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

FINAL REPORT

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ACKNOWLEDGEMENTS AND NOTES

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

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

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

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

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

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

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

EXECUTIVE SUMMARY

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

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

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

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

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

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

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

SECTION 9.

SUMMARY AND CONCLUSIONS

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

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

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

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

Unfortunately, this issue is enormously difficult to study. This is because every billboard, road, and driver is different. A study evaluating a four-second message display interval might obtain quite different results from one using eight-seconds. A study in daylight will almost certainly find different driver responses than the identical study conducted at night. And a study conducted with free-flowing traffic may have a different outcome than one that examines the same road and the same billboard when traffic demands are greater. In addition, the key selling point of DBBs is that they can change messages every

few seconds, and it is technically possible for them not to repeat the same message during a several hour cycle. Thus, studying such billboards *in situ* confronts the researcher with the added problem that it may be difficult to compare the experiences of any two (or more) drivers as they pass the DBBs under study for the simple reason that these drivers will, in all likelihood, experience signs with different content, different brightness levels, different graphics, and different font styles and sizes. This suggests that laboratory studies, despite what we believe to be important limitations, may permit better control over these inherent sign design and operational variables. Another alternative, not yet attempted with DBBs to our knowledge, involves a cooperative effort between researcher and sign operator in a field setting, so that the many relevant variables can be controlled and systematically presented to drivers, thus maintaining the validity of the field setting with some of the experimental control more commonly available only in the laboratory. Nonetheless, it is difficult if not impossible to design and conduct a research study whose results can be applied with confidence to DBBs as a whole.

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

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

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

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

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

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

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

A small number of important research studies, all published (or to be published) within the past several years, may have opened the door to a solution to the long-standing question of whether unsafe levels of driver distraction can occur from roadside billboards. The first, by Horrey and Wickens (2007) demonstrated that when making decisions that may result in road safety guidelines or regulations, we should be concerned, not with mean performance but rather with the poorest performances, those in the "tails" of the distribution. Of course, in many ways highway, traffic, and human factors engineers have been designing our vehicles and roadways in this manner for many

years. Human factors professionals speak of designing systems to accommodate the 95th percentile operator, (e.g. FHWA, 1998), roadway geometric design is often established based upon 85th percentile speeds (e.g. Schurr, et al., 2005), the size of letters on highway signs and the width of pavement markings are being increased to accommodate the older driver's deteriorating visual acuity, and even the duration of push-button actuations for pedestrian crossing signals is now based on research that focuses on the tails of the distribution (Noyce & Bentzen, 2005). Horrey's and Wickens' arguments were made in the context of a study that evaluated eyes-off-road time for interacting with in-vehicle technology, but the implications should be the same for external distracters such as DBBs, and have been so demonstrated by Chan et al. (2008).

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

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

signs than to "baseline" sites and to traditional (fixed) billboards, and, the researchers suggest, *all* measures of visual glances indicative of driver distraction would prove to be significantly worse in the presence of digital signs if a full study was to be conducted at night.

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

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

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

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

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

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

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