Digital LED Billboard Luminance Recommendations
How Bright Is Bright Enough?

DRAFT

Christian B. Luginbuhl, U.S. Naval Observatory Flagstaff Station
Howard Israel, Phoenix, Arizona
Paul Scowen, Arizona State University
Jennifer and Tom Polakis, Tempe Arizona
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Summary

Careful and sensible control of the nighttime brightness of digital LED signage is critical. Unlike previous technologies, these signs are designed to produce brightness levels that are visible during the daytime; should too large a fraction of this brightness be used at night serious consequences for driver visibility and safety are possible. A review of the lighting professional literature indicates that drivers should be subjected to brightness levels of no greater than 10 to 40 times the brightness level to which their eyes are adapted for the critical driving task. As roadway lighting and automobile headlights provide lighting levels of about one nit, this implies signage should appear no brighter than about 40 nits. Standard industry practice with previous technologies for floodlit billboards averages less than 60 nits, and rarely exceeds 100 nits. It is recommended that the new technologies should not exceed 100 nits.

Introduction

Illuminated signage, for both advertising and informational purposes, has been a fixture of the modern nighttime environment since at least the invention of electric lighting. Until recently, the principal use of artificial lighting has been to make signs legible at night: ambient lighting, including skylight and sunlight, has been considered adequate for daytime visibility. With the advent of digital LED billboards, however, this is no longer true. Digital LED billboards must generate brightness sufficient to make them legible during the daytime as well as at night. The brightness necessary to make a sign legible during a full sunlit day can be many thousands of candela per square meter (also called nits); products available on the digital LED billboard market commonly advertise maximum luminances between 6500 and 7500 nits. This creates the potential risk of a blinding nighttime brightness should an inappropriate adjustment for nighttime conditions be made. Thus, the question arises of an appropriate limit to the brightness of a sign at night, whether a digital LED billboard or any other kind of sign.

Background: Sign Brightness, Drivers, and Visibility

The principal safety and regulatory concerns for drivers viewing signage from a roadway is that 1) the sign, by its very nature, is seeking to attract the gaze of the driver, i.e. the advertiser intends the driver to look directly at the sign (and away from the roadway) for a period of time sufficient to discern the sign's message or messages. Besides the obvious issue of a driver taking his or her eyes from the driving task, viewing the sign leads to the second problem, 2) the eye adapting toward the brightness level of the sign. Thus, when the driver returns his gaze back to the roadway, in all cases illuminated to a much lower brightness than the sign, for some period of time the driver's vision is no longer optimally adapted to seeing objects on the roadway. This changing visual adaptation when brightness levels change is

referred to in the technical literature as "transient adaptation." Drivers that have their visibility reduced for objects on the roadway, even momentarily, will be at greater risk for accidents.

The Illuminating Engineering Society of North America (IESNA) recognizes this issue in numerous places in its literature. The *IESNA Lighting Handbook* (9th edition, page 3-9) states:

> "If the change in [brightness] lies completely within the range of operation of the cone photoreceptors [i.e., daytime vision], *a few minutes* is sufficient for adaptation to occur. ... As for direction of change... changes to a higher [brightness] can be achieved much more rapidly than changes to a lower [brightness]." [*emphasis added]*

This last sentence says that the eye will adapt much more quickly when moving from the dimly lighted roadway to the bright sign, but much more slowly when returning to the dim roadway.

Design brightness levels for illuminated roadways are in the range of one nit (varying from about 0.3 to 1.2 nits, depending on roadway type (IESNA RP-8-00, 2000)). Thus, a driver viewing a billboard illuminated to (for example) 100 nits, and then returning his gaze to the roadway, must adapt his eyes to a brightness range of about 100:1.

What then is an acceptable ratio for transient adaptation, such that a driver's vision will not be hampered when viewing both more brightly and less brightly illuminated areas while driving? *IESNA RP-33-99*, *Lighting for Exterior Environments* (page 42) states:

> "If... roadways are lighted to a base level, [adjacent] areas should be no brighter than ten times that level. Additional brightness will not attract more attention, and may present a hazard to motorists on adjacent roadways."

Further, in *IESNA RP-20-98 Lighting for Parking Facilities*, we find (page 2):

> "It is intended that a driver (or pedestrian) looking at the brightest spot in the field of view will also be able to detect an object in the dark areas within the field of view. This detection can occur only if the maximum-to-minimum illuminance is limited to a range that the human eye can see."

This is followed by the numerical recommendations (page 3, Table 1) of 15-20:1. In other words, the brightest area should appear no more than 20 times as bright as the faintest to assure that the brightness remains within a range that the human eye can see.

In *IESNA RP-2-01, Lighting Merchandise Areas* (page 58), we find:

> "... luminance ratios between the lighted retail area and its surroundings should not exceed 20:1. Increasing the lighting level does not add to merchandise attraction, and may create a hazard to motorists on adjacent roadways or a nuisance for neighbors. A value of 10 times the average surrounding task luminance is a maximum that should be utilized for the focus merchandise. This will provide merchandise appeal without producing hazards or creating conflicts with other nighttime events."

The IESNA recommendations for advertising sign brightness (*IESNA Lighting Handbook, 9th edition*, page 17-26) are inconsistent with all recommendations noted above. Brightnesses between 250 and 1400 nits are listed in the table titled "Recommended Luminous Background Sign Luminances." These recommendations, if visible to highway drivers, will subject drivers' eyes to a brightness ratio of 250-1400:1. According to their own recommendations this ratio is unsupportable and will lead to compromised visibility and safety on public roadways. From the maximum ratio of 20:1, and assuming roadways are illuminated to about one nit, signs should be no brighter than 20 nits. It is perhaps telling that nowhere in the discussion of recommended advertising sign brightnesses is transient adaptation or the vision of drivers mentioned.

Lighting for Conventional Floodlit Billboards

A series of measurements made for this report in August 2009 (55 billboards, Phoenix metro area), Novembr 2010 (3 billboards, Chicago area), as well as deduced from data supplied for Tucson billboards by M. Mayer, give an idea of brightness levels commonly seen in usual floodlit signs. These signs were constructed and illuminated in most cases without any restrictions on sign brightness. It seems reasonable to assume that the signs are illuminated to a brightness considered satisfactory by the industry; if they were not, in most cases there were no regulations preventing them from increasing the lighting levels.

Tucson Metro Billboards. A lighting inventory undertaken by M. Mayer lists the areas, number and types of lamp used for illumination for 510 billboard faces located throughout the Tucson metropolitan area. Since no direct luminance measures were made for this survey, we deduced approximate luminances using a set of assumptions describing the physical characteristics of the sign lighting installation[1]. These assumptions allow the conversion of total initial lamp lumens and area of the signs to the maintained luminance values shown in Figure 1.

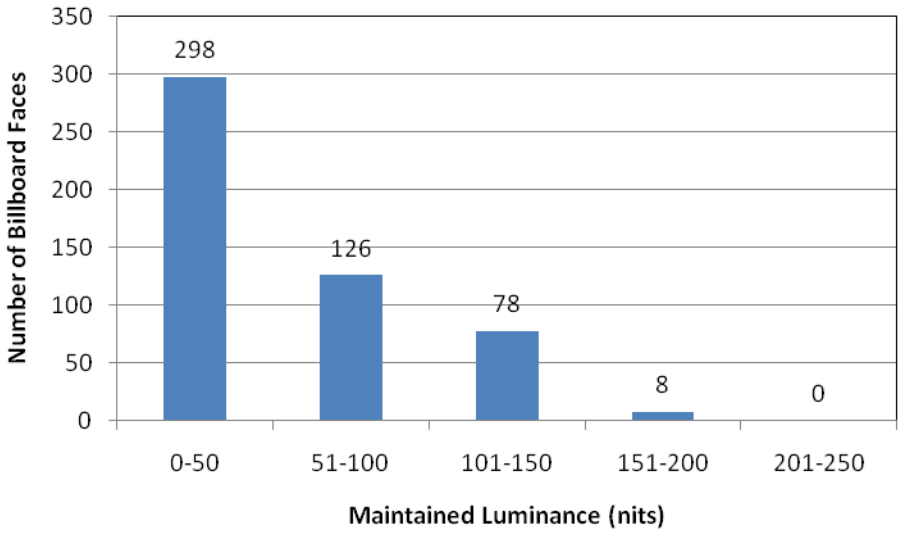

Figure 1. Number of billboard faces with indicated predicted maintained luminances in the Tucson metropolitan area.

[1] Initial lamp lumen outputs from the manufacturer's literature; Light Loss Factor (LLF) = 0.60; Application coefficient of utilization = 0.30; Diffuse reflectance of white vinyl sign surface = 0.70

Phoenix and Chicago Metro Billboards. Measures of white surfaces on 55 floodlit billboards in the Phoenix metropolitan area were made in August and November, 2009 using a Minolta LS-100 luminance meter. An additional 3 billboards were measured in th Chicago area in Novmber, 2010. All of these billboards are located in an urban environment. The results are presented in Figure 2; the data are presented in Appendix A.

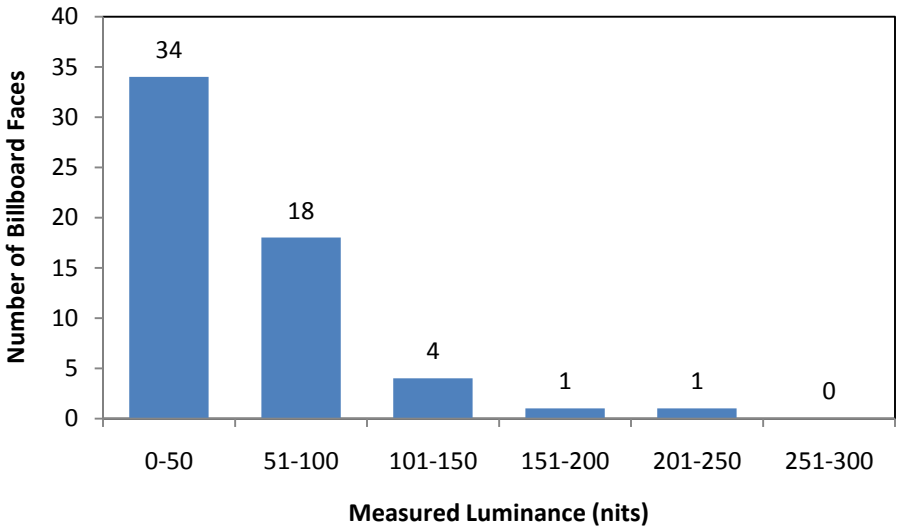

Figure 2. Number of billboard faces with indicated measured luminances in the Phoenix and Chicago metropolitan areas.

Of the total 510 billboard faces inventoried in the Tucson metropolitan area, the estimated average luminance is 59 nits; 83% (424/510) are estimated at 100 nits or less, and 98% (502/510) at 150 nits or less. The Phoenix and Chicago sample shows quite similar results, with an average luminance of 54 nits, and 90% (52/58) measured at 100 nits or less, and 97% (56/58) under 150 nits.

Toward a Sensible Standard

Following the most conservative information concerning contrast ratios and transient adaptation, it appears that the maximum luminance for signs visible to drivers on typically illuminated roadways should not exceed approximately 20 nits. This follows directly from the commonly cited maximum contrast ratio of 20:1 appearing in the IESNA literature and roadway luminances of approximately 1 nit.

Twenty nits is considerably below the brightness proposed by the OAAA report, and even below the typical floodlit sign visible to drivers today. Yet IESNA references concerning brightness ratios and transient adaptation, when discussed in any context other than that of signage (see below), indicate that choosing a value higher than 20 nits may have visibility consequences for drivers.

When discussing lighting recommendations for signs directly, IESNA recommendations begin at 20 nits but range higher, in one case much higher. *IESNA RP-19-01 Recommended Practice for Roadway Sign Lighting* recommends that roadway signs be designed with luminances between 20 and 80 nits. The lower value, 20 nits, is consistent with the value deduced from recommended maximum contrast ratios and typical roadway luminances. The higher value, 80 nits, will present drivers with a contrast ratio of

about 80:1, yet is approximately comparable to typical practice for floodlit billboards. In The IESNA Lighting Handbook (9th edition), Figure 17-37 Recommended Luminances for Poster Panels, Painted Bulletins, and Other Advertising Signs recommends illumination levels that are consistent with luminances of 45 – 111 nits[2].

Thus, we suggest that a regulated maximum luminance for any type of sign visible from a roadway, digital LED billboard or other, should not exceed 100 nits in an urban environment. Though it can be easily argued that this value is too high, this limit would be consistent with the vast majority of commercial floodlit billboards in use today, and at least would not increase potential degradation of drivers' vision above levels experienced with current floodlit billboards. As the adaptation state of drivers' eyes is generally dominated by the luminance level of the roadway illuminated by headlights, that is around one nit, it may not be necessary to require lower sign luminances in darker surroundings.

The Outdoor Advertising Association of America Report and Recommendation

To formulate its own recommendations for sign luminance limits, the Outdoor Advertising Association of America commissioned a study (Lewin, 2008; hereafter referred to as the OAAA report). This report describes "a method for specification of luminance limits for digital billboards based on accepted practice by the Illuminating Engineering Society of North America (IESNA)." Based ultimately on considerations of "light trespass," as developed in another report *(IESNA TM-11-00 Light Trespass: Research, Results and Recommendations)*, a recommended "brightness" limit and measurement technique is presented. The technique uses an illuminance meter ("footcandle" meter) held at a height of 5 feet above the ground and a distance of between 150 and 350 feet from the sign under consideration, depending on the size of the sign, and aimed at the sign. The illuminance level with the sign lighting on is compared with a measure made with the sign off: if the value differs by 0.3 foot candles or less the author proposes that the sign brightness is at an acceptable level. Though direct luminance measures or limits are not suggested in this proposed regulatory strategy, the report indicates that this method effectively limits the luminance of signage to 300-350 nits.

Issues with the OAAA Report

The OAAA proposed luminance levels are too high, about ten or more times as bright as recommended in most IESNA recommended practices, and three or more times as bright as current accepted practice reflected in billboard floodlighting. They would present drivers with contrast ratios of 300:1 or more. This is unnecessary for advertising effectiveness and unnecessarily risks roadway safety. Further, the OAAA recommendations are consistent with only the highest values gleaned from the IESNA literature, and inconsistent with IESNA recommendations for roadway signs and maximum contrast ratios to minimize transient adaptation problems.

Besides potentially serious practical issues associated with the measurement procedure proposed in the OAAA report (e.g. the location for the suggested measurement may often lie within roadways; determining compliance requires switching the sign on-and-off), there is a fundamental conceptual error in the approach used to develop the strategy and limits.

[2] IESNA recommended illuminance of 200-500 lux for light copy in dark-light surrounds combined with assumed diffuse sign reflectance of 0.70.

The details of *IESNA TM-11-00* are critical to understand if the results of that study are being appropriately applied to the problem of determining maximum sign luminances. In the study, a group of observers was presented with a variety of very brightly illuminated (2000 to 7500 nits) panels and asked to judge whether or not the panels seemed too bright. An in-depth review is beyond the scope of this discussion, but the following point is critical: the observers were asked only to rate how "objectionable" they found the illuminated panels to appear; no evaluation of visual performance - the ability to see objects or read signs - was attempted. This alone brings into serious question the applicability of theTM-11-00 study to the question of appropriate sign brightnesses, and their potential impact on driver safety.

The fundamental approach of the OAAA report has confused lighting that has been judged to cause an acceptable level of light trespass or even just an "objectionable" sensation with the much more vital issue of sign lighting that compromises the vision and therefore safety of drivers. The ability to see and light trespass/objectionability are essentially unrelated. The OAAA report recognizes this, stating "Digital billboards are not the form of lighting that TM-11-00 was developed to limit." Yet the OAAA report does just that.

Transient adaptation, and not light trespass, or "objectionability," is the overriding concern for public safety with regard to the brightness of signage.

References

IESNA, *RP-20-98 Lighting for Parking Facilities,* 1998

IESNA*, RP-33-99 Lighting for Exterior Environments, An IESNA Recommended Practice,* 1999

IESNA, *IESNA TM-11-00 IESNA Technical Memorandum on Light Trespass: Research, Results and Recommendations*

IESNA*, The IESNA Lighting Handbook, 9th Edition,* M. Rea (ed.), 2000

IESNA*, ANSI/IESNA RP-8-00 American National Standard Practice for Roadway Lighting,* 2000

IESNA*, IESNA RP-19-01 IESNA Recommended Practice for Roadway Sign Lighting,* 2001

Lewin, I., *Report to: Outdoor Advertising Association of America; Subject: Digital Billboard Recommendations,* Lighting Sciences Inc., Scottsdale, Arizona, 2008

Appendix A

Floodlit billboard luminance measurements presented in this report.

Number	Advertisement	Location	AddressLocation	Luminance (nits)	Notes
1	Miracle Auto Painting	Tempe, AZ	Tempe Marketplace	103	1
2		Chandler, AZ	202 @ McClintock Dr.	235	1
3	ClearChannel	Ahwatukee, AZ	I-10 between Ray and Chandler	114	1
4	Naumann Hobbs	Phoenix, AZ	I-10 & 43rd St.	174	2
5	Fry's	Tempe, AZ	Tempe Marketplace	124	2
6	Bankruptcy/Divorce	Phoenix, AZ	2511 W Indian School	82	2
7	Hastings & Hastings	Phoenix, AZ	I-10 & 42nd St.	42	2
8	Cox Cable	Phoenix, AZ	I-10 & 40th St.	23	2
9	Dare to Compare	Phoenix, AZ	Broadway & 40th St.	19	2
10	Select 55 Lightest Beer	Phoenix, AZ	Elwood & 40th St.	103	2
11	Recession 101	Phoenix, AZ	I-10 & 40th St.	100	2
12	100% USDA Fry's	Phoenix, AZ	Illini & 38th St.	71	2
13	MHM Inc.	Phoenix, AZ	I-10/7th St.	33	3
14	The Experts	Phoenix, AZ	I-10/7th St.	63	3
15	WhataBurger	Phoenix, AZ	I-10/Central Ave.	26	3
16	Univ. of Arizona	Phoenix, AZ	I-10/Central Ave.	40	3
17	Cricket	Phoenix, AZ	I-10/Central Ave.	44	3
18	Run Wild	Phoenix, AZ	I-10/Central Ave.	10	3
19	Kimberly-Clark	Phoenix, AZ	I-10/7th Ave.	75	3
20	Alcock	Phoenix, AZ	I-10/7th Ave.	70	3
21	Flying J	Phoenix, AZ	I-10/7th Ave.	60	3
22	Thirst – McDonalds	Phoenix, AZ	I-10/7th Ave.	30	3
23	Univ. of Arizona	Phoenix, AZ	I-10/7th Ave.	70	3
24	Arizona Heart Inst.	Phoenix, AZ	Durango Curve	53	3
25	Bud Select	Phoenix, AZ	Durango Curve	10	3
26	Park University	Phoenix, AZ	Durango Curve	57	3
27	Geico	Phoenix, AZ	Durango Curve	28	3
28	Michelob	Phoenix, AZ	Durango Curve	73	3
29	Cabella	Phoenix, AZ	22nd Ave. – I-10	24	3
30	Location	Phoenix, AZ	22nd Ave. – I-10	48	3
31	Burger King	Phoenix, AZ	22nd Ave. – I-10	25	3
32	AAA	Phoenix, AZ	16th Ave. - I-10	6	3
33	Buick	Phoenix, AZ	16th Ave. - I-10	45	3
34	Lowes	Phoenix, AZ	16th Ave. - I-10	50	3
35	AZ Lottery	Phoenix, AZ	16th Ave. - I-10	32	3
36	Landshark	Phoenix, AZ	16th Ave. - I-10	70	3
37	Qwest Espanol	Phoenix, AZ	11th Ave - I-10	30	3
38	Dex	Phoenix, AZ	11th Ave - I-10	15	3
39	Ronald McDonald	Phoenix, AZ	11th Ave - I-10	18	3
40	Coors Light	Phoenix, AZ	11th Ave - I-10	45	3
41	Senior Care	Phoenix, AZ	7th Ave. – I-10	30	3

42	KTAR	Phoenix, AZ	7th Ave. – I-10	35	3
43	Cancer	Phoenix, AZ	7th Ave. – I-10	40	3
44	Geico	Phoenix, AZ	Central – I-10	36	3
45	St. Lukes Espanol	Phoenix, AZ	Central – I-10	60	3
46	L4D	Phoenix, AZ	Central – I-10	10	3
47	Run Wild	Phoenix, AZ	Central – I-10	16	3
48	Easy Street	Phoenix, AZ	Central – I-10	42	3
49	PHX Zoo	Phoenix, AZ	Central – I-10	50	3
50	Left 4 Dead	Phoenix, AZ	7th St. – I – 10	6	3
51	Bud Light	Phoenix, AZ	7th St. – I – 10	60	3
52	Mc Donalds	Phoenix, AZ	7th St. – I – 10	60	3
53	U of Phx Espanol	Phoenix, AZ	7th St. – I – 10	46	3
54	Chipotle	Phoenix, AZ	7th St. – I – 10	56	3
55	Droid	Phoenix, AZ	16th St. – I-10	46	3
56		Plainfield, IL	12040 Aero Dr.	76	4
57		Plainfield, IL	12501 S Rte. 59	46	4
58		Naperville, IL	3004 111th St.	68	4

Notes: 1 measured by P. Scowen; 2 measured by J. and T. Polakis; 3 measured by H. Israel; 4 B. Radner, Assistant Director, Will County Land Use Department, Memorandum 1 November 2010