinances, imposing restrictions on advertising displays adjacent to any street, road, or highway equal to or greater than those imposed by the code.

County Codes and Ordinances

Staff has reviewed existing County ordinances and codes and determined that the following sections would need amending, as noted:

1. Zoning Ordinance:
   Sec. 1110, Definitions
   - Amend definitions as needed for existing sign types

- Add new definitions for digital off-premise signs and other definitions as needed

Sec. 5000, Special Area Regulations

- Section 5200, Scenic Area Regulations- Section 5210.g prohibits off-site signs in areas subject to the Scenic Area Regulations

- Section 5700, Historic/Archaeological Landmark and District Area Regulations- Section 5730 prohibits off-premise signs in areas subject to the Historic and Archaeological Landmark and Historic District Area Regulations

- Sec. 5750, Community Design Review Area Regulations- Section 5756 states "No building permit or discretionary approval pursuant to this ordinance shall be issued, nor shall any person construct or alter a building, structure, or parking area, nor shall any outdoor commercial or industrial use be established, on land subject to the Community Design Review Area Regulations until a Site Plan which conforms to the criteria established pursuant to these regulations has been submitted and approved in accordance with the Site Plan Review Procedure commencing at Section 7150"

Site Plan Permits are required for construction of new structures or alteration of existing structures in these areas.

Sec. 6200 Off-Premise Signs

No change is proposed to the requirement for an Administrative Permit to allow an off-premise sign.

- Permitted Zones- Amendments to the restrictions may be needed. Either allow in additional Use Regulations or allow off-premise signs on properties that are subject to Community Design Review Area Regulations, Scenic Area Regulations, and/or Historic/Archaeological Landmark and District Area Regulations.

- Sign Area- "Poster" sized billboards are approximately 288 s.f. (12 ft. by 24 ft.) and meet the current 300 s.f. size limitation however; larger existing "Bulletin" billboards are approximately 672 s.f. (14 ft. by 48 ft.). Amendment to this restriction may be needed to convert existing billboards to digital.

- Sign Height- Amendment to the restriction of 25 feet may be needed. Many existing billboards exceed this height limitation.

- Spacing- Amendment needed to address spacing requirements between digital billboards. State code requires 1,000 foot separation between digital billboards.

- Lighting- Amendment would be needed to allow lights (LED's or other light source) to be seen beyond a property line and to address intermittent or variable intensity lighting to accommodate digital LED technology.

- Maintenance of Nonconforming Signs- Substantial amendments to this section would be needed to allow existing nonconforming billboards to convert digital billboards. The current ordinance allows normal maintenance or repair which is limited to only the following:
    a. Advertising changes
    b. Routine cleaning and painting
    c. Replacement of nuts, bolts, screws or nails
    d. Re-leveling or plumbing the structure without the addition of guys or struts for stabilization.

    Any changes such as extensions, enlargements, replacements or the rebuilding of a nonconforming sign is prohibited.

    Industry representatives have indicated that conversion would require the installation of a new sign structure and possibly new support structure and/or footings. In addition, sign areas may increase depending on the size of the existing billboard at a location. Staff believes that a majority of existing billboards appear to be nonconforming, therefore amending this section would result significant change to the existing limited maintenance allowed for billboards.

2. County Code: Title 5, Division 1, Chapter 2- Light Pollution
    - Zone A- Amendment may be needed to address digital billboards in Zone A (add a prohibition of digital billboards in these areas) and to address measurement of LED lighting which differs from the measurements of other types of lighting in Zone B.

    - Hours of Operation- Amendment would be needed if digital billboards would be allowed to advertise between midnight and sunrise.

3. General Plan Amendment, Community Plans and Community Design Review Guidelines: Community Plans are a part of the County of San Diego General Plan. Any amendments to these documents would require a General Plan Amendment (GPA) to be processed.

    - Community Plans- Many of the adopted Community Plans contain policies which prohibit or discourage off-premise signs. Other Community Plans require comprehensive sign control or require signs to compliment the community character. These Community Plan documents may need to be amended in order to allow off-premise signs in many communities.

    - Community Design Review Guidelines- The adopted Design Review Guidelines for Alpine, Bonsall, Fallbrook, I-15 Corridor, Julian, Lakeside, Ramona, Spring Valley and Valley Center do not address Off-Premise Signs (current code prohibits these signs in areas subject to Design Review Regulations). Amending

the Zoning Ordinance to allow off-premise signs in these areas would require amendments to all of the Design Review documents.

It is anticipated that Community Planning/Sponsor Groups, billboard industry representatives as well as other interested groups and members of the public would play a critical role in crafting any code and ordinance amendments to allow the digital LED billboards.

Environmental Considerations

Implementing changes to the County's current Off-Premise Sign requirements and Light Pollution Code to allow digital LED billboards will require the Board to consider Zoning Ordinance and County Code amendments. These amendments will be discretionary actions under the California Environmental Quality Act (CEQA). It is not clear at this point what level of review will be required under CEQA. If a future ordinance amendment proposes to allow digital billboards in zones (or areas subject to Special Area Regulations) where traditional billboards are not currently allowed, and allows increase in light emissions, review of potential impacts could require preparation of an Environmental Impact Report.

Technical Review

Staff has reviewed information regarding billboards and digital technology provided by industry representatives, other jurisdictions and via the internet.

Driver Distraction:

Research and data regarding driver distraction from digital LED billboards is conflicting. Although there have been numerous studies conducted there seem to be differing conclusions or dispute over methodology used. Additional review of this issue may be required if any new studies are found which result in evidence of driver distraction from digital billboards. However, it should be noted that both the Federal Highway Administration and Caltrans allow digital billboards along our highways. Any future ordinance amendment will be in conformance with the federal and state regulations.

(sources: **"The Effects of Commercial Electronic Variable Message Signs (CEVMS) on Driver Attention and Distraction: An Update"**, Publication No. FHWA-HRT-09-018, February 2009; http://www.fhwa.dot.gov/realestate/cevms.pdf
"Driving Performance and Digital Billboards- Final Report", Virginia Tech Transportation Institute, Center for Automotive Safety Research, March 2007; www.ledadvertisingdisplay.com/index.php/download_file/70/68/
"Final Report, A Critical, Comprehensive Review Of Two Studies Recently Released By The Outdoor Advertising Association Of America", Prepared for: Maryland State Highway Administration Under Project AX137A51, Through and with full concurrence of: Positive Guidance Applications, Inc. Gerson J. Alexander, President By: Jerry Wachtel, CPE, President The Veridian Group, Inc., Berkeley, California, Consultant, October 18, 2007 http://sha.md.gov/oots/FINALREPORT10-18-GJA-JW.pdf)

Outdoor Advertising is designed to attract a motorists' attention to the advertisement. According to the group Scenic America, a national non-profit organization, a "1980 Federal Highway Administration study found a positive correlation between billboards

and accident rates. Moreover, federal and state courts have long cited traffic safety as a legitimate basis for billboard regulation." (source: Scenic America http://www.scenic.org/billboards-a-sign-control/the-truth-about-billboards)

The Federal Highway Administration (FHWA), has stated "Proposed laws, regulations, and procedures that would allow permitting CEVMS (changeable electronic variable message signs) subject to acceptable criteria … do not violate a prohibition against 'intermittent' or 'flashing' or 'moving' lights as those terms are used in the various FSAs (federal state agreements) that have been entered into during the 1960s and 1970s." Industry practices conform to federal guidance, such as display times and lighting. FHWA recommends an eight-second display time. Federal guidelines say digital billboards should "adjust brightness in response to changes in light levels so that the signs are not unreasonably bright for the safety of the motoring public." (source: OAAA http://www.oaaa.org/legislativeandregulatory/digital/aboutdigitalbillboardtechnology.aspx)

It should be noted that on January 23, 2013, Scenic America filed a lawsuit in the U.S. District Court for the District of Columbia seeking to overturn a controversial Federal Highway Administration ruling. The ruling reversed the agency's long-held position that barred intermittently changing commercial digital billboards. The lawsuit alleges that FHWA has wrongfully allowed commercial digital billboards to proliferate along federal highways nationwide. (source: Scenic America http://www.scenic.org/blog/164-lawsuit-seeks-to-overturn-fhwa-ruling-on-digital-billboards)

Lighting of Digital Billboards:

To control brightness levels on digital billboards, the signs are equipped with light sensors, which measure the amount of light available in the surrounding environment. In the brightest sun, the billboard is at its brightest to provide the necessary contrast to let the billboard be legible. At night, the billboard is much dimmer to adjust to surrounding light conditions. The billboards use the minimum amount of light necessary to provide legible copy, a practice which meets federal criteria and the lighting industry's standards.
(source: OAAA
http://www.oaaa.org/legislativeandregulatory/digital/aboutdigitalbillboardtechnology.aspx)

Currently, the County's Light Pollution Code addresses wattage, lumens, and shielding, and the zoning ordinance addresses foot-candles across property lines. Foot-candles and lumens are very similar in what they measure, however they do not really address all the concerns with light pollution.

The LEDs in LED signs are themselves intended to be seen from a distance and not intended to illuminate something external. The effects of this kind of lighting on light pollution is very complicated, as is the various terminology used in light measurement.

Information received from the International Dark Sky Association indicates that LED electronic billboards do not shine directly upwards, instead light is projected sideways at angles that are above the horizontal. "Research has shown that light emitted in this

direction produces more light polluting skyglow than light emitted at higher angles, and that the effects of this low-angle light are visible over a much broader area." (source: letter received December 20, 2012, International Dark Sky Association, see Attachments)

Additional studies that include input from lighting experts would be required to determine the appropriate method to measure the brightness of digital billboards above ambient light, shielding requirements, to ensure compliance with the purpose of the Light Pollution Code in the unincorporated county and to limit distraction to drivers.

Benefits of Digital Billboard Technology:

In addition to the typical advertising displays, digital billboards can be used by law enforcement and other public safety officials to reach mass audiences quickly. The image of a missing person or emergency information can be displayed in minutes. (source: OAAA http://www.oaaa.org/legislativeandregulatory/digital/aboutdigitalbillboardtechnology.aspx)

Digital billboards eliminate the paper/vinyl used on traditional billboards, saving fuel as well as materials and harsh chemicals used on each traditional change out. In addition, each generation of digital billboards improves power efficiency. For example, current digital billboards use half of the power of the first digital billboards manufactured.
(source: www.daktronics.com- a digital billboard manufacturer)

VI. Options

Amending County codes and ordinances would provide opportunities for billboard owners to change their existing traditional billboards to digital billboards. Owners would be required to obtain approval of an Administrative Permit or Site Plan Permit and associated building permits from Planning & Development Services, as well as an Outdoor Advertising Display Permit from Caltrans.

The following options reflect an array of approaches for addressing the siting of digital billboards for Board consideration.

Option 1: Conversion/Removal Ratio (1:3)

Allow one traditional billboard to be converted to a digital LED billboard provided the billboard owner is required to remove three traditional non-conforming billboards located in the unincorporated county. The ordinance language would require that when feasible, the removed billboards be located within the same community plan area in which the digital billboard is being placed.

Pros:

- Reduction in overall number of billboards in the county

- Removed billboards would be in the same Community Planning Area as the proposed digital billboard

Cons:
- Disadvantage to smaller sign companies with fewer billboards

Option 2: Conversion/Square Footage

Allow conversion of a traditional billboard to a digital billboard providing that an equivalent square footage of traditional billboards be removed. For example, if a billboard operator wishes to construct a 600 square foot digital LED billboard in place of an existing 200 square foot traditional billboard, the operator would need to remove multiple billboards totaling 600 square feet.

Pros:
- No increase in the square footage of existing billboards in the county
- Likely reduction in the quantity of billboards because many billboards tend to be smaller in size than the preferred size of digital billboards

Cons:
- Disadvantage to smaller sign companies with fewer billboards

Option 3: Relocation Agreement

Allow a billboard operator to relocate an existing billboard to a more preferred location for conversion to a digital LED billboard. This option can be used in conjunction with Options 1 or 2. For instance, a billboard operator can relocate a billboard and in exchange for the relocation to a preferred location would remove other existing billboards at a given ratio. Research has shown that the relocation is typically captured within a Relocation Agreement that specifies the number of existing billboards that must be removed, may include a requirement for revenue sharing with the jurisdiction and/or alleviates the expenditure of public funds for relocation required by public improvements (condemnation). This option should consider whether the relocated site is consistent with current County regulations.

Pros:
- Limitation of quantity of future digital billboards
- Limited locations for future digital billboards
- Relocation from less desirable sites
- Reduction in the number of billboards in the county

Cons:
- Disadvantage to smaller sign companies with fewer billboards

Option 4: Relocation to County Owned Properties

Allow billboard operators to relocate only onto County-owned properties. Under this option billboard operators would need to remove existing billboards in order to

relocate. This option may present opportunities to generate income on County properties.

Pros:
- Limitation of quantity of future digital billboards
- Limited locations for future digital billboards
- Relocation from less desirable sites
- Reduction in the number of billboard in the county
- Revenue generation for County

Cons:
- Potential conflict with existing or future uses on County properties

Option 5: Conversion of Conforming Billboards

Allow only the conversion of billboards that are currently in compliance with the existing zoning ordinance. For instance billboards would need to be within one of the four identified zones and would need to comply with current billboard size and height requirements.

- "Poster" size billboards (12'4" x 24'6") conform to existing size limitations in ZO
- Some smaller "Bulletin" size billboards (10' x 30') conform to existing size limitations in Zoning Ordinance

Pros:
- Minor changes to Zoning Ordinance, minor amendment to Light Pollution Code to address brightness of LED billboards

Cons:
- Bulletin sized billboards (14' x 48') would not be allowed to convert to digital
- Many existing billboards do not conform to the underlying zoning, or other criteria and very few billboards would be allowed to convert due to limited zones/locations where billboards are allowed.

Option 6: Specific Locations

Allow only billboards on specified properties to convert to digital LED billboards. Under this option staff would work with billboard operators and community groups to indentify the billboards to convert. The specific digital billboard location would be incorporated into the zoning ordinance text.

Pros:
- Certainty of location and quantity of digital billboards

Cons:
- Future Zoning Ordinance amendments would be required if additional digital billboards were

Specifications for All Proposed Options

With all the options specified above, the ordinance/code amendments would also include:

- Continued requirement for Administrative Permit for all digital billboards
- Prohibition of animation – digital copy would have to remain static
- No increase to number of existing billboards
- Provisions for public/community benefit messaging, including coordination with Office of Emergency Services (OES)
- Caltrans permit requirement – when applicable
- Restriction of digital copy change to 8 seconds
- Addressing lighting time limitations and maximum permitted light emissions
- Allow conversion of traditional billboards that have existing lighting only
- Conformance to adopted Community Plans and Community Design Guidelines
- Prohibition of digital billboards located within Zone A of the Light Pollution Code

VII. Costs and Resources

Any action to amend County codes and ordinances to address the conversion of traditional billboards to digital LED billboards is not currently budgeted. Use of a Negative Declaration to assess the environmental impacts associated with ordinance changes may be used however there are risks associated with this approach since substantial comments regarding lighting, aesthetics and community character impacts may arise during the environmental review process. Consequently, an Environmental Impact Report (EIR) will likely be required for changes to the signage portion of the Zoning Ordinance and Light Pollution Code because the proposed options would potentially result in additional billboard locations not currently permitted under existing zoning and increase in the light emitted from digital billboards as compared to existing traditional billboards. In these circumstances, new impacts associated with these locations and increase in lighting would need to be identified and, where possible, mitigated. Cost for preparation of an EIR and staff time for the ordinance amendment would be approximately $600,000. This figure includes approximately $400,000 for the EIR consultant to prepare an EIR and $200,000 for staff work for community and stakeholder outreach, environmental consultant contract management, preparation of public review documents, revisions to Community Plans and Community Design Review Guidelines, ordinance amendments and hearing preparation. Based on the experience of processing other ordinance amendments with associated EIRs, staff estimates a processing time of 18 to 24 months from the time that direction is provided by the Board until consideration of the amended ordinance by the Board.

Due to benefits this action would have for billboard operators, the Board may want to consider industry as a possible funding source for this project. However, the County cannot require the billboard industry to fund a County initiated proposal to amend the billboard ordinance. Any industry funding would need to be voluntary. If the Board decides to consider industry as a possible funding source for the work, staff would need to discuss the proposal with industry representatives and seek a voluntary funding agreement. Any industry funding would not assure the approval of ordinance amendments

authorizing digital billboards, or any particular outcome, as this would be at the discretion of the Board.

VIII. Summary

In summary, staff has researched information regarding digital billboards from industry representatives, other jurisdictions and via the internet. Pursuant to Board direction outreach to the Community Planning/Sponsor Groups, the billboard industry and other interested parties was conducted. This effort has resulted in the development of the six options for ordinance amendments provided for the Board of Supervisors consideration.

Attachments

Copies of comment letters and emails received from Community Planning/Sponsor Groups and other interested parties are attached.

BONSALL COMMUNITY SPONSOR GROUP

Dedicated to enhancing and preserving a rural lifestyle

COUNTY OF SAN DIEGO BONSALL COMMUNITY SPONSOR GROUP
REGULAR MEETING MINUTES
TUESDAY, January 8, 2013
7:00 P.M.
31505 Old River Road
Bonsall, California 92003

1. **ADMINISTRATIVE ITEMS:**

A. **Roll: Litner, Rosier, Morgan, Zales**
Absent: Norris, Davis, Carullo-Miller

B. **Pledge of Allegiance:**

C. **Approval of Minutes:** for the Regular Meeting Minutes for Tuesday, December 4, 2012.

Motion to approve the minutes, as written, was made by Lintner, seconded by Zales. All members present approved the motion.

D. Public Communication on non-agenda items: Traffic issues regarding mass transit were discussed.

E. **ACTION ITEMS:**

1. Zap 02-052 Sprint site modification.
Cabinets and wall color should be an earth tone color and match. Not the current green color. Landscaping is not required. Condition of approval is based on moving the cabinets and cell site should Gopher Canyon Rd be widened as it currently is designated in the Mobility Element to improve to 5 lanes.
Motion to approve based on condition stated above by Zales, seconded by Litner all members present approved the motion.

2. Digital LED Billboard Options –
The proposed options supplied by the County reflected interesting ideas for many communities however, the community of Bonsall does not have a need for this type of signage. We currently have two shopping areas with one additional site blighted and under developed all three are located along Highway 76.
With the dark sky policy and the close proximity of Mt Palomar to Bonsall the use of this type of billboard is not in keeping with that policy and is not supported by the Bonsall Community Plan. I have attached on a separate page of conflicting goals and policies in both the Community Plan and the Design Review Guidelines. In addition to that being said the unique setting of the San Luis Rey River and the soon to be 8 ½ mile long San Luis Rey River Regional Park in Bonsall with major wild life corridors and scenic views.

We do not support LED signs in our community but if other Planning or Sponsor Groups find it appropriate for their community we would not have a problem as long as the County does not create a one size fits all policy.

Motion by Zales second by Litner and all member present approved the motion.

F. GROUP BUSINESS
   1. Announcements and Correspondence – none submitted
      A. New Planning & Sponsor Group Coordinator – Lisa Fitzpatrick.

   2. Discussion Items
      A. Draft Template for Comments Letters regarding San Diego Region Municipal Stormwater Permit from – CPG & CSG. Approve Chair to draft letter to Stephanie Gains staff member in regard to the Watershed Protection Programs including the NPDES Stormwater Permit Reissuance. Motion by Zales second by Litner and all members present approved the motion.

G. ADJOURNED 7:50 P.M.

BONSALL COMMUNITY SPONSOR GROUP

Dedicated to enhancing and preserving a rural lifestyle

1/8/2013
Heather Lingelser

RE: Digital Message Boards

BONSALL COMMUNITY PLAN

Page 25 – Community Character

Policy 1.2.3 Require on and off-site advertising signs complement the aesthetic value and unique character of the community.

Policy 1.2.4 Prohibit development of advertising billboards and require that existing billboards are not modified and are eliminated over time.

Policy 1.2.5 Seek to eliminate existing uses that are nonconforming and are detrimental to surrounding uses.

BONSALL DESIGN GUIDELINES

Page A-8 Signage shall not adversely impact the environmental and visual quality of the area.

1. All signs shall be limited to the minimum size and height necessary to adequately identify a business location.
2. All signs shall be kept as low to the ground as possible.
3. Signs shall be used for identification, not advertisement.
4. Signage design shall be carefully integrated with the site and building design concepts to create a unified appearance for the total development.
   a. Signs shall be part of a comprehensive graphic program for each project.
5. Signs shall be predominately natural materials, non-moving, externally illuminated.
6. Off-premise signs shall be prohibited except for temporary real estate directional, community identification and directional signs, as specified in Section 6207 of the County Zoning Ordinance.

Margarette Morgan, Chair
Bonsall Sponsor Group

http://www.bcsg.org

COUNTY OF SAN DIEGO
DEPARTMENT OF PLANNING AND LAND USE: Zoning
COMMUNITY PLANNING OR SPONSOR GROUP PROJECT RECOMMENDATION

PROJECT NAME: HEATHER LINGELSER

PROJECT CASE NUMBER(s): DIGITAL BILLBOARD OPTIONS

PLANNING / SPONSOR GROUP NAME: BONSALL SPONSOR GROUP

Results of Planning / Sponsor Group Review

Meeting Date: 1/8/2013

A. Comments made by the group on the proposed project.

I HAVE ATTACHED THE MINUTES AND A ONE PAGE SUMMARY REGARDING THE SPONSOR GROUPS CONCERNS.

B. **Advisory Vote:** The Group ☐ Did or ☐ Did Not make a formal recommendation, approval or denial on the project at this time.

If a formal recommendation was made, please check the appropriate box below:

MOTION:

- ☐ Approve without conditions
- ☐ Approve with recommended conditions
- ☐ Deny
- ☐ Continue

VOTE: _____ Yes _____ No _____ Abstain

C. Recommended conditions of approval:

Reported by: Margaretta Morgan Position: Chair Date: 1/8/2013

Please email recommendations to BOTH EMAILS; Project Manager listed in email (in this format): Firstname.Lastname@sdcounty.ca.gov **and to** CommunityGroups.LUEG@sdcounty.ca.gov .

FALLBROOK COMMUNITY PLANNING GROUP
And
DESIGN REVIEW BOARD
Regular Meeting
Monday 17 December 2012, 7:00 P.M., Live Oak School, 1978 Reche Road, Fallbrook
MINUTES

Mr. Jim Russell called the meeting to order at 7:00 p.m.

Twelve (12) members were present: Anne Burdick, Donna Gebhart, Ike Perez, Roy Moosa, Tom Harrington, Steve Smith, Jack Wood, Ron Miller, Michele Bain, Jackie Heyneman, Eileen Delaney, Jean Dooley, Jim Russell and Harry Christiansen. Paul Schaden, Jackie Heyneman and Jack Wood were not present.

Mr. Russell updated the Group on the Red Tape Commission proposed changes to board policies I.1 and I.1a. He stated that the Board of Supervisors had approved most of the recommendations but had asked staff to report back on an agenda format and posting procedure. It appeared clear that the Board was no longer going to allow complete agendas to be posted in publications. There will be a notice published of where the agendas will be posted. Groups will be provided web pages where the agendas will also be posted. Another development was that the Board approved leaving Chair selection as is.

1. Open Forum. Opportunity for members of the public to speak to the Planning Group on any subject matter within the Group's jurisdiction but not on today's agenda. Three minute limitation. Non-discussion, & Non-voting item.

Mr. Monty Voigt addressed the Group and expressed appreciation for each of the Group members consistent efforts for the Community of Fallbrook.

2. Approval of the minutes for the meetings of 19 November 2012. Voting Item.

Ms. Dooley motioned to approve the minutes, it passed unanimously.

3. POD 08-006 Site Implementation Agreement request from the Department of Planning and Land Use Planners, Marcus Lubich, Marcus.Lubich@sdcounty.ca.gov and Joseph Farace,Joseph.Farace@sdcounty.ca.gov for comments and recommendations on a draft Site Implementation Agreement County of Regulatory Code amendments. The proposed ordinance introduces a new framework for a Site Implementation Agreement (SIA). The SIA would serve the function of a companion permit, in most instances, for subdivision maps. The SIA would assist in assuring the implementation of project requirements (i.e. conditions) associated with the development of subdivisions, mitigation of identified impacts, and on-going requirements after map recordation. Continued at the 29 August FCPG meeting. **Land Use Committee.** Community input. Voting item. (7/19)

Mr. Moosa reported that the Land Use Committee had discussed the item. No County Representatives were present at the meeting. The discussion raised several questions about how this procedure varied from the current process and what advantages did it offer. After limited discussion, Mr. Moosa motioned to continue the item until next month when a County representative could be present. The motion passed unanimously.

4. Request for a waiver of the B designator site plan requirement for auto sales located at 434 E. Mission Road. Owner and contact person Rosalinda Saites, 916-300-5564. County planner Debra Frischer, 858-495-5201, debra.frischer@sdcounty.ca.gov, or Dag Bunnemeyer, dag.bunnemeyer@sdcounty.ca.gov. **Design Review Committee**. Continued at the request of the applicant at the 19 Nov meeting of the FCPG. Community input. Voting item. (10/30).

Ms. Rosalinda Saites presented the request for auto sales and to install signage and landscaping at 434 E. Mission. She stated that the Design Review Committee had made a suggestion on the landscaping and requested information on the location of a trash bin.
Ms. Delaney reported the Design Review Committee had reviewed the request and had approved the request.
Ms Delaney motioned to approve the project and the motion passed unanimously.

5. Request for a minor deviation in the Site Plan for the Fallbrook Shell canopy reimage. The request is for the existing 3'x6' sign to be refaced to the new Shell specifications and we are requesting to add LED lights to three sides of the canopy. Currently there are no LED lights on the canopy. This is for the Shell Station located at 936 E.Mission Rd. Point of contact, Chris Cottam, ccottam@calcraft.com, 800 345-9645, 714 206-6072 Cell. County planner Debra Frischer, 858-495-5201, debra.frischer@sdcounty.ca.gov. **Design Review Committee**. Community input. Voting item. (11/14)

Mr. Chris Cottam introduced the request to replace signage and place L.E.D. trim around the canopies for the Shell station at 936 E. Mission Road.
Ms. Delaney reported that Mr. Cottam had not attended the Design Review Committee meeting therefore there was no Committee report on the request. The lit trim appeared to exceed size of approved signage. After limited discussion Ms. Delaney motioned to continue the request to the January group meeting to allow the Design Review Committee an opportunity to review and comment on the request. The motion passed unanimously.

6. Request for a waiver of the B designator site plan requirement to replace all signs on ATM kiosk and resurface ATM machine at 1135 S. Mission Road (APN 104-390-09-00). Owner Sudbury Development, Inc. 858-546-3000. Contact person Steve Therriault 619-571-9675, steve@signtechusa.com. County planner Debra Frischer, 858-495-5201, debra.frischer@sdcounty.ca.gov. **Design Review Committee**. Community input. Voting item (11/16)

Mr. Steve Therriault introduced the request to replace current signage with smaller L.E.D. lit signage.
Ms. Delaney stated the Design Review Committee had reviewed and approved the of the request. After limited discussion Ms. Delaney motioned to approve the request and the motion passed unanimously.

7. County staff, at the direction of the Board of Supervisors, is working on an ordinance to provide for Digital LED Billboards in San Diego County and they have requested the community provide them with our thoughts and concerns. County planner, Heather (Steven) Lingelser, Planning & Development Services, 858.495.5802, FAX 858.467.9314, heather.lingelser@sdcounty.ca.gov. **Land Use Committee**. Community input. Voting item. (11/20)

No County representative was present so Mr. Moosa reported on the Land Use Committee review of this item. He stated that there was a great deal of concern over conflicts with lit large signs (up to 14 foot by 48 foot signs in the Fallbrook area) and the Fallbrook Community plan and

character. The lit signage was also viewed as a safety concern for passing traffic. Land Use had voted to strongly object to the proposal.
Ms. Delaney reported on the Design Review meeting on this item. She stated that the proposal was intended to cover existing non-conforming off premises billboard signs. The Committee had the same concerns the Land Use Committee had.
Mr. Russell asked if the Committees had considered the businesses that utilized the signs. Ms. Delaney responded by stating that if the ordinance were to take affect it would provide an unfair advantage to the large sign users due to very different restrictions on smaller signs in the design guidelines.
After lengthily discussion Mr. Moosa motioned to strongly object to the modification of the ordinance due to the negative impacts on the rural community character as well as conflict with the Fallbrook Community Plan and design guidelines. Additional issues would be driving safety concerns in the vicinity of this type of signage and the un-fair advantage to large format sign advertisers would have over small format sign advertisers if the Ordinance modification was allowed in areas subject to design guidelines. The motion passed unanimously.

In closing Mr. Russell presented two Proclamations to outgoing members of the Group.

First Mr. Russell read the Proclamation citing the years of community service Mr. Harry Christiansen had provided to Fallbrook. Mr. Christiansen served twenty years on the Fallbrook Planning Group and was recently recognized by the Fallbrook Chamber of Commerce for all his other Community service with a Lifetime Achievement Award.

Second Mr. Russell read the Proclamation citing the service of Mr. Steve Smith to the Fallbrook Community Planning Group and the Community of Fallbrook.

The Meeting was adjourned at 7:44 pm
Tom Harrington, Secretary

Lingelser, Heather

From: jack@cableusa.com
Sent: Saturday, December 22, 2012 9:31 AM
To: Lingelser, Heather
Subject: Re: Digital Billboard Options

Heather; At their meeting on December 10th, the Julian Community Planning Group took a position to oppose digital billboards. There is only one current sign that would qualify as a billboard in the Julian Plannng Area and it is unlikely that the owner would want to convert it to digital, but we believe that digital billboards can be a distration to motorists and therfore a traffic hazard. Jack Shelver, Chair JCPG

On Sat, 22 Dec 2012 00:03:46 +0000, "Lingelser, Heather" <Heather.Lingelser@sdcounty.ca.gov> wrote:

Hello - as many of you know we met with many of you to discuss Board direction we received to explore options for the use of digital billboards.

As we explained at the meetings, staff was planning on developing options based on feedback and staff research. Attached is a list of proposed options for the Board to consider. We would appreciate if you could review and provide your input on the options at your earliest convenience.

We will attempt to schedule a joint meeting next month between industry representatives and the Community Planning/Sponsor Group representatives to further discuss this project.

Please feel free to contact me at 858-495-5802 if you have any questions and have a Happy Holiday!

Sincerely,

Heather (Steven) Lingelser
Land Use/Environmental Planner
Policy and Ordinance Development

Planning & Development Services

5510 Overland Avenue, Suite 310

San Diego, CA 92123

☎858.495.5802 |6 858.467.9314
heather.lingelser@sdcounty.ca.gov

Please consider the environment before printing this e-mail

Lingelser, Heather

From: mathews.charles@gmail.com
Sent: Saturday, December 22, 2012 6:10 AM
To: Lingelser, Heather
Cc: Farace, Joseph; Murphy, Jeff
Subject: Re: Digital Billboard Options

Heather:
Great work! The options provide the BoS worthwhile choices. One parameter that maybe I missed but would like to see is some measurement of maximum permitted light emission from each digital board and all digital boards in a defined area.
Best,
Charles Mathews,
Chair, Pala Pauma Community Sponsor Group.

Sent from my iPad

On Dec 21, 2012, at 6:03 PM, "Lingelser, Heather" <Heather.Lingelser@sdcounty.ca.gov> wrote:

Hello - as many of you know we met with many of you to discuss Board direction we received to explore options for the use of digital billboards.

As we explained at the meetings, staff was planning on developing options based on feedback and staff research. Attached is a list of proposed options for the Board to consider. We would appreciate if you could review and provide your input on the options at your earliest convenience.

We will attempt to schedule a joint meeting next month between industry representatives and the Community Planning/Sponsor Group representatives to further discuss this project.

Please feel free to contact me at 858-495-5802 if you have any questions and have a Happy Holiday!

Sincerely,

Heather (Steven) Lingelser
Land Use/Environmental Planner
Policy and Ordinance Development
Planning & Development Services
5510 Overland Avenue, Suite 310
San Diego, CA 92123

☎858.495.5802 | 🖶 858.467.9314
heather.lingelser@sdcounty.ca.gov
Please consider the environment before printing this e-mail

<OPTIONS 12-21-12.pdf>

Rainbow Community Planning Group

A San Diego County Heritage Community Since 1880
Keeping Rainbow Rural
Advising the Board of Supervisors-San Diego County

Date December 18, 2012

To: County of San Diego Planning and Development Services Advanced Planning Division

The Rainbow Community Planning Group (RPG) wishes to thank the County of San Diego Planning and Development Services Advanced Planning Division for the opportunity to comment on proposed regulations regarding the implementation of LED digital billboards in our community. Our concerns, considerations and questions regarding the design, installation, and use of such billboards are detailed as follows:

1) Safety Concerns / Considerations -- Driver safety is of paramount importance to our community and to the State of California. The I-15 corridor is heavily traveled and is shared daily by thousands of commuters and resort industry customers alike. Signs currently placed along the I-15 are often used to attract casino patrons with notices of food, gambling, musical or other entertainment promotions. With driver distractions at an all time high due to cell phone usage, on-board navigation systems, and video players, large brightly lit electronic signage only adds to the potential for hazardous distraction for drivers of motor vehicles. In addition to brightly lit flashing lights, new digital LED billboards often utilize a transitional message capability that tends to hold the viewer's attention in anticipation of the screen changing appearance. This "attention increasing" feature of transitional signage can keep a driver's attention away from the road for longer periods of time, often leading to increased potential for vehicular accidents and human fatalities.

Q) How will safety concerns for lighted signs be addressed by the County, sign companies, and advertisers? What remedies are available to the public if/when a sign is deemed to be a problem or is listed in an accident report by law enforcement personnel as a potential cause of an accident?

2) Light Pollution Concerns / Considerations -- Existing CoSD light pollution regulations are intended to protect the Palomar and Mount Laguna observatories, as well as citizens of the County from the detrimental effect that light pollution has on astronomical research. A recently installed LED digital billboard in Corona serves as an easily observable example of what such signs may look like when they are eventually installed within our community. The example sign is located approximately one quarter

mile south of the I-15 / CA-91 transition alone the west side of I-15. Upon casual observation, the example sign would appear to be brighter than other signs along the I-15. The example sign also includes a transitional message capability that tends to hold the viewer's attention in anticipation of the message changing. The sign appears to "flash" brightly when the message changes, which in addition to becoming a driver distraction, also substantially increases observable light pollution in the sign's vicinity.

Q) How will light pollution concerns for lighted signs be addressed by the County, sign companies, and advertisers? What remedies are available to the public if/when a sign is deemed to be a significant cause of light pollution within a community or for nearby communities?

3) Compliance with / Enforcement of existing regulations -- Existing off-premise signs and billboards placed within the Community of Rainbow and alone the I-15 corridor would appear to be in violation of multiple existing CoSD regulations:

Section 51.206.a.2 Hours of Operation of the County's existing light pollution regulations state that "A billboard may be lighted until midnight", yet a recent observation revealed that many lighted billboards placed within the Community of Rainbow appear to remain lighted well past midnight.

Section 6205.e.1 of the existing CoSD sign regulation states: "No portion of any sign structure shall exceed a height of 25 feet." Recent observation of existing signs along the I-15 corridor and within the community of Rainbow revealed that many lighted billboards would appear to exceed the mandated 25 foot limit.

Based on casual observation and as witnessed in the examples given above, it would appear that some existing County sign regulations are not being strictly enforced.

Q) Which CoSD department or authority is responsible for enforcing current outdoor sign regulations within our community? How will sign regulation compliance be enforced by the County? What remedies are available to the public if/when a sign is deemed to be non-compliant with current regulations?

Thank you again, for your consideration of our concerns and questions regarding LED digital billboards and CoSD sign regulations.

Respectfully,

Gary Drake
Chair, Digital Billboard Sub-Committee
On Behalf of The Rainbow Planning Group

RAMONA COMMUNITY PLANNING GROUP
15873 HWY 67, RAMONA, CALIFORNIA 92065
Phone: (760)445-8545

Jim Piva
Chair

Scotty Ensign
Vice-Chair

Kristi Mansolf
Secretary

Chad Anderson

Torry Brean

Jim Cooper

Matt Deskovick

Carl Hickman

Eb Hogervorst

Barbara Jensen

Donna Myers

Dennis Sprong

Paul Stykel

Richard Tomlinson

Kevin Wallace

January 15, 2013

Heather Lingelser
Land Use/Environmental Planner
Policy and Ordinance Development
Planning and Development Services
5510 Overland Avenue, Suite 310
San Diego, CA 92123

RE: DIGITAL LED BILLBOARD OPTIONS

The Ramona Community Planning Group reviewed the Digital LED Billboard Options at the meeting January 10, 2013. The following motion was made:

MOTION: TO SUPPORT OPTION 6 WITH THE REQUIRED REMOVAL OF 3 TRADITIONAL BILLBOARDS, WITH THE REPLACEMENT OF 1 DIGITAL LED BILLBOARD, LOCATED IN THE SAME COMMUNITY PLANNING AREA.
The motion **passed 9-5-0-0-1,** with 5 members voting no, and 1 member absent.

Sincerely,

Kristi Mansolf, Secretary

for JIM PIVA, Chair
Ramona Community Planning Group

Spring Valley Community Planning Group
Response to
Digital Billboard Options
January 8, 2012

Meeting Vote: To approve 9-0-0 no abstentions no negative votes.

Option 1:
In addition to reduction of overall number of billboards...
RECOMMEND ADDITION: FIRST priority to be given to other billboards within the Planning Group

Option 2:
This is far too large an allowance for size. In no case should a billboard conversion be larger than current one.

Options 1 and 2 should be concurrent, not optional as one thing or the other.

Option 3:
Allowing a sign to be relocated then converted, takes a lot of faith. What is to prevent the conversion stopping as soon as the billboard is moved? If a company wants to put up a digital billboard in a specific location, they should be required to remove at least three billboards elsewhere.

This would also seem to allow non-conforming, non-complying billboards to be used to get digital billboards in places where they were unable to get them before. Current non-complying/ non-conforming billboards should be removed as an agreement to allow relocation but not to be relocated.

Option 4:
Is there no other use for County properties? Is the County, producing revenue from otherwise useless properties?

Option 5:

Allowing only conversion of existing billboards that are in compliance is a good thing in part, but should include removing non-complying billboards. This would be the only way in some cases to get these undesirable, non-complying billboards out of the Community.

All billboard conversions should be smaller than the original due to the fact that their intensity makes for easier viewing at a smaller size.

Also, allowing additional lighting intensity would further pollute the environment.

Option 6:

This is very fuzzy.

Putting billboards in the ZO would give the right to have the sign there forever, even if it is proven later to be detrimental either by content, distraction or malfunction.
There should certainly be a maximum number of large advertising signs overall whether digital or regular.

In Addition To Options:

- Ordinance should also include the ability of local Planning/Sponsor groups to give input to the County on the appropriateness of the billboards within the Planning/Sponsor area.

- Copy should NOT change as fast as 8 seconds. This creates a distraction to drivers.

- Careful study of appropriate illumination day and night needs to be expanded

VALLE DE ORO COMMUNITY PLANNING GROUP
P. O. BOX 936
LA MESA, CA 91944-0936

January 17, 2013

Ms. Heather Lingelser
County of San Diego
Planning & Development Services
5510 Overland Ave., Suite 110
San Diego, CA 92123

SUBJECT: Conversion of Traditional Billboards to Digital LED Billboards

On January 15, 2013, this Planning Group considered the proposal to convert to digital LED billboards and the four County staff-prepared options to implement such a change. The Group voted unanimously (10-0) to oppose any change to the County's sign ordinances that would allow the introduction of digital LED billboards into our communities.

The Planning Group found that:

A. The many existing billboards located in our area are a significant source of visual blight wherever they are located. Emphasizing their presence by conversion to digital LED technology will only worsen their visual impact and allow the industry to introduce, at will, new unforeseen forms of visual blight into our communities.

B. The Valle de Oro Community Plan under Community Design Policies prohibits the development of new billboards or the modification of existing billboards and seeks their eventual elimination as follows:

"3. Development of advertising billboards shall be prohibited. Existing billboards shall not be modified or transferred to new owners and shall be eliminated at the earliest possible time."

Sincerely,

Jack L. Phillips
Chairman, VDOCPG
619-670-0986

Distribution: DPDS, Heather Lingelser
BOS, Supervisor Dianne Jacob

E2	Report and possible vote on VCCPG's comments on the DPDS's report to the Board of Supervisors concerning approaches for addressing the use of digital bulletin boards in the County of San Diego. (Quinley)

Discussion: Quinley presents background of proposed changes to the billboard ordinance. She explains her printed report. She says the County wants to take advantage of new technology. She describes the six options being explored by County staff:

1. Create a conversion/removal ratio in which one traditional billboard can be converted to a digital billboard if the owner also removes three traditional billboards.
2. Create a conversion/square footage ratio in which a traditional billboard may be converted to a digital billboard if an equivalent square footage of traditional billboards is removed.
3. Allow conversion of Billboards when an existing billboard is removed to a preferable location when it is converted to digital. (Can be combined with 1 and 2).
4. Allow relocation of billboards to county-owned properties. Billboard operators could relocate their billboards to county land and conversion to digital would be allowed.
5. Allow conversion only of those billboards that are currently in compliance with the existing zoning ordinances.
6. Permit only billboards located on specific properties to convert to digital billboards. This option would require billboard operators to work with county staff and the community planning groups prior to obtaining permission to convert.].

She says not much attention was paid to the Dark Sky Ordinance or the Valley Center Design Guidelines, both of which prohibit internally lighted signs. She reads her motion. Jackson asks to amend the motion to limit lighted signage to public information. Smith explains that billboards under consideration are commercial off-site billboards and he suggests the motion be limited to consider the class of billboards under consideration. David Ross, media, asks if the Lexus digital billboard next to I-15 in Escondido would qualify as a digital billboard. Yes.

Smith suggests that new billboards may qualify to be digital without replacement or reduction of existing billboards within the County. He asks how County could say no to such new billboards? Smith says such billboards may be used for public emergency announcements at times when appropriate. Tom Bumgardner, audience says the County owns land along the Rights-Of-Way of roads. Smith says such billboards could not be closer than about 50 feet to the roadway. Smith says all cities are looking at allowing such billboards in order to raise additional revenue. Smith discusses the logistics of present billboards. Davis asks for amendment to para. 3. Bret Davis asks about the placement of billboards allowed in Valley Center presently. Smith says billboards are not presently allowed and says Valley Center needs to have reasoned arguments for not allowing such billboards to have an impact at the County. Bob Davis clarifies the need to have Valley Center review of such billboard authorization. Rudolf

asks about the County staff commitment to honor Valley Center's Guidelines and Community Plan and wonders if Smith agrees. Smith says BOS can put billboards anywhere with 3 votes. Rudolf counters with need to amend the County General Plan, Valley Center's Community Plan and Valley Center's Design Guidelines before that could happen. Smith suggests deleting paragraph 3 except for the amended first sentence. Quinley defends her motion as originally presented, but relents and agrees to deletion of most of paragraph 3; Hutchison agrees to the amendment. Glavinic suggests citing billboards along Hwy. 395 and I-15. Discussion continues in several directions at once, but with no further amendments advanced.	
Motion: Valley Center is located in an area covered by the Dark Skies Ordinance and has provisions in its Design Guidelines and Community Plans that prohibit internal illumination of signs and that presume that "billboards" are not permitted. The Valley Center Community Planning Group asks that the Board of Supervisors uphold these ordinances and policies, which are already in place. It is not acceptable to allow digital billboards as alternatives to traditional billboards as long as there are fewer billboards in the end, as stated in Options 1 and 2. Nor do we support conversion to a digital billboard when a billboard is moved to a preferable location or a location specifically designated by the County as stated in Options 3 and 5. Digital LED Billboards should not be permitted in Valley Center.	
Maker/Second: Quinley/Hutchison	**Carries**/Fails: [Y-N-A] **14-0-0** Voice

Lingelser, Heather

From:	Lael Montgomery [laelmontgomery@aol.com]
Sent:	Sunday, December 30, 2012 11:26 AM
To:	Lingelser, Heather
Cc:	'Smith, Oliver'; 'Ann Quinley'; richrudolf@sbcglobal.net; jonvick2@aol.com; 'Mark Jackson'; 'Steve Hutchison'; 'Christina & Bill Lewis'; Farace, Joseph; Wardlaw, Mark; Murray, Beth; 'Jeff Herr'; 'Keith Robertson'; 'Lael Montgomery (E-mail)'; 'Robson Splane'; 'Susan Moore (E-mail)'
Subject:	Community Character? Comments on Digital LED Billboards Options 12/21/12

Dear Heather,

I am writing to suggest that the "Digital LED Billboard Options" that you circulated just before Christmas be revised to include reference to and support for the Design Guidelines for Signage that exist for several unincorporated communities: Alpine, I-15, Lakeside, Ramona, Sweetwater and Valley Center. In Valley Center's Design Guidelines, guidelines for on-premises signage are presented on pages 56-57.

1. Design Guidelines and on-premises signage: no internal illumination

VC's Design Guidelines permit illumination only by light projected on the sign; internally illuminated signs are not permitted. Presumably this includes Digital LED signs, as well. The rural character of the VC and other rural communities will be protected only if Digital LED signage regulations refer to and support our Design Guidelines.

2. Design Guidelines presume that "billboards" are not permitted.

Billboard design is not addressed in our Design Guidelines because, presumably, as we have always been told, off-premises commercial billboards are not permitted in Valley Center, period. We are concerned, however, that this issue be addressed explicitly especially for rural communities as the BOS considers options for Digital LED billboards which could quickly destroy the rural character that the community wants to protect.

Though not addressed explicitly, the INTENT of VC's signage design guidelines addresses the threat presented to rural character by allowing either billboards or Digital LED displays. It reads: *The purpose of this Guideline is to protect Valley Center's rural residential environment from the adverse impact of unnecessarily large or an excessive number of commercial signs. Valley Center's commercial properties should avoid the clutter of commercial signage common to more densely urbanized communities of the County.*

I believe that Design Guidelines for the six other communities are similar.

These concerns were discussed at the December meeting of the Valley Center Design Review Board meeting. The Board voted to pass them along to the Valley Center Planning Group, and to the County staff.

Thank you, Heather, for taking a look at the Digital LED issues in light of local community Design Guidelines and Community Plans.

Lael Montgomery, Chair
Valley Center Design Review Board

International Dark-Sky Association

"...to preserve and protect the nighttime environment and our heritage of dark skies through environmentally responsible outdoor lighting."

3223 North First Avenue, Tucson, AZ 85719, USA
tel +1.520.293.3198 | fax +1.520.293.3192
www.darksky.org | ida@darksky.org

Executive Director
Bob Parks

Managing Director
W. Scott Kardel

Emeritus
David L. Crawford, PhD

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Tyler Nordgren, PhD • *USA*
Connie Walker • *USA*

December 20, 2012

County of San Diego Planning & Development Services Advanced Planning Division
5510 Overland Avenue
San Diego, CA 92123

To County of San Diego Planning and Development Services Advanced Planning Division,

I am writing to you to express concern that San Diego County is considering allowing the use of electronic billboards. This seems to be in direct conflict with the County's existing ordinance on light pollution that seeks to "minimize light pollution to allow citizens of the County to view and enjoy the night environment and to protect the Palomar and Mount Laguna observatories from the detrimental effect that light pollution has on astronomical research."

Allowing electronic billboards would reverse these night sky protections that are in place for your citizens and the astronomers at both Palomar Observatory and Mount Laguna Observatory. Nighttime use of electronic billboards makes them a tremendous source of light pollution. Much of the light emitted from these excessively bright devices directly brightens the night sky making them a significant threat to astronomical research, one of Southern California's most valuable economic and technical assets.

While the light of an LED electronic billboard does not shine directly upwards, it is instead projected sideways at angles that are above the horizontal. Research has shown that light emitted in this direction produces more light polluting skyglow than light emitted at higher angles, and that the effects of this low-angle light are visible over a much broader area.

Because of their detrimental affects on astronomy, earlier this year the State of Arizona outlawed the use of electronic billboards located within 75-miles of astronomical observatories. It is certain that permitting the use of electronic billboards within San Diego County would have a negative impact on the observatory's nightly astronomical research programs and forever change the character of the County's back country.

Electronic billboards are significantly brighter than standard billboards and the reach of their sideways-directed light extends far beyond the roadways, making them an annoying source of light trespass, not just for motorists, but also for anyone in their path.

3223 North First Avenue, Tucson, AZ 85719, USA
tel +1.520.293.3198 | fax +1.520.293.3192
www.darksky.org | ida@darksky.org

Given the legitimate concerns expressed by others regarding electronic billboards' excessive energy use, their potential as a distraction to roadway motorists and the reasons provided above, I request that you do not allow the use of electronic billboards in the County.

Sincerely,

W. Scott Kardel
Managing Director
International Dark-Sky Association

TERRA
realty advisors, inc.

20 October 2012

Ms. Heather Lingelser
County of San Diego
5510 Overland Avenue Suite 310
San Diego, CA 92123

Re: Billboard Signs

Dear Heather,

It was very nice talking with you the other day, regarding the potential issues involving billboard signs. I'm sure your meeting with representatives of the various sign companies was informative, and educational too!

As I mentioned when we spoke on the phone, it may be a good idea for the County to explore the potential impacts and revenues of installing LED signs on County owned property, either in conjunction with, or as an independent action from the initial direction given by the Board members. Changing your ordinance to permit LED signs appears to me to be a one-sided benefit, for the sign companies, at the expense of the County, not only for processing the necessary legal changes, but in lost revenue. Exploring a potential new revenue source in conjunction with changing the ordinance may be a better option.

Terra Realty Advisors, Inc. is currently working with the City of San Pablo, County of Solano, Solano Irrigation District, Vallejo Sanitation & Flood Control District, as well as two school districts in Los Angeles right now, exploring the concept, and issuing RFP's to solicit proposals for sign companies to lease various properties to install billboard signs: both static and LED. We have over 16 years of experience with billboard signs, acquiring and selling properties and buildings with outdoor signs, and negotiating billboard agreements with the sign companies for our public and private sector clients.

For your information, I've attached a brief synopsis of Terra Realty Advisors, Inc., as well as a flyer we published last year for our clients, relating to the consulting work we have done regarding signs. If you have any questions, or wish to discuss this matter in greater detail, please give us a call.

Sincerely,

Scott Sheldon

cc Greg Sampson

2300 Boynton Ave Suite 202 • Fairfield, CA 94533 • phone 707.639.1000 • fax 707.312.5200 • www.terraadvisors.net

TERRA
realty advisors, inc.

Terra Realty Advisors, Inc. - Profile

Scott Sheldon is the founding Principal and President of Terra Realty Advisors, Inc. Terra Realty Advisors, Inc. was formed in 2008 to broaden and expand our public and private sector real estate consulting practice. We have extensive experience in the development, construction and ownership of Class A office buildings, in the Northern California area alone in excess of 500,000 square feet, over the past twenty five years. We have also developed or acquired approximately 250,000 feet of retail space, together with industrial "tilt-up" warehouses, apartment buildings, single-family home subdivisions, schools (public & private), and religious buildings.

Our consulting practice has assisted private owners and public agencies in the development, construction and/or acquisition of land for school sites, airport expansion, outdoor billboard signs, cell sites, golf course communities, storage facilities, corporation yards, auto body shop, car washes and single-family homes. During the past ten years, we have assisted many public agencies, including Cities, Counties and School Districts, throughout California with their strategic real estate needs, including: the development of public service buildings, negotiating and structuring acquisitions, sales and property exchanges, providing asset management solutions for the short and long term needs of our Clients, and interfacing with the development community to originate and implement mutually beneficial results for both.

Our thirty plus years of real estate experience allows us to be a leader in real property due diligence investigations, including forensic analysis of title, land and building matters, as well as other land use matters. We have successfully completed eminent domain work as lead negotiator and expert witness on behalf of several public sector clients; working with attorneys, appraisers, civil engineers and other consultants in both the Bay Area and Southern California. Our method is to recognize the goals and constraints of our Clients and the property, and to formulate and implement creative, market driven solutions to meet their needs, with the best information available.

Our knowledge of the strategic requirements of our clients as it relates to the use, development, due diligence coordination, entitlement and approval processes for their real estate assets, and being able to successfully complete projects and assignments, is unparalleled. A combination of professional experience and knowledge will allow Terra Realty Advisors, Inc. to successfully manage and provide timely advice to meet all your real estate needs.

Our Philosophy

Our organizational model revolves around active management, and establishing and maintaining complete and clear lines of communication. Our flat organizational structure allows

us flexibility in adapting to changing situations and markets. We accomplish this through constant monitoring and tracking of events that have happened, are happening, and need to happen. Using proprietary computer models, accounting software, scheduling software, and other databases, our team at Terra Realty Advisors, Inc. is fully committed to your real estate needs, to meet our agreed schedule. We can allocate and commit the necessary resources and personnel to accomplish our tasks in a timely way, and our past record demonstrates this ability.

Terra Realty Advisors, Inc.'s approach to our assignments are straightforward and clear; with the goal to provide timely and good quality information to our Clients, so informed decisions can be made rapidly and cost effectively, while understanding the implications of those choices. With Terra Realty Advisors, Inc. being the central repository for all information, schedules, and budgets, we are able to quickly and expeditiously answer questions and provide timely information and proposed direction, to keep everything on track and on budget. We are also the "Vital Records" keeper for all our Clients, so questions and information can be dealt with quickly, both during and after a projects' completion. To help make this happen, we have invested and embraced technology to assist us in all parts of our business; with the goal of being a "paperless" office achieved over 4 years ago.

Accurate and timely information on which to base decisions will help ensure success for our Clients. Creative solutions, with an iterative approach to resolving issues, will allow our Clients to focus on macro-decisions, not micro-processes to achieve their goals. Our approach and philosophy has proved successful time and time again for both our public, as well as private sector clients.

Representative Sign Projects

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For Strategic Real Estate Advisory Services

Contact us at:
2300 Boynton Avenue Suite 202 Fairfield CA 94533

Office: 707-639-1000
Fax: 707-312-5200

www.terraadvisors.net

TANTALA ASSOCIATES, LLC
CONSULTING ENGINEERS

A STUDY OF THE RELATIONSHIP BETWEEN DIGITAL BILLBOARDS AND TRAFFIC SAFETY IN THE GREATER READING AREA, BERKS COUNTY, PENNSLYVANIA

SUBMITTED TO

THE FOUNDATION FOR OUTDOOR ADVERTISING
RESEARCH AND EDUCATION (FOARE)
1850 M STREET, NW, SUITE 1040
WASHINGTON, DC 20036-5821

BY

MICHAEL WALTER TANTALA, P.E.
ALBERT MARTIN TANTALA, SR., P.E.

ON

2 AUGUST 2010

TANTALA ASSOCIATES, LLC
CONSULTING ENGINEERS
4903 FRANKFORD AVENUE
PHILADELPHIA, PA 19124-2617
www.TANTALA.com

A STUDY OF THE RELATIONSHIP BETWEEN DIGITAL BILLBOARDS AND TRAFFIC SAFETY IN THE GREATER READING AREA, BERKS COUNTY, PENNSLYVANIA

KEY POINTS

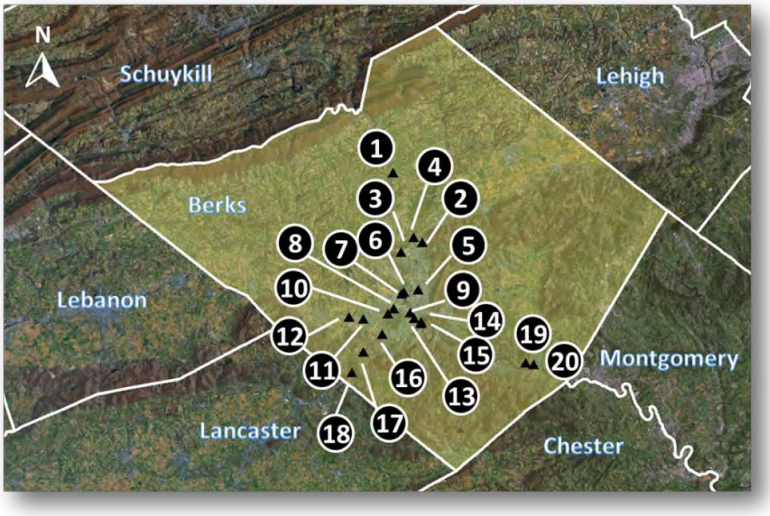
• 8 years of accident data comparisons

• 20 locations with 26 digital billboard faces

• Data show no statistically significant increase in accident rates, using before and after comparisons and using an Empirical Bayes Method Analysis for the actual and predicted comparisons

• Comparisons of driver age (young/elderly) and time of day (daytime/nighttime) are neutral factors

• Consistent results for various dwell times (6, 8 and 10 seconds)



KEY

Digital Locations in the Greater Reading Area, Berks County, Pennsylvania

1	Rte 61/ Rte 662	**11**	Rte 724 / Rte 422
2	Rte 222 N / Leesport	**12**	422 West / Green Valley
3	Rte 222 N Bypass	**13**	Lancaster at Rte 10
4	Rte 222 N Bypass	**14**	West Shore Drive / Lanc Exit
5	5th and Amity	**15**	West Shore Drive / 176 Exit
6	Warren Bypass at Rte 183	**16**	Rte 222 / Rte 724
7	Warren Bypass / Allegheny	**17**	Rte 222 / Gouglersville
8	422 Bypass / Bern	**18**	Rte 222 / RT 272
9	West Shore Drive / Penn	**19**	Rte 422 / RT662
10	422 Bypass / State Hill	**20**	Rte 422 / Old Airport

Figure 1.
Digital Billboard Locations in the Greater Reading Area, Berks County, Pennsylvania

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Eight years of data …

… no statistically significant relationship with the occurrence of accidents …

… consistent results for 6, 8 and 10 second dwell times …

OVERVIEW

The purpose of this study is to **examine the statistical relationship between digital billboards and traffic safety in the Greater Reading Area, Berks County, Pennsylvania**. This study analyzes traffic and accident data along roads near **20 locations with 26 existing, digital billboard faces** (see Figure 1) with traffic volumes on roads collectively representing approximately 233 million vehicles per year. The study uses official data as collected, complied and recorded independently by municipal police departments and the Pennsylvania Department of Transportation.

The study includes **eight years of accident data** representing approximately 35 thousand accidents near twenty locations in Berks County. The billboards were converted to digital format between 2005 and 2009 and afford periods of comparison as long as 8 years (98 months).

Temporal (*when and how frequently*) and spatial (*where and how far*) statistics are summarized near billboards within multiple vicinity ranges as large as one-half mile for areas that are upstream and downstream of the billboards. Subsets of daytime and nighttime accidents and driver age are analyzed for before and after comparisons.

Additionally, an Empirical Bayes Method (EBM) analysis is performed to estimate the number of accidents that could statistically be expected without the introduction of digital signs. This method is the basis of the safety analysis and science-based, predictive models introduced within the 2010 *Highway Safety Manual* of the American Association of State Highway Official (AASHTO, Reference 14). This report establishes benchmarks for the basis of accident records at pre-digital locations and also uses other comparison sites in Reading.

The overall conclusion of the study is that **the digital billboards in the Greater Reading Area have no statistically significant relationship with the occurrence of accidents**. This study also finds that the age of drivers (younger/elderly) and the time of day (daytime/nighttime) are neutral factors which show no significant increase in accident rates near the digital billboards. The results are consistent for 6, 8 and 10 second dwell times (see Figure 2). These conclusions are based on Police Department data and an objective statistical analysis; **the data show no significant increase in accident rates**.

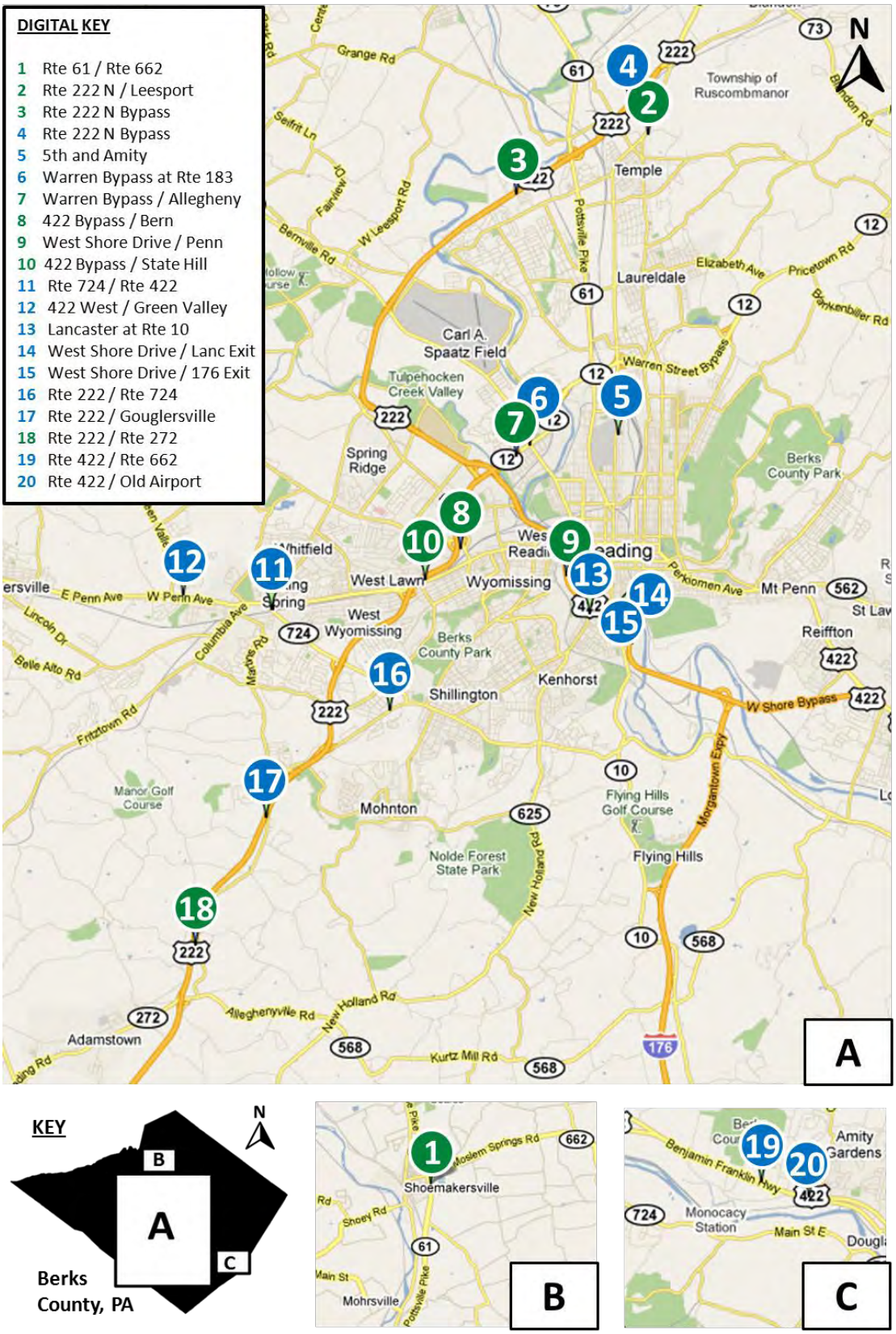


Figure 2.
Digital Billboard Locations in the Greater Reading Area. Locations in "green" have 10 second dwell times; Locations in "blue" have 6 or 8 second dwell times.

The static display on each of these digital billboards have "dwell times" of 6, 8 or 10 seconds.

STUDY REGION

The Greater Reading Area was chosen as a study region, because it has multiple digital billboards in close proximity that were in service for extended periods of time. The roads adjacent to these billboards are heavily traveled (approximately 703 thousand vehicles traveled per day collectively on the sections of road near the digital billboards).

The Greater Reading Area in Berks County, Pennsylvania, is situated in the southeastern part of the State, has an area of approximately 860 square miles, and a population of 373 thousand people and 141 thousand households (2000 census). In 2008, some 162 thousand licensed drivers drove to work in the Greater Reading Area with an average commute time of 22 minutes.

Several federal and state highways allow entry to and egress from Reading. US Route 222 Business is designated as Lancaster Avenue, Bingaman Street, South 4th Street, and 5th Street. US Route 422 Business is designated as Penn Street, Cherry Street, Franklin Street, and Perkiomen Avenue. US Route 422, the major east-west artery, circles the western edge of the city and is known locally as The West Shore Bypass. PA Route 12 is known as the Warren Street Bypass, and bypasses the city to the north. PA Route 10 is known as Morgantown Road.

BILLBOARD CHARACTERISTICS

Digital billboards display static messages which, when viewed, resemble conventional painted or printed billboards. With digital technology, a static copy “dwells” and includes no animation, flashing lights, scrolling, or full-motion video. The static display on each of these digital billboards has "dwell times” of 6, 8 or 10 seconds. The digital billboards use red, green, and blue light-emitting-diode (LED) technology to present text and graphics. The digital billboards compensate for varying light levels, including day and night viewing, by automatically monitoring and adjusting overall display brightness and gamma levels. A photocell is mounted on each digital billboard to measure ambient light. Twenty of the digital billboards that were studied are owned and operated by *Lamar;* six, by *Land Displays*.

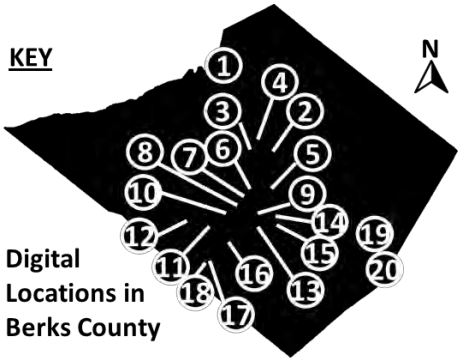
Generally, the digital billboards operated by Lamar have dwell times of six or eight seconds for the smaller poster-sized boards and ten seconds for the larger, bulletin-sized boards. Digital billboards operated by *Land Displays* have dwell times of eight seconds.

Billboard Location	Location	Operator	Configuration	Road Side	Digital Facing	Reader Side	Face Size (ft)	Dwell Time (seconds)
1	**Rte 61 / Rte 662** on Rte 61, 0.2 miles south of Rte 662	Lamar	Free standing, Center-mount, Vee	E	**N** **S**	cross right	10.5x36 10.5x36	10 10
2	**Rte 222 N / Leesport** on Rte 222 N, 0.1 miles north of Leesport Avenue	Lamar	Free standing, Center-mount	E	**S**	right	14x48	10
3	**222 N Bypass** on Rte 222 N Bypass, 1.0 mile south / Rte 61 Exit	Lamar	Free standing, Center-mount	E	**N**	cross	14x48	10
4	**222 N Bypass** on Rte 222 N Bypass, 1.0 mile north / Rte 61 Exit	Land Displays	Free standing, Center-mount, Vee	W	**N**	right	20x20	8
5	**5th and Amity** at 5th Street & Amity Street	Lamar	Free standing, Center-mount, Back-to-Back	E	**N**	left	10.5x22.75	6
6	**Warren Bypass at Rte 183** on Rte 12 (Warren Street Bypass) at Rte 183	Land Displays	Roof-top, Frame, Back-to-Back	S	**W**	right	14x48	8
7	**Warren Bypass / Allegheny** on Warren Street west of Allegheny Avenue	Lamar	Free standing, Flag, Vee	S S	**E** **W**	cross right	10.5x36 10.5x36	10 10
8	**422 Bypass / Bern** on Rte 422 Bypass, 0.2 miles west of Bern Road Exit	Lamar	Free standing, Flag, Vee	S S	**E** **W**	cross right	14x48 14x48	10 10
9	**West Shore Drive / Penn** on West Shore Drive, 0.3 miles east of Penn Street	Lamar	Free standing, Center-mount, Vee	S	**E** **W**	cross right	10.5x36 10.5x36	10 10
10	**422 Bypass / State Hill** on Rte 422 Bypass, 0.6 miles west / State Hill Rd	Lamar	Free standing, Center-mount, Vee	S	**W**	right	10.5x22.75	10
11	**Rte 724 / Rte 422** on Rte 724, 1000 feet south of Rte 422	Land Displays	Free standing, Center-mount, Vee	W	**S**	right	10.5x36	8
12	**422 West / Green Valley** on Rte 422 west, 0.1 miles east / Green Valley Rd	Lamar	Free standing, Center-mount, Back-to-Back	N	**E** **W**	right cross	10.5x22.75 10.5x22.75	8 8
13	**Lancaster at Rte 10** on Lancaster Avenue (Rte 422) at Rte 10	Land Displays	Free standing, Center-mount, Back-to-Back	W	**S**	cross	10.5x36	8
14	**West Shore Drive / Lancaster Exit** on West Shore Drive, 0.4 miles east of Lancaster Exit	Lamar	Free standing, Center-mount, Vee	N	**E**	right	10.5x22.75	6
15	**West Shore Drive / 176 Exit** on West Shore Drive, 0.5 miles of Exit 176	Lamar	Free standing, Center-mount, Single-face	N	**W**	cross	10.5x22.75	6
16	**Rte 222 / Rte 724** on Rte 222 S, 0.3 miles south of Rte 724	Lamar	Free standing, Center-mount, Vee	W	**N** **S**	right cross	11x23 11x23	8 8
17	**Rte 222 / Gouglersville** on Rte 222, 0.13 miles north / Gouglersville Exit	Land Displays	Free standing, Center-mount, Single-face	E	**N**	cross	12x25	8
18	**Rte 222 / Rte 272** on Rte 222 S, 1.0 miles north of Rte 272 / 568	Lamar	Free standing, Center-mount, Vee	E	**S**	right	14x48	10
19	**Rte 422 / Rte 662** on Rte 422, 3.0 miles west of Rte 662	Land Displays	Free standing, Center-mount, Double-face	S	**W**	right	10x20	8
20	**Rte 422 / Old Airport** on Rte 422 east, 0.1 mi west of Old Airport Road	Lamar	Free standing, Center-mount, Vee	S	**W**	right	10.5x22.75	8

Figure 3.
Digital Billboard Direction, Sizes and Other Sign Characteristics

The digital, billboard locations are numbered 1 to 20 with 26 billboard faces. The twenty locations in Reading are shown in Figures 1, 2, and 3 which summarize direction, configuration and other sign characteristics. The digital boards and their surroundings were observed during day and night conditions. A majority of the digital billboards are freestanding, single-pole, structures with one digital face; six locations have two digital boards on the same upright.

Figure 4 summarizes the conversion dates. Nine of the twenty-six billboards were converted to digital format circa December 2005 and the remaining were converted on various dates in 2007, 2008 and 2009. These dates allow for before/after comparisons as long as 8.1 years (or 98 months). Additional billboard-location photos, aerials, and map references for each digital location are included within this report as Figures 5 to 25.



Billboard Location	Digital Facing	Install Date	more than 8 years of comparison								
			2001	2002	2003	2004	2005	2006	2007	2008	2009
1	N	29Nov08								prior to	as digital
	S	22Sep06				prior to			as digital		
2	S	27Jan06			prior to			as digital			
3	N	27Jan06			prior to			as digital			
4	N	15Jun07					prior to		as digital		
5	N	13Jan06		prior to				as digital			
6	W	29Nov05		prior to				as digital			
7	E	27Jan06			prior to			as digital			
	W	1Feb08						prior to		as digital	
8	E	8Jan09								prior to	as digital
	W	8Jan09								prior to	as digital
9	E	29Nov05		prior to				as digital			
	W	29Nov05		prior to				as digital			
10	W	6Jan09								prior to	as digital
11	S	15Aug08							prior to		as digital
12	E	14Nov08							prior to		as digital
	W	22Feb08						prior to		as digital	
13	S	15Aug08							prior to		as digital
14	E	13Jan06		prior to				as digital			
15	W	13Jan06		prior to				as digital			
16	N	20Mar08						prior to		as digital	
	S	14Mar08						prior to		as digital	
17	N	15Aug08							prior to		as digital
18	S	14Apr07					prior to			as digital	
19	W	15Jun07						prior to		as digital	
20	W	14Apr07					prior to			as digital	

Figure 4.
Digital billboard Conversion Dates and Comparison Timelines for Digital Locations in the Greater Reading Area

Location No. 1 is on the east side of Route 61, approximately 0.2 miles south of Route 662. The structure is a double-face, free standing, center-mount, vee configuration. The north face is a digital bulletin and a cross reader. The north face was converted from a conventional format on 29Nov08 using the existing location. The south face is a digital bulletin and a right-hand reader. The face was converted from a conventional format on 22Sep06 using the existing location. Each face is operated by Lamar and has a 10.5x36 size with a dwell time of 10 seconds. Figure 5a is a photo of the south digital face. Figure 5b shows the location in an oblique aerial.

Figure 5. Location No. 1 (5a, left) View on Route 61; inset shows opposite-face digital, (5b, right) Oblique Aerial of location

Location No. 2 is on the east side of Route 222 North, approximately 0.1 miles north of Leesport Avenue. The structure is a double-face, free standing, center-mount, back-to-back configuration. The south face is a digital bulletin and a right-hand reader. The face was converted from a conventional format on 27Jan06 using the existing location. The face is operated by Lamar and has a 14x48 size with a dwell time of 10 seconds. Figure 6a is a photo of the digital face. Figure 6b shows the location in an oblique aerial.

Figure 6. Location No. 2 (6a, left) View on Route 222 North, (6b, right) Oblique Aerial of location

Location No. 3 is on the east side of Route 222 North Bypass, approximately 1.0 miles south of the Route 61 Exit. The structure is a single-face, free standing, center-mount configuration. The north face is a digital bulletin and a cross reader. The north face was converted from a trivision format on 27Jan06 using the existing location. The face is operated by Lamar and has a 14x48 size with a dwell time of 10 seconds. Figure 7a is a photo of the digital face. Figure 7b shows the location in an oblique aerial.

Figure 7. Location No. 3 (7a, left) View on Route 222 North Bypass, (7b, right) Oblique Aerial of location

Location No. 4 is on the west side of Route 222 North Bypass, approximately 1.0 miles north of Route 61 Exit. The structure is a double-face, free standing, center-mount, vee configuration. The north face is a digital poster and a right-hand reader. The face was converted from a stacked poster format on 15Jun07 using the existing location. The face is operated by Land Displays and has a 20x20 size with a dwell time of 8 seconds. Figure 8a is a photo of the digital face. Figure 8b shows the location in an oblique aerial.

Figure 8. Location No. 4 (8a, left) View on Route 222 North Bypass, (8b, right) Oblique Aerial of location

Location No. 5 is on the east side of 5th Street at Amity Street. The structure is a double-face, free standing, center-mount, back-to-back configuration. The north face is a digital poster and a left-hand reader. The north face was converted from a conventional format on 13Jan06 using the existing location. The face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 6 seconds. Figure 9a is a photo of the digital face. Figure 9b shows the location in an oblique aerial.

Figure 9. Location No. 5 (9a, left) View at 5th Street and Amity Street, (9b, right) Oblique Aerial of location

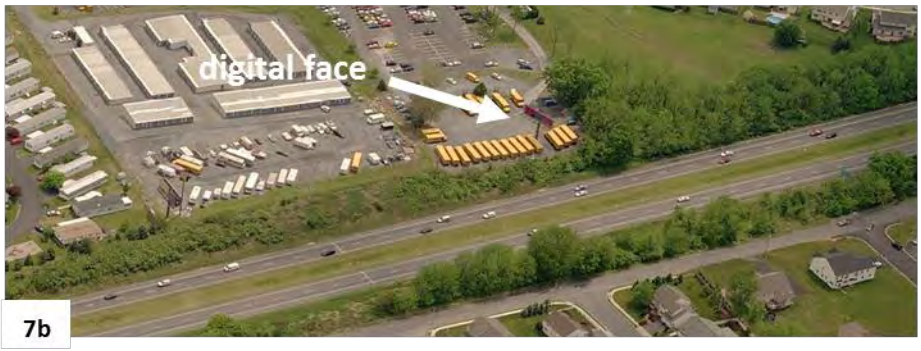
5a

5b

6a

6b

7a



7b

8a

8b

9a

9b

Location No. 6 is on the south side of Route 12 (Warren Street Bypass) at Route 183. The structure is a double-face, roof-top, frame, back-to-back configuration. The west face is a digital bulletin and a right-hand reader. The face was converted from a conventional format on 29Nov05 using the existing location. The face is operated by Land Displays and has a 14x48 size with a dwell time of 8 seconds. Figure 10a is a photo of the digital face. Figure 10b shows the location in an oblique aerial.

Figure 10. Location No. 6 (10a, left) View at Route 12 (Warren Street Bypass) at Route 183, (10b, right) Oblique Aerial of location

Location No. 7 is on the south side of the Warren Street Bypass, west of Allegheny Avenue. The structure is a double-face, free standing, flag, vee configuration. The east face is a digital bulletin and a cross reader. The east face was converted from a conventional format on 27Jan06 using the existing location. The west face is a digital bulletin and a right-hand reader. The west face was converted from a conventional format on 01Feb08 using the existing location. Each face is operated by Lamar and has a 10.5x36 size with a dwell time of 10 seconds. Figure 11a is a photo of the east digital face. Figure 11b shows the location in an oblique aerial.

Figure 11. Location No. 7 (11a, left) View at Warren Street Bypass, inset shows opposite-face digital, (11b, right) Oblique Aerial of location

Location No. 8 is on the south side of the Route 422 Bypass, approximately 0.2 miles west of the Bern Road Exit. The structure is a double-face, free standing, flag, vee configuration. The east face is a digital bulletin and a cross reader. The east face was converted from a conventional format on 08Jan09 using the existing location. The west face is a digital bulletin and a right-hand reader. The west face was converted from a conventional format on 08Jan09 using the existing location. Each face is operated by Lamar and has a 14x48 size with a dwell time of 10 seconds. Figure 12a is a photo of the east digital face. Figure 12b shows the location in an oblique aerial.

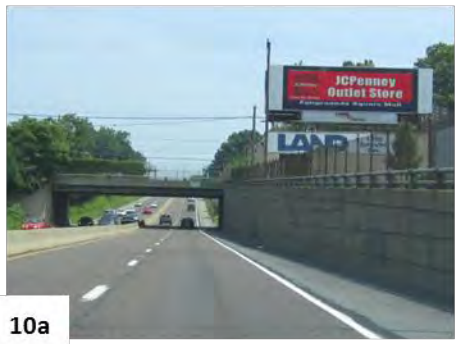
Figure 12. Location No. 8 (12a, left) View at Route 422 Bypass, inset shows opposite-face digital, (12b, right) Oblique Aerial of location

Location No. 9 is on the south side of West Shore Drive, approximately 0.3 miles east of Penn Street. The structure is a double-face, free standing, center-mount, vee configuration. The east face is a digital bulletin and a cross reader. The east face was converted from a trivision format on 29Nov05 using the existing location. The west face is a digital bulletin and a right-hand reader. The west face was converted from a trivision format on 29Nov05 using the existing location. Each face is operated by Lamar and has a 10.5x36 size with a dwell time of 10 seconds. Figure 13a is a photo of the east digital face. Figure 13b shows the location in an oblique aerial.

Figure 13. Location No. 9 (13a, left) View at West Shore Drive, inset shows opposite-face digital, (13b, right) Oblique Aerial of location

Location No. 10 is on the south side of the Route 422 Bypass, approximately 0.6 miles west of State Hill Road. The structure is a double-face, free standing, center-mount, vee configuration. The west face is a digital poster and a right-hand reader. The face was converted from a conventional format on 06Jan09 using the existing location. The face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 10 seconds. Figure 14a is a photo of the digital face. Figure 14b shows the location in an oblique aerial.

Figure 14. Location No. 10 (14a, left) View at Route 422 Bypass, (14b, right) Oblique Aerial of location



10a

10b

11a

11b

12a

12b

13a

13b

14a

14b

Location No. 11 is on the west side of Route 724, approximately 1000 feet south of Route 422. The structure is a double-face, free standing, center-mount, vee configuration. The south face is a digital bulletin and a right-hand reader. The face was converted from a conventional format on 15Aug08 using the existing location. The face is operated by Land Displays and has a 10.5x36 size with a dwell time of 8 seconds. Figure 15a is a photo of the digital face. Figure 15b shows the location in an oblique aerial.

Figure 15. Location No. 11 (15a, left) View at Route 724, (15b, right) Oblique Aerial of location

Location No. 12 is on the north side of Route 422 West, approximately 0.1 miles east of Green Valley Road. The structure is a double-face, free standing, center-mount, back-to-back configuration. The east face is a digital poster and a right-hand reader. The east face was converted from a conventional format on 14Nov08 using the existing location. The west face is a digital poster and a cross reader. The west face was converted from a conventional format on 22Feb08 using the existing location. Each face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 8 seconds. Figure 16a is a photo of the west digital face. Figure 16b shows the location in an oblique aerial.

Figure 16. Location No. 12 (16a, left) View at Route 422 West, inset shows opposite-face digital, (16b, right) Oblique Aerial of location

Location No. 13 is on the west side of Lancaster Avenue (Route 422) at Route 10. The structure is a double-face, free standing, center-mount, back-to-back configuration. The south face is a digital bulletin and a cross reader. The south face was converted from a poster format on 15Aug08 using the existing location. The face is operated by Land Displays and has a 10.5x36 size with a dwell time of 8 seconds. Figure 17a is a photo of the digital face. Figure 17b shows the location in an oblique aerial.

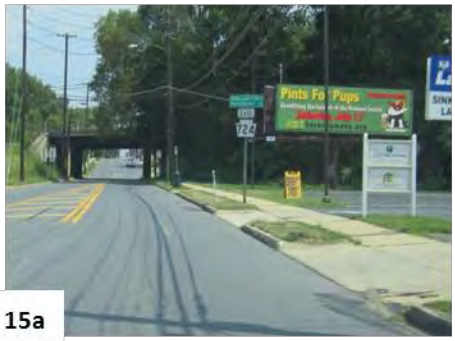
Figure 17. Location No. 13 (17a, left) View at Lancaster Avenue (Route 422) at Route 10, (17b, right) Oblique Aerial of location

Location No. 14 is on the north side of West Shore Drive, approximately 0.4 miles east of the Lancaster Exit. The structure is a double-face, free standing, center-mount, vee configuration. The east face is a digital poster and a right-hand reader. The face was converted from a conventional format on 13Jan06 using the existing location. The face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 6 seconds. Figure 18a is a photo of the digital face. Figure 18b shows the location in an oblique aerial.

Figure 18. Location No. 14 (18a, left) View at West Shore Drive, (18b, right) Oblique Aerial of location

Location No. 15 is on the north side of West Shore Drive, approximately 0.5 miles west of Exit 176. The structure is a single-face, free standing, center-mount configuration. The west face is a digital poster and a cross reader. The face was converted from a conventional format on 13Jan06 using the existing location. The face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 6 seconds. Figure 19a is a photo of the digital face. Figure 19b shows the location in an oblique aerial.

Figure 19. Location No. 15 (19a, left) View at West Shore Drive, (19b, right) Oblique Aerial of location

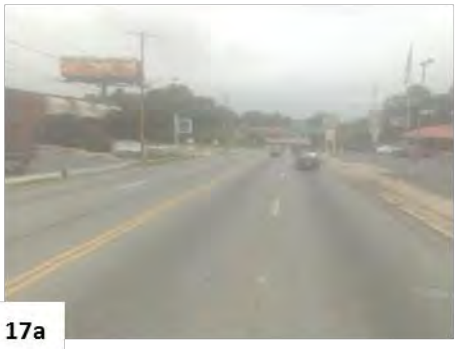


15a

15b

16a

16b

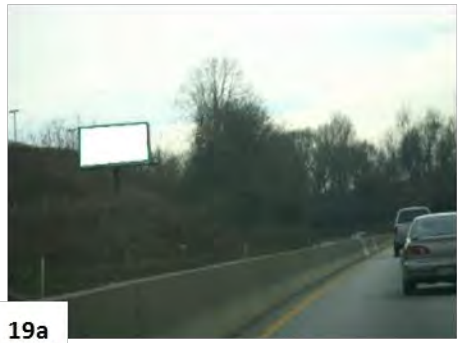


17a

17b

18a

18b



19a

19b

Location No. 16 is on the west side of Route 222 South, approximately 0.3 miles south of Route 724. The structure is a double-face, free standing, center-mount, vee configuration. The north face is a digital poster and a right-hand reader. The north face was converted from a conventional format on 20Mar08 using the existing location. The south face is a digital poster and a cross reader. The south face was converted from a conventional format on 14Mar08 using the existing location. Each face is operated by Lamar and has a 11x23 size with a dwell time of 8 seconds. Figure 20a is a photo of the north digital face. Figure 20b shows the location in an oblique aerial.

Figure 20. Location No. 16 (20a, left) View at Route 222 South, inset shows opposite-face digital, (20b, right) Oblique Aerial of location

Location No. 17 is on the east side of Route 222, approximately 0.13 miles north of the Gouglersville Exit. The structure is a single-face, free standing, center-mount configuration. The north face is a digital poster and a cross reader. The face was a new location that was installed and activated on 15Aug08. The face is operated by Land Displays and has a 12x25 size with a dwell time of 8 seconds. Figure 21a is a photo of the digital face. Figure 21b shows the location in an oblique aerial.

Figure 21. Location No. 17 (21a, left) View at Route 222, (21b, right) Oblique Aerial of location

Location No. 18 is on the east side of Route 222 South, approximately 1.0 mile north of the intersection of Routes 272 and 568. The structure is a double-face, free standing, center-mount, vee configuration. The south face is a digital bulletin and a right-hand reader. The sign was a new build and installed on 14Apr07 at this location. The face is operated by Lamar and has a 14x48 size with a dwell time of 10 seconds. Figure 22a is a photo of the digital face. Figure 22b shows the location in an oblique aerial.

Figure 22. Location No. 18 (22a, left) View at Route 222 South, (22b, right) Oblique Aerial of location

Location No. 19 is on the south side of Route 422, approximately 3.0 miles west of Route 662. The structure is a double-face, free standing, center-mount configuration. The west face is a digital poster and a right-hand reader. The face was converted from a conventional format on 15Jun07 using the existing location. The face is operated by Land Displays and has a 10x20 size with a dwell time of 8 seconds. Figure 23a is a photo of the digital face. Figure 23b shows the location in an oblique aerial.

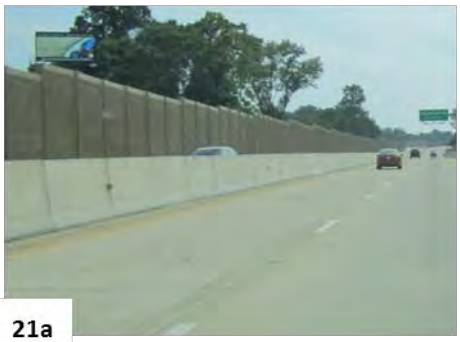
Figure 23. Location No. 19 (23a, left) View at Route 422, (23b, right) Oblique Aerial of location

Location No. 20 is on the south side of Route 422 East, approximately 0.1 miles west of Old Airport Road. The structure is a double-face, free standing, center-mount, vee configuration. The west face is a digital poster and a right-hand reader. The face was converted from a trivision format on 14Apr07 using the existing location. The face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 8 seconds. Figure 24a is a photo of the digital face. Figure 24b shows the location in an oblique aerial.

Figure 24. Location No. 20 (24a, left) View at Route 422 East, (24b, right) Oblique Aerial of location

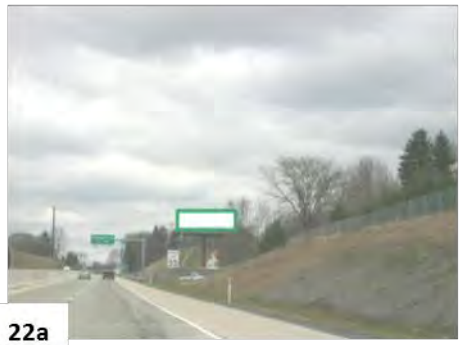
20a

20b



21a

21b



22a

22b

23a

23b

24a

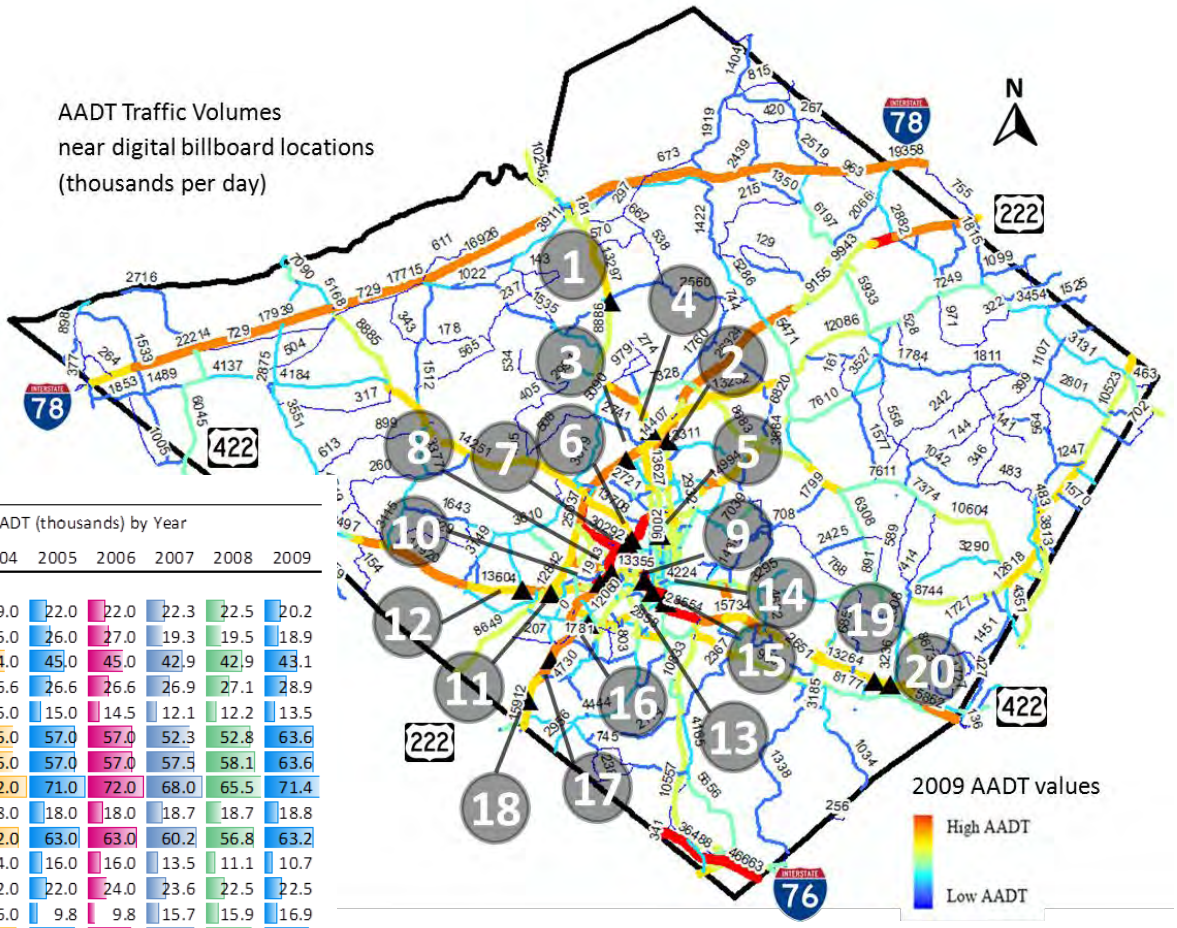
24b

AADT ranges individually near the 20 digital locations from 9 to 71 thousand vehicles per day, or equivalently 3 to 26 million vehicles per year.

TRAFFIC VOLUME DATA

Traffic volume data for the Greater Reading Area were obtained from the Pennsylvania Department of Transportation (PennDOT) and includes the annual average daily traffic (AADT), which is the average of 24-hour counts collected throughout the year. The AADT volumes were recorded in the Greater Reading area between 2002 and 2009.

The AADT values are summarized in Figure 25. AADT ranges individually near the 20 digital locations from 9 to 71 thousand vehicles per day, or equivalently 3 to 26 million vehicles per year. For each of the location, this collectively represents approximately 703 thousand vehicles per day or 256 million vehicles per year.



Location	AADT (thousands) by Year							
	2002	2003	2004	2005	2006	2007	2008	2009
1	18.0	18.0	19.0	22.0	22.0	22.3	22.5	20.2
2	24.0	24.0	25.0	26.0	27.0	19.3	19.5	18.9
3	40.0	40.0	44.0	45.0	45.0	42.9	42.9	43.1
4	22.7	23.9	26.6	26.6	26.6	26.9	27.1	28.9
5	14.5	15.0	15.0	15.0	14.5	12.1	12.2	13.5
6	62.0	54.0	55.0	57.0	57.0	52.3	52.8	63.6
7	62.0	54.0	55.0	57.0	57.0	57.5	58.1	63.6
8	71.0	68.0	72.0	71.0	72.0	68.0	65.5	71.4
9	17.0	17.0	18.0	18.0	18.0	18.7	18.7	18.8
10	60.0	60.0	62.0	63.0	63.0	60.2	56.8	63.2
11	14.0	14.0	14.0	16.0	16.0	13.5	11.1	10.7
12	20.0	20.0	22.0	22.0	24.0	23.6	22.5	22.5
13	5.8	5.8	6.0	9.8	9.8	15.7	15.9	16.9
14	52.0	59.0	58.0	57.0	55.0	58.4	53.8	57.9
15	52.0	59.0	58.0	57.0	55.0	58.4	53.8	57.9
16	9.3	9.4	9.5	9.5	9.4	9.3	9.1	9.1
17	29.0	29.0	30.0	33.0	35.5	37.9	37.9	38.2
18	29.0	29.0	30.0	33.0	35.5	31.9	30.6	30.6
19	24.0	24.0	24.0	27.0	27.0	27.5	27.8	27.3
20	24.0	24.0	24.0	27.0	27.0	26.6	27.8	27.3

Figure 25. AADT Volume Data near Digital Billboard Locations in the Greater Reading Area; the Data is summarized in a table from 2002 to 2009 (left) and thematically mapped for 2009 (above)

ACCIDENT DATA

In the Greater Reading Area, the majority of accident reports are investigated and recorded by each Township's Police Department. Data were maintained by those Police Departments and compiled by the Pennsylvania Department of Transportation. Law-enforcement officials are required to submit reports on crashes they investigate which meet reporting thresholds provided by statue, or in which someone was injured or killed in the crash. Data generally conform to the American National Standards Institute (ANSI) Standard D16.1 – 1996, Manual on Classification of Motor Vehicle Traffic Accidents.

The accident data sets provided by PennDOT include 35,000 accidents during the eight years between 2001 and 2009 and near digital billboard locations. Most of the data are specified by latitude and longitude or addresses and intersections with offset distances. Figure 26 shows the geocoded accident locations generally within Berks County.

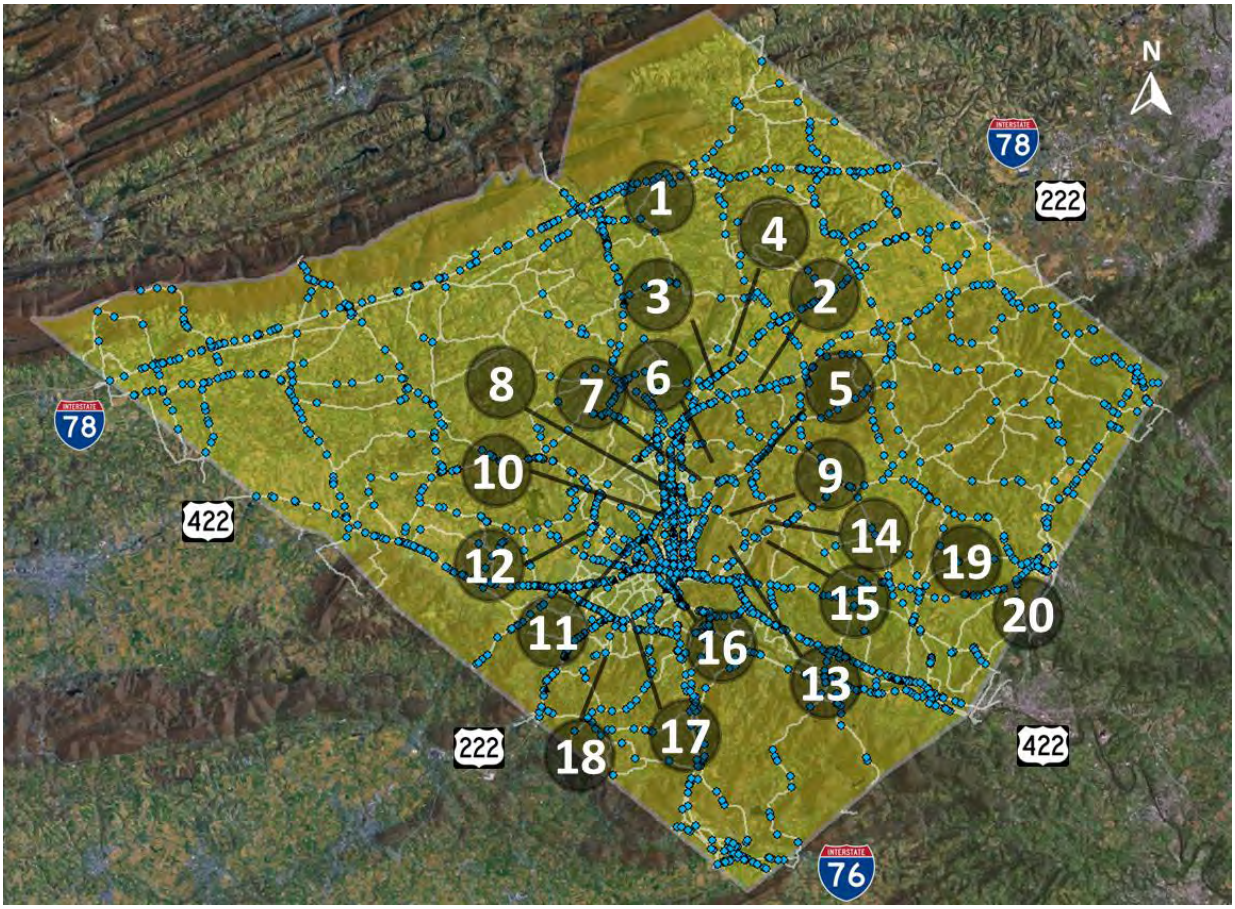


Figure 26. Traffic Accidents (blue dots) near Digital Billboard Locations in the Greater Reading Area from 2001 to 2009

Figure 27 summarizes the traffic accident data for the past seven years generally within the Greater Reading Area and show the distribution of accidents by year, month, day of week and time of day. This represents a consistent pattern of data and illustrates that more accidents occur on weekdays and at rush hour (before and after work).

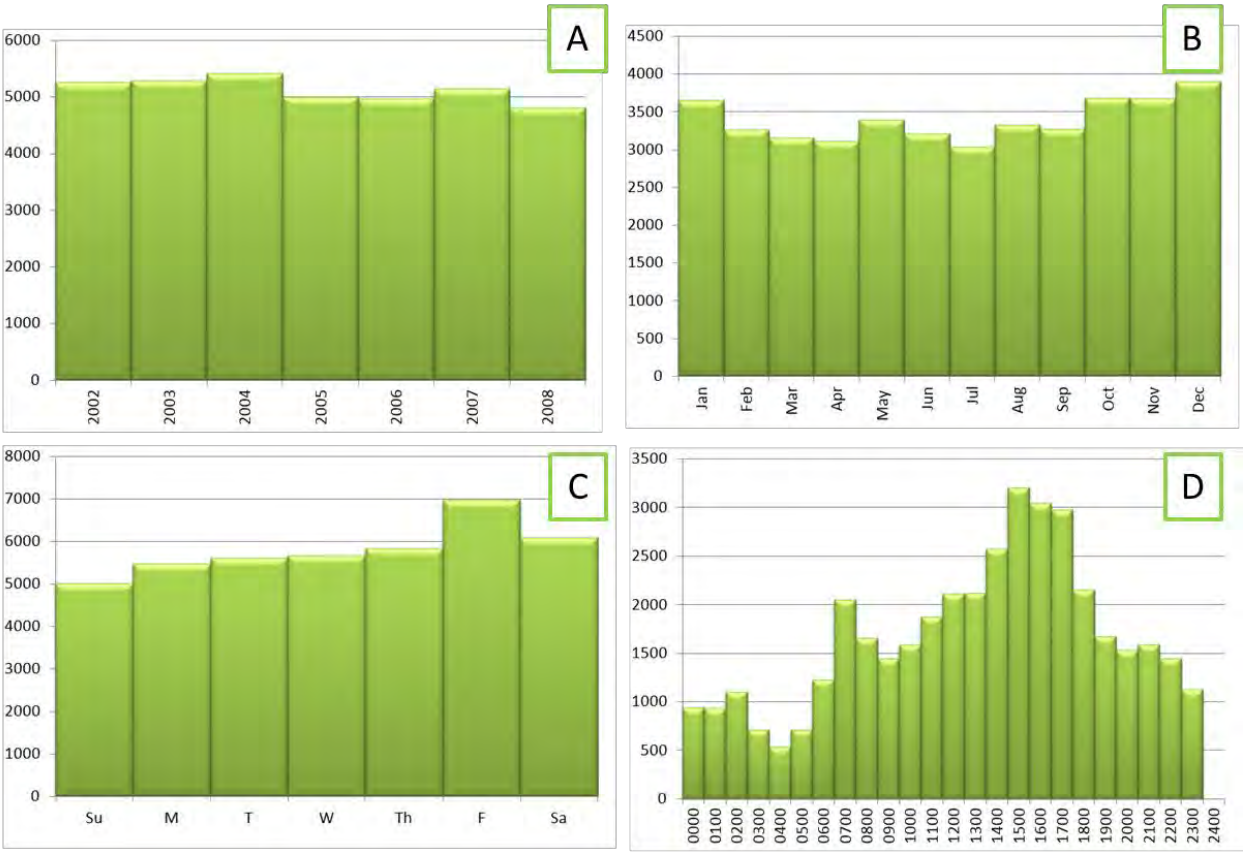


Figure 27. Histogram of Traffic Accident Data of the Past Seven Years in the Greater Reading Area and by (A) Year, (B) Month, (C) Day of Week and (D) Time of Day

The analysis of this robust data involves an engineering-statistics based approach and uses widely accepted methods to show what happened when these 26 digital billboards faces were installed in Reading.

ANALYSIS

The analysis of this robust data involves an engineering-statistics based approach and uses widely accepted methods to show what happened when these 26 digital billboard faces were installed in the Greater Reading Area.

The analysis has three parts.

Part 1 is a temporal analysis which compares *before* and *after* changes in crash rates and other metrics.

Part 2 is a spatial analysis which compares *where* and *how far* data to establish statistical correlation coefficients for various scenarios accounting for accident density and billboard proximity.

Part 3 uses the Empirical Bayes (EB) method. This method uses the 'before' accident statistics to predict the number of accidents "expected" at the locations assuming that no digital billboard technology was introduced. The method is the basis of the safety analysis and science-based, predictive models introduced within the 2010 *Highway Safety Manual* of the American Association of State Highway Official (AASHTO, Reference 14). We quantify what the actual 'after' accident statistics are and compare them with what the predicted values are from the EB analysis. This method analyzes data from the twenty billboard location and incorporates data using non-digital comparison sites.

Analysis: Part 1 – Temporal Comparisons

The first part is a temporal analysis. The incidence of traffic accidents near the digital billboards is examined for an equal length of time before and after the digital billboards were installed and activated. This part is for the purpose of establishing if traffic accidents occurred more or less frequently in the presence of these digital billboards. With information collected from police accident reports, the temporal analysis also uses metrics such as traffic volumes, the accident-rate values, the maximum number of accidents during any given month, etc.

For comparison, accident statistics were summarized near the digital billboards within multiple vicinity ranges of 0.1, 0.2, 0.3, 0.4, and 0.5 miles both upstream and downstream of each billboard. For locations on local roads, these vicinity ranges also sampled data to include: (1) accidents along the principal roads to which the digitals directly advertise, (2) accidents recorded as occurring within the intersection of the primary road and any cross roads, and (3) for crossroad accidents within a reasonable distance from the primary road to include drivers turning onto or leaving the primary road. Accident data for roads to which the digitals do not advertise or are not connected were excluded, even if they were within the specified vicinity range.

Analysis: Part 2 – Spatial Comparisons

The second part is a spatial analysis. This establishes statistical correlation coefficients between the digital billboards and accidents. Correlation coefficients are statistical measures of the "association" between two sets of data. The results are analyzed for various scenarios accounting for accident density and billboard proximity.

Additionally, subsets of accident data for age of driver and for daytime and nighttime accidents are analyzed for before and after comparisons. For a more lengthy discussion of analysis methods, please refer to previous studies (see References 6 and 7).

Analysis: Part 3 – The Empirical Bayes (EB) Method

The third part of the analysis uses the Empirical Bays (EB) method.

An Empirical Bayes (EB) Method analysis is performed to estimate the number of accidents that could statistically be expected without the introduction of digital signs.

Research literature suggests that the EB method is appropriate for this type of analysis and is a widely accepted method in the field of traffic safety (see References 14 to 31). The method is the basis of the safety analysis and science-based, predictive models introduced within the 2010 *Highway Safety Manual* of the American Association of State Highway Official (AASHTO, Reference 14).

The negative binomial distribution is established by researchers as an accurate description of yearly crash variation between sites and was previously used to model and evaluate various transportation safety projects (see References 14 through 31). The correction for regression to the mean and the use of a negative binomial distribution are strengths of the EB method.

The empirical bayes method is used to estimate the number of crashes before the site change (ie, before the introduction of digital technology). These "before" estimates are then used to predict the number of crashes that could be expected to occur at a certain location, during a specified year, without the introduction of digital technology.

The change in safety at a location is given as:

$$\Delta\, safety \;=\; B - A$$

where $\Delta\, safety$ is the change in the number of crashes, B is the expected number of crashes in the after period without the introduction of digital technology, and A is the actual number of crashes reported in the after period.

After identifying digital locations, a statistical crash estimate model (CEM) is developed. The CEM model is a multivariate, regression model used to estimate the mean and variance of the annual number of crashes that could be expected at each location. Various multivariate models were tested through an iterative process by fitting the available traits. The analysis uses a negative binomial distribution by fitting a generalized, linear model to the data by maximum likelihood estimation of the parameter vector, B.

The p-value is used as an indicator of the significance of the individual traits. The traits that produced a statistically sound model include the annual average daily traffic (AADT) for the location. The resulting CEM is then:

$$P = \alpha_{\lambda}(AADT)^{\beta_1}\,(LANE)^{\beta_2}(Speed)^{\beta_3}$$

The model parameters and the over-dispersion parameter (theta) are then calculated. The over-dispersion parameter is a measure of the extra variation in the negative binomial distributions compared to a traditional Poisson distribution; this parameter is commonly used in the calculation of the variance, or

$$variance = mean * \left(1 + \frac{mean}{\phi}\right)$$

Using the model, analyzed parameters and data, the expected number of crashes is estimated for each location, had there been no digital technology introduced.

For each location, the first year for available data was used as a base year and a normalized mean number of crashes for each year, y is calculated as

$$C_y = \frac{P_y}{P_b}$$

Where, P_y and P_b are the predicted total number of crashes from the CEM for the year y and the base year, respectively for each location. The projection of the number of crashes is independent of the choice of the base year.

The variance of the expected number of crashes, $Var(P)$ is calculated using the overdispersion parameter, as

$$Var(P) = (1 + \phi * P) * P$$

The relative weight, α, is calculated as

$$\alpha = \frac{P}{Var(P)}$$

Actual location crash counts, K, are then used to determine the EB estimate of mean and variance of the number of crashes for a site; EB and $Var(EB)$, respectively are:

$$EB = \alpha * P + (1 - \alpha) * K$$

$$Var(EB) = (1 - \alpha) * EB$$

The projection of the expected "after" treatment number of crashes is based on the weighted average of the EB estimates of number of crashes of all "before" treatment years for conversion to digital technology.

The estimate of the baseline mean and the variance number of crashes, PC_b and $Var(PC_b)$ is determined as:

$$PC_b = \frac{\sum_{before} EB}{\sum_{before} C_y}$$

$$Var(PC_b) = \frac{\sum_{before} Var(EB)}{\left(\sum_{before} C_y\right)^2}$$

The projected number of crashes for the conversion locations in the "after" conversion period is calculated by multiplying the normalized number of crashes/year, C_y, by the baseline projected number of crashes, PC_b. The mean and variance of the projected crash count in the "after" conversion period for year, *y*, B and $Var(B)$, are calculated as

$$B = C_y * PC_b$$

$$Var(B) = C_y^2 * Var(PC_b)$$

The overall index of effectiveness, theta, is then calculated by comparing the total projected number of crashes (B) in the after period to the total actual number of crashes (A) in the after period as

$$\theta = \frac{\sum A}{\sum B}$$

The unbiased estimate, θ_u, is then

$$\theta_u = \frac{\theta}{1 + \frac{\sum Var(B)}{(\sum B)^2}}$$

The percent change in total crashes due to the introduction of digital technology is

$$\Delta\, crashes\ (\%) = (1 - \theta_u) * 100$$

If the change of introducing digital technology causes crashes to be increased, then θ_u will be significantly larger than one and $\Delta\, crashes$ will be a negative value significantly lower than zero.

This analysis is applied to the data at 77 locations representing the twenty digital locations and 57 comparison sites.

The number of accidents and rates of accidents near the twenty digital billboards remained consistent within all vicinity ranges.

RESULTS

Figure 28 shows a comparison of the accident metrics for before and after conversions near all twenty digital billboards in the Greater Reading Area. The statistics are summarized for vicinity ranges of 0.1, 0.2, 0.3, 0.4, and 0.5 miles of the digital locations with 6, 8 and 10 second dwell times. Figures 29 and 30 separately summarize comparison statistics for the 6 and 8 or 10 second dwell times, respectively. The metrics in Figures 28, 29, and 30 include the total number of accidents, the average number of accidents in any given month, the peak number of accidents in any given month, etc. Other metrics, including rates and vehicle-miles traveled were also analyzed.

For 6, 8 and 10 second-dwell locations (Figure 28), the number of accidents and rates of accidents near the twenty, digital billboards decreased in all vicinity ranges. The benchmark, 0.5-mile vicinity experienced an 11.1% decrease in the number of accidents over the eight year span for all location; this includes 13.0% decrease in accident rates per million AADT vehicles.

For 6-or-8-second-dwell locations (Figure 29), the number of accidents and rates of accidents near these twelve digital locations decreased in all vicinity ranges. The benchmark 0.5 mile vicinity experienced an 11.9% decrease in the number of accidents over the eight year span; this includes 12.2% decrease in accident rates per million AADT vehicles. Within the 0.5 mile vicinity, the peak number of accidents at any one location and in any given month decreased from 10 to 9. Similar decreases and trends in both averages and peaks were observed for both smaller and larger vicinity ranges.

For 10-second-dwell locations (Figure 30), the number of accidents and rates of accidents near these eight digital locations decreased in all vicinity ranges. The benchmark 0.5 mile vicinity experienced a 10.4% decrease in the number of accidents over the eight year span; this includes 13.4% decrease in accident rates per million AADT vehicles.

Figure 31 shows the distributions of the number of accidents per month near digital billboards for 6, 8 and 10 second-dwell locations within the benchmark 0.5 mile vicinity between 2001 and 2009. Figure 32 compares this distribution with 6 or 8 second-dwell and 10 second-dwell locations separately.

A statistical t-test is used to determine whether the average difference between the two, time periods is really significant or if it is due to random difference. Using a 95% confidence interval indicates no statistically significant difference in the accident

statistics evaluated between conventional and digital billboards at these digital locations.

Additionally, consistent results were obtained for driver-age comparisons. Low correlation coefficients were calculated for the spatial analysis. Correlation coefficients were calculated and indicated a very strong correlation of accident patterns near the digital billboards when compared with the accident patterns prior to conversion.

The statistical evaluation of the Empirical Bayes method and results show that the total number of accidents is approximately equivalent to what would be statistically expected with or without the introduction of digital technology and that the safety near these locations are consistent with the model benchmarked by 77 locations within Berks County.

Between 2001 and 2009 for equal periods before and after at each location
At all 20 locations with **6, 8 and 10 second dwells**

		Vicinity Range from Digital Location (miles)				
		0.1	**0.2**	**0.3**	**0.4**	**0.5**
Prior to Installation	Total Number of Accidents for Equal Periods Before Conversion	203	501	693	872	1063
	Average Number of Accidents per Month at Each Location	0.31	0.76	1.06	1.33	1.62
	Rate of Accidents per Million Vehicles (by million AADT)	0.29	0.72	0.99	1.25	1.52
	Standard Deviation of Number of Accidents in any given month at locations	0.64	1.09	1.35	1.52	1.68
	Peak Number of Accidents in any given Month per Location	5	8	8	9	10
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	80%	58%	48%	40%	34%
As Digital Location	Total Number of Accidents for Equal Periods After Conversion	167	412	540	707	925
	Average Number of Accidents per Month at Each Location	0.25	0.63	0.82	1.08	1.41
	Rate of Accidents per Million Vehicles (by million AADT)	0.24	0.60	0.79	1.03	1.35
	Standard Deviation of Number of Accidents in any given month at locations	0.59	1.05	1.21	1.43	1.69
	Peak Number of Accidents in any given Month per Location	4	6	7	8	9
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	84%	67%	59%	51%	43%
Comparison	Change in Number of Accidents	-36	-89	-153	-165	-138
	Change in Average per Month	-0.05	-0.14	-0.23	-0.25	-0.21
	Change in Rate per million vehicles (by million AADT)	-0.05	-0.11	-0.20	-0.21	-0.17
	Percent Change in Number of Accidents	-17.7%	-17.8%	-22.1%	-18.9%	-13.0%
	Percent Change in Rate of Accidents	-15.9%	-16.0%	-20.4%	-17.1%	-11.1%

Figure 28. Summary Accident Statistics within Vicinity Ranges
near Twenty Digital-Billboards Locations with 6, 8 and 10 second Dwell Times
in the Greater Reading Area

Between 2001 and 2009 for equal periods before and after at each location
At 12 locations with **6 or 8 second dwells**

		Vicinity Range from Digital Location (miles)				
		0.1	0.2	0.3	0.4	0.5
Prior to Installation	Total Number of Accidents for Equal Periods Before Conversion	79	193	262	315	368
	Average Number of Accidents per Month at Each Location	0.29	0.71	0.96	1.16	1.35
	Rate of Accidents per Million Vehicles (by million AADT)	0.28	0.68	0.92	1.10	1.29
	Standard Deviation of Number of Accidents in any given month at locations	0.56	0.99	1.21	1.37	1.56
	Peak Number of Accidents in any given Month per Location	3	5	5	6	8
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	79%	58%	50%	46%	42%
As Digital Location	Total Number of Accidents for Equal Periods After Conversion	65	161	225	266	323
	Average Number of Accidents per Month at Each Location	0.24	0.59	0.83	0.98	1.19
	Rate of Accidents per Million Vehicles (by million AADT)	0.23	0.57	0.79	0.94	1.14
	Standard Deviation of Number of Accidents in any given month at locations	0.60	1.05	1.22	1.38	1.59
	Peak Number of Accidents in any given Month per Location	4	6	6	7	8
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	86%	69%	59%	55%	49%
Comparison	Change in Number of Accidents	-14	-32	-37	-49	-45
	Change in Average per Month	-0.05	-0.12	-0.14	-0.18	-0.17
	Change in Rate per million vehicles (by million AADT)	-0.05	-0.11	-0.13	-0.17	-0.15
	Percent Change in Number of Accidents	-17.7%	-16.6%	-14.1%	-15.6%	-12.2%
	Percent Change in Rate of Accidents	-17.4%	-16.2%	-13.8%	-15.2%	-11.9%

Figure 29. Summary Accident Statistics within Vicinity Ranges near 12 Digital Billboards Locations with 6 or 8 second Dwell Times in the Greater Reading Area

Between 2001 and 2009 for equal periods before and after at each location
At 8 locations with **10 second dwells**

		Vicinity Range from Digital Location (miles)				
		0.1	0.2	0.3	0.4	0.5
Prior to Installation	Total Number of Accidents for Equal Periods Before Conversion	124	308	431	557	695
	Average Number of Accidents per Month at Each Location	0.30	0.75	1.06	1.37	1.71
	Rate of Accidents per Million Vehicles (by million AADT)	0.30	0.74	1.04	1.34	1.68
	Standard Deviation of Number of Accidents in any given month at locations	0.67	1.12	1.40	1.57	1.71
	Peak Number of Accidents in any given Month per Location	5	8	8	9	10
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	89%	65%	54%	42%	34%
As Digital Location	Total Number of Accidents for Equal Periods After Conversion	102	251	315	441	602
	Average Number of Accidents per Month at Each Location	0.25	0.61	0.76	1.06	1.47
	Rate of Accidents per Million Vehicles (by million AADT)	0.25	0.63	0.79	1.10	1.50
	Standard Deviation of Number of Accidents in any given month at locations	0.57	1.03	1.17	1.44	1.72
	Peak Number of Accidents in any given Month per Location	3	6	7	8	9
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	92%	73%	66%	57%	46%
Comparison	Change in Number of Accidents	-22	-57	-116	-116	-93
	Change in Average per Month	-0.06	-0.15	-0.30	-0.31	-0.25
	Change in Rate per million vehicles (by million AADT)	-0.04	-0.12	-0.25	-0.24	-0.17
	Percent Change in Number of Accidents	-17.7%	-18.5%	-26.9%	-20.8%	-13.4%
	Percent Change in Rate of Accidents	-14.9%	-15.7%	-24.4%	-18.1%	-10.4%

Figure 30. Summary Accident Statistics within Vicinity Ranges near 8 Digital Billboards Locations with 10-second Dwell Times in the Greater Reading Area

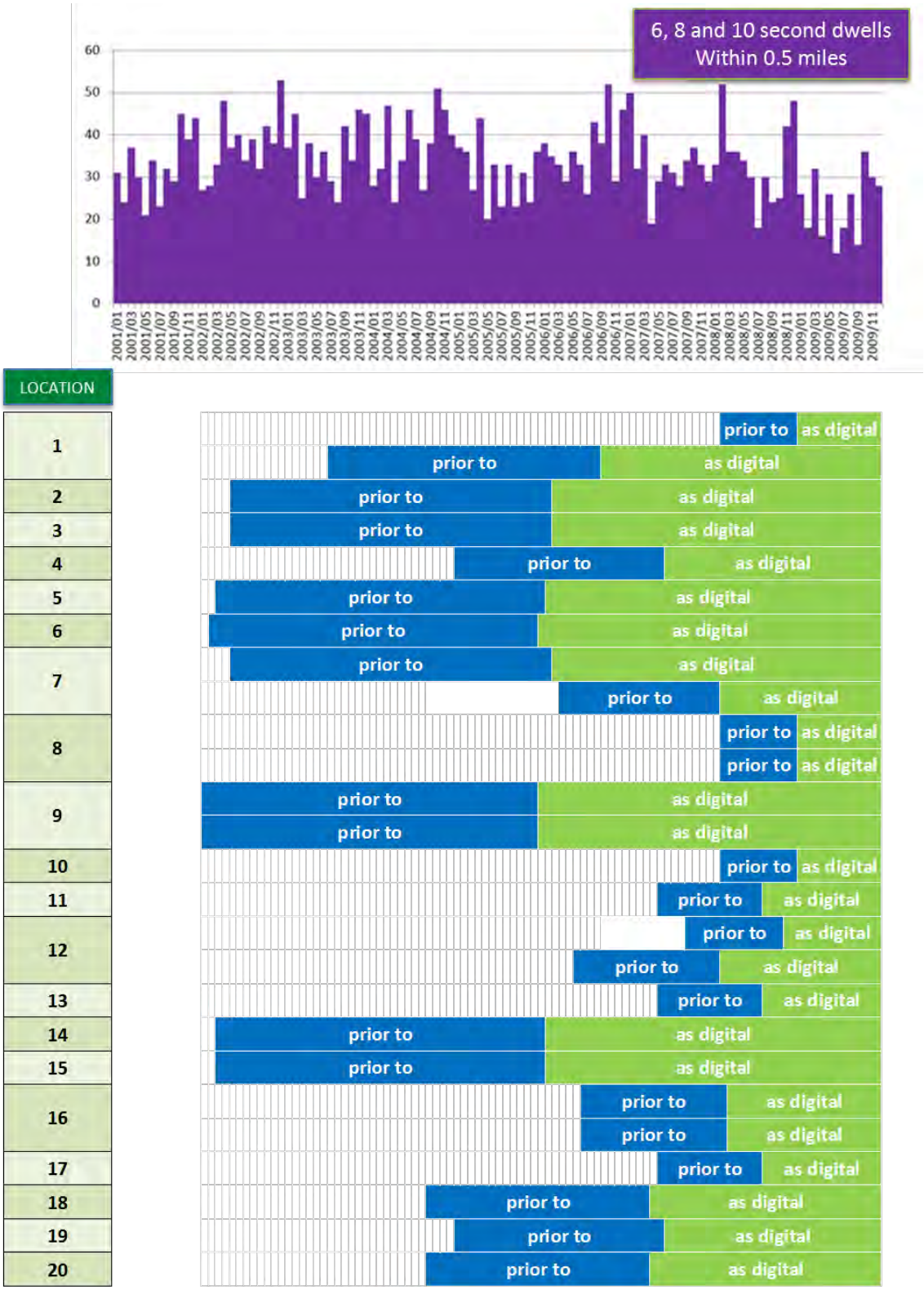


Figure 31. Distributions of the Number of Accidents per Month near Digital Billboards between 2001 and 2009 within a 0.5-mile Vicinity Range near all Digital Locations for 6, 8 and 10 Second-dwell Times (top, purple) compared with Conversion Dates and Before/After Comparison Periods

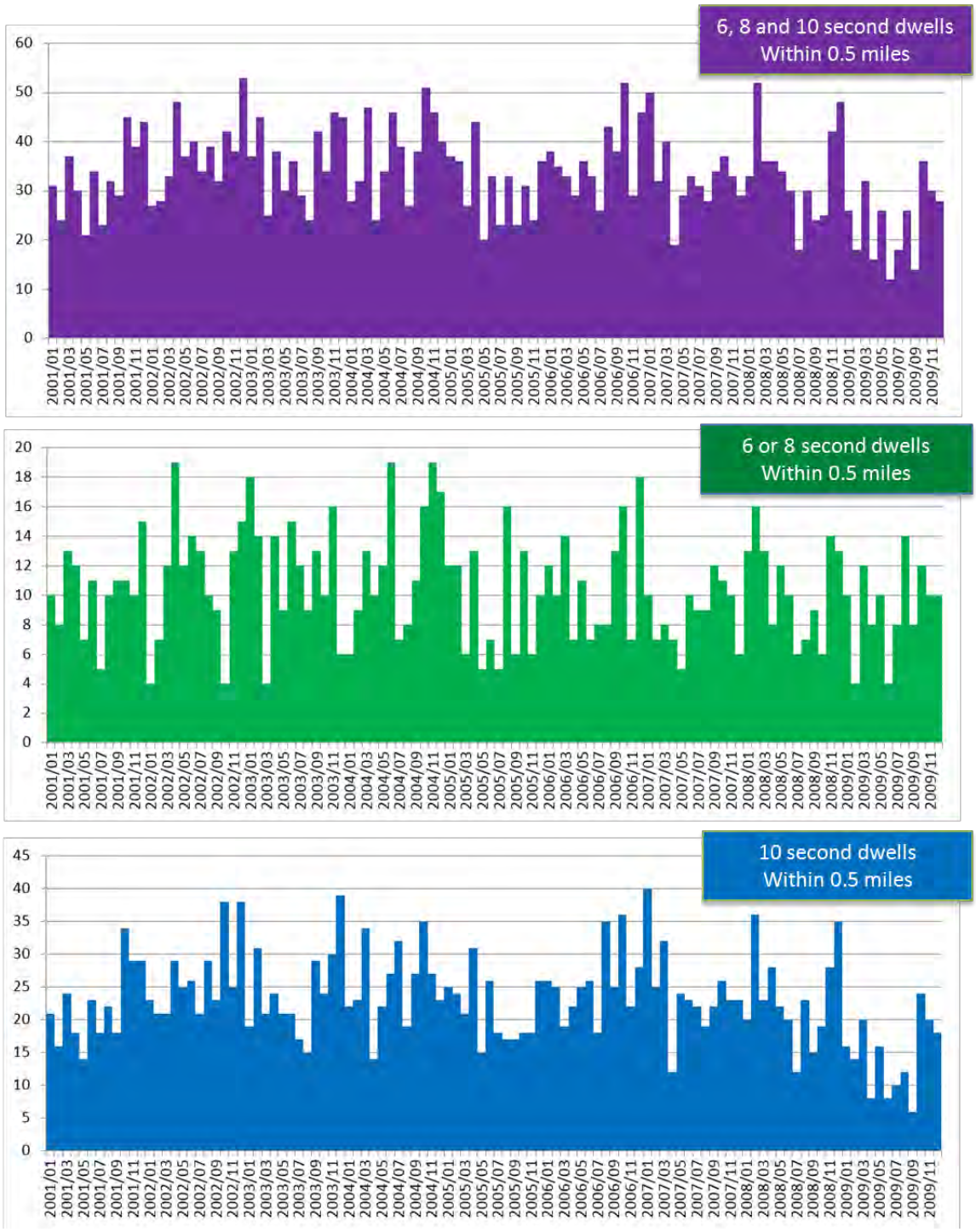


Figure 32. Distributions of the Number of Accidents per Month near Digital Billboards between 2001 and 2009 within a 0.5-mile Vicinity Range near all Digital Locations for 6, 8 and 10 Second-dwell Times (top, purple), 6 or 8 Second-dwell Times (middle, green) and 10 Second-dwell Times (bottom, blue)

Figure 33 summarizes the accident rates that account for variations in traffic volumes for all digital locations within vicinity ranges of 0.1, 0.2, 0.3, 0.4, and 0.5 miles of the digital location with 6, 8 and 10 second dwell times. The 0.5 mile benchmark vicinity experienced a decrease in accident rates over the eight-year span. The change in accident rates decreased by 0.17 accidents per million vehicles per year; an 11.1% decrease. Similar decreases and trends were observed for both smaller vicinity ranges.

Between 2001 and 2009 for equal periods before and after at each location
At all 20 locations with **6, 8 and 10 second dwells**

		Vicinity Range from Digital Location (Miles)				
		0.1	**0.2**	**0.3**	**0.4**	**0.5**
Prior to Installation	Number of Accidents per million vehicles (by million AADT)	0.29	0.72	0.99	1.25	1.52
As Digital Location	Number of Accidents per million vehicles (by million AADT)	0.24	0.60	0.79	1.03	1.35
Comparison	Change in Rate per million vehicles (by million AADT)	-0.05	-0.11	-0.20	-0.21	-0.17
	Percent Change in Rate of Accidents	-15.9%	-16.0%	-20.4%	-17.1%	-11.1%

Figure 33. Summary Accident Rates within Vicinity Ranges near Twenty Digital Billboards Locations with 6, 8 and 10 Second-dwell Times in the Greater Reading Area

COMPARISON OF ACCIDENTS BY AGE OF DRIVER

The accident statistics were also analyzed to determine if the age of the drivers involved in the accidents near digital billboards was a factor. The data were specifically studied to determine if there are increases in the accident frequency of young drivers (under 17 and under 21) or elderly drivers (65 and older). Figure 34 summarizes the accidents and accident-rates by age of driver for all accidents.

Figure 35 shows the distributions of ages of driver for all accidents within Berks County (A, purple) and for all accidents within 0.5 miles of all digital locations (B, orange).

Figure 36 shows the distributions of driver ages within 0.5 miles of all digital locations for before (green) and after (blue) periods of comparison. Figure 38 (left) also shows the correlation between before and after conversions for the number of accidents for each age. Individual accidents may have multiple cars and drivers involved, which is reflected in the analysis. In comparing the histograms in Figure 36, note the typical distribution type (shape) and typical average values. The mode driver age for accidents prior to digital conversion is 19 years; the mode drive age after conversions is 19 years.

Correlation coefficients were calculated and indicated a very strong correlation of accident patterns for age-of-driver factors. Figure 33 shows a 0.980 (98.0%) correlation coefficient when comparing accidents before conversion with those after conversion.

Between 2001 and 2009 for equal periods before and after at each location
At all 20 locations with **6, 8 and 10 second dwells**

		Crashes By Driver Age Group			
		under 17	under 21	21-65	over 65
Prior to Installation	Number of Accidents for equal periods prior to conversion	155	676	2412	533
As Digital Location	Number of Accidents for equal periods after conversion	103	440	2065	316
Comparison	Change in Number of Accidents	-52	-236	-347	-217
	Percent Change in Number of Accidents	-33.5%	-34.9%	-14.4%	-40.7%

Figure 34. Summary Accidents by Age Group within Vicinity Ranges near Twenty Digital Billboard Locations in the Greater Reading Area

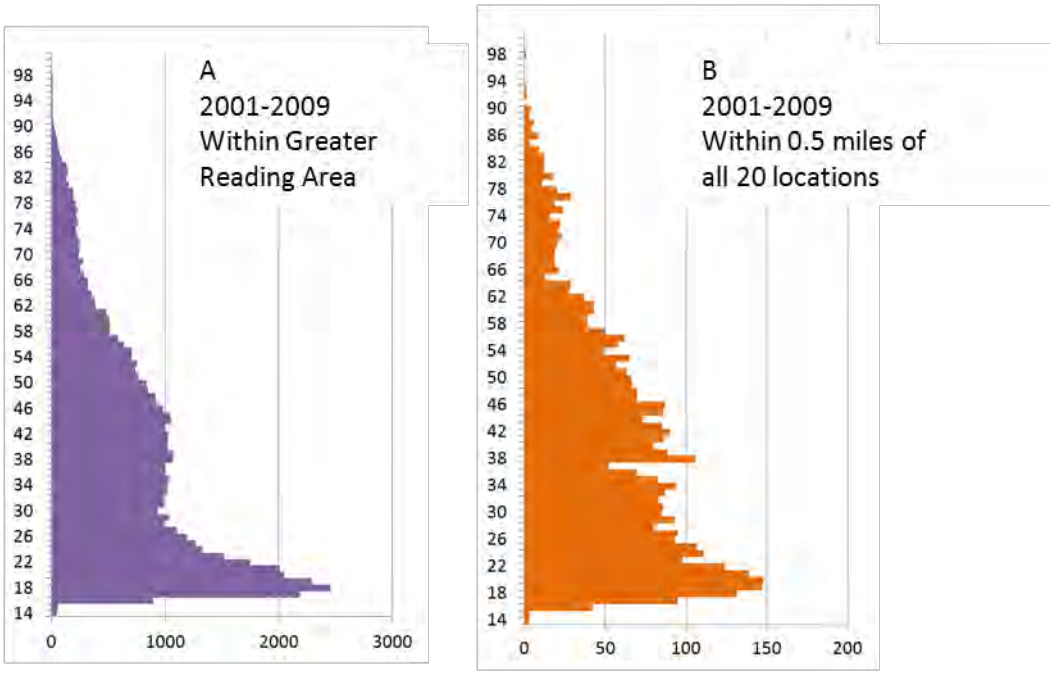


Figure 35. Distributions of Age of Drivers for all Accidents in the Greater Reading Area (left, purple), and within 0.5 miles of all Digital Locations (right, orange)

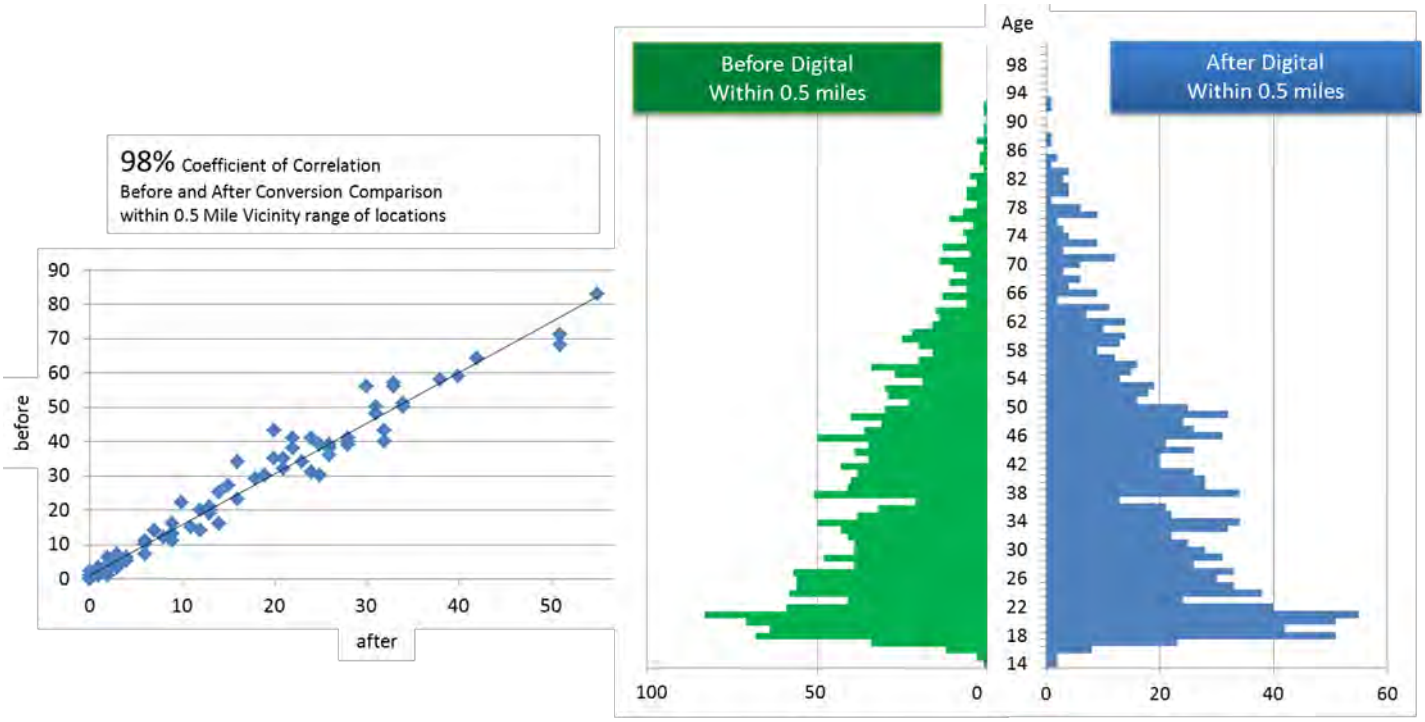


Figure 36. Distributions of Age of Drivers for all Accidents before Digital Conversion (left green histogram), after Digital Conversion (right, blue histogram) and the Correlation between Before and After Accident Counts for each Age (left).

COMPARISON OF ACCIDENTS BY TIME OF DAY

The accident statistics are also analyzed to determine if the time of day of the accidents near digital billboards is a factor.

The data were studied to determine if any increases in the accident rates during dawn, daylight, dusk and dark/nighttime conditions occurred. Figure 37 summarizes the accidents and accident-rates by time of day for all accidents within 0.5 miles of the digital locations. The daylight accident rate experienced an 8.9 percent decrease after conversion; the nighttime accident rate experienced an 11.7% decrease.

Figure 38 shows the distributions of times of accidents within 0.5 miles for before conversion (top, blue) and for after conversion (middle, green) data periods of comparison. Figure 38 (bottom) also shows the correlation between before and after conversions for the number of accidents. In comparing the histograms in Figure 38, note the typical distribution type (shape) and typical average values. Correlation coefficients were calculated and indicated a very strong correlation of accident patterns for time-of-day factors. Figure 40 shows a 0.90 (90.0%) correlation coefficient when comparing accidents before conversion with those after conversion.

Between 2001 and 2009 for equal periods before and after at each location
At all 20 locations with **6, 8 and 10 second dwells**

		During Time of Day and Lighting			
		Dawn	Daylight	Dusk	Dark
Prior to Installation	Number of Accidents for equal periods prior to conversion	15	762	73	206
	Number of Accidents per million vehicles (by million AADT)	0.02	1.09	0.10	0.29
As Digital Location	Number of Accidents for equal periods after conversion	15	679	67	178
	Number of Accidents per million vehicles (by million AADT)	0.02	0.99	0.10	0.26
Comparison	Change in Number of Accidents	0	-83	-6	-28
	Change in Rate per million vehicles (by million AADT)	0.00	-0.10	-0.01	-0.03
	Percent Change in Number of Accidents	0.0%	-10.9%	-8.2%	-13.6%
	Percent Change in Rate of Accidents	2.2%	-8.9%	-6.2%	-11.7%

Figure 37. Summary Accident Rates during Dawn, Daylight, Dusk and Dark/Nighttime Conditions within a 0.5 mile vicinity range near twenty Digital Billboards Locations with 6, 8 and 10 Second-dwell times in the Greater Reading Area

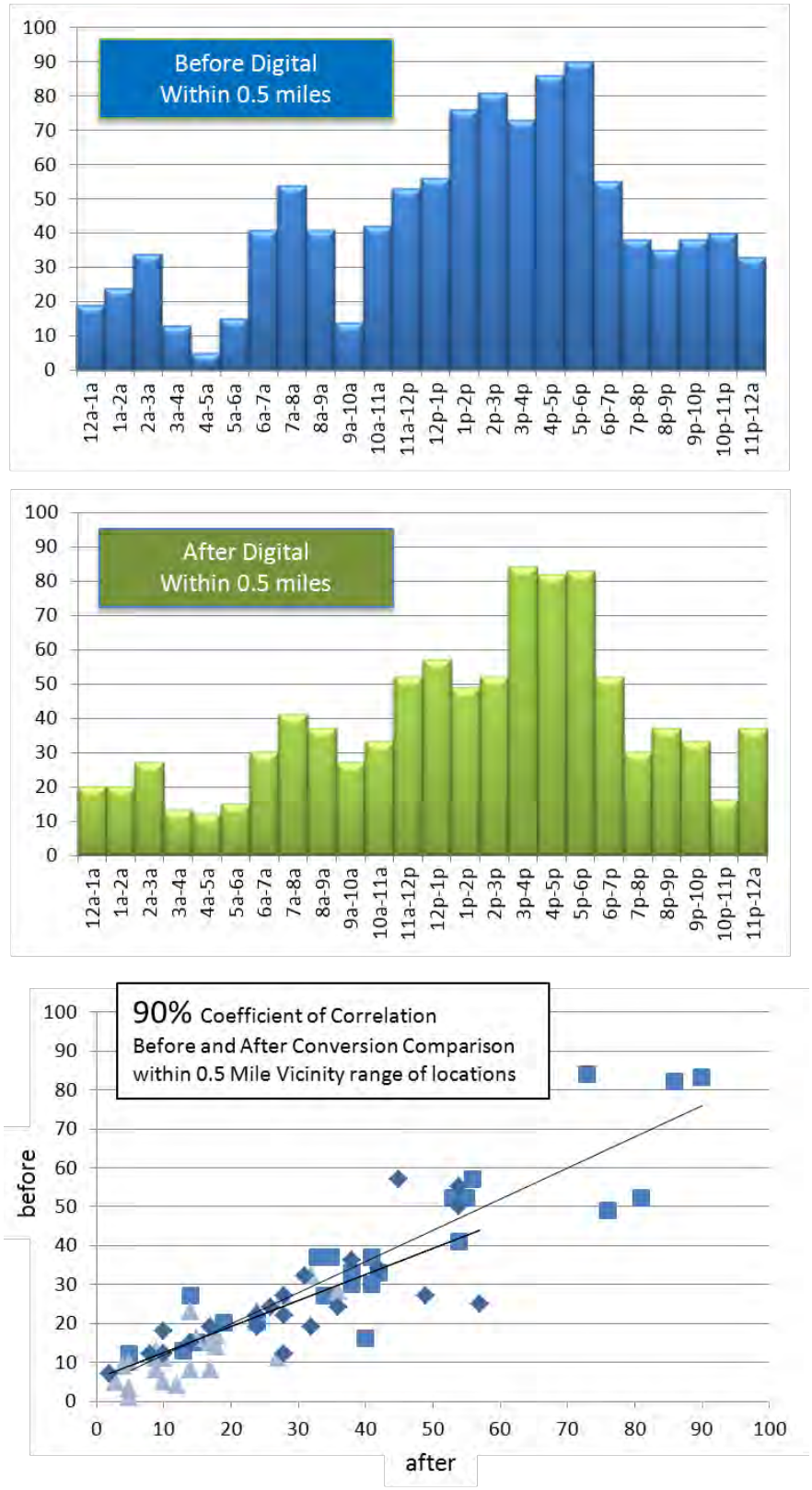


Figure 38. Distributions of Number of Accidents Accident by Time of Day within a 0.5 mile Vicinity Range prior to Digital Conversion (top, blue) and after digital conversion (middle, green) near twenty digital billboards locations with 6, 8 and 10 second-dwell times in the Greater Reading Area

STATISTICAL MODEL AND RESULTS FOR THE EMPIRICAL BAYES METHOD

The Empirical Bayes (EB) method is used to analyze available crash data for Berks County. The EB method is a rigorous method capable of estimating the safety impact of changes at a location. The EB method is well documented and used in numerous traffic-safety studies (see References 14 through 31). Simply stated, the method estimates the number of crashes at a location that would have occurred without the introduction of digital billboards. The estimates may then be compared with the actual crashes that have occurred.

The expected number of crashes as estimated by the Crash Estimation Model (CEM) and using the SAS statistical package and the parameters discussed in our methodology were computed. A multivariate, regression model was developed to estimate the mean of the expected number of crashes at a location. Our general CEM is shown in Figure 39 and models Average Annual Daily Traffic (AADT), Number of Lanes (Lane), and the posted Speed Limit (Speed) as independent variables; $\beta_0, \beta_1,\ \beta_2$ and β_3 are model parameters of the independent variables. The model is fit using the maximum likelihood method and includes 77 sites representing 20 digital billboard locations and 57 comparison sites. Figure 40 shows these locations. Figure 39 summarizes the CEM parameters using a maximum likelihood estimates for a multivariate regression model with negative binomial distribution. The CEM parameters are significant at $\alpha = 0.05$. The resulting CEM equation is also presented in Figure 39.

The projected, total crash counts were estimated for the "after" periods to represent what the number of crashes would have been in future period without the introduction of digital billboards. These were compared with the crash data that actually occurred after the introduction of digital billboards at each location to determine the overall index of effectiveness.

General CEM: $$P = (AADT)^{\beta_1}\ (LANE)^{\beta_2} (Speed)^{\beta_3}\ e^{\beta_0}$$

Explicit CEM: $$P = (AADT)^{0.1291}\ (LANE)^{0.2584} (Speed)^{-0.0231}\ e^{2.8671}$$

CEM Model Parameters:

Variable		Coefficient	Standard Error	Chi-square statistic	Pr > Chi-square	Wald 90% confidence limits	
						Lower	Upper
Intercept		2.8671	0.2490	132.63	<.0001	2.3792	3.3551
AADT	β_1	0.1291	0.0157	67.27	<.0001	0.0982	0.1599
Lanes	β_2	0.2584	0.0757	11.66	0.0006	0.1101	0.4067
Speed	β_3	-0.0231	0.0040	33.76	<.0001	-0.0309	-0.0153
Dispersion	ϕ	0.5207	0.0329			0.4562	0.5852

SAS Goodness of fit measures: deviance (value/d.f.) = 669.0944 (1.0933); Pearson chi-square (value/d.f.) = 712.7582 (1.1646); Number of observations = 616

Figure 39. General and Explicit Crash Estimation Model (CEM) and CEM Model Parameters from SAS Output

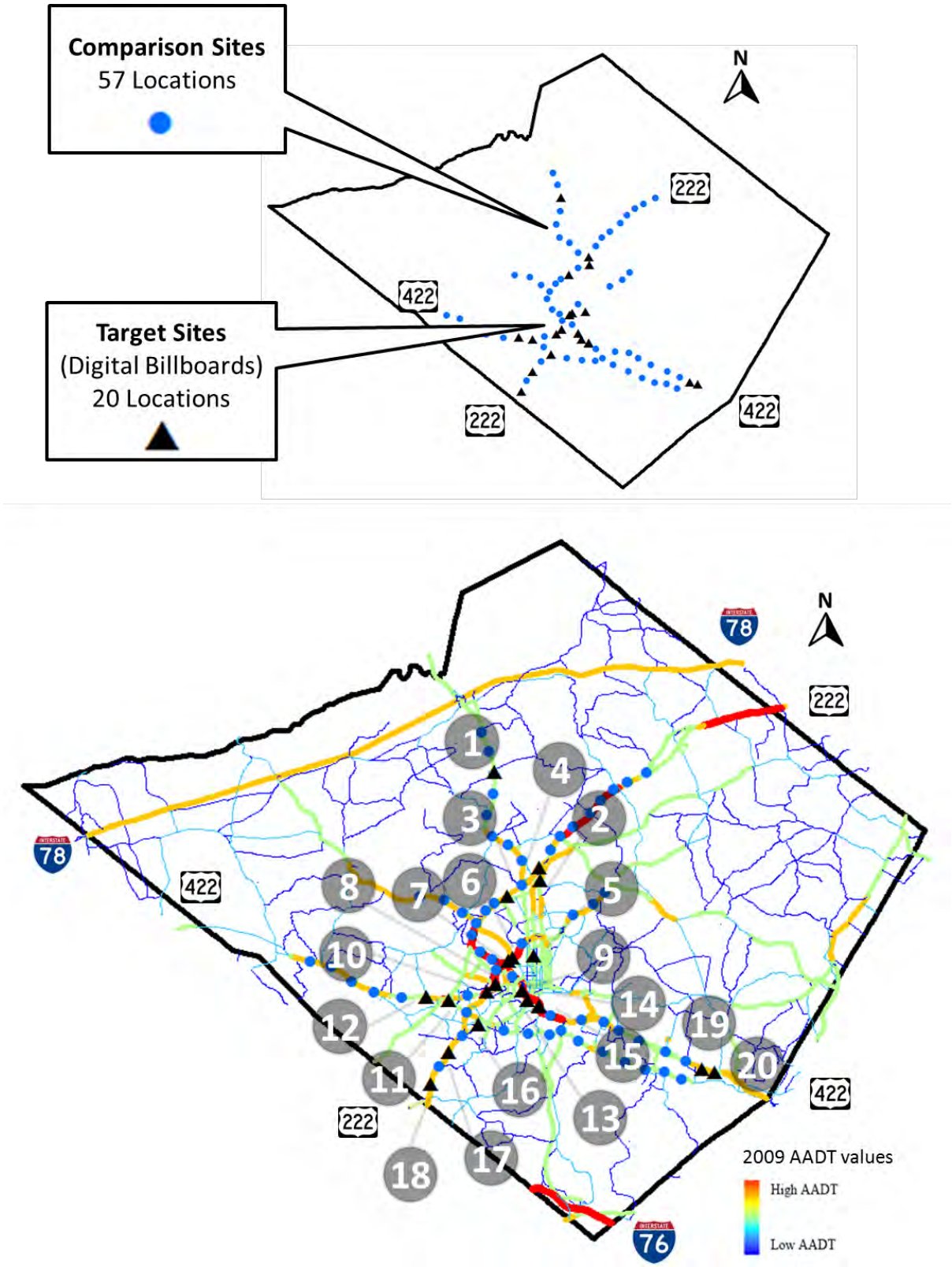


Figure 40. Crash and AADT Data for 20 Target (Digital) Locations and 57 Comparison (non-Digital) Locations

The Empirical Bayes results indicate a 0.87% (0.0087) difference between the “after” conversion crashes that occurred near the 20 digital locations and the statistically predicted Empirical Bayes mean estimate of those same locations had no digital billboards been installed. This comparison has a p-value less than 0.0001. The analysis of this data indicates that the actual and predicted means are almost statistically identical. A large sample size was used with 20 digital locations, 57 treatment or comparison sites with eight years of accident data. The statistical evaluation of the Empirical Bayes analysis shows that the total number of accidents is approximately equivalent to what would be statistically expected with or without the introduction of digital technology and that the safety near these locations are consistent with the model benchmarked by 77 locations within Berks County. Additional studies should be considered with other independent variables, consider for lower volume roads, other robust crash estimation models, and cross-comparison of results between digital.

Parameter	**Value**
Total Crashes for the "After" Period with Digital Conversion (Actual Values)	925
Total Crashes for the "After" Period assuming no Digital Conversion ever occurred (Estimate by Empirical Bayes Method)	917
Overall Index of Effectiveness	1.009
Percent Change in Crashes between actual and estimate	-0.87%

Figure 41. Results of the Empirical Bayes Estimation in Berks County with 20 digital locations, 57 treatment or comparison sites and with eight years of accident data

Simply stated, the data show no statistically significant increase of accident rates near these billboards.

FINDINGS

The Greater Reading Area of Berks County, Pennsylvania, is a unique opportunity for this study about the statistical associations between digital billboards and traffic safety using robust data-sets and analyzing multiple locations for periods of as long as eight years. The overall conclusion is that these digital billboards in Reading have no statistically significant relationship with the occurrence of accidents. This conclusion is based on local Police and PennDOT data and an objective statistical analysis; the data show no statistically significant increase in accident rates. This study also finds that **the dwell time of 6, 8 or 10 seconds,** the **age of the driver (younger, older) and the time of day (nighttime, daytime) are neutral factors** which show no increase in accident rates the near digital billboards along the local roads in the Greater Reading Area.

The specific conclusions of this study indicate the following.

- **The before and after rates of accidents near the twenty digital billboards show an 11.1% decrease** within 0.5 miles of all digital billboards over eight years near twenty locations. Similar decreases and trends in both averages and peaks are observed for both smaller and larger vicinity ranges, and for specific groups of locations by dwell time.

- **The accident statistics and metrics remain consistent**, exhibiting statistically insignificant variations at each of the digital billboards. The metrics include the total number of accidents in any given month, the average number of accidents, the peak number of accidents in any given month, and the number of accident-free months. These conclusions account for variations in traffic-volume and other metrics.

- The statistical evaluation of the Empirical Bayes method and actual versus predicted results show that the **total number of accidents is approximately equivalent to what would be statistically expected with or without the introduction of digital technology** and that the safety near this locations are consistent with the model benchmarked by 77 locations within Berks County.

- The overall conclusion of the study is that **these digital billboards in the Greater Reading Area have no statistically significant relationship with the occurrence of accidents**.

This study also finds that the age of drivers (younger/elderly) and the time of day (daytime/nighttime) are neutral factors which show no significant increase in accident rates near the digital billboards. The results are consistent for the 6, 8 and 10 second dwell times. These conclusions are based on the collected Police Department data and an objective statistical analysis.

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A STUDY OF THE RELATIONSHIP BETWEEN DIGITAL BILLBOARDS AND TRAFFIC SAFETY IN HENRICO COUNTY AND RICHMOND, VIRGINIA

SUBMITTED TO

THE FOUNDATION FOR OUTDOOR ADVERTISING
RESEARCH AND EDUCATION (FOARE)
1850 M STREET, NW, SUITE 1040
WASHINGTON, DC 20036-5821

BY

MICHAEL WALTER TANTALA, P.E.
ALBERT MARTIN TANTALA, SR., P.E.

ON

29 NOVEMBER 2010

TANTALA ASSOCIATES, LLC
CONSULTING ENGINEERS
4903 FRANKFORD AVENUE
PHILADELPHIA, PA 19124-2617
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KEY POINTS

• More than 7 years of accident data comparisons

• Ten locations with 14 digital billboard faces with 10 second duration times

• Data show no statistically significant increase in accident rates, using before and after comparisons and using an Empirical Bayes Method Analysis for the actual and predicted comparisons

• Comparisons of driver age (young/elderly) and time of day (daytime/nighttime) are neutral factors

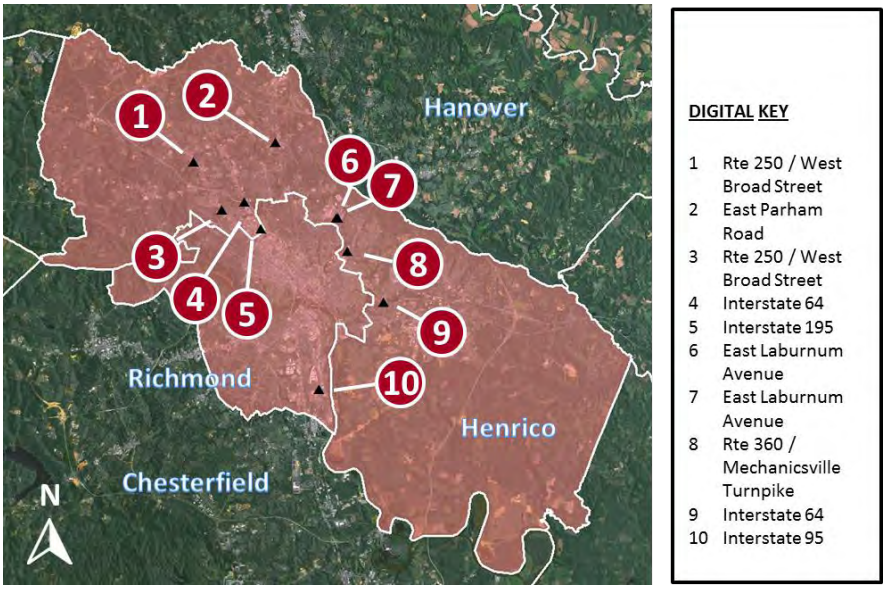

Figure 1.
Digital Billboard Locations analyzed in Henrico County and Richmond, Virginia

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More than 7 years of data …

… no statistically significant relationship with the occurrence of accidents …

… 10-second duration times …

OVERVIEW

The purpose of this study is to **examine the statistical relationship between digital billboards and traffic safety in Henrico County and Richmond, Virginia**. This study analyzes traffic and accident data along routes near **10 locations with 14 digital billboard faces** (see Figure 1) with traffic volumes on roads collectively representing approximately 154 million vehicles per year. The study uses official data as collected, complied and recorded independently by municipal police departments, Henrico County and the Virginia Department of Transportation.

The study includes more than **seven years of accident data** representing approximately 40 thousand accidents near ten locations in Richmond and Henrico County. The billboards were converted to digital format between 2006 and 2009 and allow periods of comparison as long as 7.3 years (88 months).

Temporal (*when and how frequently*) and spatial (*where and how far*) statistics are summarized near billboards within multiple vicinity ranges as large as one-half mile for areas that are upstream and downstream of the billboards. Subsets of daytime and nighttime accidents and driver age are analyzed for before and after comparisons.

Additionally, an Empirical Bayes Method (EBM) analysis is performed to estimate the number of accidents that could statistically be expected without the introduction of digital signs. This method is the basis of the safety analysis and science-based, predictive models introduced within the 2010 *Highway Safety Manual* of the American Association of State Highway Official (AASHTO, Reference 14). This report establishes benchmarks for the basis of accident records at pre-digital locations and also uses other comparison sites in Henrico County and Richmond.

The overall conclusion of the study is that **the digital billboards in Richmond, Virginia have no statistically significant relationship with the occurrence of accidents**. This study also finds that the age of drivers (younger/elderly) and the time of day (daytime/nighttime) are neutral factors which show no significant increase in accident rates near the digital billboards. These conclusions are based on Police Department data and an objective statistical analysis; **the data show no significant increase in accident rates**.

Figure 2.
Digital Billboard Locations analyzed in Henrico County and Richmond, Virginia. Each location studied has a 10 second duration time.

The static display on each of these digital billboards have "duration times" of 10 seconds.

STUDY REGION

This portion of the Greater Richmond Area was chosen as a study region, because it has multiple digital billboards in close proximity that were in service for extended periods of time. The roads adjacent to these billboards are heavily traveled (approximately 423 thousand vehicles traveled per day collectively on the sections of road near the digital billboards in Figure 2).

The study area of Henrico County and the City of Richmond, a portion of the Greater Richmond Area in Virginia, is situated in the central part of the State, and collectively has an area of approximately 308 square miles, has a population of 352 thousand people and has 174 thousand households (2000 census).

Several federal and state highways allow entry to the Greater Richmond Area as it is situated at the junction of east-west Interstate 64 and north-south Interstate 95, two of the most heavily traveled highways in the state. Henrico County is one of only two counties in Virginia that maintain their own roads. Interstate highways include Interstate 64, Interstate 95, and Interstate 295. Interstate 64 runs east-west and overlaps Interstate 95 for several miles in Richmond. Interstate 195 is a short spur from north of downtown Richmond, south into the downtown. Interstate 295 is a bypass to the east of Richmond and extends from Interstate 95 south of Petersburg. Other major highways include U.S. Route 1, U.S. Route 250 and U.S. Route 360.

BILLBOARD CHARACTERISTICS

Digital billboards display static messages which, when viewed, resemble conventional painted or printed billboards. With digital technology, a static copy displays for a duration and includes no animation, flashing lights, scrolling, or full-motion video. The static display of each of these digital billboards has a "duration time" of 10 seconds. The digital billboards use red, green, and blue light-emitting-diode (LED) technology to present text and graphics. The digital billboards compensate for varying light levels, including day and night viewing, by automatically monitoring and adjusting overall display brightness and gamma levels. A photocell is mounted on each digital billboard to measure ambient light. Each of the digital billboards that were studied is owned and operated by *Lamar*.

Billboard Location	Location	Configuration	Side of Road	Digital Facing Direction	Reader Side	Face Size (ft)	Duration Time (seconds)
1	**Rte 250 / West Broad Street** at 7912 West Broad Street (37° 37' 25.194", -77° 31' 40.515")	Free standing, Flag, Vee	N	E W	right cross	11x23 10.5x36	10 10
2	**East Parham Road** 0.25 miles west of Interstate 95 (37° 38' 6.7668", -77° 27' 40.381")	Free standing, Flag, Vee	N	**W**	cross	11x22	10
3	**Rte 250 / West Broad Street** at 5912 West Broad Street (37° 35' 32.607", -77° 30' 22.834")	Free standing, Center-mount with offset, Vee	N	E	right	11x23	10
4	**Interstate 64** 0.2 miles east of Staples Mill Road (37° 35' 49.729", -77° 29' 14.935")	Free standing, Center-mount, Vee	N	**E**	right	12.5x40	10
5	**Interstate 195** south of the Insterstates 64 and 95 intersection (37° 34' 45.757", -77° 28' 29.744")	Free standing, Flag, Vee	W	S N	cross right	14x36 14x36	10 10
6	**East Laburnum Avenue** 0.07 miles east of Carolina Avenue (37° 35' 7.3211", -77° 24' 48.898")	Free standing, Center-mount, Vee	N	**E**	right	10x21	10
7	**East Laburnum Avenue** 0.12 miles east of Carolina Avenue (37° 35' 7.3427", -77° 24' 45.050")	Free standing, Center-mount, Back-to-Back	N	E	right	10.5x36	10
8	**Rte 360 / Mechanicsville Turnpike** 0.3 miles north of Interstate 64 (37° 33' 50.011", -77° 24' 19.292")	Free standing, Center-mount, Back-to-Back	W	**S** **N**	cross right	14x28 14x28	10 10
9	**Interstate 64** 0.6 miles west of South Laburnum Avenue (37° 31' 50.091", -77° 22' 36.814")	Free standing, Center-mount, Vee	S	E	cross	12.5x42	10
10	**Interstate 95** 0.6 miles north of Bells Road / Rte 161 (37° 28' 32.231", -77° 25' 49.227")	Free standing, Center-mount, Vee	W	**N** **S**	right cross	14x48 14x48	10 10

Figure 3.
Digital Billboard Direction, Sizes and Other Sign Characteristics

Of the ten, digital-billboard locations studied, nine are located in Henrico County and one is located in the City of Richmond. Several additional digital locations were installed in the study region in 2010. These newer locations are not included as in this study because data collection would be limited to 2009; 2010 accident data was not available at the time of this study.

The digital, billboard locations are numbered 1 to 10 with 14 billboard faces. The ten locations in Henrico County and Richmond are shown in Figures 1, 2 and 3 which summarize direction, configuration and other sign characteristics. The digital boards and their surroundings were observed during day and night conditions. A majority of the digital billboards are freestanding single-pole, structures with one digital face; four locations have two digital boards on the same upright.

Figure 4 summarizes the conversion dates. Nine of the 14 billboard faces were converted to digital format prior to 2008 and the others were converted on various dates in 2008 and 2009. These dates allow for before/after comparisons as long as 7.3 years (or 88 months). Additional billboard-location photos, aerials, and map references for each digital location are included in this report as Figures 5 to 14.

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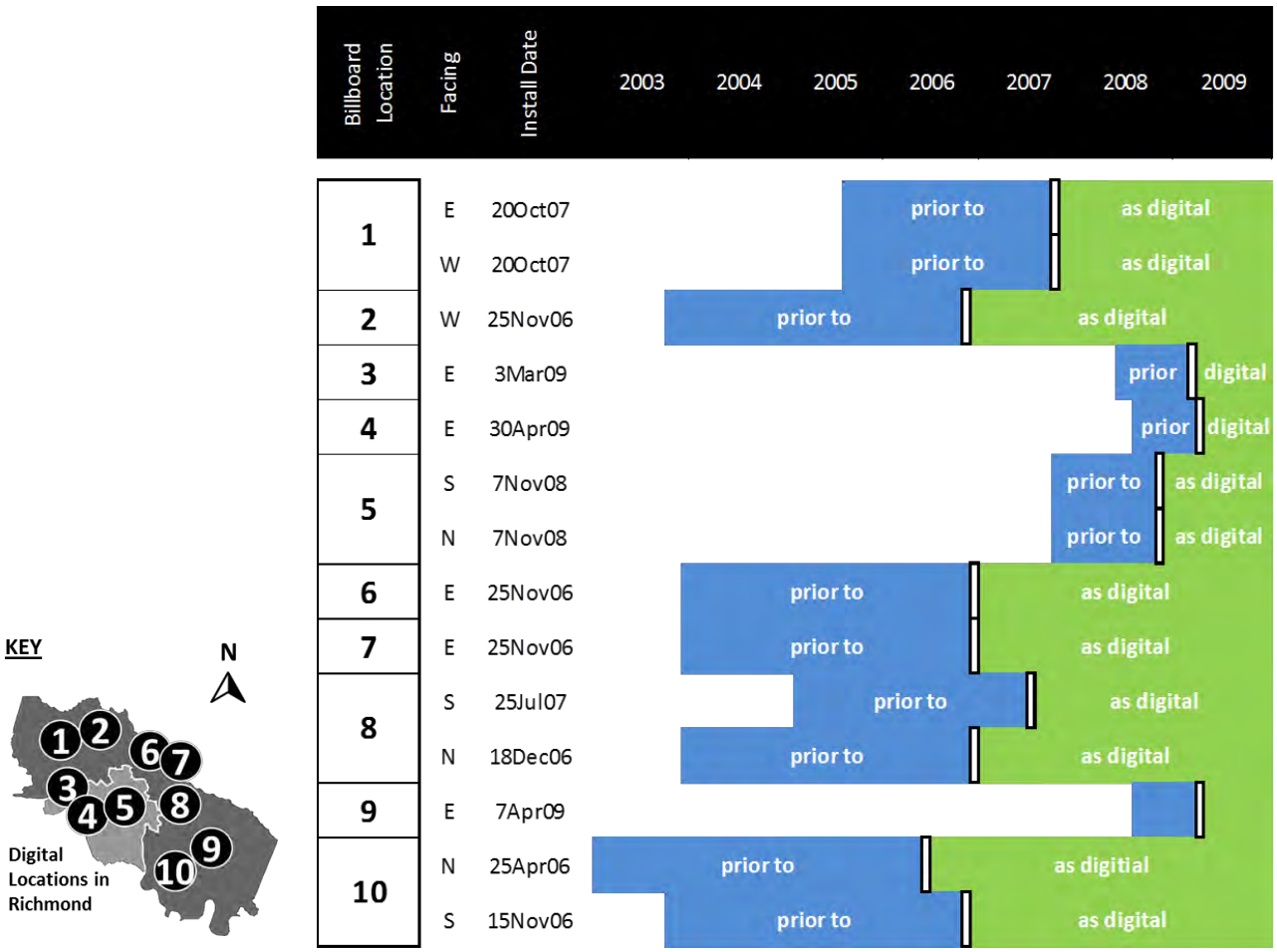


Figure 4.
Digital billboard Conversion Dates and Comparison Timelines for Digital Locations in Henrico County and Richmond, Virginia

Location No. 1 is on the north side of Route 250, at 7912 West Broad Street. The structure is a double-face, free standing, flag, vee configuration. The west face is a digital bulletin and is a right-hand reader. The west face (which faces east) has a 10.5x36 size and was a new build on 27Oct07 at this location. The east face (which faces west) is a digital poster and a cross reader. The east face has an 11x23 size and was a new build on 27Oct07. Each face is operated by Lamar, and has a duration time of 10 seconds. Figure 5a is a photo of the south digital face. Figure 5b shows the location in an oblique aerial.

Figure 5. Location No. 1 (5a, left) View on Route 250; inset shows opposite-face digital, (5b, right) Oblique Aerial of location

Location No. 2 is on the north side of East Parham Road, approximately 0.25 miles west of Interstate 95. The structure is a face, free standing, flag configuration. The east face is a digital poster and a cross reader. The face was converted from a conventional format on 25Nov06 using the existing location. The face is operated by Lamar, and has an 11x22 size with a duration time of 10 seconds. Figure 6a is a photo of the digital face. Figure 6b shows the location in an oblique aerial.

Figure 6. Location No. 2 (6a, left) View on East Parham Road North, (6b, right) Oblique Aerial of location

Location No. 3 is on the north side of Route 250, at 5912 West Broad Street. The structure is a double-face, free standing, center-mount with an offset, vee configuration. The west face is a digital poster and a right-hand reader. The north face was a new build on 3Mar09. The face is operated by Lamar, and has an 11x23 size with a duration time of 10 seconds. Figure 7a is a photo of the digital face. Figure 7b shows the location in an oblique aerial.

Figure 7. Location No. 3 (7a, left) View on Route 250, (7b, right) Oblique Aerial of location

Location No. 4 is on the north side of Interstate 64, approximately 0.2 miles east of Staples Mill Road. The structure is a double-face, free standing, center-mount, vee configuration. The west face is a digital bulletin and a right-hand reader. The face was a new build on 30Apr09 at this location. The face is operated by Lamar, and has a 12.5x40 size with a duration time of 10 seconds. Figure 8a is a photo of the digital face. Figure 8b shows the location in an oblique aerial.

Figure 8. Location No. 4 (8a, left) View on Interstate 64, (8b, right) Oblique Aerial of location

Location No. 5 is on the west side of Interstate 195 just south of the intersection of the Interstate 64 and Interstate 95. The structure is a double-face, free standing, flag, vee configuration. The north face is a digital bulletin and a cross reader. The north and south faces were converted from conventional format on 7Nov08. Each face is operated by Lamar and has a 14x36 size with a duration time of 10 seconds. Figure 9a is a photo of the digital face. Figure 9b shows the location in an oblique aerial.

Figure 9. Location No. 5 (9a, left) View on Interstate 195, inset shows opposite-face digital (9b, right) Oblique Aerial of location

5a

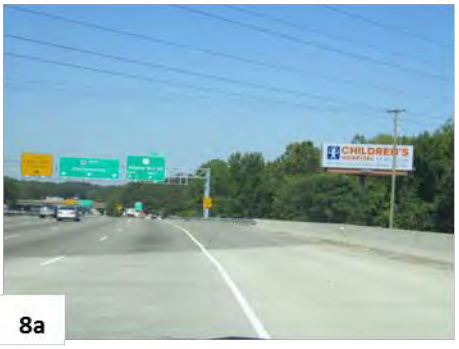
5b

6a

6b

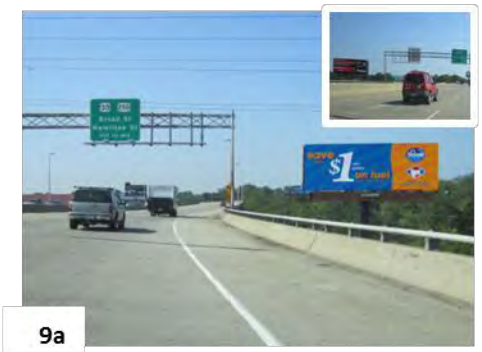
7a

7b

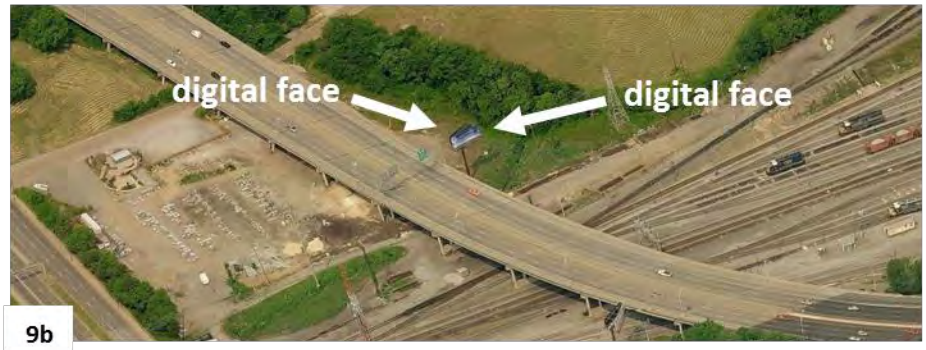


8a

8b



9a



9b

Location No. 6 is on the north side of East Laburnum Avenue, approximately 0.07 miles east of Carolina Avenue. The structure is a double-face, free standing, center-mount, vee configuration. The west face is a digital poster and a right-hand reader. The face was converted from a conventional format on 25Nov06 using the existing location. The face is operated by Lamar and has a 10x21 size with a duration time of 10 seconds. Figure 10a is a photo of the digital face. Figure 10b shows the location in an oblique aerial.

Figure 10. Location No. 6 (10a, left) View on East Laburnum Avenue, (10b, right) Oblique Aerial of location

Location No. 7 is also on the north side of East Laburnum Avenue, approximately 0.12 miles east of Carolina Avenue. The structure is a double-face, free standing, center-mount, back-to-back configuration. The west face is a digital poster and a right-hand reader. The west face was a new build on 25Nov06 at this location. The face is operated by Lamar and has a 10.5x36 size with a duration time of 10 seconds. Figure 11a is a photo of the digital face. Figure 11b shows the location in an oblique aerial.

Figure 11. Location No. 7 (11a, left) View on East Laburnum Avenue, (11b, right) Oblique Aerial of location

Location No. 8 is on the west side of the Route 360 (Mechanicsville Turnpike), approximately 0.3 miles north of Interstate 64. The structure is a double-face, free standing, back-to-back, center-mount configuration. The north face is a digital poster and a cross reader and was converted from a conventional format on 25Jul07. The south face is a digital poster and a right-hand reader. The south face was converted from a conventional format on 18Dec06. Each face is operated by Lamar and has a 14x28 size with a duration time of 10 seconds. Figure 12a is a photo of the digital face. Figure 12b shows the location in an oblique aerial.

Figure 12. Location No. 8 (12a, left) View at Route 360 (Mechanicsville Turnpike), inset shows opposite-face digital, (12b, right) Oblique Aerial of location

Location No. 9 is on the south side of Interstate 64, approximately 0.6 miles west of South Laburnum Avenue. The structure is a double-face, free standing, center-mount, vee configuration. The west face is a digital poster and a cross reader. The face is operated by Lamar, has a 12.5x42 size with a duration time of 10 seconds, and was converted on 7Apr09. Figure 13a is a photo of the east digital face. Figure 13b shows the location in an oblique aerial.

Figure 13. Location No. 9 (13a, left) View on Interstate 64, (13b, right) Oblique Aerial of location

Location No. 10 is on the west side of Interstate 95, approximately 0.6 miles north of Bells Road (Route 161). The structure is a double-face, free standing, center-mount, vee configuration. The south face is a digital poster and a right-hand reader. The south face was converted from a conventional format on 25Apr06. The north face is a digital poster and a cross reader. The north face was converted from a conventional format on 15Nov06 using the existing location. Each face is operated by Lamar and has a 14x48 size with a duration time of 10 seconds. Figure 14a is a photo of the digital face. Figure 14b shows the location in an oblique aerial.

Figure 14. Location No. 10 (14a, left) View on Interstate 95, inset shows opposite-face digital (14b, right) Oblique Aerial of location

10a

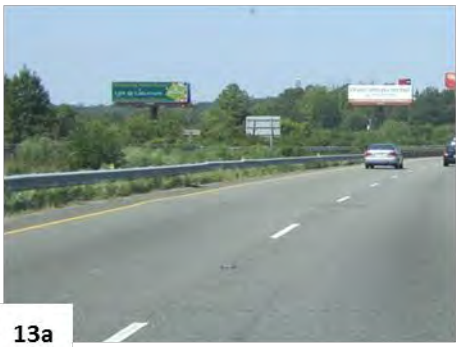
10b

11a

11b

12a

12b



13a

13b

14a

14b

AADT ranges individually near the 10 digital locations from 27 to 100 thousand vehicles per day, or equivalently 9 to 36 million vehicles per year.

TRAFFIC VOLUME DATA

Traffic volume data for Henrico County and Richmond were obtained from the Virginia Department of Transportation (VDOT) and include the annual average daily traffic (AADT), which is the average of 24-hour counts collected throughout the year. The AADT volumes were recorded for the Henrico County and Richmond between 2004 and 2009.

The AADT values are summarized in Figure 15. AADT ranges individually near the 10 digital locations from 27 to 100 thousand vehicles per day, or equivalently 9 to 36 million vehicles per year. For all locations, this collectively represents approximately 423 thousand vehicles per day or 154 million vehicles per year.

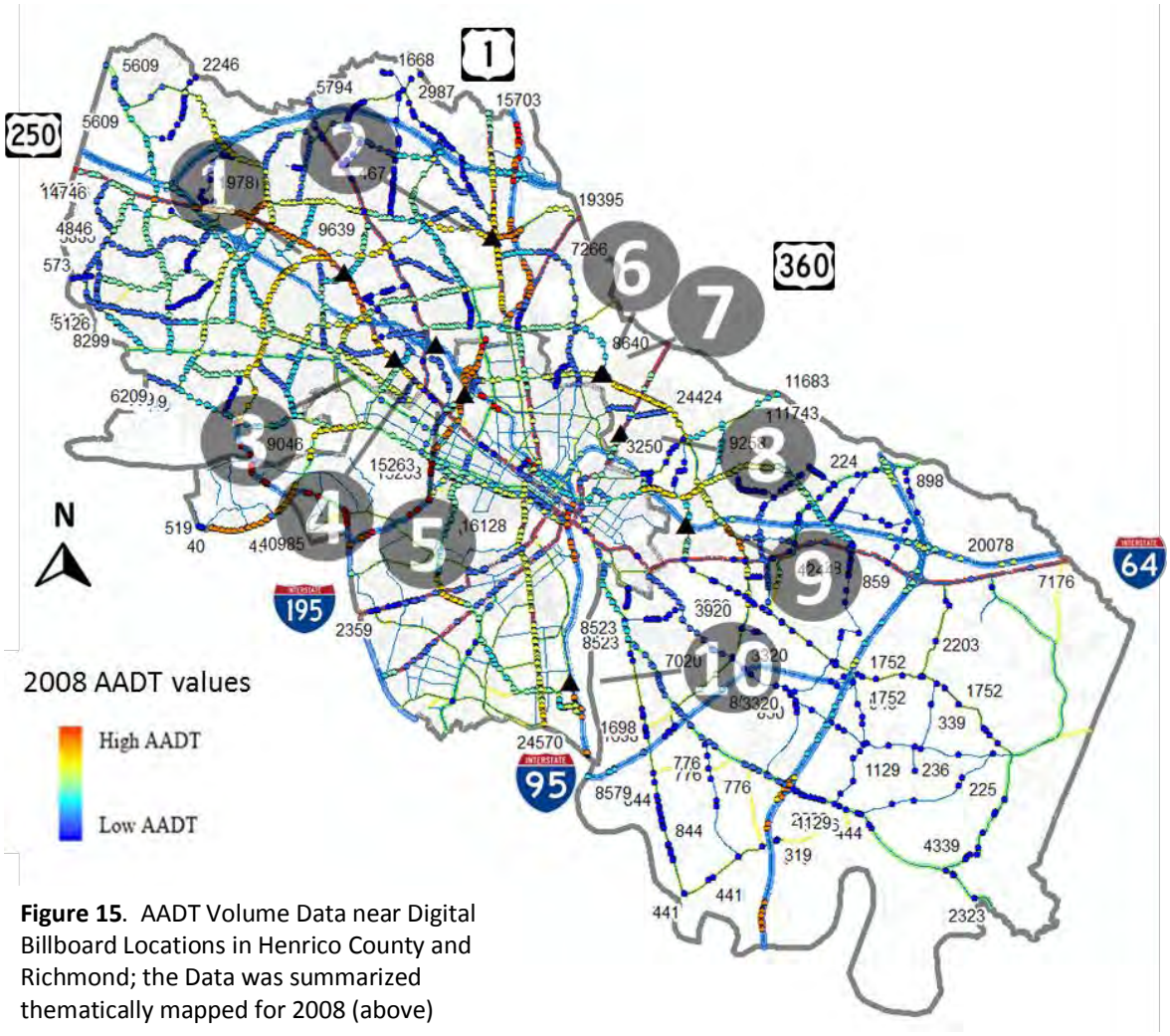


Figure 15. AADT Volume Data near Digital Billboard Locations in Henrico County and Richmond; the Data was summarized thematically mapped for 2008 (above)

ACCIDENT DATA

In this portion of the Greater Richmond Area, the majority of accident reports were investigated and recorded by each local and county Police Departments. Data were maintained by those Police Departments and compiled by the Virginia Department of Transportation. Law-enforcement officials are required to submit reports on crashes they investigate which meet reporting thresholds provided by statue, or in which someone was injured or killed. Data generally conform to the American National Standards Institute (ANSI) Standard D16.1 – 1996, Manual on Classification of Motor Vehicle Traffic Accidents.

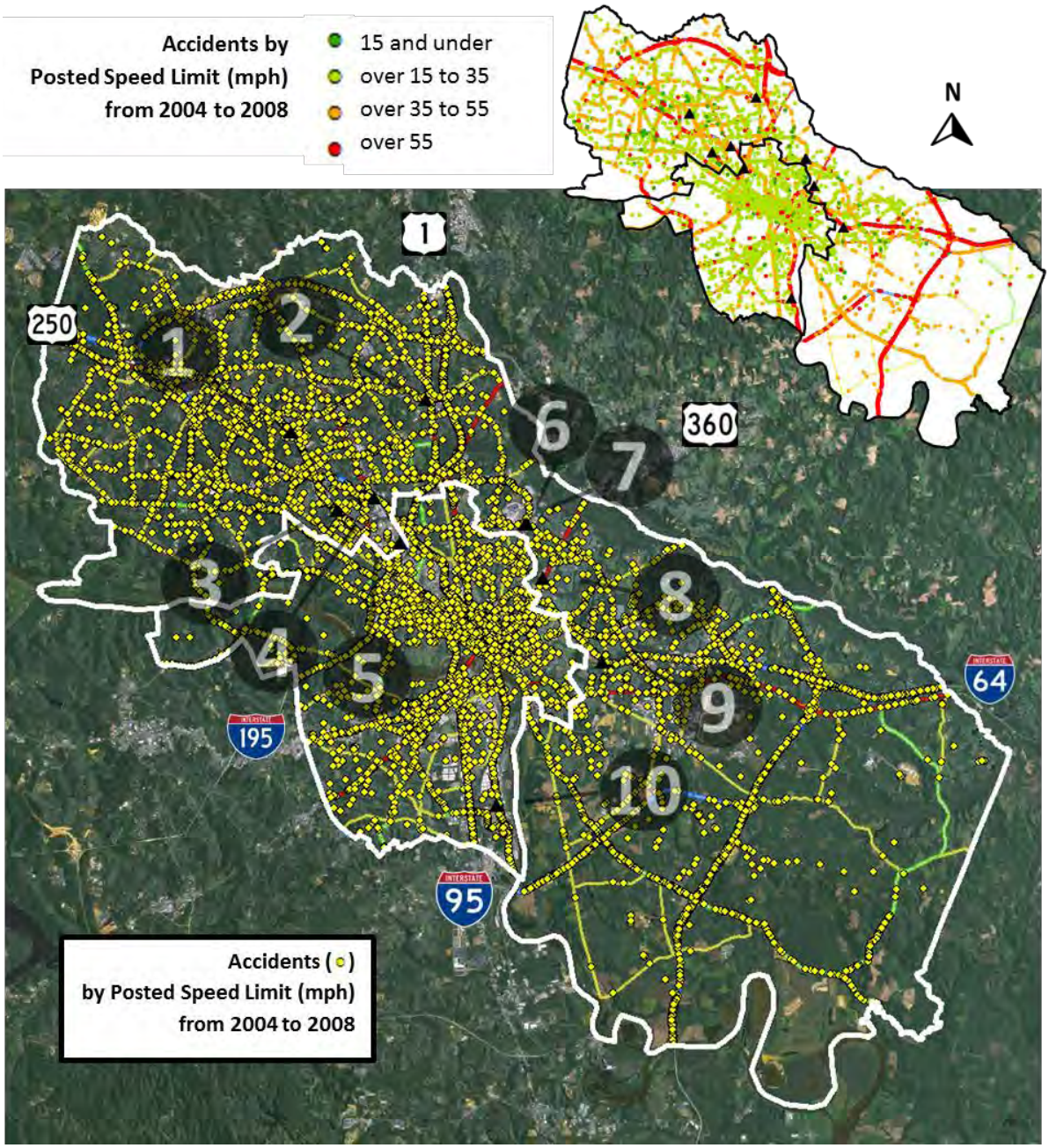


Figure 16. Traffic Accidents (yellow dots) near Digital Billboard Locations in Henrico County and Richmond, Virginia from 2004 to 2008; Inset shows Accident by Posted Speed Limit (mph)

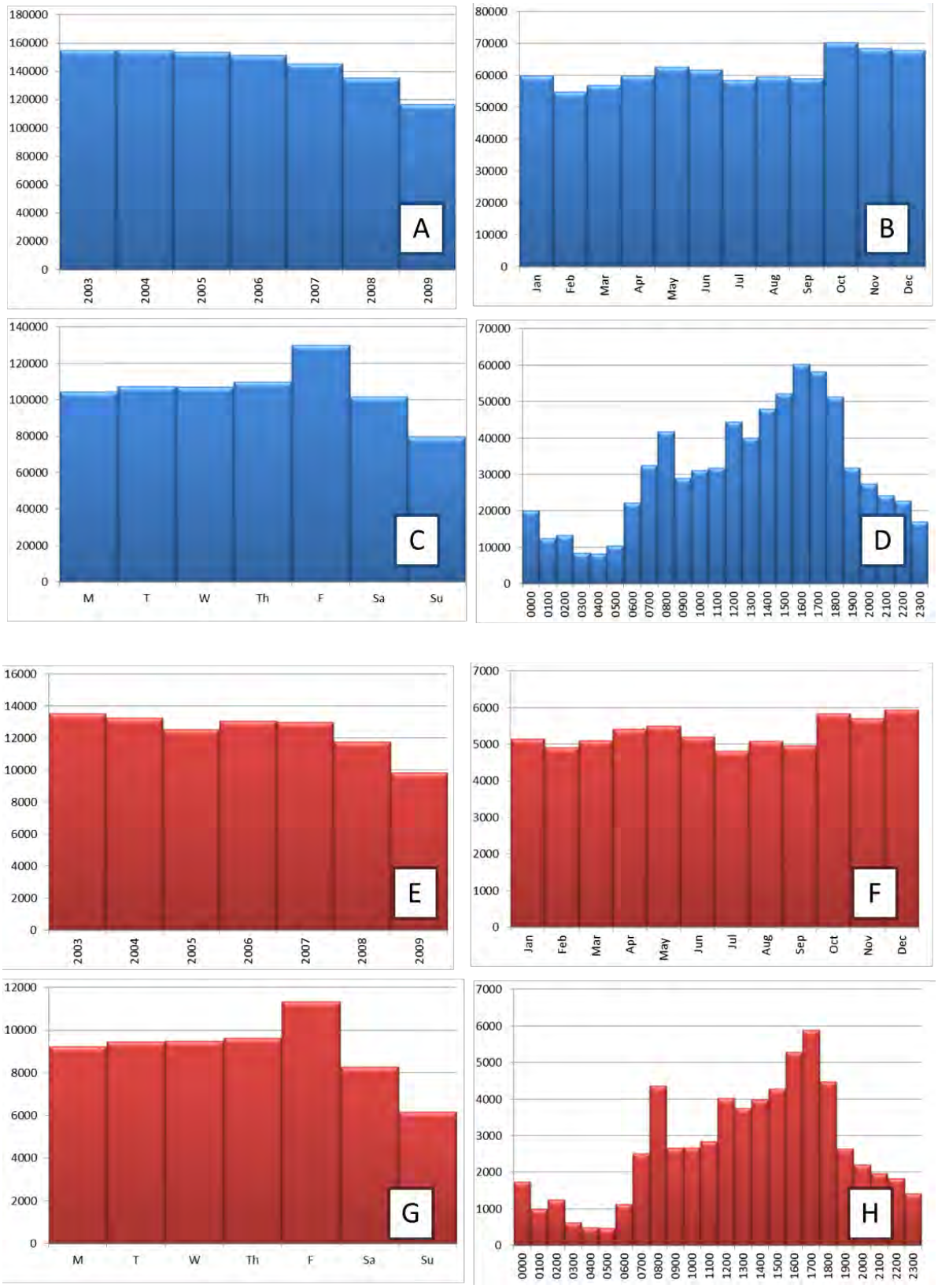


Figure 17. Histogram of Traffic Accident Data of the Past Seven Years in the State of Virginia (in blue) by Year (A), Month (B), Day of Week (C), and Time of Day (D) and in Henrico County and Richmond (in Red) by Year (E), Month (F), Day of Week (G), and Time of Day (H).

The analysis of this robust data involves an engineering-statistics based approach and uses widely accepted methods to show what happened when these 14 digital billboards faces were installed in Richmond.

The accident data-sets provided by VDOT include approximately 40,000 accidents during the seven years between 2004 and 2009 and near the digital billboard locations. Most of the data are specified by latitude and longitude or route nodes with offset distances. Figure 16 shows the geocoded accident locations generally within Henrico County and the City of Richmond.

Figure 17 summarizes the traffic accident data for the past seven years generally within the State of Virginia and within Henrico County and Richmond and show the distribution of accidents by year, month, day of week and time of day. This distribution represents a consistent pattern of data and illustrates that more accidents occur on weekdays and at rush hour (before and after work).

ANALYSIS

The analysis of this robust data involves an engineering-statistics based approach and uses widely accepted methods to show what happened when these 14 digital billboard faces were installed in Henrico County and Richmond.

The analysis has three parts.

Part 1 is a temporal analysis which compares *before* and *after* changes in crash rates and other metrics.

Part 2 is a spatial analysis which compares *where* and *how far* data to establish statistical correlation coefficients for various scenarios accounting for accident density and billboard proximity.

Part 3 uses the Empirical Bayes Method (EBM). This method uses the 'before' accident statistics to predict the number of accidents "expected" at the locations assuming that no digital billboard technology was introduced. The method is the basis of the safety analysis and science-based, predictive models introduced in the 2010 *Highway Safety Manual* of the American Association of State Highway Official (AASHTO, Reference 14). We quantify what the actual 'after' accident statistics are and compare them with what

the predicted values are from the EB analysis. This method analyzes data from the ten billboard location and incorporates data using non-digital comparison sites.

Analysis: Part 1 – Temporal Comparisons

The first part is a temporal analysis. The incidence of traffic accidents near the digital billboards is examined for an equal length of time before and after the digital billboards were installed and activated. This part is for the purpose of establishing if traffic accidents occurred more or less frequently in the presence of these digital billboards. With information collected from police accident reports, the temporal analysis also uses metrics such as traffic volumes, the accident-rate values, the maximum number of accidents during any given month, etc.

For comparison, accident statistics were summarized near the digital billboards within multiple vicinity ranges of 0.2, 0.4, 0.6, 0.8, and 1.0 miles both upstream and downstream of each billboard. For locations on local roads, these vicinity ranges also sampled data to include: (1) accidents along the principal roads to which the digitals directly advertise, (2) accidents recorded as occurring within the intersection of the primary road and any cross roads, and (3) for crossroad accidents within a reasonable distance from the primary road to include drivers turning onto or leaving the primary road. Accident data for roads to which the digitals do not advertise or are not connected were excluded, even if they were within the specified vicinity range.

Analysis: Part 2 – Spatial Comparisons

The second part is a spatial analysis. This establishes statistical correlation coefficients between the digital billboards and accidents. Correlation coefficients are statistical measures of the "association" between two sets of data. The results are analyzed for various scenarios accounting for accident density and billboard proximity.

Additionally, subsets of accident data for age of driver and for daytime and nighttime accidents are analyzed for before and after comparisons. For a more lengthy discussion of analysis methods, please refer to previous studies (see References 3 and 4).

Analysis: Part 3 – The Empirical Bayes Method (EBM)

The third part of the analysis uses the Empirical Bays Method (EBM).

An Empirical Bayes Method (EBM) analysis is performed to estimate the number of accidents that could statistically be expected without the introduction of a digital sign.

Research literature suggests that the EBM method is appropriate for this type of analysis and is a widely accepted method in the field of traffic safety (see References 14 to 31). The method is the basis of the safety analysis and science-based, predictive models

introduced within the 2010 *Highway Safety Manual* of the American Association of State Highway Official (AASHTO, Reference 14).

The negative binomial distribution is established by researchers as an accurate description of yearly crash variation between sites and was previously used to model and evaluate various transportation safety projects (see References 14 through 31). The correction for regression to the mean and the use of a negative binomial distribution are strengths of the EBM.

The EBM is used to estimate the number of crashes before the site change (i.e., before the introduction of digital technology). These "before" estimates are then used to predict the number of crashes that could be expected to occur at a certain location, during a specified year, without the introduction of digital technology.

The change in safety at a location is given as:

$$\Delta\, safety \;=\; B - A$$

where $\Delta\, safety$ is the change in the number of crashes, B is the expected number of crashes in the after period without the introduction of digital technology, and A is the actual number of crashes reported in the after period.

After identifying digital locations, a statistical crash estimate model (CEM) is developed. The CEM model is a multivariate, regression model used to estimate the mean and variance of the annual number of crashes that could be expected at each location. Various multivariate models were tested through an iterative process by fitting the available traits. The analysis uses a negative binomial distribution by fitting a generalized, linear model to the data by maximum likelihood estimation of the parameter vector, B.

The p-value is used as an indicator of the significance of the individual traits. The traits that produced a statistically sound model include the annual average daily traffic (AADT) for the location. The resulting CEM is then

$$P = \alpha_{\lambda}(AADT)^{\beta_1}\,(LANE)^{\beta_2}(Speed)^{\beta_3}.$$

The model parameters and the over-dispersion parameter (theta) are then calculated. The over-dispersion parameter is a measure of the extra variation in the negative binomial distributions compared to a traditional Poisson distribution; this parameter is commonly used in the calculation of the variance, or

$$variance = mean * \left(1 + \frac{mean}{\phi}\right).$$

Using the model, analyzed parameters and data, the expected number of crashes is estimated for each location, had no digital technology been introduced.

For each location, the first year for available data was used as a base year and a normalized mean number of crashes for each year, y is calculated as

$$C_y = \frac{P_y}{P_b}.$$

Where, P_y and P_b are the predicted total number of crashes from the CEM for the year y and the base year, respectively for each location. The projection of the number of crashes is independent of the choice of the base year.

The variance of the expected number of crashes, $Var(P)$ is calculated using the overdispersion parameter, as

$$Var(P) = (1 + \phi * P) * P.$$

The relative weight, α, is calculated as

$$\alpha = \frac{P}{Var(P)}.$$

Actual location crash counts, K, are then used to determine the EB estimate of mean and variance of the number of crashes for a site; EB and $Var(EB)$, respectively are

$$EB = \alpha * P + (1 - \alpha) * K, \text{ and}$$

$$Var(EB) = (1 - \alpha) * EB.$$

The projection of the expected "after" treatment number of crashes is based on the weighted average of the EB estimates of number of crashes of all "before" treatment years for conversion to digital technology.

The estimate of the baseline mean and the variance number of crashes, PC_b and $Var(PC_b)$ is determined as

$$PC_b = \frac{\sum_{before} EB}{\sum_{before} C_y}, \text{ and}$$

$$Var(PC_b) = \frac{\sum_{before} Var(EB)}{\left(\sum_{before} C_y\right)^2}.$$

The projected number of crashes for the conversion locations in the "after" conversion period is calculated by multiplying the normalized number of crashes/year, C_y, by the baseline projected number of crashes, PC_b. The mean and variance of the projected crash count in the "after" conversion period for year, *y*, B and $Var(B)$, are calculated as

$$B = C_y * PC_b, \text{ and}$$

$$Var(B) = C_y^2 * Var(PC_b).$$

The overall index of effectiveness, theta, is then calculated by comparing the total projected number of crashes (B) in the after period to the total actual number of crashes (A) in the after period as

$$\theta = \frac{\sum A}{\sum B}.$$

The unbiased estimate, θ_u, is then

$$\theta_u = \frac{\theta}{1+\frac{\sum Var(B)}{(\sum B)^2}}.$$

The percent change in total crashes due to the introduction of digital technology is

$$\Delta\, crashes\ (\%) = \ (1 - \theta_u) * 100.$$

If the change of introducing digital technology causes crashes to be increased, then θ_u will be significantly larger than one and $\Delta\, crashes$ will be a negative value significantly lower than zero.

This analysis is applied to the data at 66 locations representing the 10 digital locations and 56 comparison sites.

The number of accidents and rates of accidents near the ten digital billboards locations remained consistent within all vicinity ranges.

RESULTS

Figure 18 shows a comparison of the accident metrics for before and after conversions near all ten digital billboards in Henrico County and Richmond, Virginia. The statistics are summarized for vicinity ranges of 0.2, 0.4, 0.6, 0.8, and 1.0 miles of the digital locations with 10 -second duration times collectively. The metrics in Figure 18 include the total number of accidents, the average number of accidents in any given month, the peak number of accidents in any given month, etc. Other metrics, including rates and vehicle-miles traveled were also analyzed.

For all locations (Figure 18), the number of accidents and rates of accidents near the ten, digital billboards decreased in all vicinity ranges. The benchmark, 0.6-mile vicinity experienced a 4.5% decrease in the number of accidents over the seven year span for all location; this includes a 9.5% decrease in accident rates per hundred thousand AADT vehicles.

Figure 19 shows the distributions of the number of accidents per month near digital billboards within the benchmark 1.0 mile vicinity between 2003 and 2009.

A statistical t-test is used to determine whether the average difference between the two, time periods is really significant or if it is due to random difference. Using a 95% confidence interval indicates that no statistically significant difference in the accident statistics evaluated between conventional and digital billboards at these digital locations.

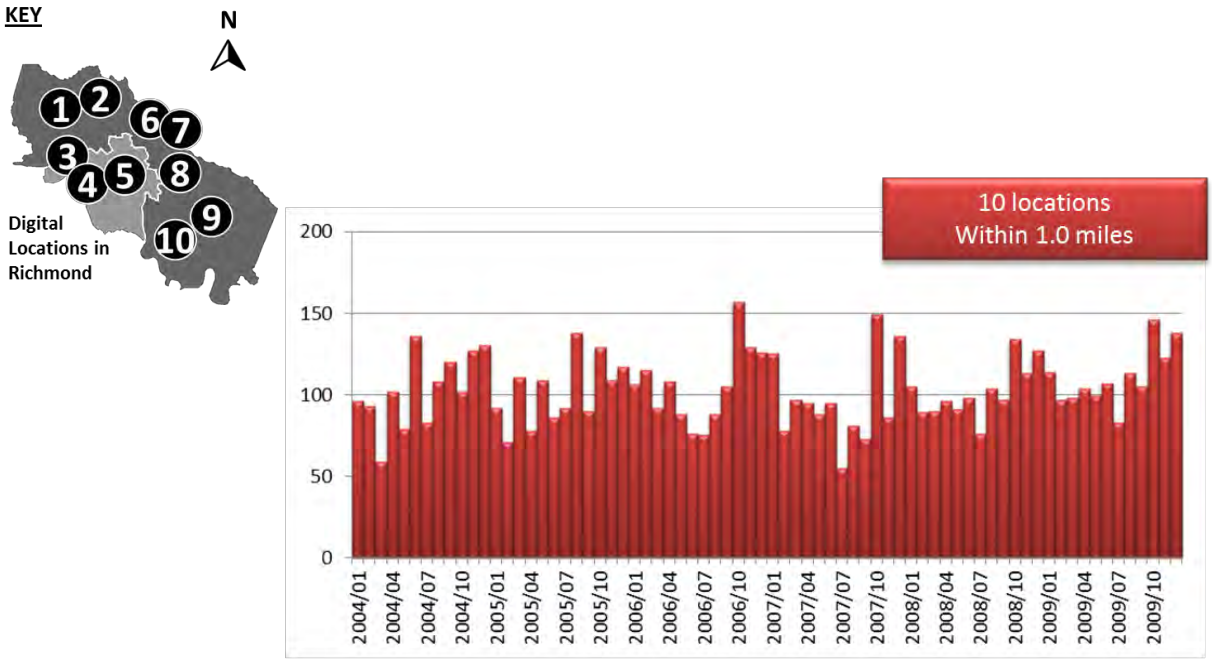
Additionally, consistent results were obtained for driver-age comparisons. Low correlation coefficients were calculated for this spatial analysis. Correlation coefficients were calculated and indicated a very strong correlation of accident patterns near the digital billboards when compared with the accident patterns prior to conversion.

The statistical evaluation of the Empirical Bayes Method and results show that the total number of accidents is approximately equivalent to what would be statistically expected with or without the introduction of digital technology and that the safety near these locations are consistent with the model benchmarked by 66 locations within Henrico County and Richmond.

Between 2003 and 2009 for equal periods before and after
At 10 locations in Henrico County and Richmond, Virginia
with 10 second duration times

		Vicinity Range from Digital Location (miles)				
		0.2	0.4	0.6	0.8	1.0
Prior to Installation	Total Number of Accidents for Equal Periods Before Conversion	241	649.75	832.25	1049.5	1243
	Average Number of Accidents per Month at Each Location	1.02	2.75	3.53	4.45	5.27
	Rate of Accidents per Vehicles (by hundred thousand AADT)	0.15	0.41	0.53	0.67	0.79
	Standard Deviation of Number of Accidents in any given month	1.82	4.01	4.97	5.89	6.84
	Peak Number of Accidents in any given Month per Location	11	19	26	28	35
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	52%	49%	40%	33%	33%
As Digital Location	Total Number of Accidents for Equal Periods After Conversion	205	617.25	795	977.25	1121
	Average Number of Accidents per Month at Each Location	0.89	2.67	3.44	4.23	4.85
	Rate of Accidents per Vehicles (by hundred thousand AADT)	0.12	0.37	0.48	0.59	0.68
	Standard Deviation of Number of Accidents in any given month	1.35	3.05	3.72	4.35	5.03
	Peak Number of Accidents in any given Month per Location	7.5	16	20	22	26.25
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	62%	52%	50%	42%	40%
Comparison	Change in Number of Accidents	-36	-32.5	-37.25	-72.25	-122
	Change in Average per Month	-0.13	-0.08	-0.08	-0.22	-0.41
	Change in Rate per vehicles (by hundred thousand AADT)	-0.03	-0.04	-0.05	-0.08	-0.12
	Percent Change in Number of Accidents	-14.9%	-5.0%	-4.5%	-6.9%	-9.8%
	Percent Change in Rate of Accidents	-19.4%	-10.0%	-9.5%	-11.8%	-14.6%

Figure 18. Summary of Accident Statistics within Vicinity Ranges near all Ten Digital-Billboards Locations with 10-second Duration Times in Henrico County and Richmond, Virginia



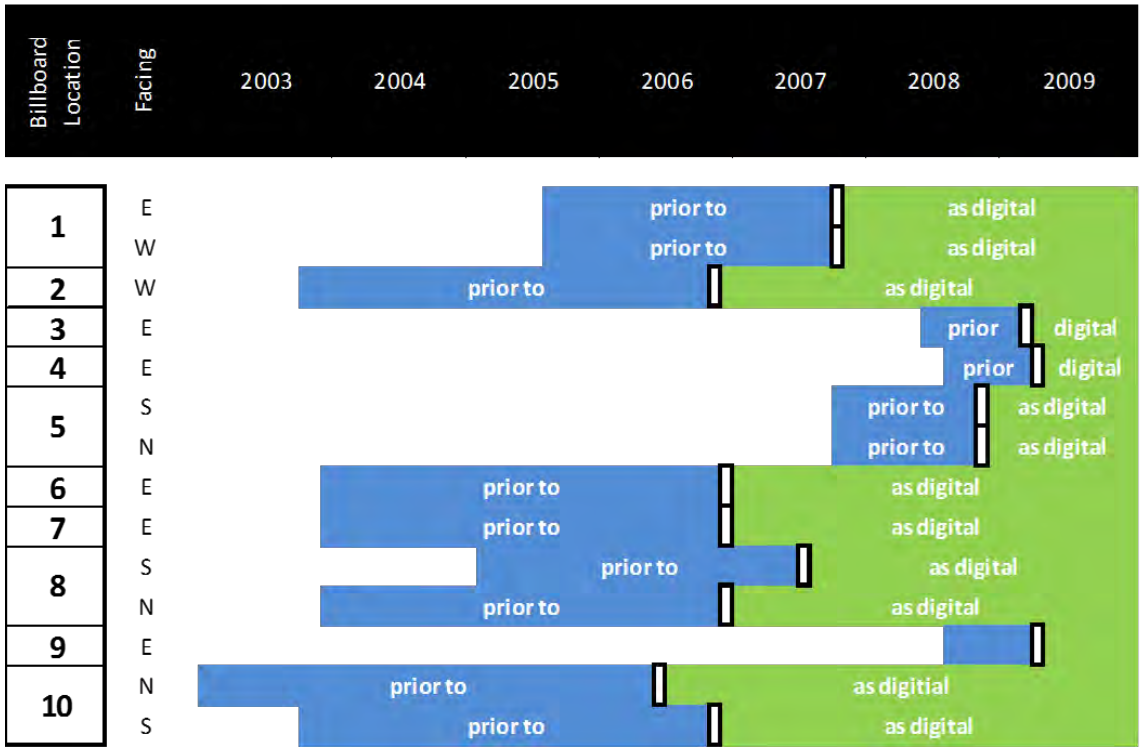


Figure 19. Distributions of the Number of Accidents per Month near Digital Billboards between 2004 and 2009, within a 1.0-mile Vicinity Range near all Digital Locations (top, red) compared with Conversion Dates and Before/After Comparison Periods

Figure 20 summarizes the accident rates that account for variations in traffic volumes for all digital locations within vicinity ranges of 0.2, 0.4, 0.6, 0.8, and 1.0 miles of the digital location. The 0.6 mile benchmark vicinity experienced a decrease in accident rates over the eight-year span. The change in accident rates decreased by 0.05 accidents per hundred thousand vehicles per year; a 9.5% decrease. Similar decreases and trends were observed for both smaller vicinity ranges.

Between 2003 and 2009 for equal periods before and after
At 10 locations in Henrico County and Richmond, Virginia
with 10 second duration times

		Vicinity Range from Digital Location (Miles)				
		0.2	0.4	0.6	0.8	1.0
Prior to Installation	Number of Accidents per million vehicles (by hundred thousand AADT)	0.15	0.41	0.53	0.67	0.79
As Digital Location	Number of Accidents per million vehicles (by hundred thousand AADT)	0.12	0.37	0.48	0.59	0.68
Comparison	Change in Rate per million vehicles (by hundred thousand AADT)	-0.03	-0.04	-0.05	-0.08	-0.12
	Percent Change in Rate of Accidents	-19.4%	-10.0%	-9.5%	-11.8%	-14.6%

Figure 20. Summary of Accident Rates within Vicinity Ranges near Ten Digital Billboards Locations 10- second-duration Times in Henrico County and Richmond, Virginia

COMPARISON OF ACCIDENTS BY AGE OF DRIVER

The accident statistics were also analyzed to determine if the age of the drivers involved in the accidents near the digital billboards was a factor. The data were specifically studied to determine if there are increases in the accident frequency of young drivers (under 17 and under 21) or elderly drivers (65 and older). Figure 21 summarizes the accidents and accident-rates by age of driver for all accidents.

Figure 22 shows the distributions of ages of driver for all accidents within Henrico County and Richmond (A, blue) and for all accidents within 1.0 miles of all digital locations (B, purple).

Figure 23 shows the distributions of driver ages within 1.0 miles of all digital locations for before (orange) and after (purple) periods of comparison. Figure 23 (left) also shows the correlation between before and after conversions for the number of accidents for each age. Individual accidents may have multiple cars and drivers involved, which is reflected in the analysis. In comparing the histograms in Figure 22 and 23, note the typical distribution type (shape) and typical average values. The mode driver age for accidents prior to digital conversion is 19 years; the mode drive age after conversions is 19 years.

Correlation coefficients were calculated and indicated a very strong correlation of accident patterns for age-of-driver factors. Figure 23 shows a 0.920 (92.0%) correlation coefficient when comparing accidents before conversion with those after conversion.

Between 2003 and 2009 for equal periods before and after
At 10 locations in Henrico County and Richmond, Virginia
with 10 second duration times

		Crashes By Driver Age Group			
		under 17	under 21	21-65	over 65
Prior to Installation	Number of Accidents for equal periods prior to conversion	6	134	1007	97
As Digital Location	Number of Accidents for equal periods after conversion	6	98	922	95
Comparison	Change in Number of Accidents	None	-36	-85	-2
	Percent Change in Number of Accidents	None	-26.9%	-8.4%	-2.1%

Figure 21. Summary of Accidents by Age Group within Vicinity Ranges near Ten Digital Billboard Locations in Henrico County and Richmond, Virginia

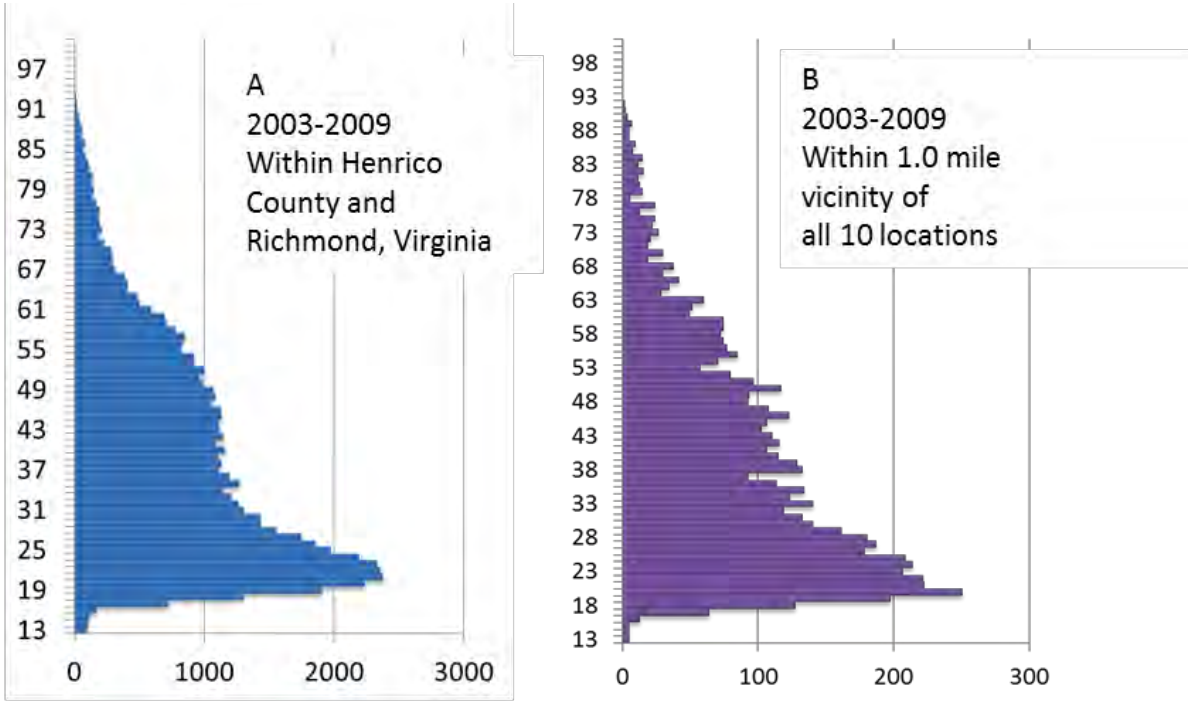


Figure 22. Distributions of Age of Drivers for all Accidents in the Henrico County and Richmond (left, blue), and within 1.0 miles of all Digital Locations (right, purple)

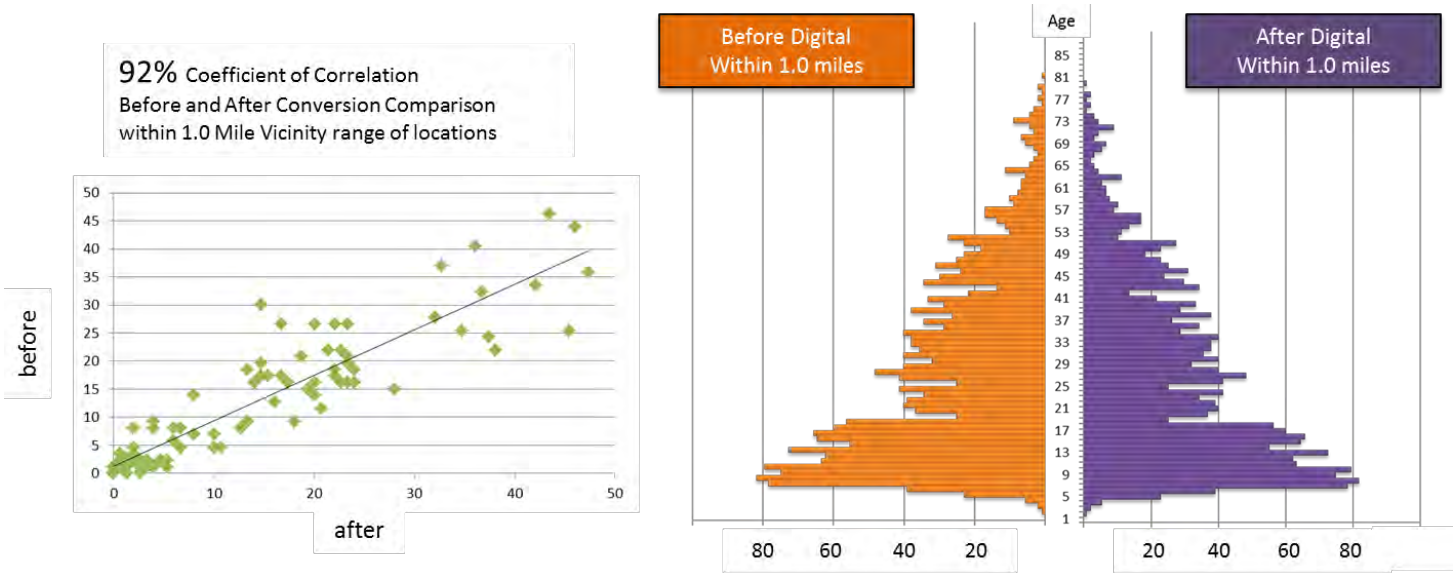


Figure 23. Distributions of Age of Drivers for all Accidents before Digital Conversion (left, orange histogram), after Digital Conversion (right, purple histogram) and the Correlation between Before and After Accident Counts for each Age (left).

COMPARISON OF ACCIDENTS BY TIME OF DAY

The accident statistics are also analyzed to determine if the time of day of the accidents near digital billboards is a factor.

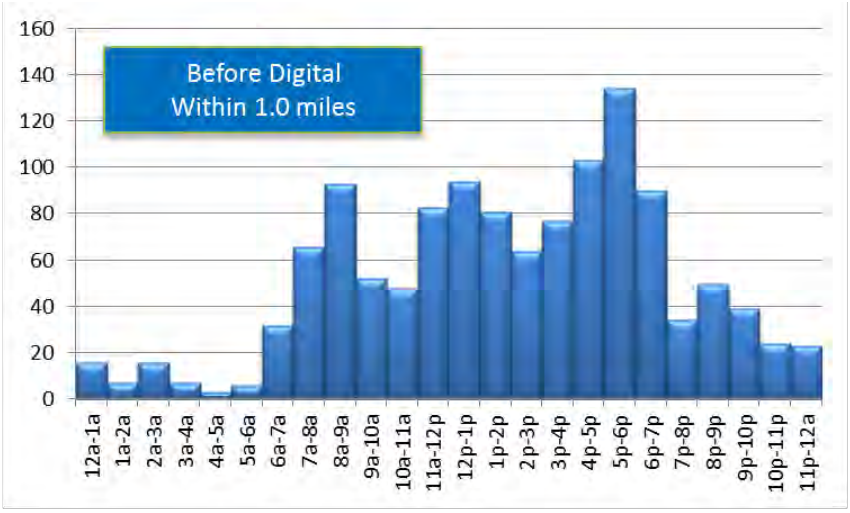
The data are studied to determine if any increases in the accident rates during dawn, daylight, dusk and dark/nighttime conditions occurred. Figure 24 summarizes the accidents and accident-rates by time of day for all accidents within 1.0 miles of the digital locations. The daylight accident rate experienced a 15.5 percent decrease after conversion; the nighttime accident rate experienced a 4.7% decrease.

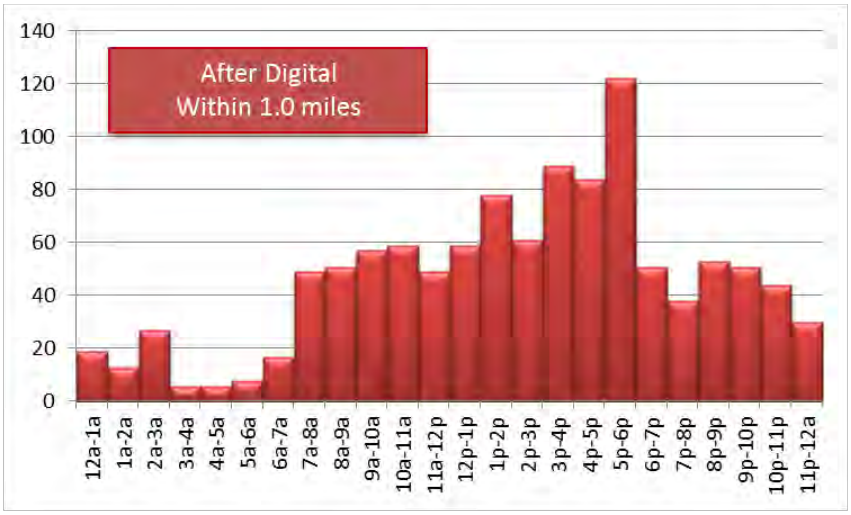
Figure 25 shows the distributions of times of accidents within 1.0 miles for before conversion (top, blue) and for after conversion (middle, red) data periods of comparison. Figure 25 (bottom) also shows the correlation between before and after conversions for the number of accidents. In comparing the histograms in Figure 25, note the typical distribution type (shape) and typical average values. Correlation coefficients were calculated and indicated a very strong correlation of accident patterns for time-of-day factors. Figure 25 shows a 0.90 (90.0%) correlation coefficient when comparing accidents before conversion with those after conversion.

Between 2003 and 2009 for equal periods before and after
At 10 locations in Henrico County and Richmond, Virginia
with 10 second duration times

		During Time of Day and Lighting			
		Dawn	Daylight	Dusk	Dark
Prior to Installation	Number of Accidents for equal periods prior to conversion	98	828	124	190
	Number of Accidents per million vehicles (by hundred thousand AADT)	0.06	0.53	0.08	0.12
As Digital Location	Number of Accidents for equal periods after conversion	66	700	88	181
	Number of Accidents per million vehicles (by hundred thousand AADT)	0.04	0.42	0.05	0.11
Comparison	Change in Number of Accidents	-32	-128	-36	-9
	Change in Rate per million vehicles (by hundred thousand AADT)	-0.02	-0.11	-0.03	-0.01
	Percent Change in Number of Accidents	-32.7%	-15.5%	-29.0%	-4.7%
	Percent Change in Rate of Accidents	-36.2%	-19.9%	-32.8%	-9.8%

Figure 24. Summary of Accident Rates during Dawn, Daylight, Dusk and Dark/Nighttime Conditions within a 0.5 mile vicinity range near ten Digital Billboards Locations with 10-second-duration times in Henrico County and Richmond, Virginia





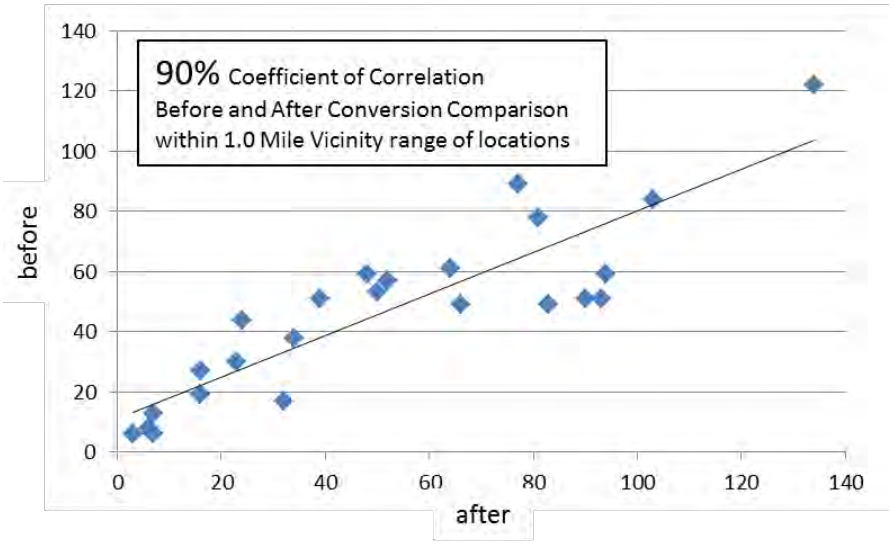


Figure 25. Distributions of Number of Accidents Accident by Time of Day within a 1.0 mile Vicinity Range prior to Digital Conversion (top, blue) and after digital conversion (middle, red) near ten digital billboards locations with 10- second-duration times in Henrico County and Richmond, Virginia

STATISTICAL MODEL AND RESULTS FOR THE EMPIRICAL BAYES METHOD

The Empirical Bayes Method (EBM) is used to analyze available crash data in Henrico County and Richmond, Virginia. The EBM method is a rigorous method capable of estimating the safety impact of changes at a location. The EBM method is well documented and used in numerous traffic-safety studies (see References 14 through 31). Simply stated, the method estimates the number of crashes at a location that would have occurred without the introduction of digital billboards. The estimates may then be compared with the actual crashes that have occurred.

The expected number of crashes as estimated by the Crash Estimation Model (CEM) and using the SAS statistical package and the parameters discussed in our methodology were computed. A multivariate, regression model was developed to estimate the mean of the expected number of crashes at a location. Our general CEM is shown in Figure 26 and models Average Annual Daily Traffic (AADT), Number of Lanes (Lane), and the posted Speed Limit (Speed) as independent variables; β_0, β_1, β_2, and β_3 are model parameters of the independent variables. The model is fit using the maximum likelihood method and includes 90 sites representing 10 digital billboard locations and 80 comparison sites. Figure 27 shows these locations. Figure 26 summarizes the CEM parameters using a maximum likelihood estimates for a multivariate regression model with negative binomial distribution. The CEM parameters are significant at $\alpha = 0.05$. The resulting CEM equation is also presented in Figure 26.

The projected, total crash counts were estimated for the "after" periods to represent what the number of crashes would have been in future period without the introduction of digital billboards. These were compared with the crash data that actually occurred after the introduction of digital billboards at each location to determine the overall index of effectiveness.

General CEM: $$P = (AADT)^{\beta_1}\ (LANE)^{\beta_2} (Speed)^{\beta_3}\ e^{\beta_0}$$

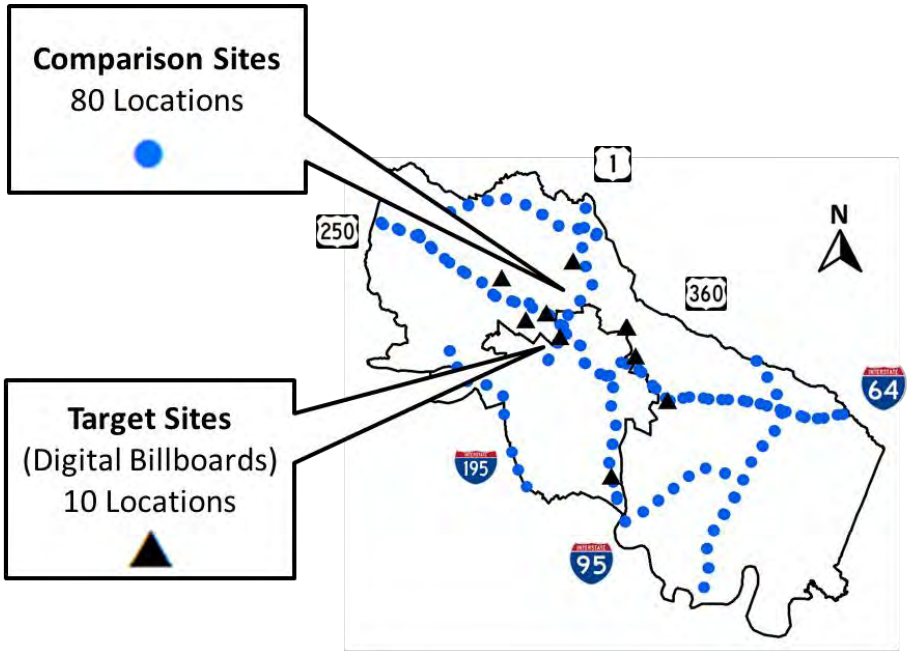
Explicit CEM: $$P = (AADT)^{.0285}\ (LANE)^{0.1381} (Speed)^{-0.0070}\ e^{2.7599}$$

CEM Model Parameters:

Variable		Coefficient	Standard Error	Chi-square statistic	Pr > Chi-square	Wald 90% confidence limits	
						Lower	Upper
Intercept		2.7599	0.1943	201.81	<.0001	2.3792	3.1407
AADT	β_1	0.0285	0.0020	205.35	<.0001	0.0246	0.0324
lanes	β_2	0.1381	0.0293	22.25	<.0001	0.0807	0.1955
speed	β_3	-0.0070	0.0022	10.45	0.0012	-0.0112	-0.0027
Dispersion	ϕ	0.4445	0.0325			0.3808	0.5081

SAS Goodness of fit measures: deviance (value/d.f.) = 438.3687 (1.1014); Pearson chi-square (value/d.f.) = 373.611 (0.9387); Number of observations = 680

Figure 26. General and Explicit Crash Estimation Model (CEM) and CEM Model Parameters from SAS Output



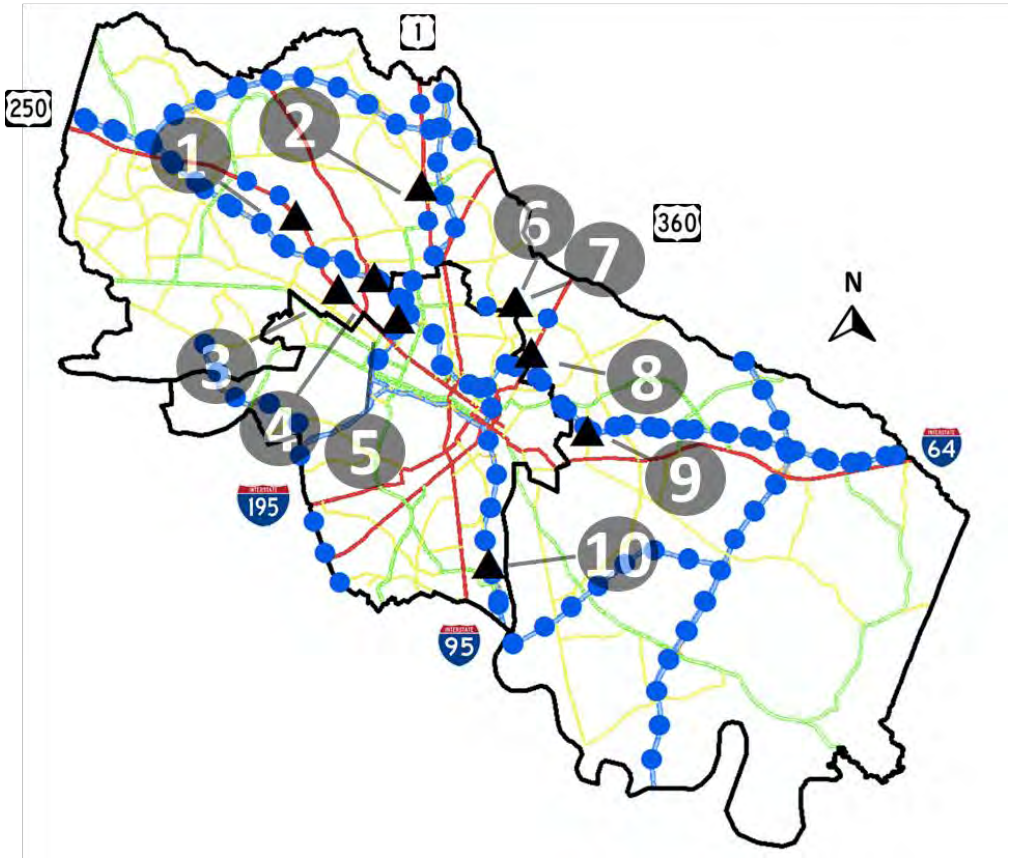


Figure 27. Crash and AADT Data for 10 Target (Digital) Locations and 80 Comparison (non-Digital) Locations

The Empirical Bayes Method results indicate a 0.0142 (1.42%) difference between the "after" conversion crashes that occurred near the 10 digital locations and the statistically predicted Empirical Bayes mean estimate of those same locations had no digital billboards been installed. This comparison has a p-value less than 0.0001. The analysis of this data indicates that the actual and predicted means are almost statistically consistent. A large sample size was used with 10 digital locations, 80 treatment or comparison sites with seven years of accident data. The statistical evaluation of the Empirical Bayes Method analysis shows that the total number of accidents is slightly less than what would be statistically expected with or without the introduction of digital technology and that the safety near these locations are consistent with the model benchmarked by 90 locations within Henrico County and Richmond, Virginia. Additional studies should be considered with other independent variables, consider for lower volume roads, other robust crash estimation models, and cross-comparison of results between digital.

Parameter	Value
Total Crashes for the "After" Period with Digital Conversion (Actual Values)	1121
Total Crashes for the "After" Period assuming no Digital Conversion ever occurred (Estimate by Empirical Bayes Method)	1137
Overall Index of Effectiveness	0.986
Percent Change in Crashes between actual and estimate	1.42%

Figure 28. Results of the Empirical Bayes Method Estimation in Henrico County and Richmond, Virginia with 10 digital locations, 80 Treatment or Comparison Sites and with Seven Years of Accident Data

Simply stated, the data show no statistically significant increase of accident rates near these billboards.

FINDINGS

Henrico County and Richmond, Virginia are a unique opportunity for this study about the statistical associations between digital billboards and traffic safety using robust data-sets and analyzing multiple locations for periods of more than seven years. The overall conclusion is that these digital billboards in Richmond have no statistically significant relationship with the occurrence of accidents. This conclusion is based on local Police and VDOT data and an objective statistical analysis; the data show no statistically significant increase in accident rates. This study also finds that **the age of the driver (younger, older)** and **the time of day (nighttime, daytime) are neutral factors** which show no increase in accident rates near these digital billboards along the routes in in Henrico County and Richmond, Virginia.

The specific conclusions of this study indicate the following.

- **The before and after rates of accidents near the 10 digital billboard locations show decreases** within 1.0 miles of all digital billboards for more than seven years. Similar decreases and trends in both averages and peaks are observed for smaller vicinity ranges.
- **The accident statistics and metrics remain consistent**, exhibiting statistically insignificant variations at each of the digital billboards. The metrics include the total number of accidents in any given month, the average number of accidents, the peak number of accidents in any given month, and the number of accident-free months. These conclusions account for variations in traffic-volume and other metrics.
- The statistical evaluation of the Empirical Bayes Method and actual versus predicted results, show that the **total number of accidents is consistent with what would be statistically expected with or without the introduction of digital technology** and that the safety near this locations are consistent with the model benchmarked by 90 locations within and near Richmond Virginia.
- The overall conclusion of the study is that **these digital billboards in Richmond have no statistically significant relationship with the occurrence of accidents**.

This study also finds that the age of drivers (younger/elderly) and the time of day (daytime/nighttime) are neutral factors which show no significant increase in accident rates near the digital billboards. These conclusions are based on the collected Police Department data and on an objective statistical analysis.

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CONSULTING ENGINEERS
4903 FRANKFORD AVENUE
PHILADELPHIA, PA 19124-2617
www.TANTALA.com

Transportation Synthesis Report

Nina McLawhorn
Research Administrator
Wisconsin Department of Transportation
608-266-3199
nina.mclawhorn@dot.state.wi.us

Electronic Billboards and Highway Safety

Prepared for
Bureau of Highway Operations
Division of Transportation Infrastructure Development

Prepared by
CTC & Associates LLC
WisDOT RD&T Program
May 2/June 10, 2003

Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research.

REQUEST FOR REPORT

Advances in outdoor display technology, and decreases in cost, support an interest in expanding deployment of high resolution and dynamic imaging in outdoor advertising. Technology has advanced sufficiently for electronic billboards (EBBs) to provide dynamic and realistic views much like color television. The advanced EBB has the capability to present multiple views and objects that have realistic motion. In contrast, tri-vision signs provide one of three views with rotating cylinders and generate mechanical motion or movement.

This raises questions about the effects that EBBs and tri-vision signs may have on driver distraction and highway safety. The RD&T Program was asked to report on the measured or predicted safety impacts of outdoor electronic advertising signs.

SUMMARY

We located two FHWA resources that are especially helpful for getting familiar with the issues: the Office of Real Estate Services (ORES) Web site and the study entitled *Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*. We provide links to the items and excerpts below, in the **Overview** section. The study affords an in-depth look at how states are regulating electronic outdoor advertising, from lenient control at one end to the prohibition of outdoor advertising at the other. Wisconsin addresses the issue with rules for the content, timing and brightness of EBBs and tri-vision signs. See **Wisconsin Regulations**. However, standard billboard guidelines governing EBBs and tri-vision signs do not exist: few states, in fact, define the term “electronic billboard.” See **State and Local Studies**. Research on the issue of electronic ads causing driver distraction would suggest that the jury is still out. While some studies conclude that extra-vehicular distractions cause crashes, it has proven difficult to identify and measure the role of electronic advertising in driver distraction. See **Driver Distraction**. However, promising methodologies have been proposed for focused study of the issue, and for trimming the risk of driver distraction from electronic advertising. See **Avenues for Research**.

OVERVIEW

Outdoor ad spending in the U.S. rose 8 percent in 2000 to $5.2 billion. Advanced electronic billboards will explode, according to one industry specialist, in towns with "street excitement and extravaganza" like Orlando, Las Vegas,

Hollywood, wherever large numbers of people congregate, though laws and safety issues may keep them off most highways.

A few years ago cities like New York and Los Angeles embraced what Hollywood's zoning department calls "jumbotrons" as a rejuvenating tool for shabby crossroads, but now cities are demanding tighter regulations. Los Angeles, a driver's city, wants hours of dimming. Many in the advertising sector see the light-emitting diode sign as the future of outdoor billboards. LED screens that recently debuted on L.A.'s Sunset strip bombard passing motorists with movie trailers, commercials and music videos. (From *The Clock* magazine, April 2001: http://www.theclockmag.com/acrobat/minute_by_minute.pdf)

A detailed history and overview of the federal outdoor advertising control program can be found on the FHWA's Office of Real Estate Services (ORES) Web site: http://www.fhwa.dot.gov/realestate/oacprog.htm. In a July 1996 memorandum to FHWA regional administrators, ORES provided additional interpretation of advertising technology to the individual states regarding off-premise changeable message signs: "Changeable message signs are acceptable for off-premise signs regardless of the type of technology used, if the interpretation of the State/Federal agreement allows such signs." In 1998, ORES reaffirmed its policy that off-premise signs using animated or scrolling displays that are dependent on flashing, intermittent or moving lights were not conforming signs. This decision was made after careful review of a videotape showing a full-motion EBB erected in Scottsbluff, Nebraska. It was concluded that such signs raise "significant highway safety questions because of the potential to be extremely bright, rapidly changing and distracting to motorists."

A majority of states have policies regarding the lighting of billboards; these policies have the effect of regulating EBBs.

A helpful overview of the EBB and tri-vision sign issue is provided in the study *Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction (*FHWA, Sept. 11, 2001- http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf). This report is a research review of potential safety implications of EBBs on driving safety. It covers the interval since a similar review was published in 1980. The study focuses on the safety aspects of EBBs and does not examine aesthetic issues. Included are a review of research on driver performance in the presence of EBBs and contacts with federal and state officials to describe state regulatory practices concerning EBBs. An account of tri-vision signs is a part of the state review. Knowledge gaps are identified based on the literature review and these gaps support the development of a set of research questions and related research findings.

From the report:

- (p. 8) Determining the effect of roadway commercial advertising billboards on safety is a difficult endeavor for several theoretical and methodological reasons.
- (p. 9) Summary of a 1994 WisDOT study examining crash rates on I-94 three years before and three years after the installation of a variable message advertising sign.
- (p. 20) At this point, it appears that there is no effective technique or method appropriate for evaluating the safety effects of EBBs on driver attention or distraction.
- (p. 19) One approach being developed for in-vehicle information systems may serve, with some refinement, as a measure of EBB distraction.
- (p. 13) Although the CMS is restricted to providing roadway related information, its legibility requirements may be relevant to the design of the simpler EBB.
- (p. 29) Although research into in-vehicle cellular telephone use does not currently appear to have direct application to EBBs or tri-vision signs, these analyses are ongoing and may still provide insights into the nature of driver distraction, the definition of distraction thresholds and approaches to minimizing distraction for safe driving.

A study performed for the South African National Roads Agency Limited (SANRAL) looks closely at the matter of *content* regulation for outdoor advertising. SANRAL promulgated regulations on outdoor advertising and control in December 2000. In applying the regulations, several problems were experienced with the evaluation of content. The study was launched to investigate an analytical approach to evaluating advertisement contents based on driver characteristics. A parallel is drawn between the reading of road signs and the reading of outdoor advertisements. A

concept of the critical zone—the 500 meters in front of an advertisement—is developed, and the control of content in this zone is quantified. Rules are proposed to evaluate the content for advertisements that are intended to provide "a more practical, defendable approach to evaluating the content of outdoor advertisements." The report can be viewed at http://www.its-traffic.co.za/publications/SANRAL%20face%20evaluation%20presentation.pdf

WISCONSIN REGULATIONS

Chapter Trans 201 of the Wisconsin Administrative Code states the rules that control outdoor advertising along and visible from highways on the interstate and federal-aid primary systems. Sections of the chapter that will interest readers of this report may be found at http://www.legis.state.wi.us/rsb/code/trans/trans201.pdf, including:

Trans 201.05 – Directional and official signs.

Trans 201.06 – Sign criteria.

Trans 201.19 – On-property signs.

Trans 201.15 – Electronic signs. This section sets standards for the use of signs whose messages may be changed by electronic process. Rules are defined for content, timing and brightness for multiple message (tri-vision) signs, and variable message (EBB) signs. The guidelines include:

Tri-vision signs

- The louver rotation time to change a message shall be one second or less;
- The time a message remains in a fixed position shall be six seconds or more.

EBBs

- No message may be displayed for less than one-half second;
- No message may be repeated at intervals of less than two seconds;
- No segmented message may last longer than 10 seconds;
- No traveling message may travel at a rate slower than 16 light columns per second or faster than 32 columns per second;
- No variable message sign lamp may be illuminated to a degree of brightness that is greater than necessary for adequate visibility.

STATE AND LOCAL STUDIES

The safety and aesthetics of commercial electronic variable message signing were reviewed by the FHWA in 1980.[1] Part of that effort included a review of published studies on the safety effect of roadside advertising signs, including several field and laboratory studies from 1951 to 1978 on non-electronic advertising billboards, and one analysis in 1976 of an electronic advertising sign in Boston. Among the findings:

1961: A study of California Route 40 concluded that road segments with billboards experienced significantly more crashes than segments without billboards.

1967: A field study compared the crash history of three locations in Chicago before and after the installation of three illuminated, commercial changeable message signs. Crash rates did not change at two of the sign locations, but the third sign location showed an increase in crashes. The third sign had alternating lights, showed several advertising messages and was illuminated by bright white lights. The rapid increase in crashes led state highway officials to request that blue lights replace the white lights.

1976: The Tele-Spot sign in Boston was an off-premise commercial electronic sign. The sign was visible from the Central Artery in the midst of complex on- and off-ramps, regulatory signs and guide signing. The Massachusetts Outdoor Advertising Board conducted an analysis of traffic crashes three years before and two and a quarter years after sign installation. The analysis showed an overall reduction in the Average Daily Traffic (ADT) and crashes along the expressway, but on the areas of the expressway from where the Tele-Spot was visible, the crash reduction was 10 percent less than the overall reduction. The board regarded the 10-percent difference as an indication that the Tele-Spot sign was a distraction and a safety risk, and consequently revoked the license for the sign.

([1]*Safety and Environmental Design Considerations in the Use of Commercial Electronic Variable-Message Signage*
Wachtel, J. and Netherton, R. [1980]
Report No. FHWA-RD-80-051. Washington, D.C: Federal Highway Administration)

Regarding tri-vision signs, a 1999 survey sponsored by and presented at the annual National Alliance of Highway Beautification Agencies (NAHBA) Conference reviewed the advertising regulations for these signs in every state and Washington, D.C:

- Nine states (18 percent) had no regulations on tri-vision signs.
- Nine states had regulations on tri-vision signs that were either being drafted or in pending legislation.
- Nine states had specific regulations governing tri-vision signs.
- Six states as well as Washington, D.C. prohibited tri-vision signs.
- Fifteen states had regulations regarding moving parts and/or lights.

The survey presented the Minimum Exposure Dwell Time and Maximum Transition Twirl time boundaries of several state tri-vision sign policies.

Overall, while common themes are present in most lighting regulations, each state's laws have unique wording. A review of state outdoor advertising regulations conducted for the 2001 FHWA study revealed that common billboard guidelines governing EBBs and tri-vision signs do not exist. While the 42 states reviewed generally have consistent regulations governing static billboards, regulations covering EBBs and tri-vision signs vary widely, and implementation practices differ significantly from state to state. Few states define the term "electronic billboard." A broad spectrum of regulations exists, ranging from lenient control to the prohibition of outdoor advertising.

Included in the findings:

- Only 10 of the 42 states (24 percent) prohibit moving or animated parts in signs, unless the signs are a public service announcement. A few states make an exception for movement related to the changing of a sign.
- Twelve states (29 percent) include some type of timing limit for the viewing of signs. Of these, only eight apply to EBBs or other types of signs with changing messages.
- Most states (36) prohibit signs that include a red, flashing, intermittent or moving light, unless it is a public service display.
- Most states (36) prohibit signs that are not sufficiently shielded to prevent beams or rays of light from causing a glare or vision impairment that affects driver vision.

Based on the review, the report identifies the following issues that may pertain to EBBs: red, flashing, intermittent or moving lights; glare; use of traffic control device (TCD) symbols and words; illumination or placement interfering with a TCD; and spacing and timing limits. Of the potential issues, timing limits may be the one issue where additional or expanded research would have the most significant benefit.

In more recent developments:

- Focusing on transportation and tourism in Vermont, Brian Searles, Secretary of the Vermont Agency of Transportation, said that the state's biggest challenge is to resolve the clash between providing appropriate development of transportation infrastructure and retaining natural beauty. Tourism is an international business for the state, responsible for $4 billion annually. Because 80 percent of tourists travel by car, he said that the state has eliminated roadside billboards, controlled development at interchanges, and applied flexibility in bridge design. (From AASHTO Weekly Transportation Report June 1, 2001: http://www.aashto.org/publications/journal.nsf/SearchSite/75D49BC8E9D64BF086256A8B00088B72?OpenDocument&Highlight=billboards. Scroll down to section on Transportation Ties to Agriculture, Recreation Examined.)
- The Oregon Department of Transportation proposed to amend the Highway Beautification Federal/State Agreement of Aug. 26, 1974, between the U.S. and the State of Oregon, to permit the use of tri-vision signs adjacent to routes controlled under the Highway Beautification Act. (From AASHTO Regs Report Aug. 22, 2001: http://www.aashto.org/publications/regs.nsf/SearchSite/1CE55B45DD85BC1D86256AB0006C202C?OpenDocument&Highlight=outdoor%20advertising)
- Legislation was approved by the Arizona House of Representatives to permit billboards to have 200-square-foot sections with lighted messages that change every six seconds. The vote came despite claims by the Arizona Department of Transportation that permitting these kinds of signs along state freeways and roads violates federal laws. The violation, according to ADOT lobbyist Kevin Biesty, could cost Arizona $50 million in federal aid. (From the Arizona Daily Star, March 12, 2003: Web link not available.)

- The above bill (SB1138) contradicted efforts represented by tough Flagstaff and Coconino County ordinances that control light pollution and another bill passed by the Legislature that requires shielded lights for new state buildings. Flagstaff is a hub for astronomical research in Arizona. Officials said that although illuminated billboards are either banned or strictly regulated under Coconino County and Flagstaff ordinances, passage of the bill could embolden the outdoor advertising industry to take a run at local regulations. (From the *Tucson Citizen*, April 24, 2003: http://www.tucsoncitizen.com/breaking/archive/4_24_03dark_skies.html)

DRIVER DISTRACTION

Commercial EBBs are designed to "catch the eye" of drivers.[*] Their presence may distract drivers from concentrating on the driving task and the visual surrounds.[2]

[*]From Outdoor Advertising Association of America Web site at http://www.oaaa.org/outdoor/:

1. … Today the advances in computer imaging and reproduction make even photographic renditions absolutely breathtaking regardless of size. Such advances have not only allowed greater durability but also entire new forms of outdoor to emerge: wallscapes, wrapped buildings, the conversion of construction sites into marketing events.
2. Technology has enabled virtually anything imaginable. The wonders out there go far beyond an oversized pretty picture. A medium that began as a simple two-dimensional sign can now talk to you (via short wave radio links), download data into your Palm Pilot (through a patented Street Beam device), connect you to the Internet (via souped-up taxi tops), and change as you pass by (through motion detectors). Add this to old-fashioned LED boards and the "no-holds-barred" street theater of Times Square and, well, you get the picture.
3. … Outdoor IS the message, and as such will always be the last mass medium, a sure fire way to get noticed, to draw attention, ultimately to sell… which is, after all, outdoor's raison d'etre. So as long as there are widgets in search of a buyer, outdoor will be out there, outdoing everything else!

([2]*Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*- FHWA, Sept. 11, 2001- p. 17
http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf)

The safety consequences of distraction from the driving task can be profound.

In one study, five years (1995 to 1999) of national Crashworthiness Data System (CDS) data are analyzed to determine the role of driver distraction in traffic crashes and the specific sources of this distraction. Results show that 8.3 percent of the drivers were distracted at the time of their crash; after adjustment for the large percentage of drivers with unknown distraction status, the percentage rose to 12.9 percent. The most frequently cited sources of driver distraction were persons, objects or events outside the vehicle (29.4 percent of distracted drivers); adjusting the radio, tape or CD player (11.4 percent); and other occupants in the vehicle (10.9 percent). Other specific distractions (moving objects in vehicle, other objects brought into vehicle, adjusting vehicle or climate controls, eating and drinking, cell phones and smoking) were each cited in only 1 to 4 percent of the cases. The likelihood of being distracted and the source of distraction varied by driver age but not by gender.[3]

([3]abstract: "The Role of Driver Distraction in Crashes: An Analysis of 1995-1999 Crashworthiness Data System Data- Association for the Advancement of Automotive Medicine," 2001
http://199.79.179.82/sundev/detail.cfm?ANNUMBER=00923438&STARTROW=91&CFID=179748&CFTOKEN=35097404)

Treat et al. found that driver inattention and improper lookout increase the likelihood of crash occurrence and are major factors underlying the causes of crashes.[4] According to Wang, et al., an analysis conducted by the National Highway Traffic Safety Administration (NHTSA) of causal factors of crashes showed that distraction by sources external to the vehicle accounted for 3.2 percent of the crashes. The external sources included people, events and non-specified objects.[5] The NHTSA analysis did not identify the external objects, nor did it identify billboards as among the sources of distraction. However, the data suggest that, on occasion, external stimuli can be sufficiently distracting to drivers, causing or resulting in a crash.[6]

([4]*Tri-Level Study of the Causes of Traffic Accidents*
Treat, J.R.; Tumbas, N.S.; McDonald, S.T.; Shinar, D.; Hume, R.D.; Mayer, R.E.; Stanisfer, R.L.; and Castellan, N.J. [1979]
Washington, D.C.: National Highway Traffic Safety Administration)

([5]*The Role of Driver Inattention in Crashes: New Statistics from the 1995 Crashworthiness Data System*
Wang, J., Knipling, R. and Goodman, M. [2000]
Obtained from the August 2000 Driver Distraction Internet Forum sponsored by the National Highway Traffic Safety Administration on the World Wide Web)

([6]*Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*- FHWA, Sept. 11, 2001- p. 10
http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf)

Research on driver search behavior in high and low volume intersections by Rahimi, Briggs and Thorn in 1990 suggests that higher volumes of traffic affect driver eye and head movements.[7] The research indicates that the greater visual complexity associated with the high volume intersection required drivers to search the environment more than in the low volume intersections. It can be conjectured that additional visual stimuli, such as billboards, may add additional demand to driver workload in high-volume intersections.[8]

([7]*A Field Evaluation of Driver Eye and Head Movement Strategies toward Environmental Targets and Distractors*
Rahimi, M., Briggs, R. and Thorn, D. [1990]
Applied Ergonomics, 21(4), pp. 267 to 274)

([8]*Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*- FHWA, Sept. 11, 2001- p. 13
http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf)

Guidance on information processing time requirements comes from research on dynamic message signs, where drivers are reading unfamiliar messages. A study (conducted by Mast and Ballas in 1976) was carried out with drivers who were driving on a low-density highway, and it showed that 85 percent of them were able to read signs with word messages only at a rate of one major word per second or better. This means that under perfect conditions, a driver with 20/20 vision traveling during the day at 100 km/h (62 mph) on a freeway reading 14-inch letters has about nine seconds during which the sign text is legible, and therefore could cope with about nine words and/or symbols. At the other extreme, a driver with 20/40 vision traveling at 80 km/h (50 mph) at night on a major highway reading six-inch letters could cope with only one word and/or symbol. Other factors that affect the time taken to read any message are the driver workload (that is, the number of tasks the driver must perform simultaneously), the message familiarity and display format. For driver workload, 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.[9]

([9]Toronto Staff Report- Feb. 6, 2001- p. 4
http://www.city.toronto.on.ca/legdocs/2001/agendas/committees/wks/wks010221/it002b.pdf)

Numerous states have attempted to identify a relationship between EBBs and safety by using traffic conditions as a surrogate measure. The states of Nevada, Utah, Texas, New York, New Hampshire and Massachusetts reported no evidence of increased traffic safety problems after the installation of electronic information displays in their city centers and along their highways. Additionally, five state DOT personnel were asked if a crash relationship with EBBs existed in their states; the responses were that a relationship between crashes and EBBs was not identifiable. However, one belief is that EBBs are typically on congested roadways where drivers have time to look at the sign, so it is difficult to determine if the EBBs cause crashes, let alone traffic congestion.[10]

([10]*Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*- FHWA, Sept. 11, 2001- p. 8
http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf)

AVENUES FOR RESEARCH

It would be beneficial to measure the effect that EBBs have on driver distraction. The FHWA report suggests methodologies involving:

The Peripheral Detection Task

Olsson and Burns describe a peripheral detection task (PDT) that is designed to measure visual distraction and driver mental workload. This study included measures of reaction time and correct detection rate for drivers who were asked to report the presence of an LED dot shown briefly at slightly different locations on a windshield while: 1) driving on country roads and a motorway and 2) performing a secondary task while driving. The dots were projected 11 to 23 degrees to the left of the straight-ahead view and two to four degrees above the horizon. This location approximates the visual angle that corresponds to a pedestrian or some roadside signs. Statistically significant results indicated that a CD manipulation task and a backwards counting task required a longer performance time and resulted in fewer correct detections than the baseline driving task.

Since these drivers missed more targets when performing a secondary task and because it took longer to report the targets that were spotted, the PDT may be useful in assessing the distractibility of in-vehicle systems. If the PDT can be applied to in-vehicle systems, it may also be applicable to stimuli external to the vehicle such as EBB and tri-vision signs.[11]

(**[11]***Measuring Driver Visual Distraction with a Peripheral Detection Task*
Olsson, S. and Burns, P.C. [2000], Obtained from the August 2000 National Highway Traffic Safety Administration Driver Distraction Internet Forum on the World Wide Web)

Work zones

Research about the effects of EBBs in work zones on safety should be performed, since the presence of additional visual distractions may elevate the risk of driver distraction and unsafe driving. Different roadway characteristics exert varying demands upon driver attention and skill. Particular roadway configurations and their characteristics may be more or less suitable for EBBs, and are important to consider when evaluating the safety effects of EBBs. The following roadway characteristics have special considerations relative to the issue of distraction and safety: horizontal and vertical curves, interchanges and intersections, and work zones. Whatever the reason for current selection of improper speed in a work zone, it is possible that the presence of an EBB or tri-vision sign would aggravate the problem.[12]

(**[12]***Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*- FHWA, Sept. 11, 2001- pp. 21 to 23
http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf)

CMS

Although the CMS is restricted to providing roadway-related information, its legibility requirements may be relevant to the design of the simpler EBB. One event that can be considered a distraction occurs when a driver passes a sign where the text has poor legibility. The weakness in legibility may be due to poor character font design, improper spacing of letters or other factors. However, if the information is of sufficient interest, the driver may try to read all of the text anyway. Such a decision could take time away from the driving task, thus increasing crash risk. If on the other hand the sign had text that met legibility standards, less effort would be required to read the sign. Although this situation is a more subtle distraction than that due to perceived motion in a sign, it still could present potential for crash risk. Garvey and Mace provide draft guidelines for the design of the elements and characters that compose a word and word groupings on a CMS, in which the character font is composed of light emitting elements. [13]

(**[13]***Changeable Message Sign Visibility*
Garvey, P.M. and Mace, D.J. [1996]
Report No. FHWA-RD-94-077. Washington, D.C: Federal Highway Administration)

The MUTCD (39) Section 2E-21 (applicable to CMS for use on freeway and expressway mainlines), states that a CMS should display no more than three lines of text. There should be a maximum of 20 characters per line. An analysis of these numbers for the simpler EBB displays, in conjunction with analyses of exposure times, may be useful.[14]

(**[14]***Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*- FHWA, Sept. 11, 2001- pp. 21 to 23
http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf)

Garvey and Mace examined CMSs to identify the features that contribute to their visibility. The authors provide guidelines that are aimed at improving the visibility of all CMSs, regardless of technology. Minimum luminance values are recommended for CMS visibility. In addition, they suggest that there should be a minimum luminous contrast between the unlighted and lighted elements on a CMS. Contrast orientation should always be positive, that is, the characters should be lighted against a dark or less luminous background. A negative contrast is likely to result in a 25 percent shorter legibility distance.[15]

(**[15]***Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*- FHWA, Sept. 11, 2001- p. 13
http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf)

A TMC pooled-fund study is under way that will assess the impacts of dynamically displaying messages on CMS and recommend updates to the MUTCD regarding design, programming and operation of such applications. The objectives of the research include conducting multitask human factors laboratory studies or studies using a driver simulator to determine the effects of using these dynamic features: flashing an entire one-frame message, flashing one line of a one-frame message, and alternating one line of text and keeping two lines constant on a three-line sign.[16]

([16]*Impacts of Using Dynamic Features to Display Messages on Changeable Message Signs*
TMC Pooled-fund Study- Current Projects
http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=31&new=0)

Cellular phones

Although research into in-vehicle cellular telephone use does not currently appear to have direct application to EBBs or tri-vision signs, these analyses are ongoing and may still provide insights into the nature of driver distraction, the definition of distraction thresholds and approaches to minimizing distraction for safe driving. In each case, the application of a new technology raised concerns about driver distraction.[17]

([17]*Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*- FHWA, Sept. 11, 2001- p. 29
http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf)

The relevance of information on cellular telephone use to EBBs lies in visual (glancing) and cognitive (mental engagement) behaviors. Viewing EBBs or using a telephone requires drivers to look away from the roadway for some period. Similarly, reading a sign could disrupt a driver's concentration, just as engaging in a telephone conversation might. According to Cain and Burris, hands-free telephone use carries about the same risk observed in hand-held use,[18] and an NHTSA report cites that a telephone conversation is a factor in crashes more frequently than dialing.[19] Cain and Burris believe that the type of conversation is significant in determining crash risk, and McKnight and McKnight believe that complex and intense conversation is the riskiest, and simple conversation is relatively risk-free.[20] Thus, becoming mentally preoccupied can be as distracting to a driver as manually operating a telephone or glancing away from the roadway.[21]

([18]*Investigations of the Use of Mobile Phones While Driving*
Cain, A., and Burris, M. [1999]
Florida, USA: Center for Urban Transportation Research, University of South Florida)

([19]*Traffic Safety Facts 1996: Young Drivers*
National Highway Traffic Safety Administration [1997] Washington, D.C.: National Highway Traffic Safety Administration)

([20]*The Effect of Cellular Phone Use Upon Driver Attention*
McKnight, J., and McKnight, A.S. [1991]
Landover, MD: National Public Services Research Institute)

([21]*Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*- FHWA, Sept. 11, 2001- p. 17
http://www.fhwa.dot.gov////realestate/elecbbrd/elecbbrd.pdf)

giffels webster Memorandum

To:	International Outdoor, Inc. Patrick Depa	Date:	9.15.15
From:	Jim Renshaw, PE, PTOE	Project:	Crash Analysis (I-75 between Mile Marker 63 – 76.8) in Troy, Madison Heights and Auburn Hills)
RE:	Billboard Traffic Safety Evaluation	Project Number:	18827.00

Introduction and Objective

Hundreds of research projects have been conducted by the Federal Highway Administration and/or the National Cooperative Highway Research Program relating to digital billboards (DBBs). Several conclusions can be drawn from these studies; however, no significant policy changes have been made to aid State agencies in regulating DBBs. There are a host of human factors, billboard operating characteristics, roadway conditions, and roadside conditions to take into account when conducting these nationwide research projects.

The purpose of this safety evaluation is quite simple. This project reviews the historical crash patterns, frequencies, and crash rates both before and after DBB installations on I-75 in southeast Michigan. This project represents the review of at least a thousand (1000) crash reports (aka UD-10 reports) along I-75 in order to determine if existing DBBs have exhibited adverse safety impacts or are safety neutral. Giffels Webster has been retained by International Outdoor Inc. to conduct this evaluation in preparation for proposed for two (2) DBB installations in the City of Troy, Michigan (identified below). In addition, this report presents the results of a "rolling" review of I-75 crashes that had been conducted by others along the same segments of I-75.

Background

International Outdoor proposes two (2) new DBB installations in Troy, Michigan. They are:

- The 1705 "Austin" DBB – located on the east side of I 75 approximately 500 feet north of Maple Road
- The 1125 "Naughton" DBB – located on the south side of I 75 approximately 1200 feet east of Rochester Road

Four (4) comparable sites (called "Comps") have been selected for safety evaluation. They are:

- The ""Comp #1" DBB – located on the east side of I 75 approximately 1300 feet north of 13 Mile Road. This DBB was installed and was operational. Installed July 2012.
- The "Comp #2" DBB – located on the west side of I-75 at the junction of the southbound 14 Mile Road entrance ramp with I-75 southbound mainlines. Installed June 2012.
- The "Comp #3" DBB – located on the west side of I-75 approximately 700 feet south of Auburn Road. Installed in 2010.
- The "Comp #4" DBB – located on the west side of I-75 near the junction of the southbound 12 Mile Road entrance ramp with I-75 southbound mainlines. Installed in 2012.

Crash history of "before" installation and "after" installation have been conducted for each of the four comparable locations within a view shed of five-hundred feet (500) in each direction of these double sided billboard signs. In like fashion, the most recent three (3) year crash history is reported for each proposed DBB location along the 500 ft. view shed/impact area. *Appendix A illustrates graphically the location of each DBB and the view shed/impact area for both proposed locations and each comparables.

International Outdoor has indicated that the operating characteristics of each of the four (4) comparable DBB locations are similar to the operating characteristics of the proposed DBB locations. In addition, the roadway environment (speed limit, # of lanes, traffic counts) are similar to the four (4) comparable DBBs locations.

Methodology and Results

Crash data and reports were collected, reviewed, and aggregated from the Southeast Michigan Council of Governments (SEMCOG) web-site and confirmed through the Michigan Highway Safety Bureau web-site. The analysis of crash statistics were conducted in conformance to recommended procedures from the Institute of Transportation Engineers (ITE) and the Highway Safety Manual (HSM). Severity, frequency and rate analysis were conducted on crashes that occurred within an approximate area of 500 feet on both sides of the double sided DBBs. This distance is the assumed view shed of the DBBs.

Crash rates, in accordance with ITE and HSM, were calculated based upon the following:

$$R = \frac{1{,}000{,}000 \times C}{365 \times N \times V}$$

Where: C = Number of crashes
N = number of years of data
V = Average Daily Traffic (vehicles per day)

A summary of the crash analyses is shown in Table 1. *Appendix B provides more detail on each crash summarized in Table 1.

Table 1 – Summary of Crash Analyses

Name	Location	No. Years	Avg. AADT[4]	PDO[3] Crashes	Injury Crashes/Type	Freq.	Rate[1]
Comp #1 **(Before)**	North of 13 Mile Rd	2.5	147,500	5	2-Possible Injuries	7	0.05
Comp #1 **(After)**	North of 13 Mile Rd	2.5	154,630	16	1 – Minor Injury	17	0.12
Comp #2 **(Before)**	South of 14 Mile Rd	2.5	147,500	31	10–Possible Injs 1 – Minor Injury	42	0.31
Comp#2 **(After)**	South of 14 Mile Rd	2.5	154,630	24	9–Possible Injuries 2 – Minor Injuries	35	0.25
Comp #2 Ramp **(Before)**	14 Mile Road Southbound Entrance Ramp	2.5	22,000[2]	5	None	5	0.25
Comp #2 Ramp **(After)**	14 Mile Road Southbound Entrance Ramp	2.5	22,000[2]	10	2–Possible Injuries	12	0.60
Comp #3 **(Before)**	South of Auburn Rd	3	116,150	14	2–Possible Injuries 1 – Minor Injury	17	0.13
Comp #3 **(After)**	South of Auburn Rd	3	131,150	24	2 – Minor Injuries	26	0.18
Comp #4 **(Before)**	South of 12 Mile Rd	2	161,550	37	6-Possible Injuries	43	0.36
Comp #4 **(After)**	South of 12 Mile Rd	2	161,400	22	5–Possible Injuries 1 – Minor Injury	28	0.24
Proposed Austin	North of Maple Road	3	128,400	1	None	1	N/A
Proposed Naughton	East of Rochester Road	3	128,400	9	None	9	0.06

Notes:

1. Crashes per million vehicles miles
2. 2013 Ramp Volumes
3. Property Damage Only
4. Average Annual Daily Traffic (vehicles per day)

Conclusions

An accident rate between 2 to 3 accidents per million vehicle mile (MVM) is considered worthy of safety countermeasures. The rates, frequency and severity of all comparables (whether "before" or "after") are modest along all spots/segments of the study area along I-75. As a result, there is no evidence that existing DBBs have any significant adverse safety consequences based upon this historical analysis. Consequently, no rational evidence exists to suggest adverse safety impacts for the proposed DBB locations.

* Appendix C provides a data summary of a similar evaluation along I 75 where segments of the freeway in advance, within, and after the view shed of existing DBB were performed. In like manner, this analysis (which was conducted by an independent certified traffic engineer) suggests that DBBs along I-75 are safety neutral.

*This data is in an excel format and included on the provided CD.

APPENDIX

*Data described in appendix A, B & C are in excel format and are included on the provided CD.

Additional national and local studies are also included on the provided CD. A list of the traffic Studies and Reports is provided on the following page.

1705 Austin - Proposed Billboard Location

Crashes 2012 - 2014

CRSH_ID	ROADNAME	MILE	PR	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
8304893	N I 75	7.647	647308	Mar	6	2012	Tue	8am	PDO	Rear-end	Clear	Daylight	Dry

Comp #1 DBB - North of 13 Mile Road

Crashes 2010 -2014

CRSH_ID	ROAD NAME	MILE	PR	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
7537588	S I 75	5.523	646106	Jan	29	2010	Fri	12pm	PDO	Swipe-sam	Clear	Daylight	Dry
7625059	S I 75	5.623	646106	May	27	2010	Thu	12pm	C-level	Rear-end	Clear	Daylight	Dry
7683710	S I 75	5.518	646106	Aug	16	2010	Mon	11am	PDO	Rear-end	Clear	Daylight	Dry
8408676	S I 75	5.623	646106	Aug	14	2012	Tue	12am	B-level	Rear-end	Cloudy	Daylight	Dry
8444307	S I 75	5.523	646106	Oct	3	2012	Wed	8am	PDO	Rear-end	Cloudy	Daylight	Wet
8651126	S I 75	5.568	646106	Jun	11	2013	Tue	2am	PDO	Swipe-sam	Cloudy	Dark	Wet
8656217	S I 75	5.556	646106	Jun	14	2013	Fri	6pm	PDO	Rear-end	Clear	Daylight	Dry
8900357	S I 75	5.673	646106	Mar	1	2014	Sat	8pm	PDO	Rear-end	Snow	Lights	Snowy
8980751	S I 75	5.623	646106	Jun	22	2014	Sun	2am	PDO	Rear-end	Clear	Lights	Dry
7521912	N I 75	5.674	647308	Jan	11	2010	Mon	4am	C-level	Single veh.	Cloudy	Lights	Snowy
7545408	N I 75	5.453	647308	Jan	18	2010	Mon	1pm	PDO	Rear-end	Cloudy	Daylight	Dry
8287617	N I 75	5.674	647308	Feb	5	2012	Sun	1pm	PDO	Swipe-sam	Cloudy	Daylight	Dry
8381289	N I 75	5.724	647308	Jul	5	2012	Thu	7am	PDO	Single veh.	Clear	Daylight	Dry
8407436	N I 75	5.674	647308	Aug	1	2012	Wed	9am	PDO	Single veh.	Clear	Daylight	Dry
8508565	N I 75	5.674	647308	Dec	5	2012	Wed	1pm	PDO	Swipe-sam	Clear	Daylight	Dry
8636116	N I 75	5.674	647308	May	20	2013	Mon	6am	PDO	Single veh.	Cloudy	Dawn	Dry
8782869	N I 75	5.613	647308	Nov	20	2013	Wed	11am	PDO	Rear-end	Clear	Daylight	Dry
8784326	N I 75	5.55	647308	Nov	19	2013	Tue	8am	PDO	Swipe-sam	Cloudy	Daylight	Dry
8822080	N I 75	5.674	647308	Dec	14	2013	Sat	12pm	PDO	Swipe-opp.	Snow	Daylight	Snowy
8910797	N I 75	5.674	647308	Mar	13	2014	Thu	9am	PDO	Rear-end	Other	Daylight	Other
8969446	N I 75	5.674	647308	Jun	6	2014	Fri	3am	PDO	Rear-end	Clear	Dark	Dry
8979863	N I 75	5.674	647308	Jun	20	2014	Fri	7pm	PDO	Rear-end	Rain	Daylight	Wet
9081264	N I 75	5.674	647308	Oct	23	2014	Thu	1pm	PDO	Rear-end	Clear	Daylight	Dry
9106980	N I 75	5.65	647308	Nov	19	2014	Wed	4pm	PDO	Single veh.	Snow	Daylight	Icy

Comp #2 - South of 14 Mile (mainlines)

Crashes 2010 - 2014

CRSH_ID	ROAD NAME	MILE	PR	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
7518864	S I 75	6.149	646106	Jan	7	2010	Thu	4pm	PDO	Swipe-sam	Snow	Daylight	Snowy
7549827	S I 75	6.299	646106	Feb	9	2010	Tue	8pm	C-level	Single veh.	Snow	Lights	Snowy
7698326	S I 75	6.199	646106	Sep	6	2010	Mon	9pm	B-level	Rear-end	Cloudy	Lights	Uncoded
7764242	S I 75	6.307	646106	Sep	22	2010	Wed	8am	PDO	Rear-end	Cloudy	Daylight	Wet
7770121	S I 75	6.2	646106	Oct	8	2010	Fri	11am	C-level	Swipe-sam	Clear	Daylight	Dry
7774338	S I 75	6.116	646106	Sep	24	2010	Fri	6pm	PDO	Swipe-sam	Cloudy	Daylight	Dry
7818788	S I 75	6.199	646106	Dec	1	2010	Wed	7am	PDO	Swipe-sam	Snow	Dawn	Dry
7863450	S I 75	6.304	646106	Jan	6	2011	Thu	8am	C-level	Rear-end	Cloudy	Daylight	Wet
7990588	S I 75	6.299	646106	Mar	14	2011	Mon	9am	C-level	Single veh.	Clear	Daylight	Dry
7994408	S I 75	6.199	646106	Mar	20	2011	Sun	6pm	C-level	Rear-end	Rain	Daylight	Wet
8023265	S I 75	6.299	646106	May	6	2011	Fri	6pm	C-level	Rear-end	Cloudy	Daylight	Dry
8032721	S I 75	6.304	646106	May	15	2011	Sun	3pm	PDO	Other	Rain	Daylight	Wet
8056856	S I 75	6.299	646106	Jun	23	2011	Thu	6pm	C-level	Rear-end	Rain	Daylight	Wet
8060128	S I 75	6.299	646106	Jul	1	2011	Fri	9pm	PDO	Rear-end	Clear	Lights	Dry
8069750	S I 75	6.149	646106	May	31	2011	Tue	7am	PDO	Rear-end	Clear	Daylight	Dry
8108376	S I 75	6.199	646106	Sep	11	2011	Sun	12am	PDO	Rear-end	Clear	Lights	Dry
8110707	S I 75	6.299	646106	Sep	8	2011	Thu	4pm	PDO	Rear-end	Rain	Daylight	Wet
8114910	S I 75	6.299	646106	Sep	20	2011	Tue	7am	PDO	Swipe-sam	Clear	Daylight	Dry
8161620	S I 75	6.149	646106	Oct	13	2011	Thu	2pm	PDO	Rear-end	Cloudy	Daylight	Dry
8194356	S I 75	6.304	646106	Mar	9	2011	Wed	6pm	C-level	Rear-end	Rain	Lights	Wet
8195716	S I 75	6.149	646106	Nov	9	2011	Wed	6pm	PDO	Rear-end	Cloudy	Lights	Dry
8205716	S I 75	6.26	646106	Nov	29	2011	Tue	9am	PDO	Rear-end	Rain	Daylight	Wet
8212607	S I 75	6.299	646106	Nov	29	2011	Tue	4pm	PDO	Rear-end	Rain	Daylight	Wet
8219953	S I 75	6.299	646106	Dec	15	2011	Thu	11am	PDO	Rear-end	Rain	Daylight	Wet
8243290	S I 75	6.149	646106	Jan	3	2012	Tue	5pm	PDO	Rear-end	Cloudy	Lights	Dry
8246878	S I 75	6.304	646106	Dec	9	2011	Fri	12pm	PDO	Swipe-sam	Clear	Daylight	Wet
8279572	S I 75	6.149	646106	Feb	11	2012	Sat	6am	PDO	Single veh.	Snow	Dark	Snowy
8357642	S I 75	6.304	646106	May	18	2012	Fri	5pm	PDO	Rear-end	Clear	Daylight	Dry
8385589	S I 75	6.199	646106	Jul	14	2012	Sat	6pm	PDO	Single veh.	Clear	Daylight	Dry
8404272	S I 75	6.199	646106	Aug	13	2012	Mon	4pm	PDO	Rear-end	Cloudy	Daylight	Dry
8435051	S I 75	6.149	646106	Sep	17	2012	Mon	8am	PDO	Rear-end	Cloudy	Dawn	Dry

Comp #2 - South of 14 Mile (mainlines)

Crashes 2010 - 2014

CRSH_ID	ROAD NAME	MILE	PR	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
8439803	S I 75	6.149	646106	Sep	26	2012	Wed	3pm	C-level	Rear-end	Clear	Daylight	Dry
8442480	S I 75	6.199	646106	Oct	6	2012	Sat	1pm	PDO	Other	Cloudy	Daylight	Dry
8469270	S I 75	6.299	646106	Oct	29	2012	Mon	7am	PDO	Rear-end	Rain	Lights	Wet
8545700	S I 75	6.199	646106	Jan	23	2013	Wed	7am	C-level	Rear-end	Cloudy	Dawn	Dry
8588144	S I 75	6.21	646106	Mar	10	2013	Sun	10pm	C-level	Other	Cloudy	Dark	Dry
8607858	S I 75	6.21	646106	Apr	10	2013	Wed	7am	C-level	Rear-end	Rain	Daylight	Wet
8607870	S I 75	6.308	646106	Apr	5	2013	Fri	10pm	PDO	Swipe-sam	Clear	Other	Dry
8623259	S I 75	6.149	646106	Apr	26	2013	Fri	4pm	PDO	Rear-end	Clear	Daylight	Dry
8675815	S I 75	6.149	646106	Jul	10	2013	Wed	6pm	PDO	Rear-end	Clear	Daylight	Dry
8684772	S I 75	6.299	646106	Jul	27	2013	Sat	6pm	PDO	Swipe-sam	Rain	Daylight	Wet
8691930	S I 75	6.149	646106	Aug	6	2013	Tue	9pm	B-level	Single veh.	Clear	Lights	Dry
8715212	S I 75	6.149	646106	Sep	3	2013	Tue	8am	B-level	Single veh.	Clear	Daylight	Dry
8763424	S I 75	6.149	646106	Oct	31	2013	Thu	2pm	PDO	Swipe-sam	Rain	Daylight	Wet
8781749	S I 75	6.274	646106	Nov	20	2013	Wed	7am	PDO	Rear-end	Clear	Dawn	Dry
8829293	S I 75	6.299	646106	Dec	21	2013	Sat	8pm	PDO	Rear-end	Rain	Dark	Wet
8924709	S I 75	6.149	646106	Jan	1	2014	Wed	8am	C-level	Single veh.	Other	Daylight	Other
8975745	S I 75	6.249	646106	Jun	13	2014	Fri	5pm	PDO	Rear-end	Cloudy	Daylight	Dry
9069536	S I 75	6.149	646106	Oct	20	2014	Mon	8am	PDO	Rear-end	Cloudy	Daylight	Wet
9076903	S I 75	6.149	646106	Oct	28	2014	Tue	5pm	C-level	Rear-end	Clear	Daylight	Dry
9128030	S I 75	6.149	646106	Dec	11	2014	Thu	6am	C-level	Rear-end	Clear	Dark	Dry
7766483	N I 75	6.3	647308	Sep	18	2010	Sat	5pm	C-level	Angle	Cloudy	Daylight	Dry
7799261	N I 75	6.3	647308	Oct	30	2010	Sat	7pm	C-level	Rear-end	Cloudy	Lights	Dry
7814366	N I 75	6.3	647308	Oct	30	2010	Sat	7pm	PDO	Single veh.	Cloudy	Lights	Dry
7863875	N I 75	6.3	647308	Dec	12	2010	Sun	7pm	PDO	Single veh.	Clear	Dark	Icy
7964123	N I 75	6.209	647308	Mar	4	2011	Fri	12pm	PDO	Rear-end	Cloudy	Daylight	Wet
8003892	N I 75	6.2	647308	Mar	4	2011	Fri	12pm	PDO	Swipe-sam	Uncoded	Daylight	Wet
8023266	N I 75	6.3	647308	May	6	2011	Fri	6pm	PDO	Other	Cloudy	Daylight	Dry
8054093	N I 75	6.3	647308	Jun	17	2011	Fri	7am	PDO	Rear-end	Clear	Daylight	Dry
8056859	N I 75	6.3	647308	Jun	25	2011	Sat	1am	PDO	Rear-end	Clear	Lights	Dry
8056875	N I 75	6.2	647308	Jun	25	2011	Sat	1am	PDO	Rear-end	Clear	Lights	Dry
8195620	N I 75	6.2	647308	Nov	9	2011	Wed	7am	PDO	Rear-end	Rain	Daylight	Wet

Comp #2 - South of 14 Mile (mainlines)

Crashes 2010 - 2014

CRSH_ID	ROAD NAME	MILE	PR	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
8240775	N I 75	6.37	647308	Dec	17	2011	Sat	6am	PDO	Swipe-sam	Clear	Dark	Dry
8264853	N I 75	6.163	647308	Jan	19	2012	Thu	8am	PDO	Single veh.	Snow	Daylight	Snowy
8351717	N I 75	6.2	647308	May	19	2012	Sat	1pm	PDO	Rear-end	Clear	Daylight	Dry
8488668	N I 75	6.305	647308	Nov	25	2012	Sun	6am	PDO	Single veh.	Snow	Dawn	Icy
8618343	N I 75	6.3	647308	Apr	22	2013	Mon	9am	C-level	Rear-end	Clear	Daylight	Dry
8619806	N I 75	6.2	647308	Apr	28	2013	Sun	2am	PDO	Single veh.	Clear	Lights	Dry
8647604	N I 75	6.2	647308	Apr	18	2013	Thu	7am	C-level	Single veh.	Cloudy	Daylight	Wet
8694701	N I 75	6.3	647308	Aug	10	2013	Sat	5pm	PDO	Rear-end	Clear	Daylight	Dry
8765940	N I 75	6.3	647308	Nov	5	2013	Tue	9pm	PDO	Rear-end	Clear	Dark	Dry
8773820	N I 75	6.305	647308	Oct	25	2013	Fri	2pm	PDO	Swipe-sam	Cloudy	Daylight	Dry
8893252	N I 75	6.154	647308	Feb	23	2014	Sun	5pm	PDO	Rear-end	Clear	Daylight	Dry
8984182	N I 75	6.3	647308	Jun	24	2014	Tue	12pm	PDO	Rear-end	Cloudy	Daylight	Wet
9040135	N I 75	6.3	647308	Sep	10	2014	Wed	11am	PDO	Rear-end	Cloudy	Daylight	Dry
9063102	N I 75	6.2	647308	Oct	9	2014	Thu	4pm	PDO	Rear-end	Clear	Daylight	Dry
9112482	N I 75	6.3	647308	Nov	19	2014	Wed	3pm	PDO	Rear-end	Snow	Daylight	Icy

Comp #3 - South of Auburn Road
Crashes After DBB Installation (2012-2014)

CRSH_ID	ROAD NAME	MILE	PR	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
8252515	S I 75	18.038	646106	Jan	5	2012	Thu	8am	PDO	Rear-end	Cloudy	Daylight	Dry
8372767	S I 75	18.019	646106	Jun	14	2012	Thu	5am	PDO	Swipe-same	Clear	Dawn	Dry
8446456	S I 75	18	646106	Sep	25	2012	Tue	9am	PDO	Swipe-same	Clear	Daylight	Dry
8531375	S I 75	18.076	646106	Dec	26	2012	Wed	2pm	PDO	Swipe-same	Snow	Daylight	Snowy
8531379	S I 75	18.076	646106	Dec	26	2012	Wed	3pm	PDO	Swipe-same	Snow	Daylight	Snowy
8584977	S I 75	17.981	646106	Feb	22	2013	Fri	11am	PDO	Single veh.	Snow	Daylight	Snowy
8615979	S I 75	18.038	646106	Apr	5	2013	Fri	9am	PDO	Rear-end	Clear	Daylight	Dry
8821024	S I 75	18.038	646106	Oct	25	2013	Fri	1pm	PDO	Swipe-same	Cloudy	Daylight	Dry
8843799	S I 75	18.038	646106	Jan	2	2014	Thu	11am	PDO	Single veh.	Snow	Daylight	Icy
8864053	S I 75	18.033	646106	Jan	16	2014	Thu	11am	PDO	Single veh.	Snow	Daylight	Snowy
9037159	S I 75	17.906	646106	Aug	26	2014	Tue	6am	PDO	Rear-end	Clear	Daylight	Dry
9054182	S I 75	18.076	646106	Sep	9	2014	Tue	8am	C-level	Rear-end	Cloudy	Daylight	Dry
9056219	S I 75	17.883	646106	Sep	18	2014	Thu	10am	C-level	Rear-end	Clear	Daylight	Dry
8287617	N I 75	5.674	647308	Feb	5	2012	Sun	1pm	PDO	Swipe-same	Cloudy	Daylight	Dry
8381289	N I 75	5.724	647308	Jul	5	2012	Thu	7am	PDO	Single veh.	Clear	Daylight	Dry
8407436	N I 75	5.674	647308	Aug	1	2012	Wed	9am	PDO	Single veh.	Clear	Daylight	Dry
8508565	N I 75	5.674	647308	Dec	5	2012	Wed	1pm	PDO	Swipe-same	Clear	Daylight	Dry
8636116	N I 75	5.674	647308	May	20	2013	Mon	6am	PDO	Single veh.	Cloudy	Dawn	Dry
8782869	N I 75	5.613	647308	Nov	20	2013	Wed	11am	PDO	Rear-end	Clear	Daylight	Dry
8784326	N I 75	5.55	647308	Nov	19	2013	Tue	8am	PDO	Swipe-same	Cloudy	Daylight	Dry
8822080	N I 75	5.674	647308	Dec	14	2013	Sat	12pm	PDO	Swipe-opp.	Snow	Daylight	Snowy
8910797	N I 75	5.674	647308	Mar	13	2014	Thu	9am	PDO	Rear-end	Other	Daylight	Other
8969446	N I 75	5.674	647308	Jun	6	2014	Fri	3am	PDO	Rear-end	Clear	Dark	Dry
8979863	N I 75	5.674	647308	Jun	20	2014	Fri	7pm	PDO	Rear-end	Rain	Daylight	Wet
9081264	N I 75	5.674	647308	Oct	23	2014	Thu	1pm	PDO	Rear-end	Clear	Daylight	Dry
9106980	N I 75	5.65	647308	Nov	19	2014	Wed	4pm	PDO	Single veh.	Snow	Daylight	Icy

Comp #3 - South of Auburn Hills
Crashes Before DBB Installation (2008 - 2010)

CRSH_ID	ROAD NAME	MILE	PR	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
6935314	S I 75	17.883	646106	Feb	15	2008	Fri	10am	PDO	Angle	Clear	Daylight	Dry
7496715	S I 75	17.944	646106	Dec	19	2009	Sat	6am	PDO	Angle	Snow	Dark	Snowy
7547114	S I 75	18.086	646106	Feb	11	2010	Thu	7am	PDO	Single veh.	Cloudy	Daylight	Snowy
7559234	S I 75	18.033	646106	Feb	22	2010	Mon	3pm	PDO	Swipe-same	Snow	Daylight	Wet
7566133	S I 75	17.883	646106	Mar	1	2010	Mon	5am	C-level	Single veh.	Clear	Dark	Dry
7597039	S I 75	17.933	646106	Apr	14	2010	Wed	9am	PDO	Other	Clear	Daylight	Dry
7634570	S I 75	18.076	646106	Jun	9	2010	Wed	7am	PDO	Single veh.	Rain	Daylight	Wet
7670446	S I 75	18.095	646106	Jul	26	2010	Mon	7am	PDO	Rear-end	Clear	Daylight	Dry
7670449	S I 75	18.038	646106	Jul	26	2010	Mon	7am	PDO	Rear-end	Clear	Daylight	Dry
7794954	S I 75	17.981	646106	Oct	27	2010	Wed	7pm	C-level	Single veh.	Clear	Dark	Dry
7804162	S I 75	17.833	646106	Nov	2	2010	Tue	8am	B-level	Rear-end	Cloudy	Dawn	Dry
6922891	N I 75	18.021	647308	Feb	6	2008	Wed	11am	PDO	Single veh.	Snow	Daylight	Icy
6972226	N I 75	17.964	647308	Mar	31	2008	Mon	6am	PDO	Single veh.	Rain	Dark	Wet
7247301	N I 75	17.92	647308	Jan	30	2009	Fri	6pm	PDO	Rear-end	Cloudy	Dark	Slushy
7588778	N I 75	17.909	647308	Mar	28	2010	Sun	1pm	PDO	Rear-end	Rain	Daylight	Wet
7679782	N I 75	17.917	647308	Aug	9	2010	Mon	8am	PDO	Single veh.	Cloudy	Daylight	Dry
7839689	N I 75	18.021	647308	Dec	12	2010	Sun	9am	PDO	Single veh.	Snow	Daylight	Slushy

Comp #4 - South of 12 Mile Road

Crashes 2010 - 2014

CRSH_ID	ROAD NAME	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
8994990	N I75	July	7	2014	Wed	5:00 PM	PDO	Single veh.	Clear	Daylight	Dry
8849498	N 175	Jan	22	2014	Fri	7:30 AM	PDO	Rear-end	Clear	Daylight	Dry
8599979	N 175	May	27	2014	Tue	11:45 PM	PDO	Rear-end	Cloudy	Lights	Dry
9028634	N 175	Aug	26	2014	Tue	7:41 PM	C-Level	Single veh.	Clear	Daylight	Wet
8835286	N 175	Jan	7	2014	Tue	7:15 AM	PDO	Single veh.	Cloudy	Daylight	Icy
8826148	N 175	Jan	2	2014	Thur	6:30 AM	PDO	Single veh.	Snow	Dawn	Snowy
8844598	S I 75	Jan	14	2014	Tue	8:00 AM	PDO	Rear End	Clear	Daylight	Dry
8555825	N I 75	Jan	28	2013	Mon	12:35 PM	C-Level	Rear End	Fog	Daylight	Wet
8740703	N I 75	Oct	6	2013	Sun	10:30 AM	PDO	Single veh.	Cloudy	Daylight	Wet
8668920	N I 75	July	6	2013	Sat	10:00 PM	PDO	Single veh.	Rain	Dark	Wet
8660331	N I 75	Feb	2	2013	Sat	6:30 AM	C-Level	Side Swipe	Snow	Dark	Snowy
8697797	N I 75	Aug	12	2013	Mon	11:00 AM	B-Level	Single veh.	Rain	Daylight	Wet
8580178	N I 75	Feb	27	2013	Wed	10:00 AM	PDO	Side Swipe	Snow	Daylight	Wet
8686859	N I 75	July	30	2013	Tue	7:40 AM	PDO	Rear-end	Clear	Daylight	Dry
8799974	N I 75	Nov	22	2013	Fri	6:30 AM	PDO	Rear-end	Cloudy	Dark	Wet
8643914	N I 75	May	27	2013	Mon	11:00 PM	PDO	Single veh.	Rain	Dark	Wet
8696928	S I 75	Aug	12	2013	Mon	9:00 AM	PDO	Single veh.	Rain	Daylight	Wet
8747559	S I 75	Oct	17	2013	Thur	7:00 PM	PDO	Rear-end	Clear	Daylight	Wet
8613287	S I 75	Apr	17	2013	Wed	4:00 PM	PDO	Rear-end	Cloudy	Daylight	Dry
8744429	S I 75	Oct	15	2013	Tue	9:00 PM	C-Level	Single veh.	Clear	Dark	Dry
8532534	S I 75	Jan	11	2013	Fri	6:00 PM	PDO	Rear-end	Clear	Dark	Wet
8656215	S I 75	Jun	10	2013	Mon	9:00 PM	C-Level	Single veh.	Rain	Dusk	Wet
8552893	S I 75	Feb	1	2013	Fri	6:00 PM	PDO	Rear-end	Cloudy	Dark	Dry
8584200	S I 75	Mar	2	2013	Sat	5:30 PM	PDO	Rear-end	Cloudy	Dusk	Dry
8735203	S I 75	Oct	5	2013	Sat	9:15 AM	PDO	Side Swipe	Cloudy	Daylight	Wet
8666756	S I 75	July	1	2013	Mon	5:30 PM	PDO	Rear-end	Rain	Daylight	Wet
8726027	S I 75	Sept	25	2013	Wed	7:00 AM	PDO	Rear-end	Cloudy	Dawn	Dry
8712347	N I 75	Sept	2	2013	Mon	5:00 PM	PDO	Single veh.	Clear	Dark	Wet
8236419	N I 75	Dec	30	2011	Fri	4:30 PM	PDO	Single veh.	Rain	Dark	Wet
7866638	N I 75	Jan	15	2011	Sat	10:30 AM	PDO	Single veh.	Snow	Daylight	Icy
8240787	N I 75	Dec	4	2011	Sun	9:45 AM	PDO	Single veh.	Snow	Daylight	Icy

Comp #4 - South of 12 Mile Road

Crashes 2010 - 2014

CRSH_ID	ROAD NAME	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
7960286	N I 75	Mar	5	2011	Sat	Mid Nit	PDO	Single veh.	Rain	Dark	Slushy
8209700	N I 75	Nov	28	2011	Mon	2:00 PM	PDO	Rear-end	Rain	Daylight	Wet
8209690	N I 75	Nov	27	2011	Sun	3:30 PM	PDO	Single veh.	Rain	Daylight	Wet
8030141	N I 75	May	15	2011	Sun	1:30 PM	PDO	Single veh.	Rain	Daylight	Wet
8220054	N I 75	Dec	14	2011	Wed	10:15 PM	PDO	Single veh.	Rain	Dark	Wet
8056874	N I 75	Jun	24	2011	Fri	11:00 PM	PDO	Rear-end	Clear	Dark	Dry
8068955	N I 75	July	1	2011	Fri	7:45 AM	C-Level	Single veh.	Clear	Daylight	Dry
8071288	S I 75	May	7	2011	Sat	5:00 AM	C-Level	Single veh.	Cloudy	Dark	Dry
8212884	S I 75	Dec	10	2011	Sat	6:00 PM	PDO	Rear-end	Clear	Dark	Dry
8212733	S I 75	Dec	6	2011	Tue	1:45 PM	PDO	Side Swipe	Clear	Daylight	Dry
7925082	S I 75	Jan	21	2011	Fri	Noon	PDO	Rear-end	Clear	Daylight	Wet
8205740	S I 75	Feb	24	2011	Thur	6:45 AM	PDO	Side Swipe	Clear	Dark	Wet
8030197	S I 75	May	19	2011	Thur	9:00 AM	PDO	Rear-end	Cloudy	Daylight	Dry
8047580	S I 75	Jun	11	2011	Sat	6:00 PM	C-Level	Rear-end	Cloudy	Daylight	Dry
8180118	S I 75	Oct	13	2011	Thur	7:00 PM	C-Level	Rear-end	Cloudy	Dusk	Dry
8018930	S I 75	Apr	13	2011	Mon	8:30 AM	PDO	Rear-end	Clear	Daylight	Dry
8121747	S I 75	Sept	26	2011	Mon	7:30 AM	PDO	Rear-end	Rain	Daylight	Wet
8073529	S I 75	July	20	2011	Wed	6:00 PM	C-Level	Rear-end	Clear	Daylight	Dry
7695508	N I 75	Aug	29	2010	Sun	7:00 PM	C-Level	Single veh.	Rain	Daylight	Wet
7563886	N I 75	Feb	27	2010	Sat	11:45 PM	PDO	Single veh.	Cloudy	Dark	Icy
7534330	N I 75	Jan	8	2010	Fri	6:45 PM	PDO	Rear-end	Cloudy	Dark	Wet
7814222	N I 75	Nov	22	2010	Mon	11:30 PM	PDO	Single veh.	Rain	Dark	Wet
7537559	N I 75	Jan	26	2010	Mon	11:00 PM	PDO	Single veh.	Snow	Dark	Icy
7704262	N I 75	Sept	11	2010	Sat	7:30 PM	PDO	Rear-end	Rain	Dark	Wet
7611541	N I 75	May	8	2010	Sat	8:00 AM	PDO	Single veh.	Cloudy	Daylight	Wet
7683259	S I 75	Aug	16	2010	Mon	6:15 AM	PDO	Rear-end	Clear	Daylight	Dry
7706781	S I 75	Sept	9	2010	Thur	4:30 PM	PDO	Angle	Cloudy	Daylight	Dry
7526089	S I 75	Jan	12	2010	Tue	4:30 PM	PDO	Rear-end	?	?	?
7526089	S I 75	Jan	12	2010	Tue	6:30 PM	PDO	Rear-end	Cloudy	Dark	Dry
7580559	S I 75	Mar	26	2010	Fri	12:30 PM	PDO	Rear-end	Clear	Daylight	Dry
7818773	S I 75	Nov	30	2010	Tue	6:05 AM	PDO	Single veh.	Rain	Dark	Wet

Comp #4 - South of 12 Mile Road

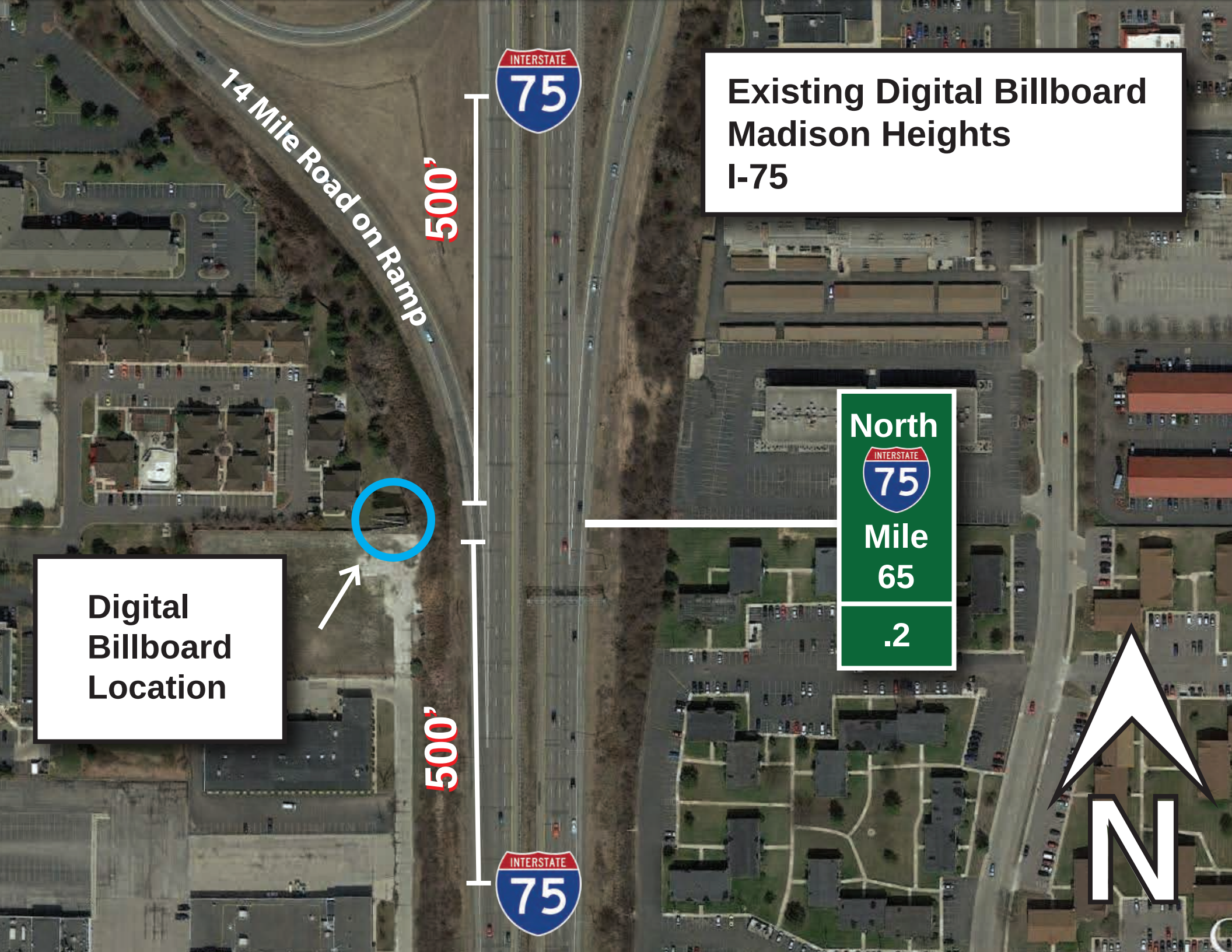
Crashes 2010 - 2014

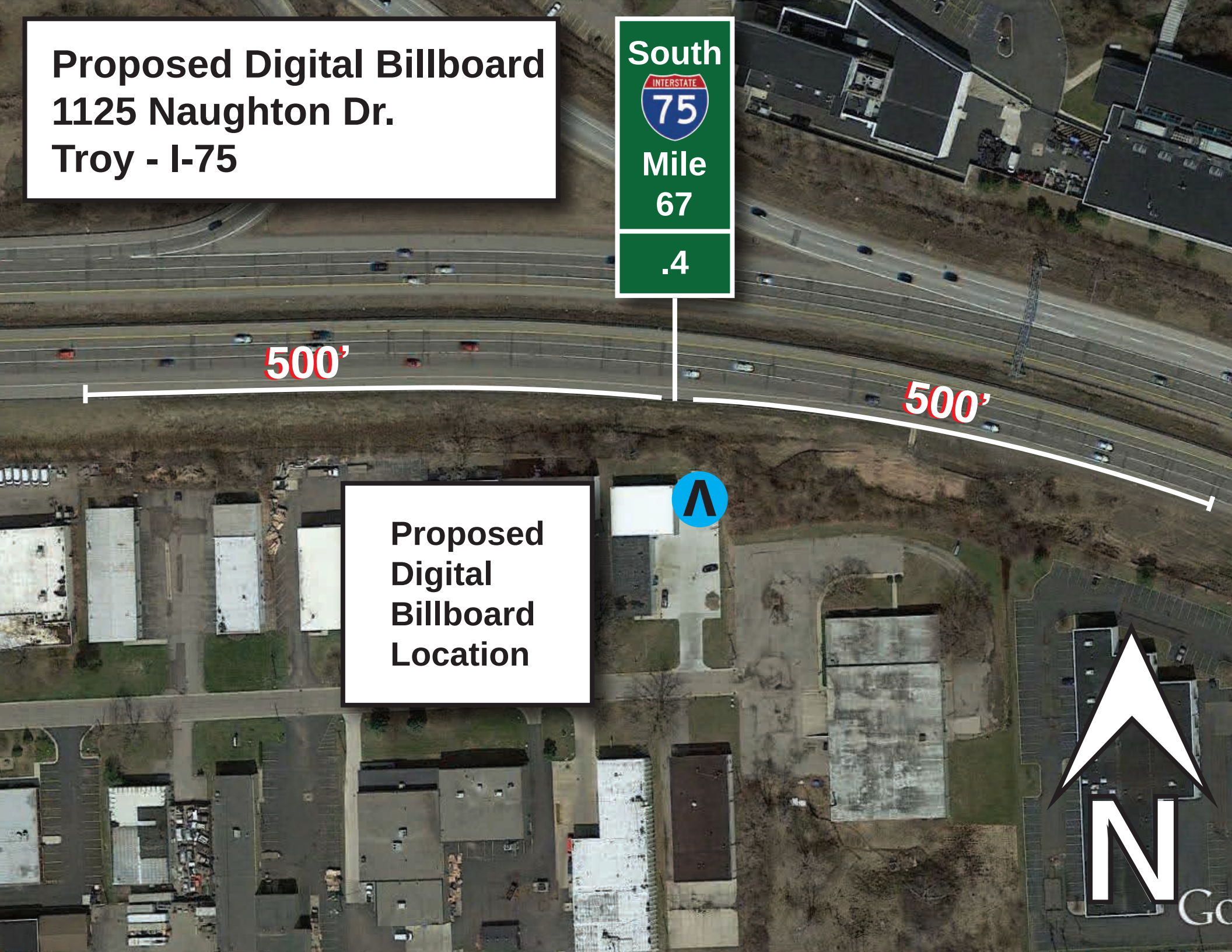
CRSH_ID	ROAD NAME	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
7533112	S I 75	Jan	13	2010	Wed	6:00 PM	PDO	Rear-end	Cloudy	Dusk	Dry
7613470	S I 75	May	13	2010	Thur	1:00 PM	PDO	Rear-end	Rain	Daylight	Wet
7824523	S I 75	Nov	22	2010	Mon	9:30 AM	PDO	Single veh.	Cloudy	Daylight	Wet
7607654	S I 75	May	1	2010	Sat	4:30 PM	PDO	Single veh.	Clear	Daylight	Dry
7647491	S I 75	Jun	30	2010	Wed	5:30 PM	PDO	Rear-end	Clear	Daylight	Dry
7770122	S I 75	Oct	4	2010	Mon	5:30 PM	PDO	Rear-end	Cloudy	Daylight	Dry
7607677	S I 75	May	7	2010	Fri	11:30 AM	PDO	Rear-end	Rain	Daylight	Wet
7857848	S I 75	Dec	26	2010	Sun	3:00 AM	PDO	Single veh.	Snow	Dark	Dry
7704278	S I 75	Sept	9	2010	Thur	4:30 PM	PDO	Rear-end	Cloudy	Daylight	Dry

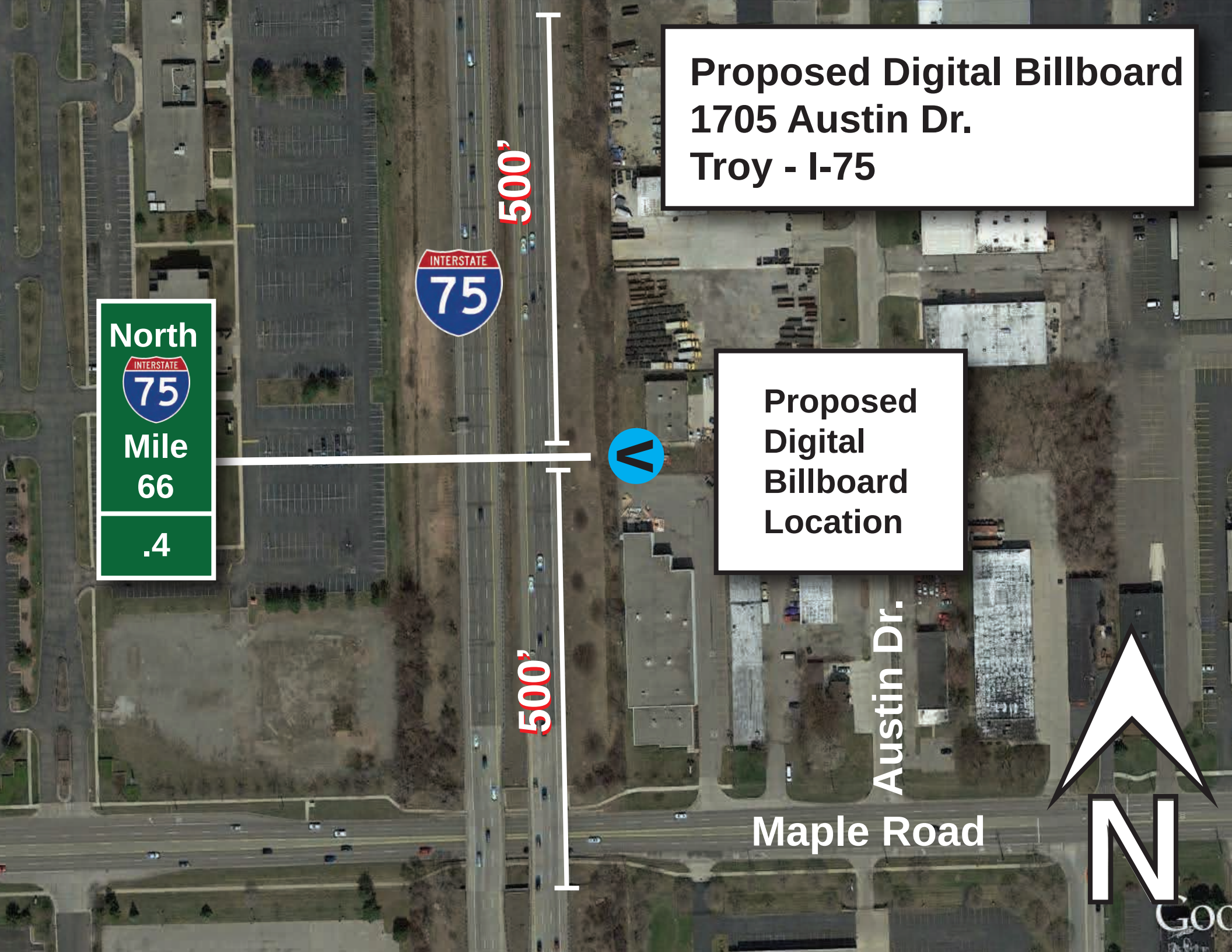
1125 Naughton - Proposed Billboard Location

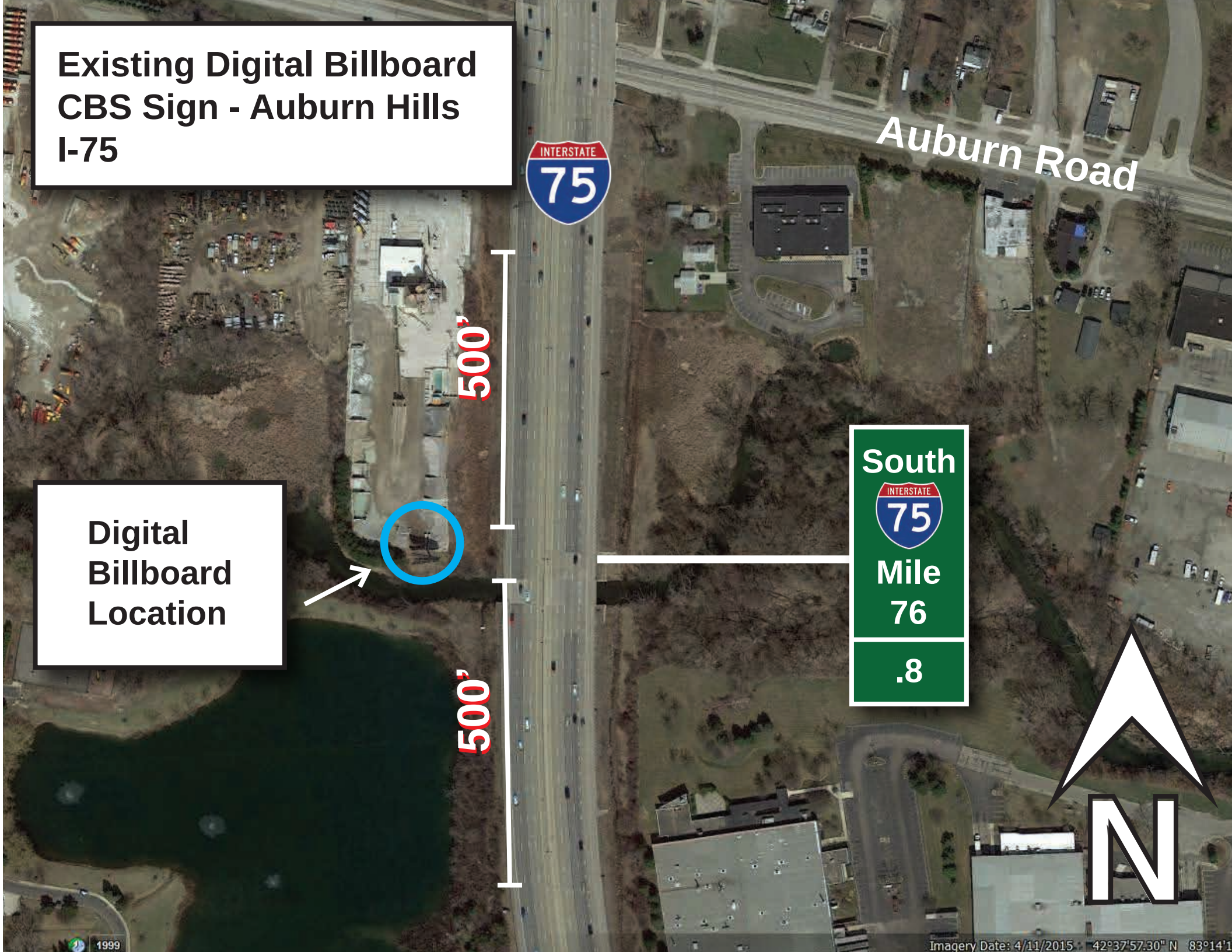
Crashes 2012-2014

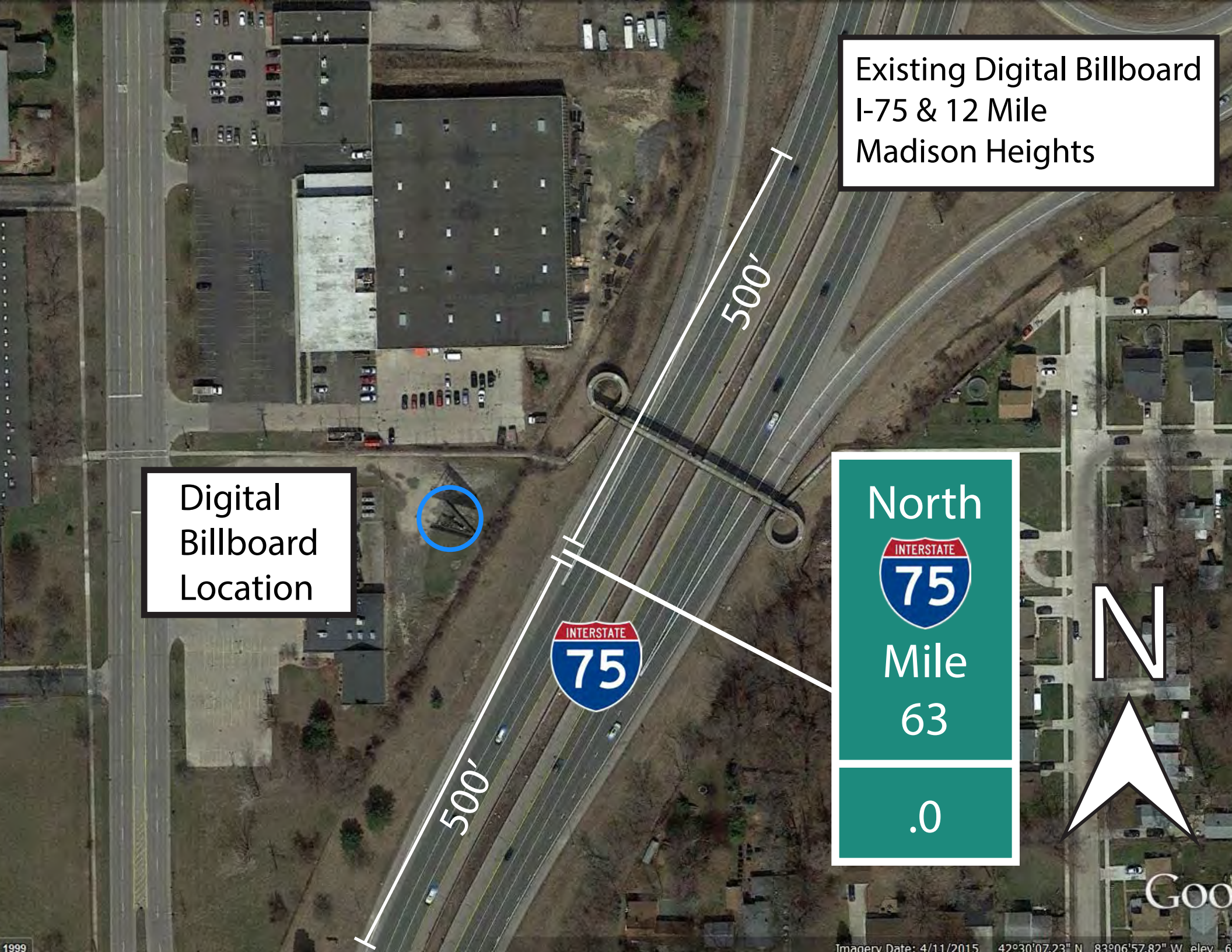
CRSH_ID	ROADNAME	MILE	PR	MONTH	DATE	YEAR	DAY	TIME	SEVERITY	TYPE	WEATHER	LIGHTING	ROAD CONDITION
8341400	S I 75	8.355	646106	Apr	30	2012	Mon	7pm	PDO	Single veh.	Rain	Daylight	Wet
8409097	S I 75	8.474	646106	Aug	4	2012	Sat	7pm	PDO	Swipe-same	Rain	Daylight	Wet
8511617	S I 75	8.503	646106	Dec	5	2012	Wed	6pm	PDO	Rear-end	Cloudy	Lights	Dry
8544399	S I 75	8.503	646106	Jan	8	2013	Tue	2pm	PDO	Rear-end	Cloudy	Daylight	Dry
8610562	S I 75	8.347	646106	Apr	12	2013	Fri	10am	PDO	Single veh.	Cloudy	Daylight	Wet
8724623	S I 75	8.409	646106	Sep	5	2013	Thu	6pm	PDO	Single veh.	Clear	Daylight	Dry
8797131	S I 75	8.56	646106	Dec	4	2013	Wed	3pm	PDO	Rear-end	Clear	Dusk	Dry
8989977	S I 75	8.541	646106	Jun	19	2014	Thu	4pm	PDO	Rear-end	Cloudy	Daylight	Dry
8626141	N I 75			Apr	20	2013	Sat	2pm	PDO	Single veh.	Clear	Daylight	Dry

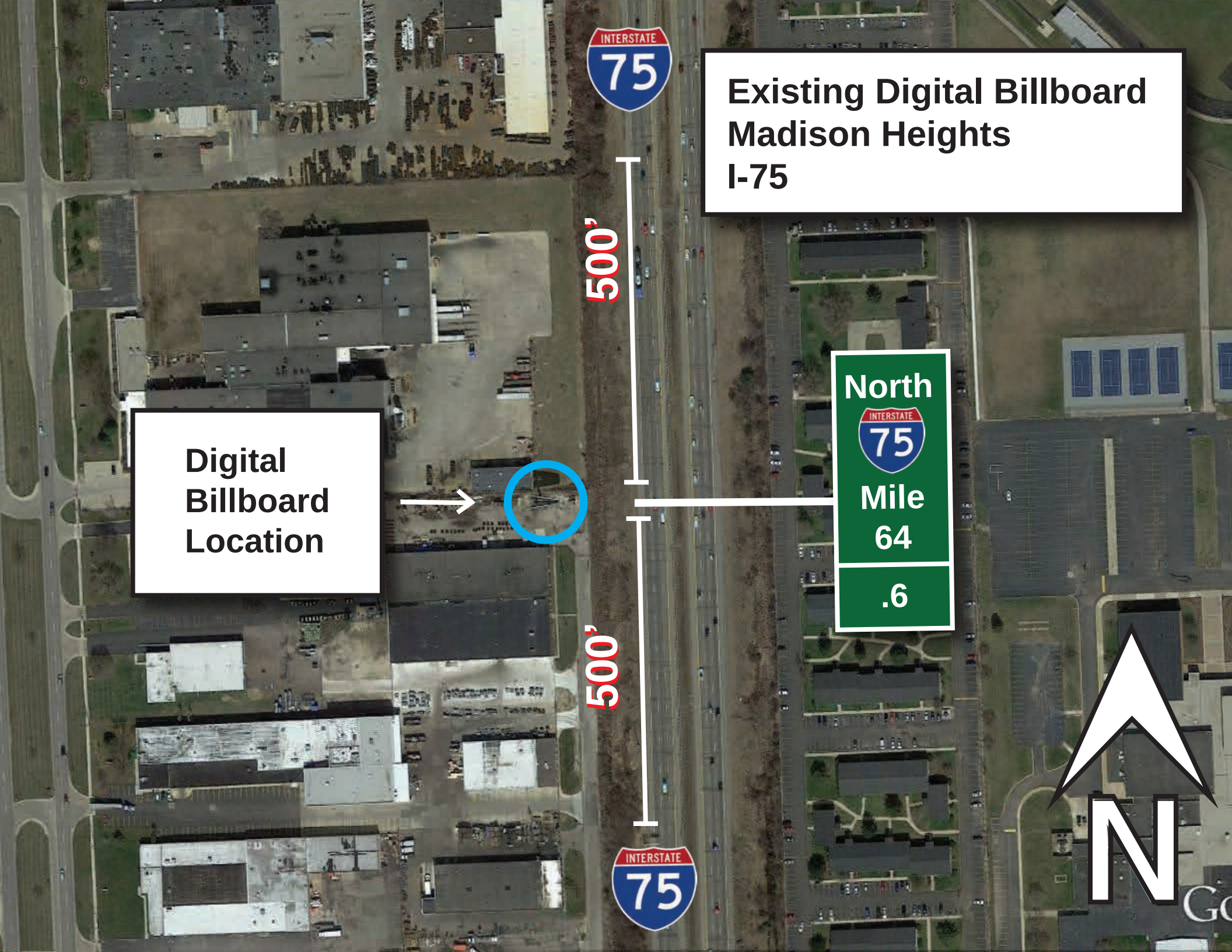

Existing Digital Billboard
Madison Heights
I-75
14 Mile Road on Ramp
500'
500'
INTERSTATE
75
INTERSTATE
75
North
INTERSTATE
75
Mile
65
.2
Digital
Billboard
Location
N


Proposed Digital Billboard
1125 Naughton Dr.
Troy - I-75
South
INTERSTATE
75
Mile
67
.4
500'
500'
Proposed
Digital
Billboard
Location
N


Proposed Digital Billboard
1705 Austin Dr.
Troy - I-75
500'
500'
INTERSTATE
75
North
INTERSTATE
75
Mile
66
.4
Proposed
Digital
Billboard
Location
Austin Dr.
Maple Road
N


Existing Digital Billboard
CBS Sign - Auburn Hills
I-75
INTERSTATE
75
Auburn Road
500'
500'
Digital
Billboard
Location
South
INTERSTATE
75
Mile
76
.8
N
1999
Imagery Date: 4/11/2015 42°37'57.30" N 83°14'1


Existing Digital Billboard
I-75 & 12 Mile
Madison Heights
Digital
Billboard
Location
500'
500'
INTERSTATE
75
North
INTERSTATE
75
Mile
63
.0
N
1999
Imagery Date: 4/11/2015 42°30'07.23" N 83°06'57.82" W elev 6


Existing Digital Billboard
Madison Heights
I-75
INTERSTATE
75
500'
500'
Digital
Billboard
Location
North
INTERSTATE
75
Mile
64
.6
INTERSTATE
75
N

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	NB I-75 from 12 Mile to 13 Mile	4.559	2011	Lose Control	3306	1250	Static	Light	80100	Wet	No
2	NB I-75 from 12 Mile to 13 Mile	4.569	2011	Rear dash end	3253	1250	Static	Daylight	80100	Wet	No
3	NB I-75 from 12 Mile to 13 Mile	4.569	2011	Rear dash end	3252.48	1250	Static	Down	80100	wet	No
4	NB I-75 from 12 Mile to 13 Mile	4.569	2011	Swipe dash same	3252.48	1250	Static	Daylight	80100	Wet	No
5	NB I-75 from 12 Mile to 13 Mile	4.619	2010	Rear dash end	2988.48	1250	Static	Daylight	80100	Dry	No
6	NB I-75 from 12 Mile to 13 Mile	4.619	2011	Single vehicle	2988.48	1250	Static	Daylight	80100	Dry	No
7	NB I-75 from 12 Mile to 13 Mile	4.619	2011	Rear dash end	2988.48	1250	Static	Daylight	80100	Wet	No
8	NB I-75 from 12 Mile to 13 Mile	4.619	2011	Rear dash end	2988.48	1250	Static	Light	80100	Wet	No
9	NB I-75 from 12 Mile to 13 Mile	4.62	2011	Rear dash end	2983.2	1250	Static	Daylight	80100	Dry	No
10	NB I-75 from 12 Mile to 13 Mile	4.621	2010	Rear dash end	2977.92	1250	Static	Daylight	80100	Dry	No
11	NB I-75 from 12 Mile to 13 Mile	4.669	2012	Rear dash end	2724.48	1250	Static	Daylight	80100	Dry	No
12	NB I-75 from 12 Mile to 13 Mile	4.759	2010	Swipe dash same	2249.28	1250	Static	Daylight	80100	Dry	No
13	NB I-75 from 12 Mile to 13 Mile	4.769	2010	Single vehicle	2196.48	1250	Static	Daylight	80100	Dry	No
14	NB I-75 from 12 Mile to 13 Mile	4.869	2010	Single vehicle	1668.48	1250	Static	Daylight	80100	Dry	No
15	NB I-75 from 12 Mile to 13 Mile	4.869	2011	Swipe dash same	1668.48	1250	Static	Dark	80100	Dry	No
16	NB I-75 from 12 Mile to 13 Mile	4.869	2012	Single vehicle	1668.48	1250	Static	Daylight	80100	Dry	No
17	NB I-75 from 12 Mile to 13 Mile	4.869	2011	Single vehicle	1668.48	1250	Static	Daylight	80100	Wet	No
18	NB I-75 from 12 Mile to 13 Mile	4.87	2012	Rear dash end	1663.2	1250	Static	Dark	80100	Dry	No
19	NB I-75 from 12 Mile to 13 Mile	4.87	2010	Rear dash end	1663.2	1250	Static	Daylight	80100	Wet	No
20	NB I-75 from 12 Mile to 13 Mile	4.924	2012	Side dash swipe	1378.08	1250	Static	Dark	80100	Dry	No
21	NB I-75 from 12 Mile to 13 Mile	4.924	2012	Rear dash end	1378.08	1250	Static	Daylight	80100	Wet	No
22	NB I-75 from 12 Mile to 13 Mile	4.924	2011	Rear dash end	1378.08	1250	Static	Daylight	80100	Wet	No
23	NB I-75 from 12 Mile to 13 Mile	5.024	2012	Swipe dash same	850.08	1250	Static	Light	80100	Wet	No
24	NB I-75 from 12 Mile to 13 Mile	5.024	2012	Rear dash end	850.08	1250	Static	Daylight	80100	Wet	No
25	NB I-75 from 12 Mile to 13 Mile	5.069	2011	Rear dash end	612.48	1250	Static	Daylight	80100	Dry	No
26	NB I-75 from 12 Mile to 13 Mile	5.169	2010	Single Vehile	84.48	1250	Static	Daylight	80100	Dry	No
27	NB I-75 from 12 Mile to 13 Mile	5.174	2011	Single Vehile	58.08	1250	Static	Daylight	80100	Dry	No
28	NB I-75 from 12 Mile to 13 Mile	5.174	2010	Swipe dash same	58.08	1250	Static	Dark	80100	Dry	No
29	NB I-75 from 12 Mile to 13 Mile	5.224	2011	Angle	-205.92	1250	Static	Daylight	80100	Dry	No
30	NB I-75 from 12 Mile to 13 Mile	5.224	2011	Rear dash end	-205.92	1250	Static	Daylight	80100	Dry	No
31	NB I-75 from 12 Mile to 13 Mile	5.224	2012	Rear dash end	-205.92	1250	Static	Daylight	80100	Dry	No
32	NB I-75 from 12 Mile to 13 Mile	5.274	2010	Swipe dash same	-469.92	1250	Static	Daylight	80100	Wet	No
33	NB I-75 from 12 Mile to 13 Mile	5.324	2010	Swipe dash same	-733.92	1250	Static	Daylight	80100	Dry	No
34	NB I-75 from 12 Mile to 13 Mile	5.324	2010	Single vehicle	-733.92	1250	Static	Daylight	80100	Dry	No
35	NB I-75 from 12 Mile to 13 Mile	5.324	2010	Rear dash end	-733.92	1250	Static	Daylight	80100	Dry	No
36	NB I-75 from 12 Mile to 13 Mile	5.324	2010	Single vehicle	-733.92	1250	Static	Daylight	80100	Dry	No
37	NB I-75 from 12 Mile to 13 Mile	5.324	2010	Single vehicle	-733.92	1250	Static	Daylight	80100	Dry	No
38	NB I-75 from 12 Mile to 13 Mile	5.324	2011	Rear dash end	-733.92	1250	Static	Dark	80100	Snow	No
39	NB I-75 from 12 Mile to 13 Mile	5.324	2012	Rear dash end	-733.92	1250	Static	Dark	80100	Wet	No
40	NB I-75 from 12 Mile to 13 Mile	5.324	2010	Rear dash end	-733.92	1250	Static	Daylight	80100	Dry	No
41	NB I-75 from 12 Mile to 13 Mile	5.325	2011	Rear dash end	-739.2	1250	Static	Daylight	80100	Dry	No
42	NB I-75 from 12 Mile to 13 Mile	5.329	2010	Rear dash end	-760.32	1250	Static	Dark	80100	Dry	No
43	NB I-75 from 12 Mile to 13 Mile	5.367	2010	Single vehicle	-960.96	1250	Static	Daylight	80100	Dry	No
44	NB I-75 from 12 Mile to 13 Mile	5.367	2011	Single vehicle	-960.96	1250	Static	Daylight	80100	Dry	No
45	NB I-75 from 12 Mile to 13 Mile	5.368	2010	Rear dash end	-966.24	1250	Static	Dark	80100	Dry	No
46	NB I-75 from 12 Mile to 13 Mile	5.386	2010	Rear dash end	-1061.28	1250	Static	Daylight	80100	Dry	No
47	NB I-75 from 12 Mile to 13 Mile	5.386	2011	Rear dash end	-1061.28	1250	Static	Daylight	80100	Dry	No
48	NB I-75 from 12 Mile to 13 Mile	5.386	2011	Rear dash end	-1061.28	1250	Static	Daylight	80100	Wet	No
49	NB I-75 from 12 Mile to 13 Mile	5.386	2011	Rear dash end	-1061.28	1250	Static	Daylight	80100	Dry	No
50	NB I-75 from 12 Mile to 13 Mile	5.386	2011	Side dash swipe	-1061.28	1250	Static	Daylight	80100	Dry	No
51	NB I-75 from 12 Mile to 13 Mile	5.386	2012	Rear dash end	-1061.28	1250	Static	Daylight	80100	Dry	No
52	NB I-75 from 12 Mile to 13 Mile	5.391	2011	Side dash swipe	-1087.68	1250	Static	Daylight	80100	Icy	No
53	NB I-75 from 12 Mile to 13 Mile	5.4	2011	Rear dash end	-1135.2	1250	Static	Dark	80100	Snowy	No
54	NB I-75 from 12 Mile to 13 Mile	5.4	2012	Side dash swipe	-1135.2	1250	Static	Daylight	80100	Dry	No
55	NB I-75 from 12 Mile to 13 Mile	5.405	2010	Rear dash end	-1161.6	1250	Static	Dark	80100	Dry	No
56	NB I-75 from 12 Mile to 13 Mile	5.045	2012	Single vehicle	739.2	1250	Static	Daylight	80100	Dry	No
57	NB I-75 from 12 Mile to 13 Mile	5.406	2010	Rear dash end	-1166.88	1250	Static	Dusk	80100	Dry	No
58	NB I-75 from 12 Mile to 13 Mile	5.41	2010	Single vehicle	-1188	1250	Static	Daylight	80100	Wet	No
59	NB I-75 from 12 Mile to 13 Mile	5.415	2010	Rear dash end	-1214.4	1250	Static	Light	80100	Dry	No
60	NB I-75 from 12 Mile to 13 Mile	5.415	2010	Other	-1214.4	1250	Static	Daylight	80100	Dry	No
61	NB I-75 from 12 Mile to 13 Mile	5.42	2011	Swipe dash same	-1240.8	1250	Static	Light	80100	Dry	No
62	NB I-75 from 12 Mile to 13 Mile	5.422	2012	single vehicle	-1251.36	1250	Static	Daylight	80100	Dry	No
63	NB I-75 from 12 Mile to 13 Mile	5.423	2010	Swipe dash same	-1256.64	1250	Static	Daylight	80100	Icy	No

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	NB I-75 from 13 Mile to 14 Mile	5.426	2012	Swipe-same	3833.28	0	Static	Daylight	80100	Dry	No
2	NB I-75 from 13 Mile to 14 Mile	5.426	2010	Swipe-same	3833.28	0	Static	Daylight	80100	Dry	No
3	NB I-75 from 13 Mile to 14 Mile	5.428	2011	Swipe-same	3822.72	0	Static	Daylight	80100	Dry	No
4	NB I-75 from 13 Mile to 14 Mile	5.432	2010	Other	3801.6	0	Static	Daylight	80100	Dry	No
5	NB I-75 from 13 Mile to 14 Mile	5.433	2012	Rear-end	3796.32	0	Static	Lights	80100	Dry	No
6	NB I-75 from 13 Mile to 14 Mile	5.433	2010	Rear-end	3796.32	0	Static	Dark	80100	Dry	No
7	NB I-75 from 13 Mile to 14 Mile	5.443	2012	Single veh.	3743.52	0	Static	Lights	80100	Snowy	No
8	NB I-75 from 13 Mile to 14 Mile	5.443	2011	Rear-end	3743.52	0	Static	Daylight	80100	Dry	No
9	NB I-75 from 13 Mile to 14 Mile	5.443	2010	Single veh.	3743.52	0	Static	Lights	80100	Dry	No
10	NB I-75 from 13 Mile to 14 Mile	5.443	2010	Rear-end	3743.52	0	Static	Daylight	80100	Dry	No
11	NB I-75 from 13 Mile to 14 Mile	5.443	2010	Rear-end	3743.52	0	Static	Daylight	80100	Dry	No
12	NB I-75 from 13 Mile to 14 Mile	5.453	2010	Rear-end	3690.72	0	Static	Daylight	80100	Dry	No
13	NB I-75 from 13 Mile to 14 Mile	5.453	2010	Rear-end	3690.72	0	Static	Daylight	80100	Dry	No
14	NB I-75 from 13 Mile to 14 Mile	5.462	2010	Single veh.	3643.2	0	Static	Dark	80100	Dry	No
15	NB I-75 from 13 Mile to 14 Mile	5.471	2012	Rear-end	3595.68	0	Static	Daylight	80100	Dry	No
16	NB I-75 from 13 Mile to 14 Mile	5.487	2010	Single veh.	3511.2	0	Static	Daylight	80100	Dry	No
17	NB I-75 from 13 Mile to 14 Mile	5.524	2011	Rear-end	3315.84	0	Static	Daylight	80100	Dry	No
18	NB I-75 from 13 Mile to 14 Mile	5.524	2011	Other	3315.84	0	Static	Daylight	80100	Dry	No
19	NB I-75 from 13 Mile to 14 Mile	5.524	2011	Rear-end	3315.84	0	Static	Daylight	80100	Dry	No
20	NB I-75 from 13 Mile to 14 Mile	5.524	2010	Swipe-same	3315.84	0	Static	Dark	80100	Snowy	No
21	NB I-75 from 13 Mile to 14 Mile	5.524	2010	Rear-end	3315.84	0	Static	Daylight	80100	Wet	No
22	NB I-75 from 13 Mile to 14 Mile	5.524	2010	Angle	3315.84	0	Static	Daylight	80100	Snowy	No
23	NB I-75 from 13 Mile to 14 Mile	5.674	2012	Swipe-same	2523.84	0	Static	Daylight	80100	Dry	No
24	NB I-75 from 13 Mile to 14 Mile	5.674	2012	Single veh.	2523.84	0	Static	Daylight	80100	Dry	No
25	NB I-75 from 13 Mile to 14 Mile	5.674	2012	Swipe-same	2523.84	0	Static	Daylight	80100	Dry	No
26	NB I-75 from 13 Mile to 14 Mile	5.674	2010	Single veh.	2523.84	0	Static	Lights	80100	Snowy	No
27	NB I-75 from 13 Mile to 14 Mile	5.724	2012	Single veh.	2259.84	0	Static	Daylight	80100	Dry	No
28	NB I-75 from 13 Mile to 14 Mile	5.9	2012	Other	1330.56	0	Static	Dark	80100	Snowy	No
29	NB I-75 from 13 Mile to 14 Mile	5.9	2012	Rear-end	1330.56	0	Static	Daylight	80100	Dry	No
30	NB I-75 from 13 Mile to 14 Mile	5.9	2012	Rear-end	1330.56	0	Static	Daylight	80100	Dry	No
31	NB I-75 from 13 Mile to 14 Mile	5.9	2012	Rear-end	1330.56	0	Static	Daylight	80100	Dry	No
32	NB I-75 from 13 Mile to 14 Mile	5.9	2011	Single veh.	1330.56	0	Static	Daylight	80100	Dry	No
33	NB I-75 from 13 Mile to 14 Mile	5.9	2011	Angle	1330.56	0	Static	Dark	80100	Dry	No
34	NB I-75 from 13 Mile to 14 Mile	5.9	2011	Swipe-same	1330.56	0	Static	Daylight	80100	Dry	No
35	NB I-75 from 13 Mile to 14 Mile	5.9	2011	Other	1330.56	0	Static	Daylight	80100	Dry	No
36	NB I-75 from 13 Mile to 14 Mile	5.9	2011	Head-on	1330.56	0	Static	Daylight	80100	Wet	No
37	NB I-75 from 13 Mile to 14 Mile	5.9	2010	Other	1330.56	0	Static	Daylight	80100	Dry	No
38	NB I-75 from 13 Mile to 14 Mile	5.9	2010	Rear-end	1330.56	0	Static	Daylight	80100	Dry	No
39	NB I-75 from 13 Mile to 14 Mile	5.924	2012	Single veh.	1203.84	0	Static	Dark	80100	Snowy	No
40	NB I-75 from 13 Mile to 14 Mile	5.924	2012	Rear-end	1203.84	0	Static	Daylight	80100	Dry	No
41	NB I-75 from 13 Mile to 14 Mile	5.924	2011	Rear-end	1203.84	0	Static	Daylight	80100	Dry	No
42	NB I-75 from 13 Mile to 14 Mile	6.15	2012	Rear-end	10.56	0	Static	Daylight	80100	Dry	No
43	NB I-75 from 13 Mile to 14 Mile	6.15	2012	Other	10.56	0	Static	Dawn	80100	Dry	No
44	NB I-75 from 13 Mile to 14 Mile	6.15	2012	Swipe-same	10.56	0	Static	Lights	80100	Dry	No
45	NB I-75 from 13 Mile to 14 Mile	6.15	2012	Swipe-same	10.56	0	Static	Daylight	80100	Dry	No
46	NB I-75 from 13 Mile to 14 Mile	6.15	2012	Other	10.56	0	Static	Daylight	80100	Dry	No
47	NB I-75 from 13 Mile to 14 Mile	6.15	2012	Rear-end	10.56	0	Static	Daylight	80100	Dry	No
48	NB I-75 from 13 Mile to 14 Mile	6.15	2011	Swipe-same	10.56	0	Static	Daylight	80100	Dry	No
49	NB I-75 from 13 Mile to 14 Mile	6.15	2011	Rear-end	10.56	0	Static	Dusk	80100	Dry	No
50	NB I-75 from 13 Mile to 14 Mile	6.15	2011	Rear-end	10.56	0	Static	Daylight	80100	Dry	No
51	NB I-75 from 13 Mile to 14 Mile	6.15	2010	Swipe-same	10.56	0	Static	Daylight	80100	Dry	No
52	NB I-75 from 13 Mile to 14 Mile	6.151	2012	Other	5.28	0	Static	Dark	80100	Dry	No

Vehicle Accident Matrix

	Accident Location/ Freeway Area Within 1,000' of Existing Billboard	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
1	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.447	2010	Swipe-same	0	1000	Static	Swipe-same	58800	Dry	No
2	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.457	2010	Rear-end	-52.8	1000	Static	Rear-end	58800	Dry	No
3	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.49	2011	Rear-end	-227.04	1000	Static	Rear-end	58800	Dry	No
4	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.495	2012	Rear-end	-253.44	1000	Static	Rear-end	58800	Dry	No
5	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.495	2012	Rear-end	-253.44	1000	Static	Rear-end	58800	Wet	No
6	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.495	2012	Rear-end	-253.44	1000	Static	Rear-end	58800	Dry	No
7	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.495	2011	Rear-end	-253.44	1000	Static	Rear-end	58800	Dry	No
8	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.495	2010	Swipe-same	-253.44	1000	Static	Swipe-same	58800	Dry	No
9	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.495	2010	Swipe-same	-253.44	1000	Static	Swipe-same	58800	Dry	No
10	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.5	2010	Single veh.	-279.84	1000	Static	Single veh.	58800	Dry	No
11	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.5	2010	Single veh.	-279.84	1000	Static	Single veh.	58800	Wet	No
12	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.503	2010	Rear-end	-295.68	1000	Static	Rear-end	58800	Dry	No
13	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.514	2010	Rear-end	-353.76	1000	Static	Rear-end	58800	Dry	No
14	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.542	2010	Single veh.	-501.6	1000	Static	Single veh.	58800	Other	No
15	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.59	2011	Swipe-same	-755.04	1000	Static	Swipe-same	58800	Wet	No
16	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.627	2011	Rear-end	-950.4	1000	Static	Rear-end	58800	Dry	No
17	NB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.627	2011	Rear-end	-950.4	1000	Static	Daylight	58800	Dry	No

Vehicle Accident Matrix

	Accident Location/ Freeway Area Within 1,000' of Existing Billboard	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
1	NB I-75 from us24conn Ramp to Eureka Ramp	8.624	2012	Swipe-same	1001.088	250	Static	Swipe-same	41550	Dry	No
2	NB I-75 from us24conn Ramp to Eureka Ramp	8.677	2012	Rear-end	721.248	250	Static	Swipe-same	41550	Dry	No
3	NB I-75 from us24conn Ramp to Eureka Ramp	8.677	2012	Single veh.	721.248	250	Static	Single veh.	41550	Dry	No
4	NB I-75 from us24conn Ramp to Eureka Ramp	8.677	2012	Single veh.	721.248	250	Static	Swipe-same	41550	Wet	No

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from proposed billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	NB I-75 from Long Lake to Crooks ramp	12.18	2011	Angle	-633.6	820	NO	Lights	58800	Dry	No
2	NB I-75 from Long Lake to Crooks ramp	12.183	2011	Rear-end	-617.76	820	NO	Dark	58800	Dry	No
3	NB I-75 from Long Lake to Crooks ramp	12.198	2010	Rear-end	-538.56	820	NO	Daylight	58800	Wet	No
4	NB I-75 from Long Lake to Crooks ramp	12.198	2010	Other	-538.56	820	NO	Daylight	58800	Dry	No
5	NB I-75 from Long Lake to Crooks ramp	12.198	2010	Rear-end	-538.56	820	NO	Daylight	58800	Dry	No
6	NB I-75 from Long Lake to Crooks ramp	12.198	2012	Rear-end	-538.56	820	NO	Daylight	58800	Dry	No
7	NB I-75 from Long Lake to Crooks ramp	12.198	2012	Other	-538.56	820	NO	Daylight	58800	Dry	No
8	NB I-75 from Long Lake to Crooks ramp	12.217	2010	Single veh.	-438.24	820	NO	Lights	58800	Wet	No
9	NB I-75 from Long Lake to Crooks ramp	12.217	2011	Other	-438.24	820	NO	Daylight	58800	Icy	No
10	NB I-75 from Long Lake to Crooks ramp	12.236	2012	Other	-337.92	820	NO	Daylight	58800	Dry	No
11	NB I-75 from Long Lake to Crooks ramp	12.273	2012	Rear-end	-142.56	820	NO	Daylight	58800	Dry	No
12	NB I-75 from Long Lake to Crooks ramp	12.274	2010	Single veh.	-137.28	820	NO	Dawn	58800	Wet	No
13	NB I-75 from Long Lake to Crooks ramp	12.362	2011	Other	327.36	820	NO	Daylight	58800	Dry	No
14	NB I-75 from Long Lake to Crooks ramp	12.368	2012	Single veh.	359.04	820	NO	Daylight	58800	Wet	No

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	NB I-75 from Wattles to Long Lake	11.197	2012	Single veh.	2597.76	2600	Static	Lights	58869	Wet	No
2	NB I-75 from Wattles to Long Lake	11.197	2011	Rear-end	2597.76	2600	Static	Daylight	58869	Dry	No
3	NB I-75 from Wattles to Long Lake	11.212	2010	Swipe-same	2518.56	2600	Static	Dark	58869	Dry	No
4	NB I-75 from Wattles to Long Lake	11.231	2012	Rear-end	2418.24	2600	Static	Daylight	58869	Dry	No
5	NB I-75 from Wattles to Long Lake	11.231	2011	Single veh.	2418.24	2600	Static	Daylight	58869	Dry	No
6	NB I-75 from Wattles to Long Lake	11.231	2011	Rear-end	2418.24	2600	Static	Daylight	58869	Dry	No
7	NB I-75 from Wattles to Long Lake	11.25	2011	Other	2317.92	2600	Static	Dark	58869	Slushy	No
8	NB I-75 from Wattles to Long Lake	11.288	2012	Rear-end	2117.28	2600	Static	Dark	58869	Dry	No
9	NB I-75 from Wattles to Long Lake	11.288	2012	Rear-end	2117.28	2600	Static	Dark	58869	Dry	No
10	NB I-75 from Wattles to Long Lake	11.288	2011	Single veh.	2117.28	2600	Static	Lights	58869	Snowy	No
11	NB I-75 from Wattles to Long Lake	11.363	2010	Other	1721.28	2600	Static	Dark	58869	Dry	No
12	NB I-75 from Wattles to Long Lake	11.382	2011	Rear-end	1620.96	2600	Static	Dawn	58869	Wet	No
13	NB I-75 from Wattles to Long Lake	11.382	2010	Other	1620.96	2600	Static	Daylight	58869	Dry	No
14	NB I-75 from Wattles to Long Lake	11.443	2010	Swipe-same	1298.88	2600	Static	Daylight	58869	Dry	No
15	NB I-75 from Wattles to Long Lake	11.572	2012	Rear-end	617.76	2600	Static	Daylight	58869	Dry	No
16	NB I-75 from Wattles to Long Lake	11.679	2010	Single veh.	52.8	2600	Static	Daylight	58869	Snowy	No
17	NB I-75 from Wattles to Long Lake	11.693	2012	Rear-end	-21.12	2600	Static	Daylight	58869	Dry	No
18	NB I-75 from Wattles to Long Lake	11.703	2012	Single veh.	-73.92	2600	Static	Dark	58869	Dry	No
19	NB I-75 from Wattles to Long Lake	11.761	2011	Rear-end	-380.16	2600	Static	Daylight	58869	Dry	No
20	NB I-75 from Wattles to Long Lake	11.895	2012	Rear-end	-1087.68	2600	Static	Daylight	58869	Dry	No
21	NB I-75 from Wattles to Long Lake	11.952	2011	Swipe-same	-1388.64	2600	Static	Dawn	58869	Dry	No
22	NB I-75 from Wattles to Long Lake	12.084	2010	Single veh.	-2085.6	2600	Static	Dark	58869	Dry	No
23	NB I-75 from Wattles to Long Lake	12.122	2012	Head-on	-2286.24	2600	Static	Daylight	58869	Dry	No
24	NB I-75 from Wattles to Long Lake	12.122	2012	Single veh.	-2286.24	2600	Static	Dark	58869	Snowy	No
26	NB I-75 from Wattles to Long Lake	12.141	2010	Rear-end	-2386.56	2600	Static	Daylight	58869	Dry	No
27	NB I-75 from Wattles to Long Lake	12.151	2012	Single veh.	-2439.36	2600	Static	Dark	58869	Dry	No
28	NB I-75 from Wattles to Long Lake	12.16	2010	Rear-end	-2486.88	2600	Static	Daylight	58869	Dry	No
29	NB I-75 from Wattles to Long Lake	12.165	2012	Rear-end	-2513.28	2600	Static	Daylight	58869	Dry	No

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	SB I-75 from 13 Mile to 14 Mile	4.768	2010	Rear-end	-2203.344	1250	Static	Daylight	80100	Dry	No
2	SB I-75 from 13 Mile to 14 Mile	4.792	2012	Rear-end	-2076.624	1250	Static	Daylight	80100	Dry	No
3	SB I-75 from 13 Mile to 14 Mile	4.823	2011	Rear-end	-1912.944	1250	Static	Daylight	80100	Wet	No
4	SB I-75 from 13 Mile to 14 Mile	4.849	2011	Rear-end	-1775.664	1250	Static	Daylight	80100	Dry	No
5	SB I-75 from 13 Mile to 14 Mile	4.852	2011	Rear-end	-1759.824	1250	Static	Daylight	80100	Dry	No
6	SB I-75 from 13 Mile to 14 Mile	4.868	2012	Rear-end	-1675.344	1250	Static	Daylight	80100	Dry	No
7	SB I-75 from 13 Mile to 14 Mile	4.868	2011	Rear-end	-1675.344	1250	Static	Daylight	80100	Dry	No
8	SB I-75 from 13 Mile to 14 Mile	4.868	2010	Single veh.	-1675.344	1250	Static	Daylight	80100	Dry	No
9	SB I-75 from 13 Mile to 14 Mile	4.923	2012	Single veh.	-1384.944	1250	Static	Dark	80100	Icy	No
10	SB I-75 from 13 Mile to 14 Mile	4.923	2012	Swipe-same	-1384.944	1250	Static	Daylight	80100	Dry	No
11	SB I-75 from 13 Mile to 14 Mile	4.923	2011	Rear-end	-1384.944	1250	Static	Lights	80100	Dry	No
12	SB I-75 from 13 Mile to 14 Mile	4.923	2011	Rear-end	-1384.944	1250	Static	Lights	80100	Dry	No
13	SB I-75 from 13 Mile to 14 Mile	4.923	2011	Other	-1384.944	1250	Static	Daylight	80100	Dry	No
14	SB I-75 from 13 Mile to 14 Mile	4.923	2011	Single veh.	-1384.944	1250	Static	Dark	80100	Dry	No
15	SB I-75 from 13 Mile to 14 Mile	5.173	2011	Rear-end	-64.944	1250	Static	Daylight	80100	Dry	No
16	SB I-75 from 13 Mile to 14 Mile	5.173	2010	Rear-end	-64.944	1250	Static	Daylight	80100	Dry	No
17	SB I-75 from 13 Mile to 14 Mile	5.177	2010	Rear-end	-43.824	1250	Static	Daylight	80100	Wet	No
18	SB I-75 from 13 Mile to 14 Mile	5.223	2011	Rear-end	199.056	1250	Static	Lights	80100	Dry	No
19	SB I-75 from 13 Mile to 14 Mile	5.223	2010	Rear-end	199.056	1250	Static	Daylight	80100	Dry	No
20	SB I-75 from 13 Mile to 14 Mile	5.323	2012	Other	727.056	1250	Static	Daylight	80100	Dry	No
21	SB I-75 from 13 Mile to 14 Mile	5.323	2011	Rear-end	727.056	1250	Static	Daylight	80100	Dry	No
22	SB I-75 from 13 Mile to 14 Mile	5.323	2010	Rear-end	727.056	1250	Static	Daylight	80100	Dry	No
23	SB I-75 from 13 Mile to 14 Mile	5.323	2010	Rear-end	727.056	1250	Static	Daylight	80100	Wet	No
24	SB I-75 from 13 Mile to 14 Mile	5.323	2010	Single veh.	727.056	1250	Static	Daylight	80100	Wet	No
25	SB I-75 from 13 Mile to 14 Mile	5.328	2012	Rear-end	753.456	1250	Static	Daylight	80100	Dry	No
26	SB I-75 from 13 Mile to 14 Mile	5.349	2011	Rear-end	864.336	1250	Static	Lights	80100	Dry	No
27	SB I-75 from 13 Mile to 14 Mile	5.366	2010	Single veh.	954.096	1250	Static	Dark	80100	Dry	No
28	SB I-75 from 13 Mile to 14 Mile	5.368	2012	Rear-end	964.656	1250	Static	Daylight	80100	Wet	No
29	SB I-75 from 13 Mile to 14 Mile	5.368	2012	Rear-end	964.656	1250	Static	Daylight	80100	Dry	No
30	SB I-75 from 13 Mile to 14 Mile	5.368	2011	Swipe-same	964.656	1250	Static	Dark	80100	Dry	No
31	SB I-75 from 13 Mile to 14 Mile	5.376	2011	Other	1006.896	1250	Static	Daylight	80100	Dry	No
32	SB I-75 from 13 Mile to 14 Mile	5.376	2010	Rear-end	1006.896	1250	Static	Daylight	80100	Wet	No
33	SB I-75 from 13 Mile to 14 Mile	5.376	2010	Swipe-same	1006.896	1250	Static	Daylight	80100	Snowy	No
34	SB I-75 from 13 Mile to 14 Mile	5.385	2012	Rear-end	1054.416	1250	Static	Lights	80100	Dry	No
35	SB I-75 from 13 Mile to 14 Mile	5.385	2012	Rear-end	1054.416	1250	Static	Daylight	80100	Dry	No
36	SB I-75 from 13 Mile to 14 Mile	5.385	2011	Rear-end	1054.416	1250	Static	Daylight	80100	Wet	No
37	SB I-75 from 13 Mile to 14 Mile	5.385	2010	Single veh.	1054.416	1250	Static	Dark	80100	Dry	No
38	SB I-75 from 13 Mile to 14 Mile	5.385	2010	Other	1054.416	1250	Static	Daylight	80100	Dry	No
39	SB I-75 from 13 Mile to 14 Mile	5.395	2012	Rear-end	1107.216	1250	Static	Lights	80100	Dry	No
40	SB I-75 from 13 Mile to 14 Mile	5.399	2012	Rear-end	1128.336	1250	Static	Daylight	80100	Dry	No
41	SB I-75 from 13 Mile to 14 Mile	5.404	2012	Rear-end	1154.736	1250	Static	Lights	80100	Dry	No
42	SB I-75 from 13 Mile to 14 Mile	5.404	2011	Rear-end	1154.736	1250	Static	Daylight	80100	Dry	No
43	SB I-75 from 13 Mile to 14 Mile	5.404	2010	Rear-end	1154.736	1250	Static	Daylight	80100	Dry	No
44	SB I-75 from 13 Mile to 14 Mile	5.414	2012	Single veh.	1207.536	1250	Static	Lights	80100	Icy	No
45	SB I-75 from 13 Mile to 14 Mile	5.414	2010	Swipe-same	1207.536	1250	Static	Lights	80100	Dry	No
46	SB I-75 from 13 Mile to 14 Mile	5.421	2011	Rear-end	1244.496	1250	Static	Dusk	80100	Dry	No

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	SB I-75 from 13 Mile to 14 Mile	5.425	2010	Rear-end	-3838.56	0	Static	Dawn	80100	Dry	No
2	SB I-75 from 13 Mile to 14 Mile	5.429	2010	Swipe-same	-3817.44	0	Static	Daylight	80100	Dry	No
3	SB I-75 from 13 Mile to 14 Mile	5.432	2012	Swipe-same	-3801.6	0	Static	Dark	80100	Wet	No
4	SB I-75 from 13 Mile to 14 Mile	5.432	2011	Rear-end	-3801.6	0	Static	Lights	80100	Dry	No
5	SB I-75 from 13 Mile to 14 Mile	5.432	2010	Rear-end	-3801.6	0	Static	Daylight	80100	Dry	No
6	SB I-75 from 13 Mile to 14 Mile	5.442	2011	Single veh.	-3748.8	0	Static	Lights	80100	Dry	No
7	SB I-75 from 13 Mile to 14 Mile	5.442	2011	Single veh.	-3748.8	0	Static	Daylight	80100	Dry	No
8	SB I-75 from 13 Mile to 14 Mile	5.442	2011	Rear-end	-3748.8	0	Static	Daylight	80100	Wet	No
9	SB I-75 from 13 Mile to 14 Mile	5.442	2010	Other	-3748.8	0	Static	Lights	80100	Wet	No
10	SB I-75 from 13 Mile to 14 Mile	5.446	2012	Rear-end	-3727.68	0	Static	Dawn	80100	Dry	No
11	SB I-75 from 13 Mile to 14 Mile	5.47	2010	Swipe-same	-3600.96	0	Static	Lights	80100	Dry	No
12	SB I-75 from 13 Mile to 14 Mile	5.489	2010	Rear-end	-3500.64	0	Static	Daylight	80100	Dry	No
13	SB I-75 from 13 Mile to 14 Mile	5.518	2010	Rear-end	-3347.52	0	Static	Daylight	80100	Dry	No
14	SB I-75 from 13 Mile to 14 Mile	5.523	2012	Rear-end	-3321.12	0	Static	Daylight	80100	Wet	No
15	SB I-75 from 13 Mile to 14 Mile	5.523	2011	Swipe-same	-3321.12	0	Static	Daylight	80100	Dry	No
16	SB I-75 from 13 Mile to 14 Mile	5.523	2011	Rear-end	-3321.12	0	Static	Daylight	80100	Dry	No
17	SB I-75 from 13 Mile to 14 Mile	5.523	2011	Rear-end	-3321.12	0	Static	Daylight	80100	Dry	No
18	SB I-75 from 13 Mile to 14 Mile	5.523	2011	Rear-end	-3321.12	0	Static	Daylight	80100	Dry	No
19	SB I-75 from 13 Mile to 14 Mile	5.523	2010	Swipe-same	-3321.12	0	Static	Lights	80100	Dry	No
20	SB I-75 from 13 Mile to 14 Mile	5.523	2010	Rear-end	-3321.12	0	Static	Daylight	80100	Dry	No
21	SB I-75 from 13 Mile to 14 Mile	5.523	2010	Rear-end	-3321.12	0	Static	Daylight	80100	Wet	No
22	SB I-75 from 13 Mile to 14 Mile	5.523	2010	Swipe-same	-3321.12	0	Static	Daylight	80100	Dry	No
23	SB I-75 from 13 Mile to 14 Mile	5.623	2012	Rear-end	-2793.12	0	Static	Daylight	80100	Dry	No
24	SB I-75 from 13 Mile to 14 Mile	5.623	2010	Rear-end	-2793.12	0	Static	Daylight	80100	Dry	No
25	SB I-75 from 13 Mile to 14 Mile	5.623	2010	Rear-end	-2793.12	0	Static	Daylight	80100	Dry	No
26	SB I-75 from 13 Mile to 14 Mile	5.823	2011	Single veh.	-1737.12	0	Static	Daylight	80100	Dry	No
27	SB I-75 from 13 Mile to 14 Mile	5.823	2010	Angle	-1737.12	0	Static	Daylight	80100	Dry	No
28	SB I-75 from 13 Mile to 14 Mile	5.899	2012	Rear-end	-1335.84	0	Static	Daylight	80100	Dry	No
29	SB I-75 from 13 Mile to 14 Mile	5.899	2012	Rear-end	-1335.84	0	Static	Daylight	80100	Dry	No
30	SB I-75 from 13 Mile to 14 Mile	5.899	2012	Single veh.	-1335.84	0	Static	Daylight	80100	Wet	No
31	SB I-75 from 13 Mile to 14 Mile	5.899	2011	Rear-end	-1335.84	0	Static	Lights	80100	Icy	No
32	SB I-75 from 13 Mile to 14 Mile	5.899	2011	Rear-end	-1335.84	0	Static	Daylight	80100	Dry	No
33	SB I-75 from 13 Mile to 14 Mile	5.899	2011	Single veh.	-1335.84	0	Static	Daylight	80100	Dry	No
34	SB I-75 from 13 Mile to 14 Mile	5.899	2011	Rear-end	-1335.84	0	Static	Dawn	80100	Wet	No
35	SB I-75 from 13 Mile to 14 Mile	5.899	2010	Swipe-same	-1335.84	0	Static	Daylight	80100	Wet	No
36	SB I-75 from 13 Mile to 14 Mile	5.899	2010	Single veh.	-1335.84	0	Static	Daylight	80100	Dry	No
37	SB I-75 from 13 Mile to 14 Mile	5.923	2012	Rear-end	-1209.12	0	Static	Dark	80100	Dry	No
38	SB I-75 from 13 Mile to 14 Mile	5.999	2010	Swipe-same	-807.84	0	Static	Daylight	80100	Dry	No
39	SB I-75 from 13 Mile to 14 Mile	5.999	2010	Rear-end	-807.84	0	Static	Lights	80100	Dry	No
40	SB I-75 from 13 Mile to 14 Mile	6.02	2011	Rear-end	-696.96	0	Static	Daylight	80100	Dry	No
41	SB I-75 from 13 Mile to 14 Mile	6.049	2011	Swipe-same	-543.84	0	Static	Daylight	80100	Dry	No
42	SB I-75 from 13 Mile to 14 Mile	6.099	2012	Rear-end	-279.84	0	Static	Daylight	80100	Dry	No

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.408	2011	Rear-end	0	776.16	Static	Daylight	58800	Dry	No
2	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.408	2010	Single veh.	0	776.16	Static	Daylight	58800	Dry	No
3	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.413	2010	Rear-end	0	749.76	Static	Daylight	58800	Dry	No
4	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.414	2012	Rear-end	0	744.48	Static	Daylight	58800	Dry	No
5	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.416	2011	Rear-end	0	733.92	Static	Daylight	58800	Wet	No
6	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.418	2011	Rear-end	0	723.36	Static	Daylight	58800	Dry	No
7	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.418	2010	Rear-end	0	723.36	Static	Daylight	58800	Dry	No
8	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.425	2012	Rear-end	0	686.4	Static	Daylight	58800	Dry	No
9	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.426	2012	Rear-end	0	681.12	Static	Daylight	58800	Dry	No
10	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.426	2010	Single veh.	0	681.12	Static	Daylight	58800	Dry	No
11	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.427	2011	Rear-end	0	675.84	Static	Daylight	58800	Wet	No
12	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.427	2011	Rear-end	0	675.84	Static	Daylight	58800	Dry	No
13	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.427	2011	Rear-end	0	675.84	Static	Daylight	58800	Dry	No
14	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.437	2012	Rear-end	0	623.04	Static	Other	58800	Other	No
15	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.437	2011	Rear-end	0	623.04	Static	Daylight	58800	Wet	No
16	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.437	2011	Rear-end	0	623.04	Static	Daylight	58800	Dry	No
17	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.437	2011	Rear-end	0	623.04	Static	Daylight	58800	Dry	No
18	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.437	2010	Rear-end	0	623.04	Static	Lights	58800	Dry	No
19	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.445	2012	Rear-end	0	580.8	Static	Daylight	58800	Dry	No
20	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.456	2011	Rear-end	0	522.72	Static	Daylight	58800	Wet	No
21	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.456	2011	Rear-end	0	522.72	Static	Daylight	58800	Wet	No
22	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.456	2011	Rear-end	0	522.72	Static	Daylight	58800	Dry	No
23	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.456	2010	Other	0	522.72	Static	Daylight	58800	Dry	No
24	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.456	2010	Rear-end	0	522.72	Static	Daylight	58800	Dry	No
25	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.465	2010	Rear-end	0	475.2	Static	Daylight	58800	Dry	No
26	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.475	2012	Rear-end	0	422.4	Static	Daylight	58800	Dry	No
27	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.475	2011	Rear-end	0	422.4	Static	Daylight	58800	Dry	No
28	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.494	2012	Rear-end	0	322.08	Static	Daylight	58800	Wet	No
29	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.494	2012	Rear-end	0	322.08	Static	Daylight	58800	Dry	No
30	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.494	2011	Rear-end	0	322.08	Static	Dusk	58800	Dry	No
31	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.494	2011	Rear-end	0	322.08	Static	Dusk	58800	Dry	No
32	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.494	2011	Rear-end	0	322.08	Static	Daylight	58800	Dry	No
33	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.494	2011	Swipe-same	0	322.08	Static	Daylight	58800	Wet	No
34	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.494	2011	Rear-end	0	322.08	Static	Daylight	58800	Dry	No
35	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.499	2012	Rear-end	0	295.68	Static	Lights	58800	Dry	No
36	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.499	2012	Single veh.	0	295.68	Static	Dark	58800	Dry	No
37	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.499	2011	Rear-end	0	295.68	Static	Daylight	58800	Dry	No
38	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.499	2011	Rear-end	0	295.68	Static	Daylight	58800	Dry	No
39	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.499	2011	Swipe-same	0	295.68	Static	Daylight	58800	Dry	No
40	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.499	2010	Rear-end	0	295.68	Static	Daylight	58800	Dry	No
41	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.499	2010	Rear-end	0	295.68	Static	Daylight	58800	Dry	No
42	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.499	2010	Rear-end	0	295.68	Static	Daylight	58800	Dry	No
43	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.499	2010	Rear-end	0	295.68	Static	Dark	58800	Dry	No
44	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.502	2012	Rear-end	0	279.84	Static	Daylight	58800	Dry	No
45	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.502	2012	Rear-end	0	279.84	Static	Daylight	58800	Dry	No
46	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.502	2011	Rear-end	0	279.84	Static	Daylight	58800	Dry	No
47	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.502	2011	Rear-end	0	279.84	Static	Daylight	58800	Dry	No
48	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.503	2010	Rear-end	0	274.56	Static	Daylight	58800	Dry	No
49	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.512	2012	Rear-end	0	227.04	Static	Daylight	58800	Dry	No
50	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.512	2011	Rear-end	0	227.04	Static	Daylight	58800	Dry	No
51	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.513	2011	Rear-end	0	221.76	Static	Daylight	58800	Dry	No
52	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.513	2010	Single veh.	0	221.76	Static	Lights	58800	Dry	No
53	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.514	2012	Rear-end	0	216.48	Static	Daylight	58800	Dry	No
54	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.521	2010	Rear-end	0	179.52	Static	Daylight	58800	Dry	No
55	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.527	2012	Rear-end	0	147.84	Static	Lights	58800	Dry	No
56	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.532	2011	Rear-end	0	121.44	Static	Daylight	58800	Dry	No
57	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.54	2011	Rear-end	0	79.2	Static	Daylight	58800	Dry	No
58	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.542	2012	Swipe-same	0	68.64	Static	Daylight	58800	Dry	No
59	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.549	2012	Rear-end	0	31.68	Static	Daylight	58800	Dry	No
60	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.551	2012	Rear-end	0	21.12	Static	Daylight	58800	Dry	No
61	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.551	2011	Rear-end	0	21.12	Static	Dark	58800	Dry	No
62	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.551	2010	Rear-end	0	21.12	Static	Daylight	58800	Dry	No
63	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2012	Rear-end	0	-174.24	Static	Daylight	58800	Dry	No
64	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2012	Swipe-same	0	-174.24	Static	Daylight	58800	Dry	No
65	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2012	Rear-end	0	-174.24	Static	Dusk	58800	Dry	No
66	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2011	Rear-end	0	-174.24	Static	Daylight	58800	Wet	No
67	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2011	Rear-end	0	-174.24	Static	Daylight	58800	Dry	No
68	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2011	Swipe-same	0	-174.24	Static	Dark	58800	Dry	No
69	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2011	Rear-end	0	-174.24	Static	Dark	58800	Dry	No
70	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2011	Rear-end	0	-174.24	Static	Daylight	58800	Dry	No
71	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2011	Rear-end	0	-174.24	Static	Daylight	58800	Wet	No
72	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2011	Swipe-same	0	-174.24	Static	Lights	58800	Dry	No
73	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.588	2010	Rear-end	0	-174.24	Static	Daylight	58800	Dry	No
74	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.596	2012	Rear-end	0	-216.48	Static	Daylight	58800	Dry	No
75	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.596	2011	Rear-end	0	-216.48	Static	Daylight	58800	Wet	No
76	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.596	2011	Rear-end	0	-216.48	Static	Daylight	58800	Dry	No
77	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.599	2011	Rear-end	0	-232.32	Static	Daylight	58800	Dry	No
78	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.599	2011	Other	0	-232.32	Static	Daylight	58800	Dry	No
79	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.599	2011	Rear-end	0	-232.32	Static	Dark	58800	Dry	No
80	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.599	2010	Rear-end	0	-232.32	Static	Dark	58800	Dry	No
81	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.607	2012	Rear-end	0	-274.56	Static	Daylight	58800	Dry	No
82	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.608	2012	Single veh.	0	-279.84	Static	Other	58800	Other	No
83	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.626	2012	Rear-end	0	-374.88	Static	Daylight	58800	Dry	No
84	SB I-75 from 14 Mile to 1000 feet north of 14 Mile	6.626	2011	Rear-end	0	-374.88	Static	Daylight	58800	Wet	No

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
2	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.869	2011	Single veh.	1557.6	250	Static	Dark	41550	Wet	No
4	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.869	2012	Single veh.	1557.6	250	Static	Dark	41550	Icy	No
5	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.885	2010	Swipe-same	1473.12	250	Static	Lights	41550	Dry	No
6	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.919	2010	Single veh.	1293.6	250	Static	Daylight	41550	Dry	No
7	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.919	2011	Single veh.	1293.6	250	Static	Daylight	41550	Dry	No
8	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.919	2011	Swipe-same	1293.6	250	Static	Dark	41550	Icy	No
9	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.919	2012	Rear-end	1293.6	250	Static	Daylight	41550	Dry	No
10	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.919	2012	Swipe-same	1293.6	250	Static	Daylight	41550	Dry	No
11	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.919	2012	Rear-end	1293.6	250	Static	Daylight	41550	Dry	No
12	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.969	2012	Rear-end	1029.6	250	Static	Daylight	41550	Dry	No
13	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.98	2011	Angle	971.52	250	Static	Lights	41550	Icy	No
14	SB I-75 from Eureka rd to 1000 feet SB on Ramp	8.98	2011	Single veh.	971.52	250	Static	Dawn	41550	Icy	No
15	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.069	2010	Rear-end	501.6	250	Static	Dark	41550	Uncoded	No
16	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.069	2011	Rear-end	501.6	250	Static	Daylight	41550	Dry	No
17	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.069	2012	Single veh.	501.6	250	Static	Dark	41550	Icy	No
18	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.074	2010	Rear-end	475.2	250	Static	Daylight	41550	Dry	No
19	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.074	2012	Rear-end	475.2	250	Static	Daylight	41550	Dry	No
20	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.074	2012	Swipe-same	475.2	250	Static	Daylight	41550	Dry	No
21	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.084	2012	Single veh.	422.4	250	Static	Dark	41550	Icy	No
22	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.122	2011	Swipe-same	221.76	250	Static	Daylight	41550	Snowy	No
23	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.131	2010	Single veh.	174.24	250	Static	Dark	41550	Dry	No
24	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.131	2012	Single veh.	174.24	250	Static	Dark	41550	Icy	No
25	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.131	2012	Rear-end	174.24	250	Static	Dark	41550	Icy	No
26	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.131	2012	Rear-end	174.24	250	Static	Daylight	41550	Dry	No
27	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.16	2011	Single veh.	21.12	250	Static	Dark	41550	Snowy	No
28	SB I-75 from Eureka rd to 1000 feet SB on Ramp	9.164	2011	Single veh.	0	250	Static	Dark	41550	Icy	No

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from Proposed billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	SB I-75 from Long Lake to Crooks ramp	12.177	2010	Single veh.	649.44	820	Static	Daylight	58800	Wet	Yes
2	SB I-75 from Long Lake to Crooks ramp	12.18	2012	Single veh.	633.6	820	Static	Daylight	58800	Wet	Yes
3	SB I-75 from Long Lake to Crooks ramp	12.181	2010	Single veh.	628.32	820	Static	Lights	58800	Icy	Yes
4	SB I-75 from Long Lake to Crooks ramp	12.182	2010	Swipe-same	623.04	820	Static	Daylight	58800	Wet	Yes
5	SB I-75 from Long Lake to Crooks ramp	12.185	2012	Single veh.	607.2	820	Static	Daylight	58800	Wet	Yes
6	SB I-75 from Long Lake to Crooks ramp	12.185	2011	Swipe-same	607.2	820	Static	Dark	58800	Wet	Yes
7	SB I-75 from Long Lake to Crooks ramp	12.185	2010	Other	607.2	820	Static	Daylight	58800	Wet	Yes
8	SB I-75 from Long Lake to Crooks ramp	12.185	2010	Single veh.	607.2	820	Static	Daylight	58800	Wet	Yes
9	SB I-75 from Long Lake to Crooks ramp	12.185	2010	Single veh.	607.2	820	Static	Daylight	58800	Wet	Yes
10	SB I-75 from Long Lake to Crooks ramp	12.187	2012	Rear-end	596.64	820	Static	Daylight	58800	Dry	Yes
11	SB I-75 from Long Lake to Crooks ramp	12.195	2011	Swipe-same	554.4	820	Static	Daylight	58800	Wet	Yes
12	SB I-75 from Long Lake to Crooks ramp	12.195	2011	Swipe-same	554.4	820	Static	Daylight	58800	Dry	Yes
13	SB I-75 from Long Lake to Crooks ramp	12.214	2010	Swipe-same	454.08	820	Static	Daylight	58800	Dry	Yes
14	SB I-75 from Long Lake to Crooks ramp	12.218	2010	Head-on	432.96	820	Static	Dark	58800	Dry	Yes
15	SB I-75 from Long Lake to Crooks ramp	12.218	2010	Single veh.	432.96	820	Static	Dark	58800	Dry	Yes
16	SB I-75 from Long Lake to Crooks ramp	12.226	2010	Rear-end	390.72	820	Static	Dark	58800	Wet	Yes
17	SB I-75 from Long Lake to Crooks ramp	12.233	2011	Single veh.	353.76	820	Static	Daylight	58800	Snowy	Yes
18	SB I-75 from Long Lake to Crooks ramp	12.252	2011	Swipe-same	253.44	820	Static	Daylight	58800	Dry	Yes
19	SB I-75 from Long Lake to Crooks ramp	12.271	2012	Swipe-same	153.12	820	Static	Daylight	58800	Dry	Yes
20	SB I-75 from Long Lake to Crooks ramp	12.271	2011	Single veh.	153.12	820	Static	Dark	58800	Wet	Yes
21	SB I-75 from Long Lake to Crooks ramp	12.271	2011	Swipe-same	153.12	820	Static	Daylight	58800	Dry	Yes
22	SB I-75 from Long Lake to Crooks ramp	12.271	2011	Single veh.	153.12	820	Static	Daylight	58800	Snowy	Yes
23	SB I-75 from Long Lake to Crooks ramp	12.292	2011	Other	42.24	820	Static	Dark	58800	Snowy	Yes
24	SB I-75 from Long Lake to Crooks ramp	12.309	2011	Swipe-same	-47.52	820	Static	Daylight	58800	Dry	Yes
25	SB I-75 from Long Lake to Crooks ramp	12.318	2012	Single veh.	-95.04	820	Static	Daylight	58800	Wet	Yes
26	SB I-75 from Long Lake to Crooks ramp	12.328	2010	Other	-147.84	820	Static	Daylight	58800	Dry	Yes
27	SB I-75 from Long Lake to Crooks ramp	12.337	2011	Other	-195.36	820	Static	Daylight	58800	Dry	Yes
28	SB I-75 from Long Lake to Crooks ramp	12.363	2011	Swipe-same	-332.64	820	Static	Dark	58800	Dry	Yes
29	SB I-75 from Long Lake to Crooks ramp	12.365	2012	Single veh.	-343.2	820	Static	Dark	58800	Wet	Yes

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	SB I-75 from Wattles to Long Lake	11.193	2011	Single veh.	2618.88	2600	NO	Dark	58869	Dry	No
2	SB I-75 from Wattles to Long Lake	11.2	2010	Swipe-same	2581.92	2600	NO	Daylight	58869	Dry	No
3	SB I-75 from Wattles to Long Lake	11.21	2011	Rear-end	2529.12	2600	NO	Daylight	58869	Dry	No
4	SB I-75 from Wattles to Long Lake	11.21	2011	Single veh.	2529.12	2600	NO	Daylight	58869	Wet	No
5	SB I-75 from Wattles to Long Lake	11.21	2010	Rear-end	2529.12	2600	NO	Daylight	58869	Dry	No
6	SB I-75 from Wattles to Long Lake	11.229	2010	Angle	2428.8	2600	NO	Dark	58869	Dry	No
7	SB I-75 from Wattles to Long Lake	11.248	2011	Other	2328.48	2600	NO	Daylight	58869	Dry	No
8	SB I-75 from Wattles to Long Lake	11.267	2011	Single veh.	2228.16	2600	NO	Dark	58869	Wet	No
9	SB I-75 from Wattles to Long Lake	11.286	2011	Other	2127.84	2600	NO	Lights	58869	Dry	No
10	SB I-75 from Wattles to Long Lake	11.286	2011	Single veh.	2127.84	2600	NO	Dark	58869	Wet	No
11	SB I-75 from Wattles to Long Lake	11.286	2010	Single veh.	2127.84	2600	NO	Daylight	58869	Wet	No
12	SB I-75 from Wattles to Long Lake	11.305	2010	Swipe-same	2027.52	2600	NO	Dark	58869	Dry	No
13	SB I-75 from Wattles to Long Lake	11.339	2011	Swipe-same	1848	2600	NO	Daylight	58869	Dry	No
14	SB I-75 from Wattles to Long Lake	11.343	2011	Rear-end	1826.88	2600	NO	Daylight	58869	Dry	No
15	SB I-75 from Wattles to Long Lake	11.343	2011	Single veh.	1826.88	2600	NO	Dark	58869	Dry	No
16	SB I-75 from Wattles to Long Lake	11.441	2011	Single veh.	1309.44	2600	NO	Daylight	58869	Dry	No
17	SB I-75 from Wattles to Long Lake	11.441	2010	Single veh.	1309.44	2600	NO	Daylight	58869	Dry	No
18	SB I-75 from Wattles to Long Lake	11.475	2012	Rear-end	1129.92	2600	NO	Daylight	58869	Dry	No
19	SB I-75 from Wattles to Long Lake	11.676	2012	Other	68.64	2600	NO	Daylight	58869	Dry	No
20	SB I-75 from Wattles to Long Lake	11.676	2011	Angle	68.64	2600	NO	Dark	58869	Snowy	No
21	SB I-75 from Wattles to Long Lake	11.691	2012	Single veh.	-10.56	2600	NO	Daylight	58869	Dry	No
21	SB I-75 from Wattles to Long Lake	11.926	2012	Other	-1251.36	2600	NO	Dusk	58869	Dry	No

22	SB I-75 from Wattles to Long Lake	11.987	2012	Single veh.	-1573.44	2600	NO	Dark	58869	Snowy	No
23	SB I-75 from Wattles to Long Lake	11.987	2010	Rear-end	-1573.44	2600	NO	Dark	58869	Dry	No
24	SB I-75 from Wattles to Long Lake	12.024	2012	Single veh.	-1768.8	2600	NO	Dark	58869	Dry	No
25	SB I-75 from Wattles to Long Lake	12.062	2011	Rear-end	-1969.44	2600	NO	Daylight	58869	Dry	No
26	SB I-75 from Wattles to Long Lake	12.062	2011	Single veh.	-1969.44	2600	NO	Dark	58869	Snowy	No
27	SB I-75 from Wattles to Long Lake	12.081	2010	Rear-end	-2069.76	2600	NO	Dark	58869	Dry	No
28	SB I-75 from Wattles to Long Lake	12.081	2010	Swipe-same	-2069.76	2600	NO	Daylight	58869	Dry	No
29	SB I-75 from Wattles to Long Lake	12.081	2010	Single veh.	-2069.76	2600	NO	Dark	58869	Wet	No
30	SB I-75 from Wattles to Long Lake	12.091	2011	Single veh.	-2122.56	2600	NO	Daylight	58869	Snowy	No
31	SB I-75 from Wattles to Long Lake	12.1	2011	Rear-end	-2170.08	2600	NO	Dark	58869	Dry	No
32	SB I-75 from Wattles to Long Lake	12.1	2010	Swipe-same	-2170.08	2600	NO	Dawn	58869	Wet	No
33	SB I-75 from Wattles to Long Lake	12.138	2011	Swipe-same	-2370.72	2600	NO	Dark	58869	Wet	No
34	SB I-75 from Wattles to Long Lake	12.157	2012	Single veh.	-2471.04	2600	NO	Daylight	58869	Wet	No
35	SB I-75 from Wattles to Long Lake	12.165	2010	Other	-2513.28	2600	NO	Daylight	58869	Wet	No
36	SB I-75 from Wattles to Long Lake	12.167	2012	Rear-end	-2523.84	2600	NO	Daylight	58869	Dry	No
37	SB I-75 from Wattles to Long Lake	12.167	2010	Single veh.	-2523.84	2600	NO	Daylight	58869	Wet	No
38	SB I-75 from Wattles to Long Lake	12.172	2011	Single veh.	-2550.24	2600	NO	Daylight	58869	Icy	No
39	SB I-75 from Wattles to Long Lake	12.175	2012	Single veh.	-2566.08	2600	NO	Dark	58869	Icy	No
40											
41											
42											
43											
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45											
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47											

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	NB I-75 from 12 Mile to 13 Mile	4.559	2011	Single veh.	744.48	1080	Digital	Lights	80100	Wet	No
2	NB I-75 from 12 Mile to 13 Mile	4.569	2011	Rear-end	691.68	1080	Digital	Daylight	80100	Wet	No
3	NB I-75 from 12 Mile to 13 Mile	4.569	2011	Rear-end	691.68	1080	Digital	Dawn	80100	Wet	No
4	NB I-75 from 12 Mile to 13 Mile	4.569	2011	Rear-end	691.68	1080	Digital	Daylight	80100	Wet	No
5	NB I-75 from 12 Mile to 13 Mile	4.619	2011	Rear-end	427.68	1080	Digital	Daylight	80100	Dry	No
6	NB I-75 from 12 Mile to 13 Mile	4.619	2011	Other	427.68	1080	Digital	Daylight	80100	Wet	No
7	NB I-75 from 12 Mile to 13 Mile	4.619	2011	Rear-end	427.68	1080	Digital	Lights	80100	Wet	No
8	NB I-75 from 12 Mile to 13 Mile	4.62	2011	Rear-end	422.4	1080	Digital	Daylight	80100	Dry	No
9	NB I-75 from 12 Mile to 13 Mile	4.869	2011	Swipe-same	-892.32	1080	Digital	Daylight	80100	Dry	No
10	NB I-75 from 12 Mile to 13 Mile	4.87	2011	Single veh.	-897.6	1080	Digital	Dark	80100	Dry	No
11	NB I-75 from 12 Mile to 13 Mile	5.024	2011	Rear-end	-1710.72	1080	Digital	Lights	80100	Wet	No
12	NB I-75 from 12 Mile to 13 Mile	5.169	2011	Rear-end	-2476.32	1080	Digital	Daylight	80100	Dry	No
13	NB I-75 from 12 Mile to 13 Mile	5.174	2011	Single veh.	-2502.72	1080	Digital	Dark	80100	Dry	No
14	NB I-75 from 12 Mile to 13 Mile	5.224	2011	Angle	-2766.72	1080	Digital	Daylight	80100	Uncoded	No
15	NB I-75 from 12 Mile to 13 Mile	5.224	2011	Rear-end	-2766.72	1080	Digital	Daylight	80100	Dry	No
16	NB I-75 from 12 Mile to 13 Mile	5.324	2011	Other	-3294.72	1080	Digital	Dark	80100	Wet	No
17	NB I-75 from 12 Mile to 13 Mile	5.329	2011	Rear-end	-3321.12	1080	Digital	Dark	80100	Dry	No
18	NB I-75 from 12 Mile to 13 Mile	5.368	2011	Single veh.	-3527.04	1080	Digital	Dark	80100	Dry	No
19	NB I-75 from 12 Mile to 13 Mile	5.386	2011	Rear-end	-3622.08	1080	Digital	Daylight	80100	Wet	No
20	NB I-75 from 12 Mile to 13 Mile	5.386	2011	Rear-end	-3622.08	1080	Digital	Daylight	80100	Dry	No
21	NB I-75 from 12 Mile to 13 Mile	5.386	2011	Rear-end	-3622.08	1080	Digital	Daylight	80100	Dry	No
22	NB I-75 from 12 Mile to 13 Mile	5.386	2011	Swipe-same	-3622.08	1080	Digital	Daylight	80100	Dry	No
23	NB I-75 from 12 Mile to 13 Mile	5.391	2011	Swipe-opp.	-3648.48	1080	Digital	Dark	80100	Snowy	No
24	NB I-75 from 12 Mile to 13 Mile	5.4	2011	Rear-end	-3696	1080	Digital	Daylight	80100	Dry	No
25	NB I-75 from 12 Mile to 13 Mile	5.42	2011	Swipe-same	-3801.6	1080	Digital	Daylight	80100	Dry	No

Vehicle Accident Matrix											
	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	NB I-75 from 12 Mile to 13 Mile	4.669	2012	Rear-end	163.68	1080	Digital	Daylight	80100	Dry	No
2	NB I-75 from 12 Mile to 13 Mile	4.869	2012	Single veh.	-892.32	1080	Digital	Daylight	80100	Wet	No
3	NB I-75 from 12 Mile to 13 Mile	4.87	2012	Single veh.	-897.6	1080	Digital	Daylight	80100	Wet	No
4	NB I-75 from 12 Mile to 13 Mile	4.924	2012	Rear-end	-1182.72	1080	Digital	Daylight	80100	Wet	No
5	NB I-75 from 12 Mile to 13 Mile	4.924	2012	Swipe-same	-1182.72	1080	Digital	Daylight	80100	Wet	No
6	NB I-75 from 12 Mile to 13 Mile	5.024	2012	Swipe-same	-1710.72	1080	Digital	Daylight	80100	Wet	No
7	NB I-75 from 12 Mile to 13 Mile	5.069	2012	Rear-end	-1948.32	1080	Digital	Daylight	80100	Dry	No
8	NB I-75 from 12 Mile to 13 Mile	5.274	2012	Rear-end	-3030.72	1080	Digital	Daylight	80100	Wet	No
9	NB I-75 from 12 Mile to 13 Mile	5.324	2012	Rear-end	-3294.72	1080	Digital	Daylight	80100	Dry	No
10	NB I-75 from 12 Mile to 13 Mile	5.386	2012	Rear-end	-3622.08	1080	Digital	Daylight	80100	Icy	No
11	NB I-75 from 12 Mile to 13 Mile	5.4	2012	Swipe-same	-3696	1080	Digital	Dark	80100	Dry	No
12	NB I-75 from 12 Mile to 13 Mile	5.405	2012	Single veh.	-3722.4	1080	Digital	Dusk	80100	Dry	No
13	NB I-75 from 12 Mile to 13 Mile	5.422	2012	Single veh.	-3812.16	1080	Digital	Daylight	80100	Icy	No

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	SB I-75 from 12 Mile to 13 Mile	4.823	2011	Rear-end	353.76	1080	Digital	Daylight	80100	Wet	No
2	SB I-75 from 12 Mile to 13 Mile	4.849	2011	Rear-end	216.48	1080	Digital	Daylight	80100	Dry	No
3	SB I-75 from 12 Mile to 13 Mile	4.852	2011	Rear-end	200.64	1080	Digital	Daylight	80100	Dry	No
4	SB I-75 from 12 Mile to 13 Mile	4.868	2011	Rear-end	116.16	1080	Digital	Daylight	80100	Dry	No
5	SB I-75 from 12 Mile to 13 Mile	4.923	2011	Single veh.	-174.24	1080	Digital	Dark	80100	Dry	No
6	SB I-75 from 12 Mile to 13 Mile	4.923	2011	Other	-174.24	1080	Digital	Daylight	80100	Dry	No
7	SB I-75 from 12 Mile to 13 Mile	4.923	2011	Rear-end	-174.24	1080	Digital	Lights	80100	Dry	No
8	SB I-75 from 12 Mile to 13 Mile	4.923	2011	Rear-end	-174.24	1080	Digital	Lights	80100	Dry	No
9	SB I-75 from 12 Mile to 13 Mile	5.173	2011	Rear-end	-1494.24	1080	Digital	Daylight	80100	Dry	No
10	SB I-75 from 12 Mile to 13 Mile	5.223	2011	Rear-end	-1758.24	1080	Digital	Lights	80100	Dry	No
11	SB I-75 from 12 Mile to 13 Mile	5.323	2011	Rear-end	-2286.24	1080	Digital	Daylight	80100	Dry	No
12	SB I-75 from 12 Mile to 13 Mile	5.349	2011	Rear-end	-2423.52	1080	Digital	Lights	80100	Dry	No
13	SB I-75 from 12 Mile to 13 Mile	5.368	2011	Swipe-same	-2523.84	1080	Digital	Dark	80100	Dry	No
14	SB I-75 from 12 Mile to 13 Mile	5.376	2011	Other	-2566.08	1080	Digital	Daylight	80100	Dry	No
15	SB I-75 from 12 Mile to 13 Mile	5.385	2011	Rear-end	-2613.6	1080	Digital	Daylight	80100	Wet	No
16	SB I-75 from 12 Mile to 13 Mile	5.404	2011	Rear-end	-2713.92	1080	Digital	Daylight	80100	Dry	No
17	SB I-75 from 12 Mile to 13 Mile	5.421	2011	Rear-end	-2803.68	1080	Digital	Dusk	80100	Dry	No

Vehicle Accident Matrix

	Accident Location/ Freeway	Mile Point	Year	Reason for Crash	Distance from exist billboard	Billboard Distance from on/off ramp	Digital or static sign	Light Condition	Traffic Counts	Weather at the time of accident	Curve in Road near accident
	Area Within 1,000' of Existing Billboard										
1	SB I-75 from 12 Mile to 13 Mile	4.792	2012	Rear-end	517.44	1080	Digital	Daylight	80100	Dry	No
2	SB I-75 from 12 Mile to 13 Mile	4.868	2012	Rear-end	116.16	1080	Digital	Daylight	80100	Dry	No
3	SB I-75 from 12 Mile to 13 Mile	4.923	2012	Swipe-same	-174.24	1080	Digital	Daylight	80100	Dry	No
4	SB I-75 from 12 Mile to 13 Mile	4.923	2012	Single veh.	-174.24	1080	Digital	Dark	80100	Icy	No
5	SB I-75 from 12 Mile to 13 Mile	5.323	2012	Other	-2286.24	1080	Digital	Daylight	80100	Dry	No
6	SB I-75 from 12 Mile to 13 Mile	5.328	2012	Rear-end	-2312.64	1080	Digital	Daylight	80100	Dry	No
7	SB I-75 from 12 Mile to 13 Mile	5.368	2012	Rear-end	-2523.84	1080	Digital	Daylight	80100	Dry	No
8	SB I-75 from 12 Mile to 13 Mile	5.368	2012	Rear-end	-2523.84	1080	Digital	Daylight	80100	Wet	No
9	SB I-75 from 12 Mile to 13 Mile	5.385	2012	Rear-end	-2613.6	1080	Digital	Daylight	80100	Dry	No
10	SB I-75 from 12 Mile to 13 Mile	5.385	2012	Rear-end	-2613.6	1080	Digital	Lights	80100	Dry	No
11	SB I-75 from 12 Mile to 13 Mile	5.395	2012	Rear-end	-2666.4	1080	Digital	Lights	80100	Dry	No
12	SB I-75 from 12 Mile to 13 Mile	5.399	2012	Rear-end	-2687.52	1080	Digital	Daylight	80100	Dry	No
13	SB I-75 from 12 Mile to 13 Mile	5.404	2012	Rear-end	-2713.92	1080	Digital	Lights	80100	Dry	No
14	SB I-75 from 12 Mile to 13 Mile	5.414	2012	Single veh.	-2766.72	1080	Digital	Lights	80100	Icy	No