SECTION 9.

SUMMARY AND CONCLUSIONS

This project has focused on three overlapping pillars of support in its effort to develop suggested guidelines for the control of DBBs: (a) human factors practices and principles; (b) guidelines and regulations currently in place in the US and abroad; and (c) the research literature.

Human factors principles have been developed over many years through empirical research, and have seen applications in practice regarding road safety throughout the developed world. Such principles and practices are codified in standards such as the MUTCD and SARTSM, to name but two, which were reviewed for this report. The wisdom of such human factors practices and principles is tested daily on streets and highways, and they are constantly being modified or supplemented when a "better mousetrap" is developed through research (recent examples include the development and implementation of the Clearview font for road signs, and the growing use of wider pavement markings to accommodate our ageing driver population).

And, in the guidelines and regulations that we reviewed, it was rewarding to learn that many of them, too, come from a solid research base. Examples of these empirically grounded guidelines include those in South Africa, Queensland, Australia, and The Netherlands (currently under development). Of course, some guidelines and regulations, even though based on sound research, either don't get enforced, or don't make it out of the draft stage. Thus, one of our goals has been to seek out the best supported and most practical guidelines that have been promulgated, review them based on their grounding in research and/or sound human factors practice, and hold them out as candidates that might serve as models for others to consider.

Our comprehensive and critical review of the literature focused on studies undertaken since the FHWA report of 2001, with the addition of several earlier studies that were included because of their relevance and because they were not previously given in-depth consideration in this context. As required by the program Statement of Work, we also separately reviewed research undertaken by or on behalf of the outdoor advertising industry.

Unfortunately, this issue is enormously difficult to study. This is because every billboard, road, and driver is different. A study evaluating a four-second message display interval might obtain quite different results from one using eight-seconds. A study in daylight will almost certainly find different driver responses than the identical study conducted at night. And a study conducted with free-flowing traffic may have a different outcome than one that examines the same road and the same billboard when traffic demands are greater. In addition, the key selling point of DBBs is that they can change messages every few seconds, and it is technically possible for them not to repeat the same message during a several hour cycle. Thus, studying such billboards *in situ* confronts the researcher with the added problem that it may be difficult to compare the experiences of any two (or more) drivers as they pass the DBBs under study for the simple reason that these drivers will, in all likelihood, experience signs with different content, different brightness levels, different graphics, and different font styles and sizes. This suggests that laboratory studies, despite what we believe to be important limitations, may permit better control over these inherent sign design and operational variables. Another alternative, not yet attempted with DBBs to our knowledge, involves a cooperative effort between researcher and sign operator in a field setting, so that the many relevant variables can be controlled and systematically presented to drivers, thus maintaining the validity of the field setting with some of the experimental control more commonly available only in the laboratory. Nonetheless, it is difficult if not impossible to design and conduct a research study whose results can be applied with confidence to DBBs as a whole.

In the recently published FHWA study, Molino and his colleagues (2009) comprehensively assessed the strengths and weaknesses of different research methods that might be applied to this challenge. When combined with the daunting number of DBB-related factors[19] (and levels within each factor), as well as the many measures that might be addressed to provide a complete answer to this research question, we believe that it is unlikely that any agency, private organization, or public-private partnership will have the resources available in the foreseeable future to undertake such a study. At best, future studies may be able to answer questions such as:

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[19] A subset of the number of DBB-related factors that must be studied to fully answer questions about DBBs and traffic safety.

Message change interval
Duration of message change
Sign luminance at night
Sign dimensions
Distance of DBB to traveled lanes
Angle of sign orientation to the approaching driver
Proximity of DBB to official signs, or on-premise advertising signs
Number and width of lanes of travel
Roadway geometry – vertical and horizontal curvature
Speed limits and prevailing speeds
Traffic volume
Traffic mix (e.g. percentage of large trucks, buses)
Proximity of DBB to exit or entrance ramps, gores, lane drops, route divides
Familiarity of the motorist with the roadway
Weather conditions
Environment in which DBB is located (e.g. urban, suburban, rural)
Amount of information presented on a DBB
Information presentation (color, contrast, font, etc.).

- Is a DBB that changes its message every eight seconds more distracting than one whose message is fixed for 60 seconds or longer?
- Is a sign of night luminance X more distracting than one of luminance Y?
- Do DBBs within certain defined distances of entrance or exit ramps contribute to more erratic or delayed vehicle movements than DBBs at greater distances?

In short, the issue of the role of DBBs in traffic safety is extremely complex, and there is no single research study approach that can provide answers to all of the many questions that must be raised in looking at this issue. When we recognize that not every study is designed well or conducted rigorously, or where inappropriate assumptions are made or questions asked, there should be little wonder why research has not yet been able to fully "resolve" this issue.

Adding to the challenges of developing empirical answers that will satisfy the criteria for the development of guidelines or regulations is the fact that DBB technology and applications are evolving quickly. As costs come down and capabilities increase, new applications will be found for this technology. What will be the benefit of research that addresses the distracting effects of DBBs when on-premise LED signs will soon be proliferating – signs that may be larger, brighter, closer to the road, and displaying animation and full-motion video? Regulations promulgated for off-premise DBBs may seem quaint almost as soon as they are written. Potential research, even now, is years behind the implementation of the types of signs that are the subject of the research. How will we address the questions posed by roadside digital advertising that interact with the driver in real time by sending personalized messages to mobile phones, and requesting real-time responses by text messaging? And how will (or should) we address issues raised by digital signs that record potentially personal information about drivers passing such signs?

These are not questions that can be resolved in this report. There is hopeful news, however, about progress that has been made in forming and responding to key research questions. Almost without exception, the research studies discussed in this report have made dramatic advances in methodological sophistication, statistical power, and control of extraneous variables compared to those studies discussed in earlier research reviews. As a result, these more recent studies (primarily those completed within the past ten years) typically produce results and conclusions that are more reliable and valid than those of which their predecessors were capable. And, tellingly, the results of the most recent research are remarkably consistent.

A small number of important research studies, all published (or to be published) within the past several years, may have opened the door to a solution to the long-standing question of whether unsafe levels of driver distraction can occur from roadside billboards. The first, by Horrey and Wickens (2007) demonstrated that when making decisions that may result in road safety guidelines or regulations, we should be concerned, not with mean performance but rather with the poorest performances, those in the "tails" of the distribution. Of course, in many ways highway, traffic, and human factors engineers have been designing our vehicles and roadways in this manner for many years. Human factors professionals speak of designing systems to accommodate the 95^{th} percentile operator, (e.g. FHWA, 1998), roadway geometric design is often established based upon 85^{th} percentile speeds (e.g. Schurr, et al., 2005), the size of letters on highway signs and the width of pavement markings are being increased to accommodate the older driver's deteriorating visual acuity, and even the duration of push-button actuations for pedestrian crossing signals is now based on research that focuses on the tails of the distribution (Noyce & Bentzen, 2005). Horrey's and Wickens' arguments were made in the context of a study that evaluated eyes-off-road time for interacting with in-vehicle technology, but the implications should be the same for external distracters such as DBBs, and have been so demonstrated by Chan et al. (2008).

The second study, a breakthrough known as the 100 car naturalistic driving study, has produced a number of separate reports (for example, Klauer, et al., 2005, Klauer, et al., 2006a, Klauer, et al., 2006b). Although "naturalistic" driving studies had been conducted on a small scale previously, Klauer and her colleagues at Virginia Tech Transportation Institute (VTTI) were the first to employ this methodology on a large scale. As discussed earlier in the present paper, these researchers placed 100 highly (but unobtrusively) instrumented cars in the hands of 100 people and allowed them full use of these vehicles for 18 months. There were no experimenters present in the vehicles, data was collected without any interference to the driver and was downloaded remotely, and the participants were free to drive these vehicles in any way they wished, as if they were their own. One finding from this work that is of particular interest in our discussion of DBBs is that a driver's eyes-off-road time due to external-to-the-vehicle distraction or inattention was estimated to cause more than 23% of all crashes and near crashes that occurred.

The third study of relevance here (Chan, et al., 2008), also discussed earlier in the present report, used a driving simulator to study the tails of the distribution when participants drove a five mile route while performing a series of in-vehicle and external-to-the-vehicle distracting tasks. The authors found, as they expected, that younger drivers, when dealing with the in-vehicle task, took their eyes off the road for a significantly longer time than did the older drivers (2.76 seconds vs. 1.63 seconds, respectively, when the measure was the mean length of the maximum episode of continuous inattention). Quite to the researchers' surprise however, were their findings that: (a) the maximum episode durations were much longer for the out-of-vehicle tasks than for the in-vehicle tasks, and (b) that the difference between the older and younger drivers in the out-of-vehicle tasks was small (pp. 16-17). Specifically, they found that the average maximum duration for the out-of-vehicle tasks (for all participants) was 3.54 seconds, vs. that for the in-vehicle tasks of 1.35 seconds, a highly significant difference. The difference in average maximum duration for out-of-vehicle tasks between the older and younger drivers, however, was 3.41 vs. 3.67 seconds, an insignificant difference. The authors' conclusion is that younger and older drivers are "equally bad" in being distracted by external stimuli, in that neither age/experience group has "learned to limit the durations of their glances off to the side of the vehicle" (p.22). Finally, even a study sponsored by the outdoor advertising industry (Lee, McElheny, & Gibbons, 2007), despite an experimental design that sought to minimize the differences between DBBs and other roadside stimuli, has produced results showing significantly longer average glance durations to roadside digital signs than to "baseline" sites and to traditional (fixed) billboards, and, the researchers suggest, *all* measures of visual glances indicative of driver distraction would prove to be significantly worse in the presence of digital signs if a full study was to be conducted at night.

In short, we have made substantial progress in our understanding of the impacts on driver distraction from external-to-vehicle sources since the late 1990s. We now know that extended episodes (two seconds or longer) in which a driver's eyes are not attending to the driving task greatly increases (by 3.7 times) the likelihood of a crash (Klauer, et al., 2006a). Other researchers have suggested that the upper limit for an acceptable distraction episode may be 0.75 second (Beijer, et al., 2004, Smiley, et al., 2005) or 1.6 seconds (Wierwille and Tijerina, 1998). And, as shown both by Beijer (2002) in an on-road study, and by Chan and her colleagues (2008), in a simulator study, there is growing evidence that billboards can attract and hold a driver's attention for the extended periods of time that we now know to be unsafe. As stated succinctly by Beijer, his findings seem to show that "drivers are comfortable turning their attention away from the road for a set period of time, regardless of the demands of the driving task" (p. 76). And, as Chan, et al., describe it: "These data … indicate that it is likely that our out-of-vehicle tasks (which not only engage attention but also draw the eyes and visual attention away from in front of the vehicle) would have quite significant detrimental effects on processing the roadway in front of the vehicle" (p.22).

We also have data to show, despite a lack of analysis by the researchers, that an on-road study (Lee, et al., 2007) using an instrumented vehicle found many more such long glances made to DBBs and similar "comparison sites" consisting of (among other things) on-premise digital signs, than there were to sites containing traditional, static billboards, or sites with no obvious visual elements. Indeed, the mean values for these long glance durations proved to be significantly greater for the sites with digital signs than for the others. From the same study, we have evidence expressed by the researchers that if we were to conduct our research at night we would find that *all* measures of eye glance behavior would demonstrate significantly greater amounts of distraction to digital advertisements than to fixed billboards or to the natural roadside environment, and that driver vehicle control behaviors such as lane-keeping and speed maintenance would also suffer in the presence of these digital signs. Because the design of this study minimized the differences between the characteristics of DBB sites and the others, and did not report all of the pertinent data collected, it seems reasonable to believe that the differences found might be more pronounced in a more rigorous experiment.

When we add the results of these recent, applied research studies, to the earlier theoretical work by Theeuwes and his colleagues (1998, 1999), in which they demonstrated that our attention and our eye gaze is reflexively drawn to an object of different luminance in the visual field, that this occurs even when we are engaged in a primary task, and regardless of whether we have any interest in this irrelevant stimulus, and that we may have no recollection of having been attracted to it, we have a growing, and consistent picture of the adverse impact of irrelevant, outside-the-vehicle distracters such as DBBs on driver performance.

Beyond the issues of research, however, we also face what we might call a “criterion problem.” States and local jurisdictions must ask themselves this question: What level of knowledge and what degree of certainty must we have before we can be confident in the issuance of guidelines or regulations about DBBs? For example, must we have demonstrable proof that DBBs *cause* crashes? This is the argument raised by the outdoor advertising industry whenever it challenges a local code or ordinance, or goes to court to overturn a permit denial. If crash causation is the standard that must be met, we may never get there. This is not necessarily because DBBs are not a causative factor in crashes; it is, as most researchers believe, more likely that our research methods are not sufficiently sensitive to identify this linkage. This, in turn, is a result of the substantial difficulties involved in conducting post-hoc statistical analyses of crash summaries for an issue that is so profoundly complex. When we know that more than 80% of accidents are not reported to the police, that drivers would not likely admit crashing as a result of such distraction, and that research has clearly shown that our attention as well as our eyes are reflexively drawn to objects such as DBBs even when we have no interest in them and have a more important task to perform, and that we may well be unaware of attending to them at all, it is little wonder that such epidemiological studies may simply be incapable of adding to our knowledge of the traffic safety impacts of DBBs.

Then again, we have rarely required proof of actual crash causation prior to setting speed limits, restricting in-vehicle mobile telephone use, or even developing current billboard operational and location restrictions. The argument against the control of DBBs because studies to date have not proven a cause and effect relationship between DBBs and crashes is simply spurious. It would seem sufficient to initiate action based on a level of consistency achieved in research. And such consistency is now being achieved.

It is likely that those who feel that no guidance or regulations can be promulgated until we have clear proof of causality will continue to argue that there is insufficient information to take any action in this regard regarding roadside DBBs. But those who think that their job is to do what they can to enhance safety for the traveling public based upon the best available information, now have, in our opinion, access to a strong and growing body of evidence, including evidence from industry supported research, that roadside digital advertising, attract drivers’ eyes away from the road for extended, demonstrably unsafe periods of time.

States and local jurisdictions faced with permit applications or challenges to denied permits need to have a sound basis for their decisions. The research underway by FHWA as this is written may begin to provide specific, directed answers to assist these officials in their work. In the interim, these governmental agencies and toll road operators, faced with the need to make such decisions now have, in our opinion, a sufficient and sound basis for doing so.