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:

Interstate and Controlled Access Highways

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 ($1/10^{th}$) 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.