ON-PREMISE SIGN RESEARCH REVIEW

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In 1996, Penn State University, through its transportation department, began a series of research projects, for the United States Sign Council (USSC) and the United States Sign Council Foundation (USSCF), related to on-premise signs. Objective: to study the design characteristics of on-premise signs from the perspective of the motorist and traffic safety.

Previously, negligible original research relative to on-premise design and safety characteristics existed. Traffic engineers, seeking to develop a directional sign system for motorists on local and interstate highways, had promulgated earlier academic research that, although useful as a starting point, didn't directly relate to the distinct qualities of private on-premise signs. By virtue of their diversity and placement on private property, on-premise signs exist as a totally separate class of motorist-oriented communication, encompassing unique design challenges and traffic-safety implications.

Penn State research provides a unique, objective scientific basis for understanding the manner in which motorists receive and respond to the informational content of the private, roadside sign system. The research and corresponding analyses afford designers and sign regulators with insight into legibility, size, illumination and placement characteristics necessary for effective roadside communication to occur.

The Thomas D. Larson Pennsylvania Transportation Institute, Penn State's transportation research center, is a major multidisciplinary unit within the College of Engineering. Since its inception in 1968, Larson has maintained a threefold mission of research, education, and service. The Larson Institute is the locus for transportation-related research conducted by Penn State faculty from more than 14 colleges and research centers, with areas of specialization ranging from civil, computer, electrical, architectural, industrial and mechanical engineering to agriculture, information sciences and technology, supply-chain management, economics, geography, psychology and statistics.

The institute provides a unique focal point of collaboration for expert faculty and enterprising students from across the university, together with public and private stakeholders, to address critical transportation-related needs of the individual user and the world at large. Penn State was selected by the USSC to perform its research based on its robust background in traffic-safety studies, and having an existing test-track facility.

Penn State / USSC strive to facilitate research that addresses on-premise, sign design decisions and sign regulations, including special approvals and variances. Planning decisions, sign design choices and local sign regulation can all benefit from objective sign research.

In this session, principal Penn State researcher Phil Garvey will provide an overview of PSU on-premise, sign-research projects conducted over the past 18 years, as well as discuss the most recently completed Penn State study on LED EMC lighting levels. Richard Crawford, Mercer Sign Consultants and USSC Legislative Consultant, will then describe how the collaboration with Penn State was initiated and how it has evolved, including a discussion on the need for the research, how it fits within a larger framework, and practical applications for the research results.

All the Penn State research discussed will be made available at and after the session at no charge, via a specified website. Currently, the research is available online for purchase, and to association members, but it will be made available to all NSREC attendees and the Signage Foundation, Inc. at no charge.

Research has shown that good planning, design and regulatory outcomes at the local level should consider motorist and traffic-safety needs, particularly regarding sign area, sign height, letter legibility, sign orientation, and sign illumination.

To date, 10 studies have been completed at the Transportation Institute, as well as one white paper and a handbook of sign-illumination guidelines and terms:

1. SIGN VISIBILITY, Research and Traffic Safety Overview (1996)
2. SIGN LEGIBILITY, The Impact of Color and Illumination (1998)
3. REAL WORLD ON-PREMISE SIGN VISIBILITY, the Impact of the Driving Task on Sign Detection and Legibility (2002)
4. SIGN VISIBILITY, Effects of Traffic Characteristics and Mounting Height (2003)

5. ON-PREMISE COMMERCIAL SIGNS AND DRIVER INFORMATION LOAD (2003) (White Paper)
6. ENVIRONMENTAL IMPACT OF ON-PREMISE SIGN LIGHTING, With Respect to Potential Light Trespass, Sky Glow, and Glare (2004)
7. RELATIVE VISIBILITY OF INTERNALLY AND EXTERNALLY ILLUMINATED ON-PREMISE SIGNS (2004)
8. ELECTRONIC MESSAGE CENTER RESEARCH REVIEW (2005)
9. ON-PREMISE SIGNS, Determination of Parallel Sign Legibility & Letter Heights, (2006)
10. INTERNALLY ILLUMINATED SIGN LIGHTING, The effects of internally illuminated on-premise sign brightness on nighttime sign visibility and traffic safety (2008)
11. INTERNAL vs. EXTERNAL ON-PREMISE SIGN LIGHTING: Visibility and Safety in the Real World (2009)
12. ON-PREMISE SIGN LIGHTING**,** Terms, Definitions, Measurement (2010) (Handbook guide)

Penn State is currently completing research on lighting levels for on-premise Electronic Message Centers (EMCs), a two-phase project initiated in 2009. Final results are not known at this writing, but may be complete in October 2014.

Penn State on-premise sign research can be organized into group headings for easy reference:

Sign Visibility and Legibility

1. SIGN VISIBILITY, Research and Traffic Safety Overview (1996)

The initial Penn State – USSC collaboration; the purpose of this research was to provide an organized synthesis of existing literature related to sign visibility and on-premise signs in particular; the overview included sections on basic definitions related to on-premise signs, sign regulations (including ways in which sign usage is controlled on private property), and an extensive literature review. The “Sign Visibility Overview” provided the basis and context for further Penn State research, as it delineated what research existed, and what areas required attention.

2. SIGN LEGIBILITY, The Impact of Color and Illumination (1998)

This test-track study assessed the performance of four nighttime-illumination technologies commonly used by on-premise sign owners. The primary research objective was to determine the impact of the technologies and sign colors on legibility distance. These illumination technologies were field tested at night and during the day with different combinations of text and background color.

The study goal was met by (1) determining recognition and legibility distances for each font, color, and illumination technology combination under investigation during day and night conditions; and (2) by using the recognition and legibility distances to determine the time available for a driver to read a sign's message at various traffic approach speeds.

The secondary research objective was to determine the time available for a driver to read a sign message at various approach speeds.
Many factors contribute to sign legibility and detectability, most of which interact with each other. As with similar research, this sign-legibility study made various basic assumptions regarding on-premise signs:

1. The sign is perpendicular to the observer's line of sight.
2. The sign has five or fewer critical elements.
3. The observer is alert and looking for the sign.
4. The observer is not familiar with the sign.
5. The observer has 20/40 or better visual acuity.
6. Sign copy is alphanumeric.
7. Sign copy is displayed in lower case.
8. Copy is not abbreviated.

The net result of this study was the ability to create a sign and letter legibility chart based on the research findings, and a re-evaluation of the then commonly accepted notion that a letter at 1" height is legible from a 50'-0" viewing distance. The study demonstrated that, for on-premise signs and legibility, the truer rule of thumb is a 1" letter is visible at 30'-0", depending on other associated factors.

3. REAL WORLD ON-PREMISE SIGN VISIBILITY, the Impact of the Driving Task on Sign Detection and Legibility (2002)

The Real World On-Premise Sign study was a follow-up or corollary to the 1998 test-track study on sign visibility and legibility. The goal was to determine the detectability and legibility of various on-premise signs under real-life environmental conditions. This was achieved by conducting an open-field research study on public roadways in a small downtown area and along a commercial strip development zone. Data were collected during the day and at night using older and younger subjects as vehicle operators. The study evaluated two specific sign variables: 1) sign orientation (parallel to the direction of travel versus perpendicular to the direction of travel) and 2) negative space (the open area around the words or graphic elements of a sign).

The study documented a marked difference between legibility-index results obtained from the relatively distraction-free test track environment and observations taken from real-world driving situations involving increased levels of driver workload in complex and/or congested environments.

This difference lead to an essential conclusion; notably, the driving task, particularly in environments involving a high degree of visual stimuli, produces a significant reduction in the basic test-track, legibility-index values.

This reduction, or legibility-index deterioration, is essentially a manifestation of delayed detection caused by increased driver workload, and is clearly measurable as a percentage decrease in the standard legibility index. In a comparison analysis of the test-track values versus values produced from real-world observation, an average decrease of at least 35% of the standard legibility-index values was documented, with extreme values as low as seven feet of distance per inch of letter height in highly complex environments.
In general, and across a median range of complexity, this decrease can conservatively result in a reduction in the average legibility-index value of 30 feet of distance per inch of letter height to 20 feet of distance per inch of letter height, particularly as the complexity of the driver’s visual load is increased.

Not only does the Real World Sign Visibility study support and bolster the findings of the 1998 study, but it helps to further refine the conclusions, even so far as to suggest that legality factors found in the 1998 study may in fact be too conservative for real world driving conditions.

Sign Height and Visibility

4. SIGN VISIBILITY, Effects of Traffic Characteristics and Mounting Height (2003)

In the early 2000’s, USSCF came to the researchers at Penn State with a perceived growing problem: a movement in local government regulations (i.e., sign ordinances) toward restricting the mounting height of on-premise, commercial signs and other roadside-oriented signs. These restrictions often dictated the maximum height to the bottom or top of a sign, or in some instances, they would only allow these signs to be mounted flush with the existing grade level (i.e., on the ground). This, in turn, caused some concern among sign designers and fabricators in both the on-premise, commercial sign industry and the professional, graphic-design community regarding the intended audience’s (drivers’) ability to actually see and read many of these low-profile (or “ground mounted” or “monument”) signs.

The potential visibility difficulties identified by Penn State were caused by the presence of other vehicles; in front of the subject vehicle, in the adjacent travel lane, or those traveling in the opposite direction; all of which blocked the line of sight between the subject vehicle driver and any low-mounted, roadside sign. This visibility problem could be exacerbated by high volumes of traffic or vehicle mixes that included numerous oversize vehicles (i.e., trucks, buses, and recreational vehicles).

Penn State devised an analytical study to examine sign-mounting height and sign visibility. Some existing research considered the influence of traffic and roadway geometry on the sign visibility, but none examined this problem as it related to on-premise, commercial signing or the potential effect of passenger cars.

This sign-height research sought to determine the probability of another automobile (i.e., object vehicle) blocking the line of sight between the driver of a subject vehicle and an on-premise, low-mounted, roadside sign. Factors would include the position of the subject vehicle, the position(s) of one or more object vehicles, and the volume and speed of vehicles on the road.

Eight traffic scenarios were analyzed, based on a four-lane undivided highway, and either 35 or 45 miles per hour as the speed of travel. These conditions were chosen to simulate the general characteristics of roadways traversing commercial zones throughout the United States. The signs (assumed to be 10 feet wide) were located either 10 or 20 feet from the edge of the roadway and on either the right- or left-hand side of the road. The findings clearly found a quantifiable loss of visibility across the full range of sign placement as traffic flow rates increase. For signs providing information in primarily vehicular-oriented environments, the height above grade of the sign and/or sign copy greatly affects an approaching motorist's ability to detect and read the message displayed.

For regulators, this information is vital. The simple presence of other vehicles on a road (i.e., in front, in an adjacent travel lane, or in travel lanes in the opposite direction) can potentially prevent a motorist from detecting a sign. If a sign is situated at or below five feet above grade, other vehicles may block the motorist's view, and the sign copy will not be legible. The research resulted in predictions of the percentage of times other vehicles blocked the view of an approaching motorist, thus preventing him/her from detecting a low mounted sign (5 feet or less above grade). The percent of blockage was computed as a function of the traffic-flow rate, the position of the subject motorist in the traffic stream, and the position and setback of the sign. Oversize vehicles (such as trucks, buses, and recreational vehicles) were not included in the calculations, even though their normal presence in the vehicular mix would have, undoubtedly, increased the percentages noted in the study.

Based upon the research, a municipality that mandates low-mounted, on-premise signs, and prohibits freestanding signs of greater height, in fact runs counter to the traffic safety needs of the driver.

Parallel Sign Visibility and Legibility

9. ON-PREMISE SIGNS, Determination of Parallel Sign Legibility & Letter Heights, (2006)

The original on-premise sign visibility and legibility research performed by Penn Stata aimed at quantifying various aspects of on-premise sign functionality, including sign size, legibility and height for on-premise signs that are perpendicular to the driver. These signs are typically referred to as freestanding signs, pylon signs, monument signs, or projecting signs.

Research performed in 2006 extended this inquiry to the subject of "parallel" signs. Parallel signs present unique challenges for the driver. Parallel signs (wall signs, building signs, façade signs, and other on-premise signs affixed to a building structure) are typically parallel to the roadway and the driver's line of sight, instead of perpendicular.

The research describes the development of, and rationale for, a mathematical model that calculates letter heights for parallel-mounted, on-premise signs. The parallel sign research integrated the original data described in the earlier tests, so the letter heights developed for perpendicular signs form the basis for letter heights on parallel signs with various lateral offsets (distance from the edge of the roadway to the sign).

A parallel on-premise sign is more difficult to read because of its orientation, or tilt, with respect to the driver. It's impossible to see the sign face at certain distances and offsets. Even when a driver can see the sign face, the sign content is often foreshortened and distorted. A driver must get close to the sign in order to increase the viewing angle enough for the sign to become legible. Yet, as a driver approaches the sign, the time available to read the sign becomes shorter, and the sign moves further into the driver's peripheral vision. Therefore, parallel signs must be read using a series of very quick glances at large visual angles during small windows of viewing opportunity.

Consequently, letter heights previously developed for perpendicular signs, where drivers have more time and can take longer straight ahead glances, do not provide adequate parallel sign legibility.

Researchers have identified multiple factors pertinent to construction of a comprehensive model for determining letter heights for parallel signs along typical roadway cross-sections (number of lanes) and lateral sign offsets.

1. Glance Angle: The maximum angle at which drivers look away from the road to read signs.
2. Glance Duration: The length of time drivers look away from the road to read signs.
3. Glance Frequency: The number of glances that drivers make at any given sign.
4. Sign reading speed.
5. Observation Angle: The angle, or tilt, at which signs become legible.

The study provides equations and look-up charts to assist in determining appropriate, parallel-sign letter sizes for motorist visibility and legibility.

Sign Illumination

Penn State has completed five on-premise, sign-lighting studies and reports to examine how on-premise, illuminated signs function at night, and to address questions on the best type of lighting at night for driver and traffic safety. These studies examine:

- □The environmental impact of on-premise sign lighting
- □The best type of sign lighting for driver detection and legibility
- □Whether a real-world environment changes detection and legibility results
- □What lighting level, or brightness, is best at night for driver detection and legibility

Testing has shown that on-premise signs are easier for drivers to (a) see and (b) read during the day. These two concepts are often referred to as “detection” and “legibility”. Because of this, for traffic safety, sign-illumination practices at night should get as close as possible to the daytime benchmarks. The functions of on-premise signs are no less critical after dark, and their functional value may be even more critical to the safety and cognitive implications for older drivers, whose visual acuity has been shown to deteriorate markedly at night.

On-premise, sign-lighting standards also reflect the informational transfer and communication aspects unique to on-premise signs; these signs provide a principal means of roadside communication and situational awareness for drivers, in both form and function. This place-based orientation gives on-premise signs their unique character, but it also limits their communicative ability to a relativity short time span.

6. ENVIRONMENTAL IMPACT OF ON-PREMISE SIGN LIGHTING, With Respect to Potential Light Trespass, Sky Glow, and Glare (2004)

Initially, researchers investigated the potential consequences of sign lighting design. A literature review was conducted on the main study topics (light trespass, sky glow, and glare) followed by field measurements of a wide variety of on-premise signs.

First, in regard to “sky glow” (sky brightness caused by artificial light reflecting off the atmosphere), no agreed-upon, objective methods physically measure overall sky glow, and there are no universally agreed-upon levels of acceptable or unacceptable sky glow. Moreover, no metric measures sky glow from a single light source, like a sign, and no objective standard or measurement technique currently establishes the effect of on-premise identification sign lighting on sky glow.

Second, in regard to “light trespass,” researchers found that (a) light trespass is a concept related to sign illuminance (light falling where it is not wanted or intended) and is not related to the needs of the driver or traffic safety; and (b) the illuminance of all sign lighting designs measured in the research had a mean vertical illuminance below 3.0 lux (or .3 footcandles) at a reasonable distance from the signs measured, a light level which is not associated with light trespass.

With increasing initiatives involving energy savings achieved through reduced sign luminance from optimum levels, such reductions could potentially compromise traffic safety. Unlike outdoor lighting in the nighttime landscape, on-premise signs are specifically designed to provide vital wayfinding and situational awareness information to drivers. Consequently, they should be permitted to maintain illumination levels consistent with optimum legibility and viewer reaction-time parameters. The minimum luminance value for standard sign illumination should be structured to comply with these parameters.

7. RELATIVE VISIBILITY OF INTERNALLY AND EXTERNALLY ILLUMINATED ON-PREMISE SIGNS (2004)

Due to increasing regulation of sign lighting, and even numerous prohibitions on internal sign illumination, PSU and USSCF moved next to determine optimum illumination for a driver in terms of visibility, legibility and traffic safety.

This study would evaluate the relative performance of internally and externally illuminated on-premise signs. Six signs, different in mode of illumination, text and background colors, and contrast orientation (i.e., light letters on a darker background and dark letters on a lighter background) were evaluated.

These signs were field tested (test track) with older and younger motorists in both daytime and night conditions. The two measures of effectiveness were sign recognition distance and legibility distance.

All six signs were standard in the sign industry. Two signs were internally illuminated. The four externally illuminated signs used standard external lighting sources, mounting distances, and heights. However, the externally illuminated signs maximized sign brightness and light uniformity. Before each experimental session, the lighting was checked to ensure it was still optimal.

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Even with ideal, controlled, test-track conditions, the results indicate internally illuminated signs provided significantly longer visibility distances and longer available reading times than externally illuminated signs. This conclusion is based on the higher mean average recognition and legibility distances and average available reading times that the signs were projected to provide motorists at various speeds. The internally illuminated signs had 40% and 60% longer average nighttime recognition and legibility distances and could be comfortably read while traveling 10 mph faster than the externally illuminated signs.

The difference between the nighttime visibility of the internally and externally illuminated signs was exacerbated with routed, externally illuminated signs. In these cases, nighttime recognition and legibility of the internally illuminated signs were 86% and 145% longer than the externally illuminated signs. The internally illuminated signs provided sufficient reading time at speeds up to 35 mph, compared to only 20 mph for the routed signs (recognition task). This superiority of internal illumination concurs with a previous study of on-premise sign illumination, which found that internally illuminated signs provide longer visibility distances, compared to externally illuminated signs.

10. INTERNALLY ILLUMINATED SIGN LIGHTING, The effects of internally illuminated, on-premise sign brightness on nighttime sign visibility and traffic safety (2008)

The sign industry has standards for internally illuminated sign cabinets with a plastic face and a fluorescent lighting system: the lamps are generally spaced on 12” centers, vertically or horizontally, and the space from lamp to face is approximately 8”, to insure for proper diffusion of light and prevent hot spots.

At the same time, due to increased activity by organizations like the International Dark-Sky Association, and so-called Green Codes and Green Initiatives, some call for the dimming of outdoor lighting at night, including on-premise signs.

So Penn State wondered: in regard to on-premise internally illuminated sign visibility and legibility, is the “industry standard” correct? Is it just right, too high, or too low? If signs are “dimmed”, does visibility or legibility increase or decrease?

Penn Stated devised a controlled, test-track study wherein a representative sample of the driving population read on-premise signs in the daytime and at night. The nighttime tests involved internally illuminated signs that varied in brightness. These sign cabinets were fabricated to sign-industry standards. Seven lighting levels were developed. The middle level (sign brightness level 4) was the U. S. standard sign lighting. The seven levels were as follows:

1. Brightness Level 1 – 40 percent of Level 4
2. Brightness Level 2 – 55 percent of Level 4
3. Brightness Level 3 – 95 percent of Level 4
4. Brightness Level 4 – Industry Standard
5. Brightness Level 5 – 1.50 times brighter than Level 4
6. Brightness Level 6 – 1.75 times brighter than Level 4
7. Brightness Level 7 – 2.15 times brighter than Level 4

The study concluded that maintaining the brightness of internally illuminated, on-premise signs at optimum levels could improve driver safety and comfort by giving drivers more time to read the signs. It did not find that internally illuminated, on-premise signs should be as bright as possible, because the study also demonstrated that both sign legibility and recognition distance decline when signs become overly bright. Sign brightness levels 4 through 6 performed best for recognition and legibility combined.

11. INTERNAL vs. EXTERNAL ON-PREMISE SIGN LIGHTING: Visibility and Safety in the Real World (2009)

The primary objective of this follow-up research project was to conduct a one-to-one comparison between internally and externally illuminated, on-premise signs on open roadways, using real drivers, and actual in-use signs. To ensure fair evaluation, the signs used were identical in all aspects other than lighting design. This was accomplished by fabricating exact internally illuminated replicas of the existing externally illuminated signs and placing them in front of the existing signs, so that not just the signs, but the locations and offsets (and therefore the visual surround and roadway characteristics) were identical.

The results of this research clearly demonstrate the superiority of internally illuminated signs across a wide variety of driving conditions, sign offsets, sign sizes, shapes, colors, and external lighting designs and quality levels. The overwhelmingly positive response from the participating establishments and their patrons also demonstrates the fallacy that internally illuminated signs are inherently less aesthetically pleasing than externally illuminated signs.

Legibility: The difference in legibility between internal and external sign illumination has been calculated to provide as much as a 70% advantage in legibility, favoring internal over external sign lighting. Because sign lighting and traffic safety are inextricably intertwined, the use of internally illuminated signs should neither be prohibited nor curtailed in any zone or district where vehicular traffic is present.

Distance: Research has shown conclusively that internally illuminated, on-premise signs are read from a much greater distance than externally illuminated signs. This was first demonstrated in test-track research, where 40-60% longer reading distances were found with internally illuminated signs. In subsequent, real-world studies that directly compared internal and external illumination, drivers on average read the internally illuminated signs more rapidly and at a greater viewing distance.

Time: In a majority of cases, externally illuminated signs did not afford the driver adequate time to detect and read the sign, and execute a driving maneuver. Internally illuminated signs gave drivers on average an additional 2 seconds more time than externally illuminated signs to read the signs and execute a driving maneuver. Also, an externally illuminated sign must be increased in size by 40% over the size of an internally illuminated sign, to achieve the same legibility factor, or the speed of traffic must be reduced by 40% to achieve the same legibility values, internal vs external illumination.

In any driving environment where posted speeds are 25 MPH or higher, on-premise signs provide motorists with wayfinding and situational awareness information, and the time required to process that information is critical. These research findings in regard to sign illumination have significant traffic safety implications for sign users and sign regulators.

12. ON-PREMISE SIGN LIGHTING**,** Terms, Definitions, Measurement (2010) (Handbook guide)

Due to the technical and, at times, confusing aspects of on-premise sign lighting, the USSCF asked Penn State to author a handbook/guidebook related to sign lighting.
The purpose of the document is to:

1.) Examine the role and function of illuminated on-premise signs as a critical factor in motorist wayfinding systems;

2.) Present cohesive and comprehensive methods of measuring the light output of these signs to provide designers and regulators with tools to achieve optimum levels of visibility, legibility, and traffic safety in any nighttime environment in which illuminated, on-premise signs are used;

3.) Define critical lighting terms.

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