

City of Toronto

**SAFETY IMPACTS AND REGULATIONS OF ELECTRONIC
STATIC ROADSIDE ADVERTISING SIGNS
TECHNICAL MEMORANDUM #1 – CURRENT RESEARCH
LITERATURE REVIEW**

FINAL REPORT



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1 Introduction

Like many other industries, the outdoor advertising industry is embracing and applying new technologies. As technology continues to advance, the industry is taking advantage of electronic signs, some of which are Static Electronic Signs (SES). SES are electronic, or digital signs that use an LED display and have the ability to automatically change the message shown on the sign at regular intervals. The ability to show multiple advertisement copies on a single sign, along with their brightness, high-resolution capacities and attention-grabbing potential is appealing to the outdoor advertising industry. These signs are usually controlled remotely and some can even display full-motion videos. For the purpose of this study, only electronic signs showing static copies are being considered, and video advertising signs are not included.

The advertising industry is, by nature, seeking people's attention and roadside SES can be highly conspicuous and compete for drivers' attention. While studies have proven that electronic advertising displays have impacts on driver distraction, the actual effects of this sign technology on collision experience have been difficult to prove conclusively. As a result, many government agencies are adopting guidelines or regulations for SES in response to an ever-increasing number of installation requests. The objective of these guidelines is to control aspects of the placement and operation of these signs, such as brightness, message duration, and message change intervals, which can have impacts on the surrounding environment and traffic.

In order to gain a better understanding of the safety impacts of SES the City directed CIMA to undertake a 3-part review of electronic static advertising signs, which included the following components:

- 1) Review of current research literature;
- 2) Before/after collision analysis of existing electronic signs, including:
 - a) Transit shelter scrolling advertising signs
 - b) Electronic signs at mid-block locations (expressways and arterial roads)
 - c) Electronic signs at signalized intersections;
- 3) Review of best practice guidelines and regulations in other jurisdictions.

This technical memo addresses the first component, a review of current research literature. In the sections that follow, this memorandum discusses the significance of a landmark report from NCHRP in 2009 on digital sign technology and summarizes the findings of research literature published since the 2009 NCHRP report. In addition, the City directed CIMA to include any research literature related to scrollable or changeable advertising signs located on public transit shelters as this type of advertising signage have similar ability to display changing static copy, similarly targets road users, presents similar safety concerns and are presently installed throughout the City. CIMA's review of literature on changeable transit shelter signage included studies predating the 2009 NCHRP report, as that report did not include this specific type of signage.

2 Background and Significance of NCHRP Report “Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs”, Wachtel, 2009

A thorough and comprehensive critical review of significant research on the subject was undertaken by the National Cooperative Highway Research Program (NCHRP), a research arm of the American Association of State Highway and Transportation Officials (AASHTO), in 2009. The study entitled “Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs” included an extensive and critical review of research literature published between 1983 and 2009.

2.1 Summary of Report

This document is deemed a landmark report by the City due to the extensive, comprehensive and critical review of all the recent research literature on the subject matter up to the time of its publishing, including 45 studies between 1983 and 2009. The conclusions of this report are as follows:

- Research studying the link between digital billboards and an effect on collisions have resulted in the following findings:
 - There has been no study proving a statistically significant proof of causation between digital billboards and collisions.
- Research studying the link between digital billboards and an effect on collisions have some weaknesses in that:
 - Collisions are rare events that are typically due to a chain of contributory events.
 - Collisions are under-reported. Some studies show that up to 80% of collisions may not be reported,
 - No police investigation is completed, and therefore no details are available, unless the collisions are serious.
 - The location of the collision is usually identified as the point of rest of the vehicle(s), and therefore may not be representative of where the events leading to the collisions have originated, and any potential cause to the collision. In terms of impacts of digital billboards, this would mean that some collisions for which a digital billboard may have contributed to the collision are identified as located downstream from the location of the sign.
 - Drivers tend to not report their own inattention, and identifying digital billboards as contributory to collisions may be difficult.
 - Near-misses or near-collisions are not considered as they are not documented.
- Research studying driver distraction have resulted in the following findings:

- Acceptable driver distraction duration varies between 0.75 second, 1.6 second and 2.0 seconds. Distractions resulting in looking away from the roadway for a longer period than these values are considered to be unsafe.
- Looking away from the roadway ahead for a period longer than two seconds almost doubles the risks of a collision or near collision.
- Advertising posters attract and hold drivers’ attention at the expense of the drivers’ need to scan for hazards. Their presence also increases the time for drivers to respond to hazards.
- The drivers’ experience does not seem to be a factor in the drivers’ response, but the number of distractions does. A high number of signs has an impact on the drivers’ response.
- Impacts of digital billboards on drivers’ glances and distraction have been proven and studies are fairly in agreement on the fact that digital billboards do attract drivers’ glance and distract them.
- Billboards attract drivers’ attention, regardless of the interest or relevance of the message.
- The concept of “spare attentional capacity” has been raised in some studies, and has also been used by the outdoor advertising industry to minimize the impacts of distractions caused by advertising on road safety. According to this concept, drivers would have attentional capacity that is not being used for driving tasks (spare) that would be used to look at elements irrelevant to their driving. When put in presence of roadside advertising, it is this spare attentional capacity that would be used to look at and process the advertising. The attention used to observe advertising would therefore not be taken from the driving tasks, but from this spare attentional capacity, which would have been used to observe other irrelevant elements should the advertising not been there.
- “Visual clutter has an effect on 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.”
- More long glances are made to digital billboards and other digital signs than to other traditional static billboards or at sites with “no obvious visual elements”.
- Research studying driver distraction have some weaknesses in that:
 - Studies should not only look at the mean number and duration of distractions. They should also include an analysis of the greatest number of distractions and the longest duration of glances.
 - Eye gaze is hard to measure with exactitude and requires intrusive equipment.
 - Simulations cannot reproduce appropriately the sign luminance relative to their environment, and are a simplification of driving tasks.
- The authors provided recommendations for digital billboards regulation guidelines:
 - The minimum acceptable dwell time should be calculated as the ratio of the sight distance to the digital billboards divided by the speed limit.
 - The transition time “should be essentially zero”.

- The transition between messages should not include special effects.
- Message sequencing should not be allowed.
- The amount of information displayed should be somewhat minimized, and items requiring long reading time or that drivers want to record/copy should be avoided. Specific maximum amounts of information have not been included as the authors felt more research is needed and that these amounts will vary based on different factors that vary with sign location.
- Information presentation can have a strong impact on driver distraction, but the authors felt making recommendations on this topic was “beyond the scope of their report, and, possibly, outside the authority of regulators”.
- The size of digital billboards can also have an impact on driver distraction, but the authors felt recommendations on this characteristic was “inappropriate” as regulations on the size of digital billboards depends on other factors such as land use and zoning.
- Luminance levels should be set for daytime and nighttime conditions. A maximum level above the ambient brightness level should be also set, and controlled with automatic sensors and dimmers. Additionally, a maximum luminance level should be set for fog conditions, either through a separate regulation or through automatic sensors able to detect fog conditions.
- In the event of failure, the luminance should not be higher than permitted under working conditions, and if the digital billboards cannot achieve these levels, it should automatically be turned off in case of failure.
- A minimum longitudinal spacing between digital billboards facing the same direction should be determined and not allow for more than one digital billboard to be visible to a driver at all times, on any side of the roadway.
- The authors suggest that guidelines in terms of placement of digital billboards in relation to traffic control devices and driver decision and action points on the roadway should be developed, and that guidance provided by other jurisdictions (Queensland and New South Wales, Australia, and South Africa) can be used as a starting point. These guidance include elements such as:
 - Exclusion zones with length based on the speed (v). Examples include 1.2*v for local streets, 2.5*v for multi-lane freeways, 5.0*v in advance of on-ramps and 7.5*v in advance of exit ramps.
 - The advertisement location cannot negatively impact the visibility, sight distance or efficiency of a traffic sign, or distract the drivers’ attention from a traffic sign.
 - The advertisement cannot “disrupt the flow of information from road traffic signs to drivers who encounter a series of road traffic signs”.
 - Specified minimum distances to traffic signals, lane drop, traffic sign, ramp or merge, in meters, for different environments (roadside-urban, roadside-rural, overpass, freeways).
- Roadway authorities may consider granting permits for shorter periods, such as one year, and require the permits to be renewed regularly.

- General report conclusions include:
 - “It is difficult if not impossible to design and conduct a research study whose results can be applied with confidence to DBBs [digital billboards] as a whole.” The study cites the vast number and complexity of variables affecting DBBs as challenging factors.
 - “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.”
 - Digital billboards have been proven to distract drivers, but have not been proven to have a statistically significant impact on collisions.
 - Consistency has been achieved in research results across various studies.
 - There is “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”.
 - There has not yet been proof in research studies that digital billboards cause collisions, or that they have a statistically significant impact on the number of collisions. However, this is not necessarily the standard that should be met in order to regulate digital billboards. Additionally, this lack of proof “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”.

3 Recent Research on the Impacts of Static Electronic Signs on Road Safety

The review of each study includes the following information, which is documented on a “Summary of Findings” sheet.

- Title, Authors, Date of Publication;
- Location the study was based in;
- Category of research completed (example may include: laboratory research in driver’s response; field research in driver’s response; road safety analysis; policy, standard or position of jurisdictions);
- Brief description of the study and its intent;
- Assessment of quality of background upon which the conclusions or positions were founded to document the quality of the research, leading to the degree to which the study should be considered and depended upon; and,
- Conclusions or positions relevant for the City.

These “Summary of Findings” sheets will be presented as an Appendix to the Final Report. The key information points are summarized in this section, using the following categories:

- General Study Information;
- Description and Assessment of Study; and,
- Conclusions or Positions Relevant to the City.

3.1 “The Effects of Commercial Electronic Variable Message Signs (CEVMS) on Driver Attention and Distraction: An Update”, Molino et al., 2009

3.1.1 General Study Information

In 2009, Molino and his colleagues, Jerry Wachtel, John E. Farbry, Megan B. Hermosillo, Thomas M. Granda, completed a study for the Federal Highway Administration (FHWA) in which they discussed the various types of studies that can be undertaken to identify the impacts of commercial electronic variable message signs (CEVMS) on traffic safety and their respective weaknesses (Molino et al., 2009). The study was based in the United States.

3.1.2 Description and Assessment of Study

This government agency-sponsored study discusses the types of studies that can be undertaken to understand the impacts of commercial electronic variable message signs (CEVMS) on safety, and the conclusions drawn from the experience of the authors, discussing the various study types.

For the challenges of laboratory and simulation type studies, the authors argued that the participants need to adapt to driving in a simulator, which would be substantially different from driving a real vehicle, and that there are limitations in reproducing the visual effects of a CEVMS on a simulator screen. The authors also discuss the “spare attentional capacity” theory, according to which drivers can look at CEVMS and other advertising signs when the driving task is not demanding. This theory has led to some restrictions on the placement of CEVMS in some countries.

The authors also identified weaknesses for post-hoc collision studies as follows:

- A large amount of collisions are not reported to the police;
- Causes of collisions are not always reported, especially when driver distraction or inattention is a factor;
- The police rarely has time to complete a full investigation to identify the true causes of the collision; and,
- Data needs to be collected for long periods of time, and for comparable locations.

The authors identified a number of key independent and dependent variables that can be considered in future impact studies. The recommended independent variables were billboard, roadway, driver, vehicle, and environment attributes; while the vehicle behaviour, driver and vehicle interactions, as well as driver attention and distraction were considered as dependent variables. Finally, the authors suggested a future research program in three stages. The first two stages relate to impacts on driver distraction: Stage 1 is to determine the potential for distraction of CEVMS, and Stage 2 is to determine the basis for CEVMS regulations based on eye glance and safety surrogate evaluations. Stage 3 is the determination of the relationship between CEVMS and collisions.

3.1.3 Conclusions or Positions Relevant to the City

The authors indicated that “distraction from a roadside billboard may be unconscious” and that drivers are not always aware of the fact that they are being distracted. They also implied that CEVMS with frequently changing messages can be more distracting, and can be distracting for a longer distance, as drivers may look at the sign to try to read each message until they are able to do so. In addition, the authors identified the weaknesses of the post-hoc collision studies as follows:

- A large amount of collisions are not reported to the police;
- Causes of collisions are not always reported, especially when driver distraction or inattention is a factor;
- The police rarely has time to complete a full investigation to identify the true causes of the collision; and,
- Data needs to be collected for long periods of time, and for comparable locations.

3.2 “Investigating Driver Distraction: the Effect of Video and Static Advertising”, Chattington et al., 2009

3.2.1 General Study Information

In 2009, a study was conducted in London, UK, for Transport for London (TfL), using a driving simulator and integrated eye-tracking system to compare driving behaviour across a number of experimental static and video advertising conditions, namely advert type, position of adverts and exposure during adverts (Chattington et al., 2009). The study was completed in the United Kingdom, by M. Chattington, N. Reed, D. Basacik, A. Flint, and A. Parkes.

3.2.2 Description and Assessment of Study

The main purpose of this government-sponsored study is to provide guidance on the relative level of distraction caused by roadside billboard advertising with reference to advertising type (static vs. video/dynamic), the placement of the sign relative to the road, and exposure time.

Two simulated driving routes were created in a dense, urban simulation environment, CarSim, and 48 participants, mixed by age and gender, were recruited to drive each route in both directions. Each route contained seven adverts plus some additional blank advertising boards. The objective data collected through the simulator and eye tracker were supplemented by participants’ subjective opinions collected using questionnaires. The questionnaires tested the participants’ recall of advertising, their mental workload during hazardous situations, how distracting they found video advertising, and whether they felt such advertising billboards would have an effect on safety.

It was also found that participants were more aware that their driving was impaired by the presence of video adverts than static adverts.

3.2.3 Conclusions or Positions Relevant to the City

Trial results indicated that when passing roadside adverts, drivers:

- Spent longer looking at video adverts than static adverts and glanced at them more frequently;
- Tended to show greater variation in lateral lane position with video adverts;

- Braked harder on the approach to video adverts; and
- Drove more slowly past video adverts.

3.3 “A Study of the Relationship between Digital Billboards and Traffic Safety in Albuquerque, NM”, “A Study of the Relationship between Digital Billboards and Traffic Safety in the Greater Reading Area, Berks County, Pennsylvania” and “A Study of the Relationship between Digital Billboards and Traffic Safety in Henrico County and Richmond, Virginia”, Tantala and Tantala (2010a, 2010b, 2010c)

3.3.1 General Study Information

In 2010, the authors, M.W. Tantala and A.M. Tantala Sr., conducted three research studies for the Foundation of Outdoor Advertising Research and Education (FOARE), an arm of the Outdoor Advertising Association of America (OAAA). The studies were completed for locations in New Mexico, Pennsylvania, and Virginia, respectively. The purpose of these studies was to examine the statistical relationship between digital billboards and traffic safety.

3.3.2 Description and Assessment of Study

For the first study, in Albuquerque, the authors completed a statistical analysis of collision based on collision reports. The authors analyzed up to seven (7) years of collision information, with a minimum of two years of ‘before’ and two years of ‘after’ data for each location, for 17 locations on local roads where billboards were converted to digital billboards, and summarized the data in two parts. The first part included an aggregated temporal analysis, which showed the numbers and rates of collisions before and after the installation of the billboards. The second part consisted in a spatial analysis, which is described by the authors as: “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.” Although the authors do not further discuss their methodology, and do not provide any numerical results for these coefficients, they found that “Correlation coefficients were calculated and indicated a very strong correlation of accident patterns near digital billboards when compared with the accident patterns prior to conversion.”

The second study was located in the Greater Reading Area, Berks County, Pennsylvania, and the authors analyzed up to eight (8) years of collision information, with a minimum of less than one year of ‘before’ and less than one year of ‘after’ data for each location, for 20 locations with 26 digital billboard faces, where billboards were converted to digital billboards. The third study was located in Henrico County and Richmond, Virginia, and the authors analyzed up to seven (7) years of collision information, with a minimum of less than one year of ‘before’ and less than one year of ‘after’ data for each location, for 10 locations with 14 digital billboard faces, where billboards were converted to digital billboards. For these studies the authors conducted an analysis in three parts.

The first two parts are similar to the first study: a temporal analysis and a spatial analysis. The third part consisted in a before and after analysis using the Empirical Bayes method and comparison sites. Safety performance functions were developed and used in the determination of the index of effectiveness.

These studies show weaknesses. In all three studies, the authors used short before and after periods on some sites. For the first study the minimum period was approximately two years, where for the second and third studies, some sites had less than one year of ‘before’ data and less than one year of ‘after’ data. The authors do not seem to have eliminated any of the data for the period shortly after the installation in order to eliminate the collisions due to the novelty of the digital signs. Additionally, although the second and third studies use a before and after study with EB method and comparison sites, the methodologies used in the first study and in the first two parts of the second and third studies show weaknesses. Temporal statistics such as the change and percent change in the number of collisions, the change in the average number of collisions per month, or the peak, minimum or average number of collisions per month do not consider any other factors and are not necessarily representative of the impact of the installation of digital billboards. The change and percent change in the rate of collisions per million vehicles does provide consideration for traffic volumes. The temporal statistics calculated by the authors do not control for the regression-to-the-mean phenomenon. The before and after study with EB methodology does, however, account for this phenomenon, and it was used in the later two studies. The analysis completed in terms of “spatial statistics” was not described by the authors, and no information was provided, other than the description provided above. It is therefore impossible to assess and comment on the methodology used.

3.3.3 Conclusions or Positions Relevant to the City

For all three studies, the authors concluded that the installation of digital billboards had no statistically significant impact on the number of collisions in the vicinity of the signs. They also found that the age of the driver (younger vs. older driver) and the time of day (daytime vs. nighttime) had no impact on the number of collisions in the vicinity of the digital billboards. For the later two studies, the authors also mentioned that the before and after study with EB method showed no statistically significant increases in collisions after the installation of the digital billboard, and “that the safety near this locations are consistent with the model benchmarked” by the comparison sites.

When considering these conclusions, the city should take into consideration that some of the authors’ analyses do not consider any other factors, such as traffic volumes, and some consider traffic volumes but not the regression-to-the-mean phenomenon. Some of their analyses are briefly explained and it is therefore difficult to understand what specific analysis was done.

3.4 “Assessing the Empirical Evidence on the Safety Impact of Electronic Static Displays” and “Are Roadside Electronic Static Displays a Threat to Safety?”, Friswell et al., 2011a and 2011b

3.4.1 General Study Information

In 2011, Friswell and her colleagues completed an international literature review on electronic static displays, which was documented in two separate conferences (Friswell et al., 2011a & 2011b). This study was undertaken to summarize some of SES’ safety implications for policy makers to establish a regulatory balance between protecting public safety and satisfying the interests of businesses. Both papers were authored by R. Friswell, E. Vecellio, R. Grzebieta, J. Hatfield, L. Mooren, M. Cleaver, and M. DeRoos. The first one was presented at the Australasian College of Road Safety Conference in September 2011, and the second one was presented at the Australasian Road Safety Research, Policing and Education Conference in November 2011.

3.4.2 Description and Assessment of Study

The study sponsor is unknown, but the study provided a broad basis for critical analysis of research findings, in the past decade, on the safety impact of electronic static displays and the nature of driver distraction. The study highlighted the limitations of various study types. They mentioned that real-world studies conducted under normal traffic conditions have the benefit of incorporating real-world driving conditions, but that capturing all of the relevant information and its complexity is difficult. Laboratory studies of simulated driving typically can better detect and document drivers' responses as they are much more precise in their instrumentation. However, these studies have limitations in terms of realism as the driving environment may be simplified and different from a real driving environment. On-road condition studies require a comparison of conditions before and after the installation of an SES, but also require that no other variable changes. Comparison sites used in the analysis are helpful in terms of controlling for the changes in other variables, but it is very difficult to find comparison sites that are "truly comparable". These studies also need to cover lengthy periods of time to have sufficient data, and the full distance where SES are visible, as well as some distance after passing the sign should be used. The authors also warn that study sampling should be carefully considered, as different driver types may have different driving behaviours and process information at different speeds. Moreover, Advertisements often target certain groups, and therefore may have a larger distracting impact on those groups than other.

Studies of surrogate measures, such as gaze, driving behaviour and collisions also have limitations. Measuring gaze behaviour does not account for cognitive distraction, when a driver's gaze is directed towards the road, but the driver's attention is elsewhere. Different driving behaviours may not be affected in the same way by driver distractions, and such studies can lead to bias results. Collision analyses study very rare events (collisions) that are caused by a multitude of factors, and cannot be only attributed to the installation of SES. Additionally, collisions are often under-reported. Collision analyses should take into account collision trends and compare collisions prior to and after the installation of SES. Bayesian estimation techniques are therefore preferred for this type of analysis as they yield more accurate conclusions.

The authors reviewed 11 studies that were directly related to SES, six of which were completed by Tantala and Tantala. The authors also mentioned that most of the studies reviewed analyzed collision data across various sites, and that most SES were in fact replacing pre-existing static advertisement signs.

3.4.3 Conclusions or Positions Relevant to the City

It was found that factors that are likely to affect the relationship between SES, distraction and safe driving are: the extent to which images changes, the perceptual quality of the images, the physical dimensions and location of the image relative to the driver, the dwell time, the transition time, the speed limit of the road, the spacing between signs on the roadway, the sign luminance, the sign size, lateral position and elevation, the salience of the images, the extent to which SES resemble other important information such as traffic signs and signals, characteristics of the driver (age, experience, etc.), the complexity of the driving task, and the ability of the driver to ignore SES or adapt their driving (Friswell et al., 2011a).

The study also provided some guidelines to investigate the effect of electronic static displays relating to the length of roadway over which the effects of signs are measured. According to the authors, an accurate estimate of the impact of an electronic static display would require measures over the entire

distance from which the sign may be seen and this distance will vary according to the size and location of each sign.

The authors also concluded that “there does seem to be evidence that ESDs [SES] can have a negative impact on attention, driving performance and safety” and recommend that SES be prohibited.

3.5 “Statistical Analysis of the Relationship between On-Premise Digital Signage and Traffic Safety”, Hawkins et al., 2012

3.5.1 General Study Information

The authors of this study completed a statistical analysis of the relationship between first party digital signage and traffic safety, with the objective of conducting “a robust statistical analysis of the safety impacts of on-premise digital signs” (Hawkins et al., 2012). This study was sponsored by the Signage Foundation, Inc., and the Texas Engineering Extension Service. This paper was authored by H.G. Hawkins, Jr., P-F Kuo, D. Lord.

3.5.2 Description and Assessment of Study

This United States-based industry-sponsored study evaluated the impacts on safety of first party digital signs using sites in four states: California, North Carolina, Ohio and Washington. The authors used a very sound methodology, completing a before and after study with Empirical Bayes, using Safety Performance Functions (SPFs) and calibration factors for each location. The report also presents a thorough description and discussion of various before and after methodologies, demonstrating the understanding of the authors. The authors used a sample size of 135 treated sites on major roads, in four states.

The collision and road characteristics information were found in the FHWA Highway Safety Information System (HSIS). The SPFs were selected from the Highway Safety Manual (HSM) (roads with 2 to 5 lanes) and from a Texas Transportation Institute study (Bonneson and Pratt, 2008) for roads with 6 and 8 lanes. Calibration factors were calculated and used for each site and each year of the study using the HSM methodology. Sign information was obtained from two sign manufacturing companies. Data sets were merged, and sign locations were verified through online digital images (Google Streetsview). A total of 135 sites were chosen for the study, all located on major roadways (for which collision information was available through the Highway Safety Information System (HSIS)). All signs were installed in 2006 or 2007, providing enough information in both the before and the after period. Only first party digital signs were included in this study.

The authors used the Empirical Bayes methodology for their analysis, and the Naïve before and after methodology for comparison purposes only. They calculated the index of effectiveness, θ , which shows the impact of the installation of SES on the number of collisions. A positive value of θ shows an increase in the number of collisions, a negative value of θ shows a decrease in the number of collisions, and a value of $\theta=1$ shows that there is no change in the number of collisions. They also calculated and showed lower bound and upper bound values, which represent the 95% confidence interval. A confidence interval for the value of θ which includes the value 1.0 shows that there is insufficient evidence to conclude that the index of effectiveness, θ , is different from 1. For example, a value of $\theta=1.25$, with a lower bound of 0.00 and an upper bound of 2.53 would suggest that it is impossible to conclude that θ is different from 1. In this case, it would be impossible to conclude that the installation of a SES would have a negative or positive impact on the number of collisions.

3.5.3 Conclusions or Positions Relevant to the City

Using the Empirical Bayes methodology, the authors found that for all four states combined or for each state individually, all of the intervals included a safety effect of 1.0 and it was impossible to conclude that the index of effectiveness, θ , is different from 1. The authors therefore concluded that there was no statistically significant change in the number of collisions after the installation of first party digital signs.

The authors also analyzed collisions by type, and found no changes in multi-vehicle collisions. They also found no changes in single-vehicle collisions, except in California where there was a statistically significant decrease in the number of collisions. However, the authors only used 6 sites in California, therefore the results for all states combined have not been impacted.

The authors also analyzed the impacts of signs with different characteristics, using an “ANOVA analysis method to evaluate whether the means of the safety index (θ) among the different characteristics of signs are equal”, and found no statistically significant differences between the means of safety indexes for the following characteristics:

- Colour: single colour vs. multiple colour;
- Sign dimensions: less than 10 ft², 10-15 ft², more than 15 ft²; and,
- Business type: restaurant, pharmacy or retail store, hotel, gas station, auto shop, other.

Results from this study should be taken with consideration when applied to third-party SES, as the authors only used first party SES to complete their analysis.

3.6 “A statistical Analysis of the Impact of Advertising Signs on Road Safety”, Yannis et al., 2012

3.6.1 General Study Information

In 2012, Yannis and his colleagues completed a statistical analysis of the impact of advertising signs on road safety in the greater Athens area, Greece (Yannis et al., 2012). Although this study was not specifically completed on SES, the methodology and results can identify correlations between the placement or removal of static advertising signs and the number of collisions. This paper was authored by G. Yannis, E. Papadimitriou, P. Papantoniou, and C. Voulgari.

3.6.2 Description and Assessment of Study

The sponsors to this study are unknown. The authors completed a before and after study with comparison group, using one comparison site for each treated site. The analysis was performed for nine treated sites with various characteristics (installation vs. removal of sign, segment length, number of lanes, traffic separation) in peri-urban and urban areas. The authors weighted the safety effects using an odds-ratio for the before and after periods.

The authors followed a sound methodology, however the sample size is rather small, especially as characteristics vary from one site to the other. Additionally, the results should be used with caution as this study was completed for the installation and removal of static signs as opposed SES. It is however believed that the results are consistent with other studies, completed for SES signs.

3.6.3 Conclusions or Positions Relevant to the City

The authors found no statistically significant impacts on the number of collisions from either placement or removal of an advertising sign, for each specific site and for the group of sites as a whole. It was argued that drivers are already overloaded with distracting information, such as traffic signs, direction signs, on-site advertisement, presence of pedestrians, and traffic, and the advertising signs do not further distract the drivers. The authors also mention that in previous researches “it has been proved that in-vehicle distraction factors are more dangerous than external ones”.

3.7 “Effects of Electronic Billboards on Driver Distraction”, Dukic et al., 2013

3.7.1 General Study Information

Following the installation of some SES along a four-lane motorway in central Stockholm, the Swedish Transport Administration sponsored a study in 2012 to evaluate the effects of electronic billboards on the attention of drivers (Dukic et al., 2013). This paper was authored by T. Dukic, C. Ahlstrom, C. Patten, C. Kettwich, K. Kircher

3.7.2 Description and Assessment of Study

The objective of this government-sponsored study was to evaluate, in a field setting, the effects of electronic billboards on the visual behaviour and driving performance of drivers. The study included 41 experienced drivers, between 35 and 55 years old. Twenty participants drove during daytime, while 21 drove during nighttime. The experimental freeway route was 40 km long, and took approximately 40 min to complete. Navigational instructions were provided by an experimenter present in the vehicle. The route included 4 electronic signs, with static messages changing every 7 seconds, one large static billboard, and 7 traffic signs, including 3 overhead gantries with navigation information, 2 guide signs and one bus lane sign. The visual behaviour of drivers was measured with a head-mounted eye tracker in an instrumented vehicle. Following the field data collection, statistical analyses were completed with a two-way analysis of variance for time-of-day and sign type. The authors defined that “a driver is considered to be visually distracted when looking at a billboard for more than two seconds with a single long glance or if the driver looks away from the road for a high percentage of time”.

The author found a statistically significant increase in the indicators studied for electronic billboards as compared to other signs. The confidence level used for the analysis was 0.95, and results showed increases both during daytime and nighttime. The indicators studied by the authors were:

- The dwell time, which is the “accumulated total time that the participants looked at a sign”;
- The visual time sharing, which is the “percentage of time that the driver looked at a sign, defined as the dwell time divided by the exposure time”;
- The number of fixations, which is the “total amount of fixations directed towards a sign”; and
- The maximum fixation duration, which is the “duration of the longest fixation directed towards a sign”

3.7.3 Conclusions or Positions Relevant to the City

The authors found that drivers may be glancing at electronic signs in different ways. Drivers can perform routine scanning leading to identification of the electronic sign, followed by a glance to read and understand the sign after ensuring the traffic conditions allow time to do so, in which case the glance is planned and unlikely to result in a dangerous situation. However, the drivers' attention can also be absorbed by the electronic sign, or be involuntary attracted to the sign, leading to the driver being distracted from the driving tasks.

The authors concluded that "Overall, the electronic billboards attract more visual attention than the other traffic signs included in the study. Dwell times are longer, the visual time sharing intensity is higher, very long single glances are more frequent, and the number of fixations is greater for the electronic billboards". However, the comparison results indicated that there was no evidence to conclude that the number of times drivers looked at electronic signs during daytime and nighttime were statistically different. The authors also concluded that "No consistent significant changes in driving behaviour with respect to speed, lateral placement of the vehicle or headway could be found between the phases before the billboard was visible, while it was visible and after it was passed."

3.8 Conclusions

Key conclusions from the studies reviewed by CIMA, along with their consistency with the conclusions of the NCHRP report, are discussed below.

- Driver Distraction:
 - "Distraction from a roadside billboard may be unconscious" and drivers are not always aware of the fact that they are being distracted. (Molino et al., 2009)
 - SES are generally more distracting than other static billboards or traffic signs (Molino et al., 2009; Dukic et al., 2013)
 - Driver distraction from SES is affected by various characteristics of the SES (content, format, location), speed limit of the roadway and characteristics of the driver. (Friswell et al., 2011a and 2011b)
 - Driver distraction should be measured for the entire length for which the sign can be seen. (Friswell et al., 2011a and 2011b)
 - There is evidence that SES can be distractive and have a negative impact on safety, and they should be prohibited. (Friswell et al., 2011a and 2011b)
 - Driver attention can be diverted to SES in an intentional, planned way when drivers consciously decide to look at SES after ensuring the traffic conditions allow time to do so. Driver may also be distracted when their attention is involuntary attracted to the sign. (Dukic et al., 2013)
 - There is no evidence to conclude that the number of times drivers looked at electronic signs during daytime and nighttime were statistically different. (Dukic et al., 2013)
- Collisions
 - No statistically significant impact of SES on collisions was found by Tantala and Tantala (Tantala and Tantala, 2010a, 2010b, 2010c).

- In a sound industry-sponsored study, first party digital signs were not found to have a statistically significant impact on the number of collisions. (Hawkins et al., 2012)
- In the same sound industry-sponsored study of first party digital signs, it was found that the following attributes do not have a statistically significant impact on the means of safety indexes: sign colours, sign dimensions, and type of business advertised. (Hawkins et al., 2012)
- A study of placement and removal of static advertising signs in Greece found no statistically significant impacts on the number of collisions from either placement or removal of an advertising sign, for each specific site and for the group of sites as a whole. (Yannis et al., 2012)

Most of the above conclusions, found in literature published after the publication of the NCHRP “Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs” by Wachtel et al. in 2009, are consistent with the conclusions found in this landmark report. The studies published since 2009 do not reiterate all of the conclusions found by the comprehensive study undertaken by Wachtel and his colleagues, but the conclusions that were reached by the reviewed studies are in line with those of Wachtel et al.

Most industry-sponsored studies reviewed were also found to have flaws in their methodology, as the ones discussed in Wachtel et al. However, the study by Hawkins, Kuo and Lord (Hawkins et al., 2009), which was sponsored by the industry, was found to have a sound methodology for a before and after analysis of collisions at a large number of locations. The authors’ conclusions that no statistically significant impact on the number of collisions was found for the 135 first party signs studies, are consistent with the conclusions of other studies and those of Wachtel et al.

4 Bus Shelter Advertising Signs

A comprehensive review of research literature was conducted on the impacts of scrolling, or changeable, bus shelter advertising on traffic safety, however, no research-based studies were found.

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