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On-Premise Signs

Determination of Parallel Sign Legibility and Letter Heights

USSCF ON-PREMISE SIGNS / RESEARCH CONCLUSIONS

ON-PREMISE SIGNS
Determination of Parallel Sign Legibility and Letter Heights

A Research Project Of The
UNITED STATES SIGN COUNCIL FOUNDATION

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Abstract

The USSCF has published research-based legibility tables to help the signage community determine appropriate on-premise commercial sign letter heights. These indices were developed to ensure adequate readability of signs that are mounted *perpendicular* to the roadway. On-premise signs however, are often oriented *parallel* to the driver‘s line of sight (for example, wall signs) and this type of sign is more difficult to read.

This document describes the development of, and rationale for, a mathematical model that calculates letter heights for parallel-mounted on-premise commercial signs. This model can be applied to the current USSCF legibility standards so that the letter heights developed for perpendicular signs form the basis for letter heights on parallel signs with various lateral offsets. A letter height lookup table is provided for many typical parallel sign scenarios.

Background

In 1998, the United States Sign Council Foundation (USSCF) published a research-based legibility table to help the signage community determine appropriate on-premise commercial sign letter heights (Table 1). The legibility indices in that table were developed to ensure adequate readability of projecting and free-standing signs that are mounted *perpendicular* to the roadway (Figure 1). On-premise wall signs however, are often oriented *parallel* to the driver's line of sight (Figure 2). Everyday experience teaches us that parallel signs are more difficult to read, and research conducted for the USSCF corroborates those subjective impressions with scientific evidence (Zineddin, Garvey, and Pietrucha, 2005).

Table 1. USSCF Legibility Index Table.

ILLUMINATION	LETTER STYLE	LETTER COLOR	Background COLOR	LEGIBILITY INDEX	
				Upper & Lower Case	ALL CAPS
External	Helvetica	Black	White	**29**	**25**
External	Helvetica	Yellow	Green	**26**	**22**
External	Helvetica	White	Black	**26**	**22**
External	Clarendon	Black	White	**28**	**24**
External	Clarendon	Yellow	Green	**31**	**26**
External	Clarendon	White	Black	**24**	**20**
Internal Translucent	Helvetica	Black	White	**29**	**25**
Internal Translucent	Helvetica	Yellow	Green	**37**	**31**
Internal Translucent	Clarendon	Black	White	**31**	**26**
Internal Translucent	Clarendon	Yellow	Green	**37**	**31**
Internal Opaque	Helvetica	White	Black	**37**	**29**
Internal Opaque	Helvetica	Yellow	Green	**36**	**31**
Internal Opaque	Clarendon	White	Black	**34**	**30**
Internal Opaque	Clarendon	Yellow	Green	**37**	**28**
Neon	Helvetica	Red	Black	**29**	**25**
Neon	Helvetica	White	Black	**38**	**32**

Figure 1. Perpendicular on-premise freestanding sign.

Figure 2. Parallel on-premise wall sign.

A parallel sign is harder to read because its orientation, or tilt, with respect to the driver makes it impossible to see the sign face at certain distances and offsets (Figure 3). When the driver *can* see the sign face, the content is often foreshortened and distorted. The driver must get close to the sign in order to increase the viewing angle to the point where the sign becomes legible. However, as drivers approach the sign, the time they have to read it gets shorter, while the sign moves further into their peripheral vision. Therefore, parallel signs must be read using a series of very quick glances at large visual angles during small windows of opportunity. Because of this, the letter heights developed for perpendicular signs, where drivers have more time and can take longer straight ahead glances, will not provide adequate parallel sign legibility.

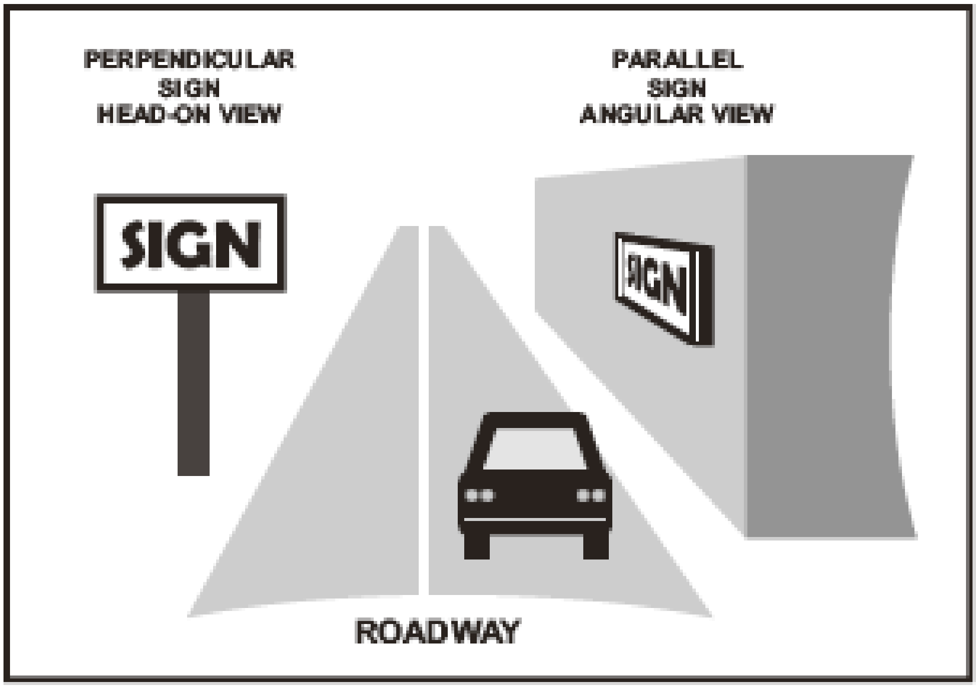

Figure 3. Observation angle determines relative legibility

Objective

The objective of this study was to develop a simple mathematical model to determine appropriate parallel-mounted on-premise commercial sign letter heights. Using that model, a lookup table was constructed to provide users with ready access to parallel sign letter heights for a typical sign at representative roadway cross-sections (number of lanes) and lateral sign offsets. Two simple equations are also provided: one for users with atypical offsets, and the other to be combined with Table 1 for users who have detailed information about sign characteristics such as typeface and lighting design.

A literature review was conducted, and the results of past research in applied eye tracking and applied and basic reading speed were used to provide specific input into the model and to support its general validity. Several components were considered in developing the model:

1. Glance Angle: The maximum angle 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.
6. Lateral sign offset.
7. Vehicle travel speed.

Literature Review

Glance Angle

It is well known that target detectability is poor for signs located away from the center of the driver's visual field. For example, Claus and Claus (1975) stated that signs should be placed within 30 degrees of the driver's line of sight, and Jenkins and Cole (1986) wrote, "If a sign is to be noticed . . . it will be within 10 degrees of his line of sight." These studies illustrate how difficult it is to passively detect signs with large lateral offsets. Other research indicates that the vast majority of active scanning behavior is also in a very small cone of vision located straight ahead of the driver.

While no studies have evaluated how far to the left or right drivers are willing to look for on-premise signs, several researchers have assessed driver eye scanning in the presence of outdoor advertising (i.e., billboards). In 2003, Beijer evaluated driver glances toward outdoor advertising signs and found that the average lateral glance angle (how far from straight ahead the drivers looked) was only 9°. Although he did find instances where the driver looked as far off as 75° degrees, 80 percent of glances were within 10° of center and 98 percent were within 25°.

In 2004, Smiley and her colleagues studied the impact of video advertising on driver fixation patterns and found that in the presence of large electronic message centers (EMCs), 76 percent of glances were straight ahead at traffic, seven percent were at street name signs, six percent at pedestrians, and only 1.5 percent at the advertising signs. Similar to Beijer's results, Smiley's research found that 69 percent of glances were within 15° of straight ahead and 77 percent were within 20°. The maximum horizontal angle was smaller than Beijer's at only 31°.

Glance Duration

One of the main hypotheses behind the parallel sign letter height model developed for this project was that these signs must be read in a small fraction of a second. Therefore, determining the length of time that drivers look away from the road to read signs was critical. Some researchers suggest that two seconds is the maximum time drivers are typically willing to look away from the road for any reason (e.g., Smiley, et al., 2004). Beijer (2003) reviewed the literature on driver eye movement and reported evidence for "spare visual capacity" during driving that would allow for safe non-driving related glances of slightly greater than one second. A review of the research however, shows that drivers typically use much shorter "look away" times to read signs.

Serafin (1994) reviewed the highway literature and found that glance duration was about 600 ms on average for any road feature (one millisecond (ms) = 1/1000 of a second; 500 ms is ½ second). In her own research, Serafin found average glance durations at roadway features to be shorter than this, about 158 ms, with younger drivers having slightly longer durations (174 ms) than older drivers (145 ms). Mourant, et al. (1969) found glance duration for road signs to be about 1/3 second, while Zwahlen (1987 and 1988) found average glance duration to vary depending on sign type: stop ahead signs 650-820 ms; stop signs 370-660 ms; curve signs (with advisory) 580-610 and without advisory 510-580 ms.

In Beijer's (2003) research on outdoor advertising signs, he found average glance duration to be about 500 ms with a minimum of 130 ms and a maximum of 2.07 seconds. His research also showed that only 22 percent of glances were longer than ¾ of a second. Smiley, et al. (2004) found glance duration for EMC's to average 480 ms with a maximum of 1.47 seconds.

Although one would expect glance duration to be inversely related to glance angle, no research was found that evaluated this relationship. In other words, although common sense dictates that drivers take shorter glances when looking further to the left or right (which they need to do for parallel mounted signs), this has not been confirmed by the existing research.

Glance Frequency

Smiley, et al. (2004) reviewed the literature on driver eye movements and found that drivers typically look two to three times at guide signs and about two times at warning and regulatory signs. Smiley's own research on driver fixation patterns for EMCs resulted in an average of 1.9 glances per sign. Beijer (2003) found that drivers glance at EMCs an average of 1.3 times. Neither Beijer nor Smiley discussed whether the low number of glances per sign was a function of the limited time available, or if one to two glances was sufficient for drivers to gather as much information as they needed from the signs.

Sign Reading Speed

Roadside signs can only be read in short spurts as the driver looks from the road to the sign and back to the road again. This type of reading task is known as "glance legibility," for which reading speed is a critical element. The research on reading speed was reviewed to determine how long it takes to read roadside signs and how to maximize sign reading speed in order to minimize the time drivers must look away from the road.

Proffitt, Wade, and Lynn (1998) reported normal text reading speed (book or monitor) for adults to be about 250 words per minute, or 4.2 words per second. However, research on highway sign reading provides evidence that it takes drivers anywhere from 0.5 to 2.0 seconds to read and process a single sign word or unit of information (Garvey and Kuhn, 2004). This is two to eight times slower than normal reading speed. A concept known as *critical print size* may explain some of the disparity between normal reading speed and the time it takes to read a roadside sign.

One reason drivers read signs slowly is that they begin to read them as soon as they become legible; that is, at acuity threshold. Von Hemel and Von Hemel (2004) wrote, "Typically, people need letters larger than their acuity limit to read quickly and without fatigue." Reading speed increases with above threshold print size up to a point, levels off, and then drops again at very large print sizes (Chung, et al., 1998). The point where reading speed levels off is the critical print size, defined as the smallest letter height necessary for maximum reading speed. Although it varies a great deal depending on the viewer and the task, critical print size is typically believed to be between two to three times size threshold (Van Hemel and Van Hemel, 2004; and Cheong, Lovie-Kitchin, and Bowers, 2002). Although the research on this topic has been limited to small formats, applying this concept to parallel sign letter height could help maximize sign reading speed.

Observation Angle

As drivers get closer to a parallel mounted sign, the angle increases from nearly 0° when they are far down the road, to 90° when the car is beside the sign (Figure 4). At 90° the sign is optimally legible, however at that angle the sign can only be viewed through either the passenger or driver side window.

Signs begin to be legible at a "threshold observation angle" somewhere between 0° and 90°. Of course, the threshold observation angle is not a static number and will vary as a function of letter height and width, color and luminance contrast, typeface style, and letter spacing. This angle however, is critical to the development of a mathematical model for parallel commercial sign letter height. For that model to be generalizable, the selected threshold angle must represent most sign conditions, for an error (such as choosing 45° when in reality it is 30°, or vice versa) could result in signs with half or twice the required letter height.

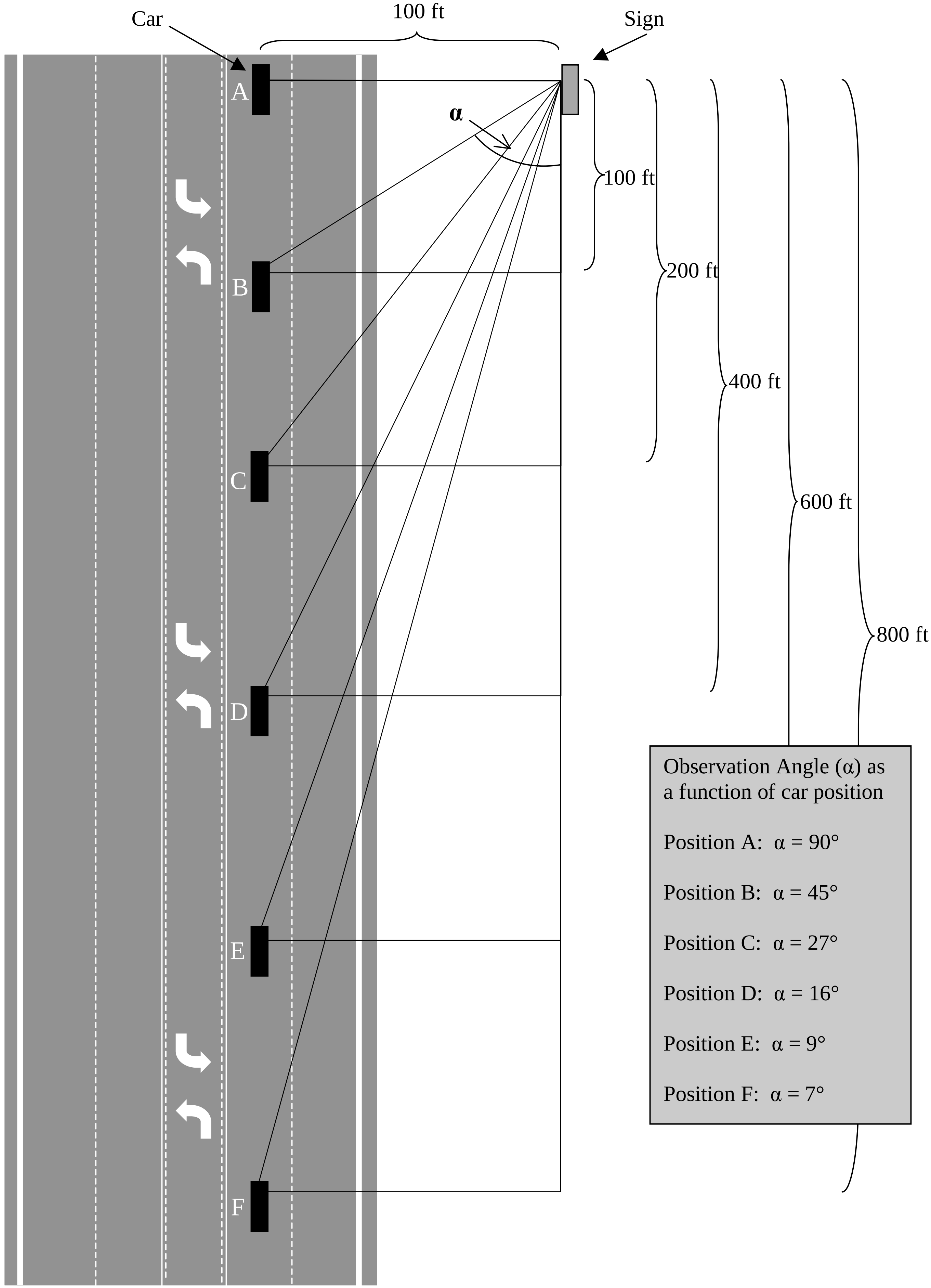

Figure 4. Change in observation angle with distance.

In their Signage System Overview document (FIP, 1992), the Treasury Board of Canada wrote, "Ideally, a sign should be placed at a right angle to the observer's central line of vision; that is, the viewing angle should be nearly 90 degrees. The legibility of a sign message deteriorates when the viewing angle is less than 45 degrees." Prince (1958) actually recommended that the messages on signs at angles smaller than 20 degrees be manipulated through increases in height and/or width to appear "normal" to the observer. And in a section on parking signs in the Manual on Uniform Traffic Control Devices (USDOT, 2003), the U.S. Federal Highway Administration wrote, "signs should be set at an angle of not less than 30 degrees nor more than 45 degrees with the line of traffic flow in order to be visible to approaching traffic." David Young (2003) discussed the effect of observation angle on the legibility of safety signs. Although the report offered no data, Young stated, "I recommend the angle between the sign and the line of sight should not be less than 30°."

In a literature review of research on visual displays, Buckler (1977) found reading performance to decline beginning somewhere between 19° and 38° from perpendicular (71° and 52° observation angles). He recommended a minimum observation angle of 60° for classroom viewing of CRTs. Rothblum (1983) reviewed the literature on dot matrix displays and concluded that "legibility begins to decrease with viewing angles larger than 30° to 45°" (observation angles of 60° to 45°).

Griffin and Bailey (2002) conducted the one empirical research effort that specifically evaluated the effect of observation angle on sign legibility. These researchers tested a single font (Snellen) with two intercharacter spacings (greater than letter width; and about ¼ letter width) and a letter height set slightly above acuity threshold. They found that with the tighter spacings, their subjects were able to correctly read 85 percent of the sign letters at an observation angle of about 58°, with performance dropping off dramatically at tighter angles (less than 25 percent correct letter identification at 30°). However, when perceived letter height was doubled and intercharacter spacings were large, the subjects were able to correctly identify 85 percent of the sign letters at an observation angle of about 30°, even though they were wearing special glasses that blurred their vision.

Model
Overview

The minimum distance at which a sign must become legible is a function of the time it takes to read the sign and the decisions and maneuvers required to comply with the sign. This is sometimes called the perception-reaction or PIEV time (Perception, Identification, Emotion, and Volition) and combined with travel speed the resulting distance is known as the minimum required legibility distance. Given the MRLD, the sign's letter size is back-calculated using an LI or legibility index.

The LI is expressed in feet of legibility distance as a function of letter height in inches (ft/in). For example, an LI of 30 means that a sign with an MRLD of 570 feet must have 19-inch letters (570 / 30 = 19). As mentioned earlier, a legibility index table was developed by the USSCF to help users select appropriate letter heights for perpendicular mounted signs with known MRLDs (Table 1).

Restricted viewing angles curtail parallel sign sight distance, therefore the distance used for calculating their letter height is not the MRLD, but rather the MALD or maximum available legibility distance. This is the sight distance between the driver and the sign at the angle where the sign first becomes legible. This distance is calculated using the number of travel lanes, the sign's lateral offset from the curb, and the threshold observation angle discussed above. For the model this is assumed to be 30º (Figure 5 illustrates how letter height is calculated).

Technically, the MALD is the *hypotenuse* (longest leg) of a 30-60-90° triangle (Figure 5, lower right). The *adjacent* leg of the triangle is the horizontal offset of the sign from the driver's eye. Using the special characteristics of 30-60-90° triangles, we know that the hypotenuse is double the length of the adjacent leg, so the MALD is double the offset from the driver's eye. The *opposite* leg is the distance the driver must travel along the road from the MALD to the point where the vehicle is alongside the sign. The time it takes to travel this distance is a function of speed and represents the absolute maximum window of opportunity that drivers have to read parallel signs (Table 2). The actual time they spend looking at these signs will of course be a small fraction of this window and will be a function of traffic volume and environmental conditions that include weather as well as potential blocking of the sign by other vehicles and roadside obstacles (Pietrucha, et al., 2003).

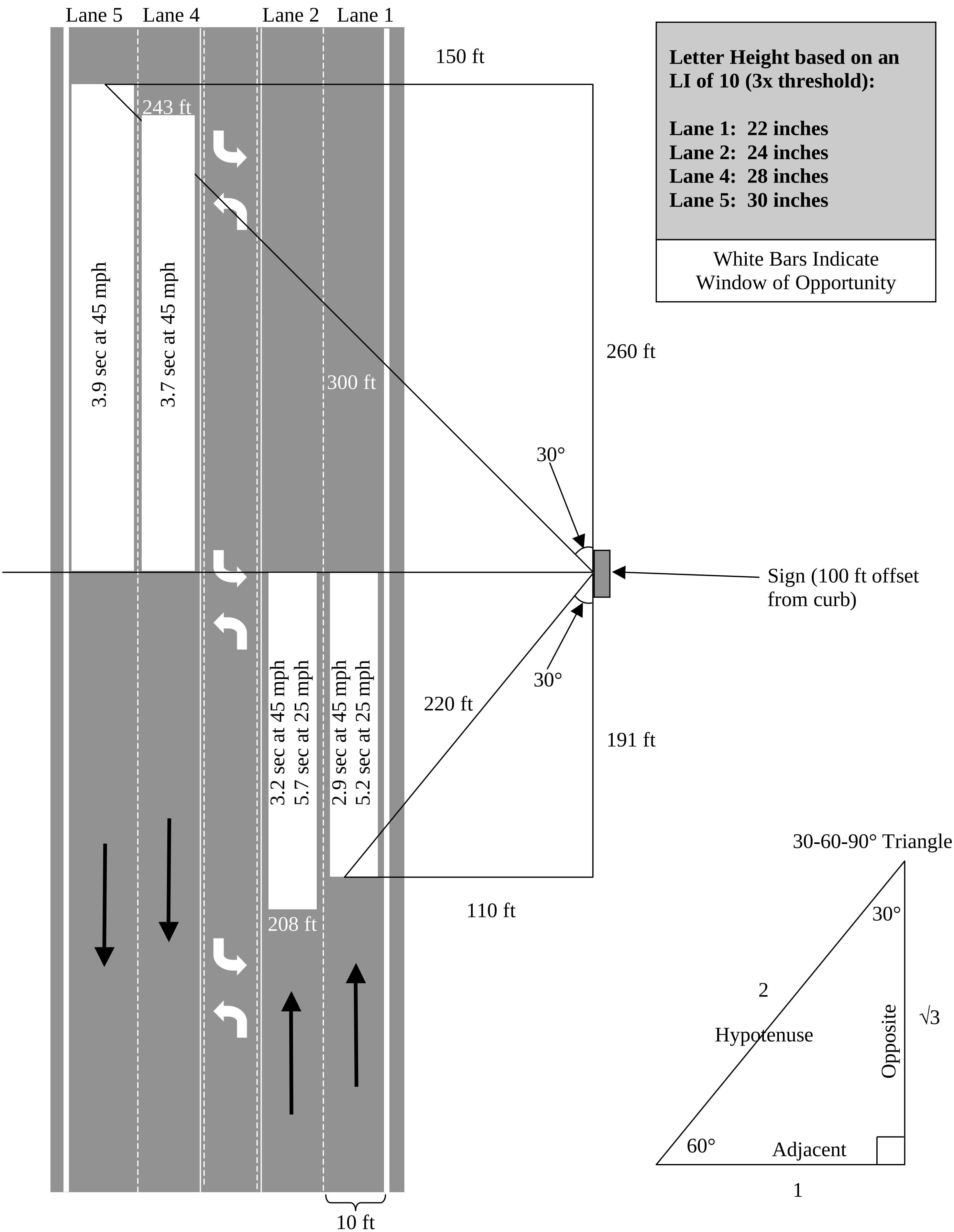

Figure 5. Example calculation for letter height model.

Table 2. Window of opportunity to read parallel signs (in seconds).

25 mph Speed Limit

Offset from Curb	Number of Lanes 1	2	3	4	5
10	0.94	1.42	1.89	2.36	2.83
20	1.42	1.89	2.36	2.83	3.31
40	2.36	2.83	3.31	3.78	4.25
60	3.31	3.78	4.25	4.72	5.20
80	4.25	4.72	5.20	5.67	6.14
100	5.20	5.67	6.14	6.61	7.09
125	6.38	6.85	7.32	7.79	8.27
150	7.56	8.03	8.50	8.98	9.45
175	8.74	9.21	9.68	10.16	10.63
200	9.92	10.39	10.86	11.34	11.81

45 mph Speed Limit

Offset from Curb	Number of Lanes 1	2	3	4	5
10	0.52	0.79	1.05	1.31	1.57
20	0.79	1.05	1.31	1.57	1.84
40	1.31	1.57	1.84	2.10	2.36
60	1.84	2.10	2.36	2.62	2.89
80	2.36	2.62	2.89	3.15	3.41
100	2.89	3.15	3.41	3.67	3.94
125	3.54	3.81	4.07	4.33	4.59
150	4.20	4.46	4.72	4.99	5.25
175	4.85	5.12	5.38	5.64	5.90
200	5.51	5.77	6.04	6.30	6.56
225	6.17	6.43	6.69	6.95	7.22
250	6.82	7.09	7.35	7.61	7.87
275	7.48	7.74	8.00	8.27	8.53
300	8.14	8.40	8.66	8.92	9.19
325	8.79	9.05	9.32	9.58	9.84
350	9.45	9.71	9.97	10.23	10.50
375	10.10	10.37	10.63	10.89	11.15
400	10.76	11.02	11.28	11.55	11.81

Optimizing Reading Speed

It is essential to optimize reading speed for parallel mounted signs in order to minimize the duration and frequency of glances that drivers must make at these signs and to maximize the time they have for the primary visual driving tasks. In other words, to minimize driver distraction.

The research on *acuity reserve* (the difference between size threshold and critical print size) was used to determine how much larger than threshold parallel sign letters must be to minimize glance duration and frequency. As mentioned earlier, the research shows that people read the fastest at about two to three times threshold letter height. To ensure adequate letter height, a multiplier of three times threshold was selected for use in the model. This increase in threshold letter height will also improve the likelihood that drivers will be able to begin reading signs at the 30° observation angle (Griffin and Bailey, 2002). A threshold legibility index of 30 ft/in was chosen as an average of the USSCF LIs. Providing a minimum angle of resolution of just under 2.0 minutes of arc, the LI of 30 is consistent with threshold letter height for drivers with 20/40 visual acuity (the minimum acuity allowed to obtain a driver's license in most states). Three times the threshold letter height results in an LI of 10 ft/in.

Equations and Lookup Table

The following equations can be used to determine appropriate letter heights for parallel mounted signs given the number of lanes of travel and the lateral offset of the sign from the curb. Equation #1 uses an average LI of 10, while Equation #2 allows users to input the LI that most closely matches their sign conditions from the USSCF LI table (Table 1) and applies the three times threshold constant to that LI. A parallel sign letter height lookup table is provided for typical roadway cross-sections and lateral sign offsets (Table 3).

When using the equations or the lookup table
always use the maximum number of lanes on the primary target road.

Parallel Letter Height Model Equations

Equation #1: LH = (LN * 10 + LO) / 5

Equation #2: LH = (LN * 10 + LO) / (LI/6)

where:

LH is letter height in inches.

LN is the number of lanes of traffic.

LO is the lateral offset from curb in feet.

LI is the legibility index from Table 1.

Practical Examples:

2-Lane Roadway
Lateral offset is 37 feet from the curb.
User does not know the letter style.

Equation #1: LH = (LN * 10 + LO) / 5

LH = (2 * 10 + 37) / 5

LH = 57 / 5

LH = 11.4 inches

Same scenario, but user knows the sign is:

External Illuminated, Helvetica, all Caps, Light Letters on Dark Background

(USSCF LI = 22 ft/in)

Equation #2: LH = (LN * 10 + LO) / (LI/6)

LH = (2 * 10 + 37) / (22/6)

LH = 57 / 3.67

LH = 15.5 inches

Table 3. Parallel sign letter height lookup table.

	Letter Height in Inches				
	Number of Lanes				
Offset from Curb (ft)	1	2	3	4	5
10	4	6	8	10	12
20	6	8	10	12	14
40	10	12	14	16	18
60	14	16	18	20	22
80	18	20	22	24	26
100	22	24	26	28	30
125	27	29	31	33	35
150	32	34	36	38	40
175	37	39	41	43	45
200	42	44	46	48	50
225	47	49	51	53	55
250	52	54	56	58	60
275	57	59	61	63	65
300	62	64	66	68	70
325	67	69	71	73	75
350	72	74	76	78	80
375	77	79	81	83	85
400	82	84	86	88	90

References

Beijer, D. (2004). Observed driver glance behavior at roadside advertising. Presented at Transportation Research Board Annual Meeting, Washington, D.C., 14 pgs.

Bowers, A.R. and Reid, V.M. (1997). Eye movement and reading with simulated visual impairment. Ophthalmology and Physiological Optics, 17(5), 492-402.

Buckler, A.T. (1977). A review of the literature on the legibility of alphanumerics on electronic displays. U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, Technical Memorandum 16-77 (ADA 040 625).

Cheong, A.M., Lovie-Kitchin, J.E., and Bowers, A.R. (2003). Fixed versus individualized acuity reserve methods for determining magnification for low vision reading. Clinical Experimental Optometry, Vol. 85, 229-237.

Chung, S.T.L., Mansfield, J.S., and Legge, G.E. (1998). The effect of print size on reading speed in normal peripheral vision. Psychophysics of Reading: XVIII. Reprinted from Vision Research, Vol. 38 (19), 2949-2962.

Claus, J.R. and Claus, K. (1975). Visual communication through signage. Volume 2: Sign Evaluation. Cincinnati, OH: Signs of the Times Publishing Co.

FIP. (1992). Signage System Overview Document. The Treasury Board of Canada

Garvey, P.M. and Kuhn, B.T. (2004). Highway sign visibility. Chapter 11 in Handbook of Transportation Engineering, M. Kutz, Editor. McGraw-Hill, New York, New York.

Griffin, J.R. and Bailey, J.E. (2002). Horizontal obliquity: Word readability and logo identification. Signage Foundation for Communication Excellence Final Report. 28 pgs. plus Figures and Appendices.

Jenkins, S.E. and Cole, B.L. (1986). Daytime conspicuity of road traffic control devices. Transportation Research Record, 1093, 74-80.

Lovie-Kitchin, J.E., Bowers, A.R., and Woods, R.L. (2000). Oral and silent reading performance with macular degeneration. Ophthalmology and Physiological Optics, 20(5), 360-370.

Mourant, R.R., Rockwell, T.H., and Rackoff, N.J. (1969). Drivers' eye movements and visual workload. Highway Research Record, 292, 1-10.

Pietrucha, M.T., Donnell, E.T., Lertworawanich, P., and Elefteriadou, L. (2003). Sign visibility: Effects of traffic characteristics and mounting height, United States Sign Council.

Proffitt, D.R., Wade, M.M., and Lynn, C. (1998). Creating effective variable message signs: human factors issues. Virginia Department of Transportation, VTRC 98-CR31, Final Contract Report; Project No. 9816-040-940, 25 pgs.

Rothblum, A.M., (1983). Towards guidelines for the effective use of visual displays in voice terminals. Research conducted for American Bell.

Serafin, C. (1994). Driver eye fixations on rural roads: Insight into safe driving behavior. Federal Highway Administration Contract DTFH61-92-X-00018. University of Michigan Report No. UMTRI-94-21.

Smiley, A., Smahel, T., and Eizenman, M. (2004). The impact of video advertising on driver fixation patterns. Presented at the Transportation Research Board's Annual Meeting, Washington, D.C., 18 pgs.

Smiley, A., Houghton, J., and Philip, C. (2004). Highway signing for drivers' needs. Presentation at the Road Safety Engineering-New Developments and Initiatives Session of the Annual Conference of the Transportation Association of Canada.

USDOT (2003). Manual on Uniform Traffic Control Devices. Available at http://mutcd.fhwa.dot.gov

USSCF. (1998). Sign legibility. Overview and calculation methodology: sign legibility index. Member Resource Folio/Legislative Information. United States Sign Council, 211 Radcliffe Street, Bristol, PA.

Van Hemel, P.L. and Van Hemel, S.B., Editors (2004). Visual impairments: Determining eligibility for social security benefits. Committee on Disability Determination for Individuals with Visual Impairments, National Academy Press. Washington, D.C.

Yager, D., Aquilante, K., and Plass, R. (1998). High and low luminance letters, acuity reserve, and font effects on reading speed. Vision Research, 38, 2527-2531.

Young, D. (2003). Safety sign placement on large substations. IAEI News: The Magazine.

Zineddin, A.Z., Garvey, P.M., and Pietrucha, M.T. (2005). Impact of sign orientation on on-premise commercial signs. Journal of Transportation Engineering. Vol. 131(1), 11-17.

Zwahlen, H.T. (1987). Advisory speed signs and curve signs and their effect on driver eye scanning and driving performance. Transportation Research Record, 1111, 110-120.

Zwahlen, H.T. (1988). Stop Ahead and Stop signs and their effect on driver eye scanning and driving performance. Transportation Research Record, 1168, 16-24.

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