Evaluating Nighttime Sign Surrounds

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The accuracy of a variety of instruments that might be suitable for field measurement of nighttime sign surrounds was evaluated by comparing measurements made with them with measurements made with a laboratory-quality telephotometer. A technique for the evaluation of surrounds that identifies them by luminance measurements was developed. The measurement of numerous surrounds leads to the conclusions that conventional descriptions are often inappropriate, that opposite sides of the same roadway may vary in luminaire intensity, and that roadway geometrics may cause variations in surrounds. Photographs and luminance values that represent four generalized luminance levels and a description of each are given.

Research on the nighttime performance of signs has shown a close relation between the luminance of a sign versus its nighttime background or surround and its visibility and legibility. However, beginning with the work of Smyth (1) and continuing to the present time, this research has used either blank laboratory surrounds that were varied in luminance only for purposes of the research or natural night surrounds that were identified only by verbal descriptions or pictures. There has been little or no systematic work that measured the highly variegated night surrounds occurring on highways (particularly those in the vicinity of official traffic signs).

Lythgoe (2), Smyth (1), Allen and Straub (3), Allen and others (4), and Forbes (5) have shown that increased sign luminance is required where sign surrounds possess increasing luminance. This is in agreement with the requirements of some standards (6, 7). Some of the luminance values for sign legends or backgrounds as a function of surround luminance are summarized below (1 cd/m^2 = 0.292 ft•L).

	Surround Luminance (cd/m^2)		
Investigator	Dark	Medium	Bright
Smyth	15 to 25	25 to 65	65 to 170
Illuminating Engineering Society	25	50	100
Allen and others	35	70	350
Forbes	2.9 to 26	26 to 87	87 to 274

Surround luminance is high at night in urban locations where street lighting, advertising signs, and commercial lighting displays form the background for essential traffic signs. It is low on dark, rural, two-lane roads that have low traffic volumes and few intersections. Greater understanding of the spectrum represented by these extremes is desirable for

1. Accurate identification of the nighttime surround,
2. Selection of appropriate materials to achieve the necessary luminance levels and ratios of contrast, and
3. Achievement of the maximum economic benefit by the selection of materials that are appropriate to the environment of the sign.

Various federal specifications (8, 9) describe numerous performance levels for reflective materials, and there are a wide variety of lighting designs and luminaire fixtures available. However, to select the appropriate sign luminances, the nighttime surrounds should be measured and identified first. Thus, this paper evaluates practical methods of measuring nighttime sign surrounds and six available instruments, and presents a survey of measurements made with some of them.

The selection of suitable instruments must recognize the extremely varied nature of the roadside surround. Woltman (10) has reported an inventory of sign surrounds for daylight, and luminance observations of dark, rural, nighttime sign surrounds have been made (11), but the best photographs cannot convey the variety of luminance levels that occur, and the colors and extremes of contrast, both dynamic and static, to which the driver is subjected. As Luckiesh (12) points out,

> A thorough diagnosis of visibility and seeing conditions involves
>
> 1. Brightness levels of the task and the immediate and entire surroundings,
> 2. Brightness contrast between critical details and their background,
> 3. Brightness ratio of the surroundings and the task, and
> 4. Brightnesses and brightness ratios in the entire visual field.

VISUAL FIELD

The surroundings of the visual task can include the entire visual field, but there are practical reasons for limiting it. Luckiesh has noted that

> At 30° from the optical axis, visual acuity is only 1 percent of its value in the central 1° field. The effect of a glare source, and also the effect of brightness of the surroundings, decrease as the angular distance from the line of vision increases.

Matson (13) and Greenshields (14) consider the visual field of a driver within the confines of an automobile and busy with the driving task to be 6 and 10°. The majority of roadside shoulder and overhead signs are within this field.

The act of seeing fine detail is accomplished in a small field (about 1° in extent) on the optical axis of the eye. Glare sources close to this field are the most troublesome, particularly at night, when the critical task of sign reading may involve relatively low luminances and short time intervals.

The central field contains the visual task (the sign and the most important elements of the surround). According to Finch (personal communication), interfering luminances are those in a 3 to 5° field, and an average expressed as an integrated value of such sources is necessary. Olson (personal communication) agrees that an average luminance measure that surrounds the sign to the extent of one or two sign diameters is probably satisfactory.

Although other methods of evaluating the sign surround have been considered, the most immediately practical are the Pritchard type telephotometers that can selectively evaluate discreet areas of interest. The use of such instruments at sign-reading distances permits the measurement of the luminance level of the task and the surround and the determination of luminance ratios and luminances of any objects or surfaces in the visual field. A selection of probe sizes is available, and integration over an area of 1° is possible by the use of the 1° probe. This is of particular importance for the measurement of surround luminance: One degree is equivalent to a diameter of 0.53 m (21 in) at a distance of 30 m (100 ft), and at a distance of approximately 90 m (300 ft) the 1° probe gives an integrated reading of a 1.5-m (5-ft) diameter area, where the sign itself displaces approximately 0.5°. Thus, a 2.5° field, which corresponds closely to the recommended 1 to 3° field, can be examined by measuring tangentially at the edges of the sign.

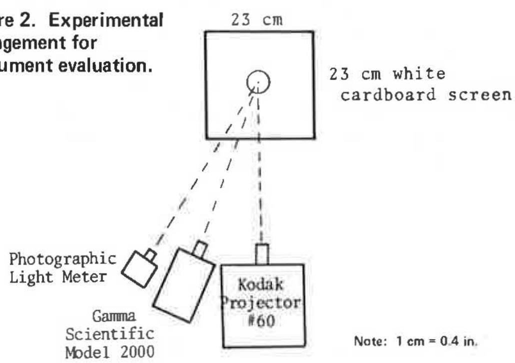
INSTRUMENT EVALUATION

The following small, portable instruments (Figure 1) that might be suitable for field measurements of surround luminances were evaluated.

Figure 1. Instruments evaluated for the measurement of nighttime surrounds.

Note: Left to right at front: instruments 2, 3, 6, 5, 4, and 3.
At rear: instrument 1.

Figure 2. Experimental arrangement for instrument evaluation.



Note: 1 cm = 0.4 in.

1. Gamma Scientific, Inc., model 2000 telephotometer: This is a scientific, Pritchard type instrument and has a transistorized photomultiplier and electrometer amplifier, a portable power supply, a 1° sensing probe (an acceptable angle), photopic color correction, a measurement range of 0.003 to 120 000 cd/m² (0.001 to 35 000 ft·L), and internal standardization and calibration. It was calibrated with a National Bureau of Standards source over a number of tests and averaged ±2.5 percent.

2. Minolta TV Auto-spot: This instrument is essentially a studio, spot-reading, photographic light meter with a cadmium sulfide cell. The 1° measured area is enclosed by an illuminated etched circle. The output is given in footlamberts, and the range is 1.1 to 17 140 cd/m² (0.32 to 5000 ft·L).

3. Honeywell Pentax 1°/21° meter: This instrument is essentially a studio, spot-reading, photographic light meter with a cadmium sulfide cell. The 1° measured area is enclosed by an etched circle, which may be illuminated. The output is given as a light level with a range of 3 to 18, which corresponds to 1.0 to 34 280 cd/m² (0.3 to 10 000 ft·L).

4. Soligor Spot Sensor: This instrument is essentially a studio, spot-reading, photographic light meter with a cadmium sulfide cell. The 1° measured area is enclosed by an etched circle in the viewing field. The reticule is not illuminated. The output is given as an exposure value range of 3 to 18, which corresponds to 1.0 to 34 280 cd/m² (0.3 to 10 000 ft·L).

5. Gossen Luna-Pro: This instrument is a 30° reflected light or incident light-measuring, studio, photographic light meter. It has an incident light range of 0.17 to 344 320 lx (0.016 to 32 000 ft·c).

6. Sekonic Auto-Lumi model 86: This instrument is a 30° reflected light meter. It has an exposure value range of 6 to 18, which corresponds to approximately 6.5 to 27 425 cd/m² (1.9 to 8000 ft·L).

The experimental arrangement for the evaluation of instruments 2 through 6 relative to instrument 1 is shown in Figure 2. The photographic light meters, the scientific telephotometer, and the projector were all in the same plane. A 1° probe was used. The screen was moved from 1 to approximately 12 m (3.3 to 39 ft) to decrease the luminance.

The nighttime evaluation of these meters showed reasonably close correlations between meters 1 and 2

Table 1. Laboratory data for correlation of scientific telephotometer and photographic light meters.

	Measured Target Luminance (cd/m²)											
Instrument	White Target								Red Target		Blue Target	
No. 1												
Gamma Scientific	2.2	5.6	11.0	18.8	26.7	28.4	28.7	61.7	5.9	17.5	1.8	3.9
No. 2												
Minolta	1.4	3.1	6.9	13.7	13.7	25.7	37.7	54.8	4.3	17.5	1.5	3.8
No. 3												
Honeywell Pentax	1.7	4.8	8.6	19.9	24.0	26.7	37.7	51.4	5.5	22.3	2.1	4.5
Honeywell Pentax 2	2.1	5.8	10.3	19.2	25.7	28.4	38.7	51.4	6.9	17.5	2.7	6.9
No. 4												
Soligor Spot Sensor	2.1	3.4	8.9	16.4	20.6	22.3	32.6	46.3	5.5	17.8	1.4	2.4

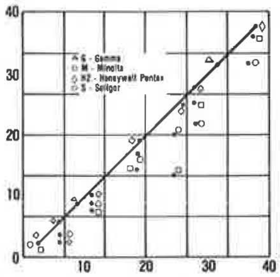
Note: 1 cd/m² = 0.292 ft·L.

Table 2. Correlation of scientific telephotometer and photographic light meters.

	Error Relative to Measurement by Meter 1 (%)											
Instrument	White Target								Red Target		Blue Target	
Minolta	-37	-44	-38	-27	-49	-10	-3	-11	-27	-2	-19	-4
Honeywell Pentax	-21	-14	-22	5	-10	-6	-3	-17	-6	27	13	14
Honeywell Pentax 2	-5	5	-6	2	-4	0	0	-17	17	0	51	75
Soligor Spot Meter	-5	-38	-19	-13	-23	-22	-16	-25	-6	2	-25	-39

Table 3. Correlation of scientific telephotometer and photographic light meters.

	Avg Error Relative to Measurements by Meter 1 (%)			
Instrument	All Targets	White Target	Red Target	Blue Target
Minolta	-22.6	-27.3	-14.5	-11.5
Honeywell Pentax	-3.3	-11.0	10.5	13.5
Honeywell Pentax 2	9.8	-3.1	8.5	63.0
Soligor	-19.1	-20.1	-2.0	-32.0



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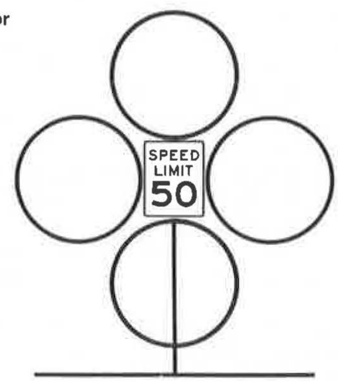

Figure 4. Probe locations for measuring sign-surround luminance.

through 4. Under high luminance conditions, meters 5 and 6 indicated higher light levels than the actual sign surrounds, and under many moderate nighttime conditions, readings lower than those measured by meters 1 through 4 were common. The wide acceptance angle of these instruments, 30°, includes too much background—either luminaires of the bright surround or black sky of the darker surround. Thus, the surround immediately adjacent to the sign was not measured as accurately as the 1° acceptance angles of instruments 1 through 4.

The laboratory data for the correlation of meters 2 through 4 relative to meter 1 are given in Table 1, and the correlation is given in Tables 2 and 3 and illustrated for the luminance range of 3.5 to 34.5 cd/m² (1.0 to 10.0 ft·L) in Figure 3. The correlation is generally linear, but the values obtained with the less expensive instruments are somewhat lower than those obtained with the laboratory instrument.

FIELD EVALUATION OF NIGHTTIME SURROUNDS

The nighttime luminance of the dark sky above, to the immediate right, below, and to the immediate left of 90 signs was measured with the laboratory instrument, as illustrated in Figure 4. The measurements were made on dark, rural sections of interstate routes in winter against earth, sky, and snow-covered backgrounds. The presence of snow or moonlight appeared to be of little significance.

The use of instruments 2, 3, and 4 involves some compromises and requires some improvements in data gathering since these instruments do not read below 0.86 cd/m² (0.25 ft·L). (Values up to approximately 2 cd/m² (0.6 ft·L) represent dark surrounds.) However, by the use of these instruments, more data can be gathered with greater convenience and less training of the operators than with the larger laboratory instrument. In practice, the driver operates the smaller instrument, and another person records the data. The output of two of the instruments is read in exposure values (EV), a

Table 4. Distribution of nighttime sign surrounds for various study sites.

	Dark (less than 2 cd/m²)		Slight (2 to 6 cd/m²)		Moderate (6 to 17 cd/m²)		Bright (17 cd/m²)		
Location	Measured Value (cd/m²)	% of Total	Measured Value (cd/m²)	% of Total	Measured Value (cd/m²)	% of Total	Measured Value (cd/m²)	% of Total	Total
Detroit									
Woodward Ave.	4	17	4	17	11	45	5	21	24
Grand River Ave.	0	–	2	18	3	27	6	55	11
Telegraph Rd.	0	–	5	19	16	62	5	19	26
Dearborn, Mich.									
Michigan Ave.	0	–	1	10	4	40	5	50	10
Kalamazoo, Mich.									
Michigan Ave.	0	–	5	25	11	55	4	20	20
Kalamazoo Ave.	3	18	6	35	7	41	1	6	17
Lansing, Mich.									
Saginaw St.	1	11	2	22	2	22	4	45	9
I-496	5	56	0	–	3	33	1	11	9
MI-143	0	–	2	28	0	–	5	72	7
US-127	5	62	2	25	1	13	–	–	8
Minneapolis									
Lake St.	0	–	1	6	7	47	7	47	15
I-35W	0	–	1	50	1	50	0	–	2
St. Paul									
White Bear Ave.	4	50	2	25	2	25	0	–	8
Unlighted, rural Interstate highways in Calif., Tenn., Iowa, and Ariz.	90	100	0	–	0	–	0	–	90

Note: 1 cd/m² = 0.29 ft·L.

Figure 5. Dark surround.

Figure 6. Slightly illuminated surround.

numerical value that is converted to conventional luminance terms. The nonlinear relation of the EV and conventional luminance values (candelas per square meter or footlamberts) requires conversion of the EVs to conventional values and then the averaging of the results. The light weight, portability, and small size of these instruments make field use of them completely satisfactory. Instruments 2 and 3 have an internal illumination of the EV scale that is desirable for readings at low luminance levels.

The inclusion of only identical light sources in the surround is essential for similar readings. On the average, the measurement of a series of signs along a single route will produce similar data, although there will be some inevitable differences between observers measuring the same sign because they may stop at different distances from it or at differing offsets with respect to the traveled way.

The most satisfactory method of measuring surround data is as follows:

1. The observations are made from a vehicle in the traveled lane, while the driver's normal viewing point is maintained. A large offset, as within a driveway or parking area, displaces the sign with respect to its normal surround and leads to a slightly different surround that may have more or less luminance than does the actual one.

2. The observations are made from distances of approximately 90 m (300 ft) for the smaller regulatory and warning signs on the shoulder and approximately 180 m

Figure 7. Moderately illuminated surround.

Figure 8. Brightly illuminated surround.

Table 5. Descriptions of sign surrounds illustrated in Figures 5, 6, 7, and 8.

Surround	Description	Avg Luminance range (cd/m^2)	No. of Readings
Dark	Occasional street or highway lighting; few commercial signs or other light sources; generally dark behind sign	<2.0	112
Slightly illuminated	Some street lighting or highway luminaires; occasional commercial signs and other moderately intense light sources adjacent to and behind sign	2 to 6	21
Moderately illuminated	Continuous street or highway lighting; frequent commercial signs adjacent to and behind sign	6 to 17	67
Brightly illuminated	Bright commercial signs, luminaires, and other light sources immediately adjacent to and behind sign	>17	40

Note: 1 cd/m^2 = 0.29 ft·L.

(600 ft) for the larger guide signs. These correspond to the distances in which motorists must observe signs and still have sufficient time to read them.

3. The area of interest is that immediately around the sign, and four representative measurements, as illustrated in Figure 4, are desirable for averaging to obtain the surround luminance.

Instruments 1 and 3 showed good agreement in a field-comparison measurement of approximately 30 sign surrounds.

Surround measurements of 166 signs were made by using instrument 3. The areas in which these measurements were made include (a) dark, rural roads; (b) illuminated, depressed freeway sections; (c) illuminated, at-grade freeway sections in both rural and urban areas; (d) suburban shopping centers; (e) downtown local streets; and (f) older, built-up highways. These areas are typical of those that can be found anywhere in the United States. Readings taken in six states and in six cities are given in Table 4.

Typical sign surrounds are illustrated in Figures 5 through 8. Their descriptions and measurements are given in Table 5.

RESULTS AND CONCLUSIONS

The dark category has few lights, and these are not troublesome. Reflective signs generally have sufficient contrast against this light level for good visibility.

The slightly illuminated category is variegated and involves light sources that diminish sign performance. At the lower end of the range, there may be one or more street-lighting luminaires close to a sign, but the other side of the sign will have good contrast against a dark background. At the upper level of the range, there will be street lighting, traffic signals, and distant commercial signs or displays. These additional light sources diminish the attention-catching value of the sign.

The moderately illuminated category is consistently troublesome above the 6.0-cd/m^2 (2.0-ft•L) level, where the detection of traditional traffic-control signs becomes difficult. The contrast is frequently negative; i.e., the sign is darker than the light sources around its edge.

The brightly illuminated category presents a highly variegated background that consists of street lighting, large areas of internally illuminated commercial signs, frequent intense sources such as spotlights and large incandescent bulbs, and static and flashing displays, all close to each other and to the road edge.

The evaluation of nighttime sign surrounds by measurements made with a spot-reading photographic light meter is suggested. These instruments have a relatively close correlation with laboratory-quality instruments and measure a 1° area. This corresponds closely to the critical area at the center of the visual field where maximum visual acuity is most seriously affected by proximate sources of glare, which reduce the legibility distance and require higher luminance of the sign.

The evaluation of numerous surrounds showed that terms such as dark, rural and bright, downtown, although illustrative, are misleading. There are many rural locations where distant sources of glare make the area as luminous as heavily developed, bright, downtown areas. Similarly, bright, downtown areas have frequent dark sections that are equivalent to dark, rural areas. The lack of correlation with traditional verbal descriptions is common.

There are also many locations where one side of a tangent section of a roadway has frequent glare sources, but the opposite side is relatively dark, e.g., the opposite sides of a roadway approaching a commercial development.

In many cases, overhead signs are seen against the night sky, which is a dark surround, but shoulder-mounted signs on the same road may have a moderate or bright surround. The pattern of night lighting is frequently concentrated along road edges and provides little above the road. This requires separate evaluation of overhead and shoulder-mounted signs. Separate evaluation is also necessary on curved roadways. Both moderate and abrupt changes in horizontal or vertical alignment may also align traffic signs with glare sources in an otherwise dark environment, and individual assessment of such situations is required to determine the exact location and extent of the surround luminance.

Future research should develop recommendations for appropriate sign-luminance levels for various night surrounds so that the highway engineer can design signs that are appropriate to their night surrounds.

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