Lighting Expert Report

IES RP-39-19 and its Impact on the Sign and Billboard Industries and Sign Users

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Part One: Findings

This report concerns the Illuminating Engineering Society (hereinafter "IES") and its publication "**Recommended Practice, Off-Roadway Sign Luminance IES/ANSI RP-39-19"** (hereinafter "RP-39") published in 2019. IES is an industry-backed, not-for-profit, learned technical society that was founded in New York City on January 10, 1906. The IES's stated mission is "To improve the lighted environment by bringing together those with lighting knowledge and by translating that knowledge into actions that benefit the public[1]." IES Standards and Guides are developed through committee consensus and published by the IES Office in New York. RP-39 has ramifications on the entire sign industry with the potential for influencing North American and world-wide sign and billboard practices and regulations.

IES Recommended Practices (RPs) are among the most important documents published by the IES. They are the North American reference standards for the professional practice of lighting design and application. Many IES RPs also achieve the American National Standards Institute (ANSI) accreditation giving them even higher professional and legal significance. IES/ANSI RP-39 is an ANSI accredited IES RP, approved by the IES Board of Directors. The IES Standards Committee approved RP-39-19 on January 31, 2019, as a Transaction of the Illuminating Engineering Society. Following ANSI procedures, the document was submitted and approved as an American National Standard, April 9, 2019.

The IES Outdoor Environmental Lighting Committee (the "Committee") is credited with developing RP-39. Bob Parks was the Committee Chair and David Keith was the Committee Secretary for RP-39. At the time of publication, the Committee had 17 members, 22 advisory members and 1 honorary member. The Committee's charge is to be "responsible for writing and maintaining IES standards covering the visual aspects of outdoor lighting, such as nighttime vision and glare, for ***general pedestrian applications*** (emphasis added) inclusive of non-roadway environmental components (e.g., walkways, landscaping, art, monuments, and building facades), and for establishing lighting guidelines for the nighttime environmental factors of sky glow and wildlife preservation[2]." The Committee's scope includes "Nighttime illumination recommendations for outdoor spaces including pathways, plazas, landscaping, building facades, art, and monuments that address both visual and environmental factors. Not Included: special applications that require additional visual expertise beyond the visual and environmental impacts stated above, such as lighting for roadways, sporting facilities, industrial plants, airports, port terminals, or applications targeted to light and human health."[3]

Based on my studies funded by the Sign Research Foundation and with considerable input and advice from the sign industry's technical advisory group[4] over a nearly two-year period, the following are my principal findings.

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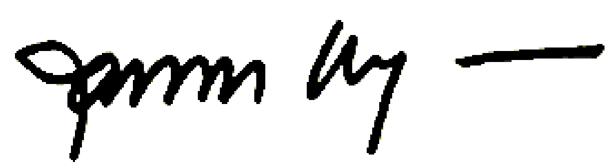
[1] Wikipedia
[2] https://www.ies.org/about/ies-committees/detail/?committee_id=bd2f321a-0050-c773-d948-925d7caf4445
[3] Ibid (3)
[4] See **The Sign Industry and Its Support for this Report,** page 17

1. Billboards and many other types of signs are “off-roadway” because they do not provide roadway information to the driver. But they more often part of the total roadway environment and less often part of the outdoor pedestrian environment. Therefore the scope of RP-39 exceeds the Committee’s scope and charge.
2. Signs and billboards require specialized illuminating engineering expertise beyond the Committee’s scope. None of the committee members were believed to be part of the sign industry, which has its own technical and lighting experts who could have served as committee members and provided needed knowledge and experience, but were apparently not asked.
3. RP-39 does not provide names, identification, or lighting technology descriptions for all sign and billboard types, and does not provide specific recommendations for them.
4. RP-39 does not adequately address current sign technology.
5. The references listed in RP-39 do not adequately represent recent and current important research findings applicable to the contents of RP-39.
6. RP-39 was supposedly not developed with regulatory applications in mind, and yet the practical use of RP-39 will be regulatory and in fact already has been.
7. RP-39 does not identify or address any of the current sign and billboard regulations that include hours of operation, transitions from day to night and back again, and other restrictions, that are among the issues that should have been presented in RP-39 but were not.
8. RP-39 provides a luminance measurement procedure that will be difficult to repeat and will often be inaccurate. It will not work with electronic signs unless the sign images can be frozen to a specific message and measured during each of the ordinance timeframes.
9. The Committee’s primary charge as defined by IES is biased towards environmental considerations, a prejudice that could affect objectivity in the development of an appropriate Recommended Practice for signs and billboards.
10. The ANSI process requires a consensus of affected parties for approval. No one from the sign and billboard industries (ISA and OAAA) were given the opportunity to participate in the review of the document nor were they included in the ANSI process of developing, reviewing, and commenting on RP-39 prior to its ANSI certification.

Based on these findings, I recommend that the IES Board disapprove RP-39-19, remove its ANSI certification, delete RP-39 from its publications and web access, and consider a working relationship with the sign industry for the development of a joint Recommended Practice. Following are information that support these findings and suggestions on technical details and how a future joint RP might be developed.



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Part Two: Supporting Information

Background

Since the invention of electric lighting, one of its desirable applications was to light signs and billboards. As a general rule, lighting for **billboards** and **signs**[5] [6] was once completely external to the sign and its message, with the exception of exposed neon tubing formed to create letters, script or icons. The sign itself was lighted using incandescent RLM sign lights, PAR spot and floodlights, or for the last half of the twentieth century, HID and fluorescent luminaires, specified by electrical engineers using illuminating engineering principles. Historically, billboards in particular employed either downlit floodlights, or, more commonly today, uplit floodlights. Recommended lighting levels and methods were provided in the IES Lighting Handbook through the end of the twentieth century. Self-illuminated signs using exposed neon and cold cathode lamps, once popular as signs and as artwork for many venues, gained popularity as well.

The mid-20th century emergence of **cabinet signs** and **channel letter** signs minimized the role of the consulting engineer as the sign industry no longer needed external lighting. Both of these sign types employ internal light sources, and the faces of the cabinet are largely formed from translucent plastics with embedded color and applied messages. The cabinet signs are most commonly rectangular boxes, while channel letter signs consist of a cabinet formed into a letter or number. Other common variations include cabinets of various rectilinear and abstract shapes and using translucent plastics and dyes or paints to create graphics, information and/or and directional signs. The internal illumination is produced by some combination of fluorescent or cold cathode lamps, or more recently, LED panels. As these various sign types were introduced, the illuminating engineering of them moved mostly to the sign industry and standards of light source characteristics became an integral part of the manufacturing engineering of the signs.

The single most important development in signs affecting standards and regulatory interest, however, is the 21st century emergence of the digital (“electronic”) sign. As LED light sources became increasingly powerful and energy efficient, by 2020 virtually all other light sources became history. LED’s superiority was obvious in light source life, energy efficiency, intensity, temperature and weatherability, and above all, controllability. Electronic driver circuits replaced large, heavy transformers and enabled signs with enough LEDs to become digital scoreboards, marquees, and giant television and computer screens. With the dawn of the LED era the sign industry effectively took over the illuminating engineering of signs, and with the 10th and final IES Lighting Handbook, published in 2011, recommendations for lighting for signs and billboards was no longer provided.

[5] From field measurement of signs other than billboards in a major city downtown district, we determined that definitions of sign types and their locations should play a role in proposed regulating standards..

[6] Signs and billboards are typically classified as “off-roadway” signs as they do not contain traffic information and speed and directional information for drivers.

Throughout the history of lighted signs, however, the brightness of signs and billboards has been an issue. Increasingly better light sources and optics allowed for signs that were arguably operated too brightly for the surroundings at night. This first caused concern especially with the International Dark Sky Association, a Tucson, Arizona-based organization formed in 1989 by astronomers who observed increased sky glow affecting their work due to the uplighting of freeway billboards. Based largely on the work of the late Dr. Ian Lewin, FIES, founder of Lighting Sciences, Inc, (LSI) in Scottsdale, the practice of lighting billboards from below became prohibited in Arizona and a number of other states and the amount of allowed light became a consideration, especially in sensitive outdoor environments.

More recently, Dr. Lewin and other scientists were called on again by the sign industry because of the brightness of LED light sources and their ability to frequently change still messages. Governing bodies are now focused on the safety aspects of signs, limiting the brightness of the signs and the rate of message changes dramatically along highways and arterial roadways. The sign ordinances of hundreds of communities, if not thousands, have been changed to control the impacts that can occur from LED signs.

In the course of this work, I initially intended to measure the luminance of a number of signs to serve as a database of "reality". Measurements were taken of a number of signs and analyzed, resulting in a discussion among the technical committee members, discussed later.

Relevant Recent Research

Ian Lewin, PhD (works through 2014)

The late Dr. Ian Lewin was a Fellow of IES and one of its most respected and prolific illuminating engineers. Lewin was a superb engineer and scientist, and according to legend and publications, he became active in research and writing papers involving billboard signs over concerns of light pollution. His work spanned two decades including the evolution of digital sign technology and LED sign technology. Among his many contributions, his 1973 paper A Luminance Approach to Highway Sign Lighting[7] introduced the theory of measuring sign brightness. His 2009 paper Digital Billboard Recommendations and Comparisons to Conventional Billboards was the one of first to address digital billboards sign luminance, lighting zones and environmental considerations, and to present a method for measuring billboard lighting remotely using an illuminance (footcandle) meter. A complementary review of the 2009 paper was written by Nancy Clanton PE, FIES in which she stated that the threshold of "too bright" for some observers was 600 nits and by all observers, 1000 nits.

One of Lewin's last significant papers, Digital Billboard Recommendations and Comparisons to Conventional Billboards (2014), served as both a guide to the technology and challenges of LED signs now in common use. As predicted by Lewin, LEDs allowed the sign industry to show video images and digital messaging, raising concern by both traffic safety experts and by persons living close to a sign using them. Lacking published standards, communities have no direction on how to limit sign brightness to generally acceptable levels other than to adopt standards

[7] Leukos, formerly The Journal of the Illuminating Engineering Society Volume 3 Issue 2 1973

created by one of the few early-adopter communities. It should be noted that hundreds of localities across the United States and several state Departments of Transportation have adopted the Lewin standards, either in whole or in part, as a solution to the problem of overly bright digital signs and billboards.

John Bullough, PhD (works through 2019)

More recently, continued research on signs and lighting was taken on by Dr. John Bullough, FIES, a Fellow of IES who directs research in the areas of transportation lighting and safety at the Light and Health Research Center at Rensselaer Polytechnic Institute in Troy, New York. including contributions to the Sign Research Foundation. Significant works include Factors Affecting Sign Visibility, Conspicuity and Legibility: Review and Annotated Bibliography **(**2017**)** and Brief Communication: Impact of Sign Panel Luminance on Visual Comfort (2019) that includes 11 applicable references. His works contributed significantly to this report.

Tomczuk et al (works through 2020)

A recent significant work is Procedure for Measuring the Luminance of Roadway Billboards and Preliminary Results by Tomczuk, Chrzanowicz and Jaskowski, published in Leukos (the Journal of the IES) on October 16, 2020. The authors are Polish, and their work reflects the standards and expectations of western and central Europe. However, the work shows a complete approach with suggested conclusions based on substantial research. This appears to be the most up-to-date learned research on the topic and for the purposes of this report, has helped serve to influence recommendations, as described later.

Sample Prior and Current Recommended Practices

IES Recommendations (IES Handbook)

Most of the recommended practices of the IES in the 1900's were included in the IES Lighting Handbook, a 500+ page hardcover resource. Lighting for roadway signs is among separate Recommended Practices, but billboards are not.

The first *Handbook* was published in 1949, followed by the second in 1952, the third in 1959, and the fourth in 1966. The *Fifth Edition IES Handbook*, published in 1972, and the Ninth Edition, published in 2000, were used as a reference which today are separated into individual recommended practice documents such as RP-39. In the IES 5th Edition IES Lighting Handbook[8] and the 9th Edition IES Lighting Handbook[9] recommended luminance for signs was listed in the following tables[10]:

[8] Edited by John Kaufman

[9] Edited by Mark Rea

[10] Re-published by Bill Dundas, Signs of the Times, May 13, 2020, and confirmed consistent with IES Handbook, 5th Edition, 1972, Figure 23-8

IES Lighting Handbook ,5th Edition 1973	
Recommended Luminance, nits	**Application**
70-350	Lighted facades and fascia signs
250-500	Bright fascia signs as in shopping centers
450-700	Low brightness areas where signs are isolated or have dark surrounds
700-1000	Average commercial signs such as gas-station information
1000-1400	High-rise signs and signs in areas of concentrated sign competition
1400-1700	For emergency traffic control conditions where communication is critical

IES Lighting Handbook, 9th Edition 2000		
Recommended Luminance, nits		**Relevant Conditions**
Min	Max	
70	350	Night, lighted fascia
250	500	Night, bright fascia
450	700	Night, low ambient brightness
1000	1400	Night, average commercial area
1400	1700	Night, emergency traffic control

Note: A table like this did *not* appear in the 10th Edition IES Lighting Handbook (2012) because signs and billboards are not mentioned. The chart appearing in the 5th Edition handbook used foot-lamberts and these values were converted to nits by me and rounded to the nearest 100 nits.

Digital Billboard Recommendations & Comparisons to Conventional Billboards, (Lewin 2009)
Lewin's 2009 paper was among the first to address direct LED lighting and the relevant differences between it and conventional billboards. He was also among the first to note that digital billboards could be "aimed" with photometric methods. While Lewin did not suggest significantly different approaches to "aimable" digital lighting, he did propose recommended maximum luminance levels for billboards **in Lighting Zone 2** as follows:

Lewin's Proposed Luminance Limits for Lighting Zone 2 (2009)		
Billboard Dimensions (ft)	Measuring Distance (ft)[11]	Luminance (nits)
11 x 22	150	300
10.5 x 36	200	342
14 x 48	250	300
20 x 60	350	330

[11] Based on illuminance measurement system described by the Author pp 6-9

Factors Affecting Sign Visibility, Conspicuity and Legibility (Bullough 2014)
Bullough was retained by the Sign Research Foundation to produce thorough and up-to-date research on the underlying vision science issues of signs under the project "Illuminated Sign Conspicuity: What Factors Make a Sign Noticeable and Legible" managed by Sapna Budev. On Page 8. Bullough provides a table of various minimum and maximum recommended sign luminance from a variety of sources.

The range of recommended values that Bullough cites is interesting, if not confusing. Ignoring minimum luminance and focusing on maximum luminance, and interpreting conditions into lighting zones, Bullough developed the following summary table for this paper.

Bullough 2014 Survey of Proposed Luminance Limits		
SOURCE	LIGHTING ZONE*	MAXIMUM LUMINANCE (NITS)
Allen (1962)	LZ1	100
	LZ2/3	340
	LZ4	1700
AASHTO (2005)	LZ1	40
	LZ2	90
	LZ3	180
Bullough & Skinner (2011)	(LZ2 or LZ3)	280
	Day	23000
City of Hutto (2014)	Day	7000
	(LZ2 or LZ3)	500
City of Mesa	LZ3	2500
	Day	7000
Elstad (1962)	LZ2	70
	LZ3	400
ILE (2001)*	LZ1	100
	LZ2	300-600
	LZ3	400-800
	LZ4	600-1000

* *Assignment of lighting zones determined by the author of this report from report contents.*

RP-39 (2019)
RP-39 references referenced 13 papers, including the 10th Edition Handbook, one citing a 2006 paper including Bullough, none of them citing Lewin, and no relevant papers concerning the LED technology and methods now the standard in the sign and billboard industry.

In the 10th Edition of the IES Handbook, the IES Lighting Zone system[12] was set forth as a means to set appropriate lighting and luminance levels with corresponding lighting efficiency and consideration for the environment. Lighting Zone 0 (LZ0) describes a completely natural environment where anthropogenic light is to be avoided and the opposite, Lighting Zone 4 (LZ4) describes an urban or industrial environment where high lighting levels and their related light pollution are the case. The Lighting Zone system has been coordinated with the CIE system (E0-E4) and are the basis of lighting design recommendations and corresponding codes and standards worldwide. These lighting zones serve as the basis of all outdoor lighting recommendations and most corresponding codes, worldwide. RP-39 Table 4-1 puts forth "maximum sign luminance by lighting zone" recommendations as follows[13]:

IES/ANSI RP-39-19 Table 4-1		
LIGHTING ZONE	**NIGHTTIME (NITS)**	**DAYTIME (NITS)**
LZ0	0	0
LZ1	20	3500
LZ2	40	3500
LZ3	80	3500
LZ4	160	3500

Recent Sign Ordinance: City of West Hollywood (2019)

This is an example of a lighting ordinance that represents a community's effort to address signs and billboards with specific attention to current electronic billboard technology. My familiarity with the location and issues of this community come from both my work with the California Energy Commission in the development of Title 24 and with several projects and personal experiences involving this community.

The City of West Hollywood (CA) developed a modern ordinance in 2019 to address digital signs used along Sunset Boulevard including the "Sunset Strip". Sunset runs parallel to the Santa Monica Mountains and based on California Title 24 Part 1 Section 10-114 and Title 24 Part 11 "CALGreen"; the nearby environmentally sensitive area should limit the lighting zone for the Sunset Boulevard to Lighting Zone 3[14]. The Ordinance restricts daytime luminance to 6000 nits and requires dimming to 300 nits after sunset and requires nighttime dimming when outdoor illumination is less than 100 foot-candles. The fade rate is required to be at least 20 minutes. There are additional restrictions on the rate of image change, no animated content or moving patterns from 2AM to sunrise, and a 1 second minimum fade out and transition rate between messages[15].

LIGHTING ZONE	NIGHTTIME (NITS)	DAYTIME (NITS)
LZ3	300	6000

[12] The lighting zone system as described originated in the IDA-IES Joint Model Lighting Ordinance, published in 2011, the IES 10th edition Lighting Handbook Table 26-4, and IES RP-33-14, Lighting for Exterior Environments..
[13] Rp-39-19, Page 3 Table 4-1
[14] My professional opinion. I note that the adjacent sensitive zone (the Santa Monica Mountains) should be LZ0.
[15] City of West Hollywood Ordinance 19-1063

Tomczuk, et al Recommendations (2020)

Arguably a very well- and fully researched paper with substantial research and citations[16], this group of Polish scientists approached the challenge thoroughly. As with findings of Lewin and others, the luminance should be a function of sign size. They reported IES 2000 proposed nighttime and their conclusions for allowed luminance limits in nits as follows*:*

<table>
<tr><th colspan="5">Tomczuk et al 2020</th></tr>
<tr><th rowspan="2">LIGHTING ZONE</th><th rowspan="2">IES 2000[17]</th><th colspan="2">NIGHTTIME</th><th rowspan="2">DAYTIME</th></tr>
<tr><th>≤10m^2</th><th>>10m^2</th></tr>
<tr><td>LZ0</td><td>0</td><td>0</td><td>0</td><td rowspan="5">5000</td></tr>
<tr><td>LZ1</td><td>50</td><td>100</td><td>0</td></tr>
<tr><td>LZ2</td><td>400</td><td>400</td><td>200</td></tr>
<tr><td>LZ3</td><td>800</td><td>600</td><td>300</td></tr>
<tr><td>LZ4</td><td>1000</td><td>600</td><td>300</td></tr>
</table>

Summary of Observations and Recommendations

There are concurrent concepts and goals among recent papers and opinions regarding the luminance of signs and billboards that appear to be shared to a greater or lesser extent:

1. The Lighting Zone system is a sound basis for recommended limits.
2. Separate daytime and nighttime limits are appropriate.
3. The nighttime limits should be at least an order of magnitude lower than daytime.
4. Lighting Zone Zero (LZ0) should not have illuminated signs.
5. Lighting Zone One (LZ1) should allow for illuminated signs, but lower than the higher-numbered zones.
6. Lighting Zones Two, Three and Four (LZ 2, LZ3 and LZ4) should allow increasingly bright signs.
7. Daytime luminance level recommendations vary widely with few supporting arguments or apparent research. Without more evidence to support them, daytime limits should probably be further addressed by experts.

While there is no perfect agreement of the proposed tables of limits on luminance, I believe there are several nexuses apparent to this author among modern (since 2009) proposed recommended **nighttime** luminance limits. In my opinion, these are:

- Lighting Zone Zero ("LZ0") should have no anthropogenic lighting at all. (California Title 24[18] limits electric lighting to marking trailheads and restroom/shelter facilities, with requirement of full shielding.. This is consistent with the intent of LZ0 to only permit lighting of true necessity and not for convenience or sales.)

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[16] Tomczuk, Chrzaniwicz and Jaskowski, Procedure for Measuring the Luminance of Roadway Billboards and Preliminary Results**,** Leukos**,** Volume 18, 2022 Issue 1
[17] Per Tomczuk et al, IES TM-11-00
[18] 24CCR Parts 1, 6, and 11 (Administration, Energy Code and CALGreen, the sustainability code)

- Lighting Zone One ("LZ1") is intended for natural and rural areas where lighting is uncommon. The range of proposed night maximum luminance is 20 to 100 nits. In my opinion, it is the apparent consensus is the maximum night luminance should be limited to **100 nits**, with suggestions of using much lower luminance whenever practical.
- Lighting Zone Two ("LZ2") is intended for rural and suburban areas where lighting should be used carefully and in limited amounts to support everyday life and commerce. Light levels are lower than in cities and not as continuous. In my opinion, it is the apparent consensus is the night luminance levels should be limited to **250-300 nits.**
- Lighting Zone Three ("LZ3") are suburban and outer urban commercial areas where lighting after dark plays a significant role in commerce. In my opinion, it is the apparent consensus is that night luminance levels should be limited to 400-**450 nits.**
- Lighting Zone Four ("LZ4") are urban and industrialized areas where signs are part of an environment with relatively high light levels and a considerable number of light sources supporting this environment. The apparent consensus is that night luminance levels should be limited to **600 nits.**
- There are too few sign size-related opinions to allow for a consensus.

Daytime luminance levels do not appear to be as well researched. I recommend commissioning better studies based on electronic LED sign capabilities and whether ambient daylight should be considered to reduce luminance due to cloud cover or time of day. The features required to adjust lighting levels based on ambient daylight are commonly included by many manufacturers of the equipment. See Part Three.

Considering the availability several proposed maximum luminance values at the time of the development of RP-39, there is no evidence that other researched, reasonable opinions were considered, nor given reasonable weight. For example, compared to Tomczuk, RP-39 values are an average of 82.5% lower without supportive research, evidence, or other justification.

Part Three – Additional Considerations and Suggestions

Important Considerations for Luminance Standards

From our work in luminance standards and studies, it is apparent that with all of the emphasis on luminance, not enough thought has gone into other important everyday realities of signs in operation today. These include:

- Transitions from day to night and back again, addressing the predictable phases of sunset and sunrise (civil, nautical and astronomical) and the changing adaptation of the human eye throughout these transitions
- Socially normal periods of preferred darkness, e.g. accommodating residents' preferred bedtimes
- Environmental impacts of anthropogenic light at night in each lighting zone that could be mitigated by operating schedules

Daytime light levels range from almost night to sunny day illuminance levels over 10,000 footcandles. White surfaces can be as bright as 50,000 nits. The luminance of the sky at the horizon on a clear or lightly cloudy day can easily attain 5000 nits[19]. On the other hand, the luminance of a cloudy sky can vary from 50 nits to over 5,000 nits depending on time of day, sun location relative to the viewing direction, and the type and density of cloud cover. In my professional opinion, under most circumstances a 10:1 luminance ratio is commonplace and supports a daytime sign or billboard luminance of 6,000 nits. However, what is not sufficiently discussed in the literature is the transition from nighttime to daytime or daytime to nighttime. With LED technology, dimming between values can be timed from a clock/calendar and should be easily addressed. Less easily addressed are the following regularly occurring periods of transition and changing light:

- **Daylight to commercial night**. Illuminance levels fall over a period of about 45 minutes from sunset levels to commercial night levels. Sunset levels for signs should also dim to follow as electric illumination systems take over from nature.
- **Evening to end of commercial night**. Electric illumination systems are the source of light. At the end of commercial night, a lower lighting level will limit the light output created by signs in most locations to allow for residents to retire with minimal need for window shades.
- **End of commercial night to close of businesses**. Typically established by statutory closing of bars, light levels should be dramatically reduced. Transitions from higher lighting zone levels to lower lighting zone levels should be applied.
- **Beginning of commercial morning**. Morning businesses including service stations, food services and transit become active. Especially during the winter, electric illumination systems are the source of light until after dawn, and the lighting response should be a reversal of the gradual lowering of light levels at night.
- **Dawn to daylight**. Illuminance levels climb over a period of about 45 minutes from commercial morning levels to sunrise levels where electric illumination systems cease operation.

A photoelectric application (photocell dimming) has also been discussed, and is in common use in the industry. Nonetheless, little guidance is provided to schedule these transitions other than local ordinances and codes. Two recent cases of our work illustrate this dilemma.

1. High-rise signs in major cities serve as building and corporate identity. However, with the expansion in the number and height of high-rise residential buildings there is more attention to arguably bright illumination of high-rise building signs after ordinary business and commercial night. Dimming or extinguishing exterior lighting between the end of commercial night and the beginning of commercial morning could prove a reasonable and practical compromise.

[19] The luminance of the sun is 1,670,000,000 nits at noon on a clear day.

2. Service stations and many other similar facilities need to maintain a high level of illumination through sunset and twilight until a totally night sky foments adaptation and light levels can then be diminished; the reverse occurs at dawn.

Moreover, this straw man of proposed limits to luminance does not address the difference between “on-premise” and “off-premise” signage. It is my experience that on-premise signs (signs located on the actual site of commercial activity) are typically allowed more luminance than “off-premise” signs, such as advertising along a roadway. For instance, in commercial entertainment districts like Las Vegas’ strip and Times Square, high resolution video signs operating at nit levels far exceeding normal night-time levels are considered part of the attraction and are zoned accordingly.

The Problems of Luminance

The only practical field method of ensuring a sign or billboard meets an intended luminance limit is to measure it. There are two ways to “field measure” a sign.

(1) Using an illuminance meter in a location directly in front of the center of the sign at a known distance at least several times the largest dimension of the sign and with no other nearby light sources[20], measure the illuminance in the plane parallel to the sign face. Using a simple formula, determine the average luminance.
(2) Using a luminance meter, measure a number of spots on the sign or billboard and average them.

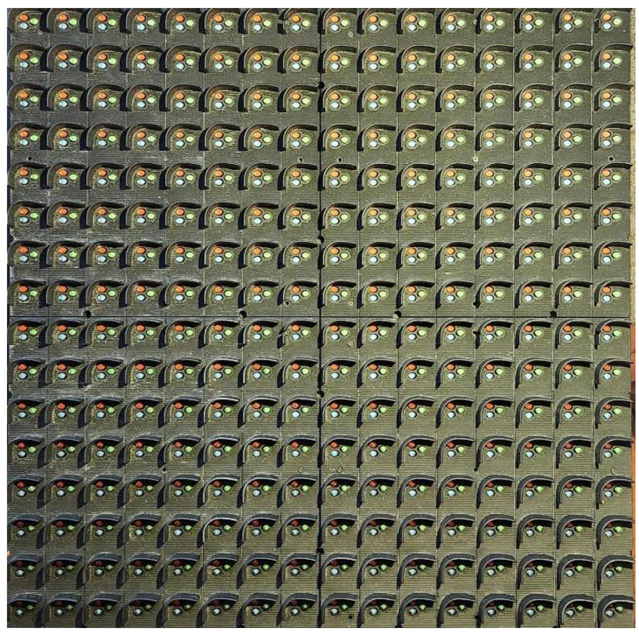
The **illuminance meter method** requires a professional grade meter that has been recently calibrated to NIST standards and is accurate to .01 lux. At low levels a tripod is absolutely necessary. While inexpensive meters may work, the process requires more precision than is obvious. Because an illuminance meter will measure all light emitted in the hemisphere in front of it, eliminating light sources other than the sign is difficult or impossible because the person taking the measurement is unlikely going to be able to extinguish either the sign itself or the other ambient lights[21]. Since this method was developed for measuring mostly billboards on rural freeways, that is in general its practical limit of its usefulness.

The **luminance meter**, popularly known as the “nit gun” is a variation on a through-the-lens exposure meter and is required by RP-39. It should be recently calibrated to NIST standards. The nit gun directly measures the luminance of a circular “spot” on a sign at a fixed acceptance (aperture) angle. Two of the more popular field meters in North America today are the Minolta LS-150, with a 1° acceptance angle, and the Minolta LS-160, with a 1/3° acceptance angle. The acceptance angle determines the diameter of the area being measured. For instance, at a distance of 100’, the LS-150 measures the average brightness of a circle 21” in diameter and the LS-160

[20] Being able to switch the sign or billboard off will allow measuring ambient light that can then be subtracted from the combination of sign and ambient light.
[21] Some have employed a clever “cut out” board, painted black, through which only the sign as a light source can be removed from or added to the ambient light measurement.

measures the luminance of a circle 7" in diameter. The meters are "through the lens" such that the person making the measurement of luminance can view exactly what is being measured. To measure the luminance of a sign, the process described in RP-39 requires the person taking the measurement to acquire a number of sample readings and then average them.

For a cabinet sign or channel letter sign with an unchanging light source, one takes a series of measurements from a single position and averages them. The chosen points represent an average of the luminance of the sign such as carefully weighing the percentage of areas of each color. This is the first of several reasons why luminance measurements will tend to be inaccurate, as one must determine the exact points to measure such that the average of the readings represents the average luminance of the sign. Also, the process introduces errors because the luminance varies with the vertical and horizontal angles of measurement. But the principal reason that this process is inaccurate is because it is often not possible to get to a measurement location that is even remotely ideal. For example, measuring a high-rise sign in-situ can be performed from the ground, from the roof of an adjacent building, or through the window of a taller adjacent building. The window is an obvious problem, as the transmittance of modern window glass is often 50% or less, of unknown dirt and spectrally altering[22]. The angle of measurement must also be measured carefully and from any of these vantage points an inclinometer will probably be needed (although usually impractical) and the measurement will probably still be inaccurate.



Finally there is the LED digital or electronic sign. Each "pixel" consists of at least a red LED, a green LED, and a blue LED ("RGB"). The spacing between pixels determines the resolution of the sign. The image at right is a portion of a digital sign.

LED manufacturers are innovating with new technologies to address specific concerns related to lighting impacts. Several manufacturers offer products with unique cut-off capabilities to address specific concerns.

In my opinion, considering the complexity and cost[23] of field measurements and the likelihood of inaccurate results, the industry should consider **calculated** outcomes instead. The photometric

[22] And very hard to get the data.

[23] From my professional experience, luminance measurements are uncommon due to lack of expertise and cost. Few if any communities own a "nit gun" that costs about $5,000 and employ anyone trained to use it. Sign industry companies, some academic institutions and some consulting engineering firms own a "nit gun" and may have one or two employees skilled in their use. In a dispute concerning luminance, the cost of measurements by an independent party, preferably a Professional Engineer or PhD, could easily cost $5,000 to $7,500 **for each sign face**, including

distribution of an RGB module like this could easily be measured in a goniophotometer, and knowing its exact location, the light emitted by it at any given nearby location can be predicted[24] with at least comparable accuracy to any field measurement. The light output settings would be automatically adjusted according to a calendar and weather conditions. Additionally, the decline in light output of the LEDs due to aging and weathering could be compensated by control electronics, and other special functions and events can readily be programmed in. It is easy to predict a future where any sign using LEDs can be measured at the factory, calibrated, and placed in service using the Internet or a remote control or terminal. While there will always be disputes, in my opinion field measurements should be a last resort to the process of placing billboards and signs into service and resolving concerns in the community. Experts with nit guns will be needed, but mostly relegated to legal disputes and similar challenges. Since manufacturers typically have nit guns and know how to use them properly, a factory self-certification is one other option for compliance.

Planned Field Measurements Canceled

The original plan and scope of work for this project was to take a number of luminance measurements on sample signs in the Lighting Zones available to me and Sign Industry Technical Committee (TC) members. The intent of this exercise was to determine the range of average sign luminance in situ by location, e.g. freeway off-premise or downtown entertainment district on-premise. As part of this exercise, TC members were to subjectively rate whether the sign was sufficiently bright or too bright for the application. The measurement protocols included taking safety precautions and measuring the sign itself. The primary outcome expected from these measurements was to determine the range of sign luminance in practice and use the results to address maximum values contained in RP-39.

After my T-10A and LS-100[25] meters were calibrated and I acquired a Spike smartphone measuring device, I took measurements on I-80 billboards within a 20-mile radius of my office. I found reasonable points of view, but the process was a challenge. Access to signs was often limited to standing next to my car due to fences and ditches, which led to inconsistent measuring distances and challenges with using Spike. Five of the billboards were conventionally lighted with linear uplights or downlights, with only 2 being digital and 2 having digital windows. I was unable to get to the proper measuring distance on any billboard. I nonetheless took nighttime readings between 225 and 490 nits, average on all conventional billboards. The digital billboards changed images every 8-20 seconds, making it impossible to take a series of representative points of luminance. It was in the course of planning and/or taking these measurements (and

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professional fees, travel, and meter calibration fees (NIST traceable calibration is $750 and recommended for any significant new case.) Casual measurements by persons of modest training should be minimized or not allowed.

[24] Using software like AGI32 and its competitors.

[25] Forerunner of the LS-150 mentioned earlier.

others in the course of my expert work) that I concluded that field measurements of sign luminance were difficult to make and generally not exact or repeatable as discussed above[26].

Based on this experience and others including testing and certifying existing signs and working for a client trying to certify a new digital billboard under a strict local ordinance, I concluded that, like new lighting installations in or near buildings, field measurements should be very seldomly taken because the **illuminating engineering should be done in the design phase**. During design, candidate products are analyzed, their installations engineered and specified and their performance, while capable of being adjusted, once installed and commissioned will perform as needed and within standards established in design. I proposed this idea to the technical advisory committee (see below) and received unanimous support.

The Sign Industry and Its Support for this Report

This report was developed at the request of and with funding from the Sign Research Foundation (SRF). Sapna Budev, the Executive Director of the SRF, oversaw this work and directed its overall course. David Hickey, Vice President of Advocacy of the International Sign Association (ISA) and James Carpentier, Director of State and Local Government Affairs of the ISA, managed project team meetings and provided technical oversight and commentary.

As part of this Project I reviewed materials supplied by SRF, ISA and the Out of Home Advertising Association of America (OAAA). The sign industry has produced a number of useful documents, both for standardization and education. It is also my opinion that SRF has funded quality scientific work by reputable scientists, notably those cited in this document.

My work was carried out with the assistance, counsel and knowledge of the sign industry technical advisory group, chaired by Rod Wardle of YESCO. Members of the group were from the on-premises and off-premises sign industries, including James Carpentier (ISA), David Hickey (ISA), Jeremy Johnson (Daktronics), G. Todd Lathan (Outfront Media), Brad Miller (Lamar), Lou Musica (Clear Channel), Bill Ripp (Lamar) and Kerry Yoakum (OAAA). Over the course of this project, their input was extremely relevant, timely and useful. Among the group's most significant contributions was their enormous skill and experience; their expressed frustration with the issues of luminance measurement and how it relates to the current regulatory situations; their concerns over lack of technical substance in sign-related standards and regulations and the failure to include them in it; and lack of standardization and consistency among standards and regulations at all governing levels. The ideas presented in this report were discussed and generally supported by all members.

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[26] The exact same result was difficult or impossible to obtain with two separate measurements, both of sign size and of luminance, even when taken by the same person. Differences between persons taking measurements were evident and sometimes significant.