



Designation: D8379/D8379M – 21

# Standard Practice for Evaluating Nighttime Retroreflective Sheeting Effectiveness Using Positive-Contrast Textual Sign Scenario Performance Analysis<sup>1</sup>

This standard is issued under the fixed designation D8379/D8379M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice provides a framework to evaluate retroreflective sheeting performance in nighttime driving conditions without a need for field evaluations through a set of sign viewing scenarios representing common use-cases. The evaluation of performance of a specific sheeting is achieved by comparing the luminance provided by a sheeting to the luminance needed by drivers in each scenario. This comparison is expressed in terms of a “Performance Index,” which is a measure for how well the luminance provided to the driver meets their needs, in each of the scenarios. Comparison of the performance index values for different sheeting allows the user to predict differences in nighttime retroreflective performance when those sheeting are used on installed signs.

1.2 The driver-needs data is based on textual signs (not on symbolic signs) with positive contrast (sign text being brighter than its background), and the headlamp illumination is assumed to be low-beams; therefore, performance index is applicable only to textual signs viewed under low-beam headlamp illumination.

1.3 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The value stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

*Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards*:<sup>2</sup>

**B209/B209M** Specification for Aluminum and Aluminum-Alloy Sheet and Plate

**B449** Specification for Chromates on Aluminum

**D8** Terminology Relating to Materials for Roads and Pavements

**E284** Terminology of Appearance

**E808** Practice for Describing Retroreflection

**E809** Practice for Measuring Photometric Characteristics of Retroreflectors

2.2 *BSI Standard*:<sup>3</sup>

**BS 8408:2005** Road Traffic Signs. Testing and Performance of Microprismatic Retroreflective Sheeting Materials. Specification (Withdrawn)

## 3. Terminology

3.1 *Definitions*—For definitions of technical terms used in this practice, see Terminologies **D8** and **E284**.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *legibility index, n*—a surrogate metric for the size of the image on the retina, expressed in terms of the longitudinal (roadway) distance to the sign divided by the height of the uppercase alphanumeric on the text.

3.2.2 *legibility range, n*—the range of distances to a sign, expressed longitudinally along the roadway centerline, that are between a legibility index of 40 ft/in. [4.8 m/cm] and 20 ft/in. [2.4 m/cm].

3.2.3 *performance index, n*—a measure that approximates a sign sheeting’s performance, in terms of luminance observed by the driver, in a given scenario.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.

<sup>3</sup> Available from British Standards Institution (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., <http://www.bsigroup.com>.

3.2.4  $R_A$  multiplier,  $n$ —a factor derived from the illuminance at the sign per headlight, measured facing the headlight in a scenario, while also incorporating windshield transmission and the cosine of viewing angle.

3.2.4.1 *Discussion*— $R_A$  multiplier is defined at each distance for a single headlight, and when multiplied by the coefficient of retroreflection for the corresponding scenario and distance, the result is the luminance observed by the driver. The formula for obtaining the  $R_A$  multipliers is given in [Appendix X1](#).

3.2.5 *scenario, n*—a particular use-case for retroreflective sign sheeting, determined by sign mounting location, vehicle type, the size of the text on the sign, and the surrounding scene complexity, as viewed by the driver within the legibility range.

## 4. Summary of Practice

4.1 This practice outlines a procedure to calculate the performance index of a retroreflective sheeting by comparing the luminance provided by the sheeting, to the luminance required by the driver in a set of nighttime traffic sign viewing scenarios.

4.2 The procedure requires the following steps:

4.2.1 Obtain retroreflective sheeting,

4.2.2 Prepare samples,

4.2.3 Select the scenarios of interest, for example, vehicle types, sign locations, and letter heights as defined in [Table A1.1](#).

4.2.3.1 Determine the corresponding applicable tables under the “Measurement Angles and  $R_A$  Multiplier Table” column for the selected scenario(s) in [Table A1.1](#) ([Table A1.3](#) through [Table A1.11](#)). Also determine the corresponding performance index table(s) for the same scenarios under the “Performance Index Table” column for later use in [4.2.6](#).

NOTE 1—[Table A1.3](#) through [Table A1.11](#) provide the pre-determined measurement angles for the sheeting representing the angular combinations under which the sheeting is observed by the driver in the corresponding scenarios. If the user is not considering all scenarios at this time, it is still recommended that all pre-determined angular sets in [Table A1.3](#) through [Table A1.11](#) are considered for measurement for future purposes.

4.2.4 Measure sheeting  $R_A$  values for the set of pre-defined measurement angles given in the corresponding “Measurement Angles and  $R_A$  Multiplier Table(s)” [Table A1.3](#) through [Table A1.11](#).

4.2.5 Calculate the luminance observed by the driver for selected scenario(s) by multiplying the  $R_A$  values (from [4.2.4](#)) with the corresponding  $R_A$  Multipliers, which are also given in [Table A1.3](#) through [Table A1.11](#) for right and left headlights separately, and add the luminance from the right and left headlights to determine total observed luminance. Do this calculation for each distance and for all three distinct headlights, representing the 25<sup>th</sup>, 50<sup>th</sup>, and the 75<sup>th</sup> percentile low-beams.

4.2.6 Calculate the performance index for each of the selected scenarios, at each distance and headlight percentile, by comparing the observed luminance (from [4.2.5](#)) to the luminance required by the driver given tables in [Annex A1](#), given in [Table A1.12](#) through [Table A1.15](#).

4.2.7 Calculate the overall performance index for each scenario by averaging the performance indexes calculated for each distance and each headlight percentile.

4.2.8 An example walkthrough for the calculation of performance index for one of the scenarios is provided in [Annex A2](#).

## 5. Significance and Use

5.1 Retroreflective sheeting is commonly used to improve the nighttime visibility and legibility of traffic signs under vehicle headlight illumination. This standard provides a procedure for evaluating the nighttime retroreflective performance of sign sheeting used in roadway signing in terms of an overall average performance index for predefined road scenarios.

5.2 A procedure to characterize the relationship between sign luminance supply and driver luminance demand at night without conducting field work helps traffic engineers and transportation agencies responsible for specifying highway construction materials and maintaining roadway safety in making informed decisions about the performance of retroreflective sheeting on the signs. The procedure requires the comprehensive measurement of the retroreflective properties of a sheeting according to Practice [E809](#) over a wide range of angles.

5.3 A variety of retroreflective sheeting is available for use on traffic signs. Coefficients of retroreflection are typically measured for a standard set of angle combinations and are used, in part, to certify conformance to a specification or standard. However, while coefficients of retroreflection on some standard angle sets can provide a general idea about a sheeting’s retroreflectivity and help certify conformance to a standard, a more comprehensive analysis is needed to determine how well a sheeting is expected to serve drivers in general, or in specific use-cases. Drivers of different vehicles viewing a multitude of signs in the real world experience a much more complex set of angular combinations than those captured in the standard angle sets. Furthermore, drivers observe luminance, which is affected by not only the coefficient of retroreflection, but also by headlight illumination, distance from the vehicle to the sign, and light attenuation, among other factors.

5.4 This practice utilizes a set of driver sign viewing scenarios. When combined with the coefficients of retroreflection at the corresponding geometry, the luminance as observed by the driver is calculated. The luminance requirements of the driver for varying percentiles are also tabulated for the user. Comparing the luminance supply from the sign with the luminance demand of drivers provides an assessment of the expected “performance index” in each scenario.

5.5 The data on the luminance needs of the driver represents the visual performance of a subset of legal drivers in the United States of 55 years of age or older and may not represent the visual performance of the entire driver demographics.

## 6. Scenarios

6.1 A scenario refers to any unique combination of the variables listed in [6.2.1](#) – [6.2.4](#), at the levels outlined in [Table](#)

1 in 6.3. The three distinct headlight percentile levels (25<sup>th</sup> percentile, 50<sup>th</sup> percentile, and 75<sup>th</sup> percentile) do not each yield a different scenario but collectively make up a single scenario. This ensures the effect of headlight variability to be incorporated into the performance index calculations. For clarity, the variables are given in three groups: the ones that affect the luminance provided by the sheeting, the ones that affect the luminance required by the driver, and the ones that affect both. The full list of scenarios referenced with scenario numbers are given in [Annex A1](#).

6.2 *Variables*—Five variables known to affect the sign luminance observed or needed by the driver are identified to define the sign use-case scenarios. These variables are as follows:

- 6.2.1 Sign placement,
- 6.2.2 Vehicle type,
- 6.2.3 Letter size on sign,
- 6.2.4 Visual complexity of the sign’s surroundings, and
- 6.2.5 Headlamps.

6.3 *Variable Levels*—The scenarios consist of all combinations of the above variables, at levels indicated in [Table 1](#). Each scenario shall also incorporate the fixed parameters given in [6.5](#). There is a total of 36 scenarios (three sign locations, three vehicle types, two letter sizes, and two visual complexity levels). Each scenario contains all three headlight percentiles and is given a scenario number as given in [Table A1.1](#). The Tables in [A1.1.3](#) and [A1.1.4](#) provide the relevant angles, multipliers for luminance calculation, and the demand luminances, and are referenced to the applicable scenario numbers for clarity.

6.4 *Variable Groups*—The scenario variables are divided in three groups: (1) variables that affect the luminance provided by the sheeting, (2) variables that affect the luminance required by the driver, and (3) variables that affect both the luminance provided by the sheeting and the luminance required by the driver.

6.4.1 *Variables That Affect Sign Luminance As Observed By the Driver:*

- 6.4.1.1 Retroreflective sheeting.

6.4.1.2 *Sign Placement*—Three sign locations: (1) left shoulder mounted, (2) right shoulder mounted, and (3) overhead mounted. Dimensions for sign placement are given in [6.5.5](#).

6.4.1.3 *Vehicle Type*—Three vehicle types: (1) heavy vehicle, (2) sedan, and (3) SUV. The positions of the driver and the headlights for each vehicle type are given in [6.5.5](#).

NOTE 2—Vehicle type primarily affects the location of the driver and the location of the headlights, changing the viewing geometry at which the coefficient of retroreflection has to be measured.

6.4.1.4 *Headlamps*—Three headlamps: (1) UMTRI 25<sup>th</sup> percentile, (2) UMTRI 50<sup>th</sup> percentile, and (3) UMTRI 75<sup>th</sup> percentile low-beams, all 2011 data for vehicles sold in the U.S. market. The headlamp luminous intensity matrices as a function of vertical and horizontal beam angles are given in [Table A1.2](#).

6.4.2 *Variables That Affect the Luminance Needed By the Driver:*

6.4.2.1 *Visual Complexity*—Two levels: (1) Low/Medium, and (2) High. Visual complexity does not affect the luminance provided by the sheeting, but it affects the luminance needed by the driver. In general, signs located in areas with higher nighttime visual complexity require higher levels of luminance to provide the same level of service to drivers.

6.4.2.2 *Letter Size*—Two letters heights: (1) 12 in. [0.3048 m], and (2) 16 in. [0.4064 m] letter heights. At any given distance, letter size has a direct effect on the luminance needed for legibility. Although letter size does not affect the luminance observed by the driver, it affects the legibility range in terms of absolute distance to the sign. A discussion of the general practice in letter size as a function of roadway classification is given in [Appendix X2](#).

6.4.3 *Variables That Affect Both the Luminance Provided By the Sheeting and the Luminance Needed By the Driver:*

6.4.3.1 *Distance to Sign*—The distance to the sign (as measured between two parallel vertical planes, one containing the vehicle headlights and the other containing the sign center) in all scenarios shall include the legibility range for the corresponding letter height. In all scenarios, distances are given in 10-ft intervals and calculations shall be performed at each distance. The user shall use the appropriate distance range for the selected letter height. Because a large portion of these two distance ranges overlap, they are combined in [Table A1.3](#) through [Table A1.11](#) for both letter heights.

(1) For 16 in. [40.64 cm] letter height scenarios, only the distance range of 640 ft to 320 ft [192.07 m to 97.54 m] shall be used.

(2) For 12 in. [30.48 cm] letter height, only the 480 ft to 240 ft [146.3 m to 73.15 m].

6.5 *Dimensions, Fixed and Dependent Parameters*—Values for some additional parameters known to affect sign performance, as well as the dimensions for the three sign placements and three vehicle types, shall be as follows.

6.5.1 *Roadway Geometry*—Roadway is straight and level.

**TABLE 1 Selected Variables and Corresponding Levels for Standard Sign Viewing Scenarios**

Variable	Level
Sign Placement	Right Shoulder Left Shoulder Overhead
Vehicle Type	Sedan SUV/Minivan/LT HV
Headlamps	UMTRI 25 <sup>th</sup> , 50 <sup>th</sup> , 75 <sup>th</sup> percentile U.S. 2011 low-beam headlights (Schoettle et al. (1))
Visual Complexity	Low/Medium High (without sign lighting)
Letter Size	Small (12 in. [0.3048 m]) Large (16 in. [0.4064 m])

6.5.2 *Windshield Transmission Factor*—A windshield transmission factor of 72 % has been used in the calculation of  $R_A$  multipliers (UMTRI (2)).<sup>4</sup>

6.5.2.1 An automobile windshield acts similarly to a neutral density filter in the visible spectrum, reducing the luminance of the objects seen by the driver behind it. The  $R_A$  multipliers provided in this standard include the effect of windshield transmission, and when multiplied by the corresponding coefficient of retroreflection, yield the luminance as observed by the driver behind a windshield. No further correction in luminance is required by the user.

6.5.3 *Sign Tilt and Twist*—Right and left shoulder-mounted signs shall have a twist of 4° outward (sign axis, which is perpendicular to the sign surface, pointing away from the roadway), and the overhead sign shall have a tilt of 4° upward (sign axis pointing upward and away from the roadway).

6.5.4 The angles given in Table A1.3 through Table A1.11 incorporate sign tilt and twist, and as such, the coefficients of retroreflection shall be measured at the angles given in these tables with no additional correction or adjustment by the user.

6.5.5 *Sign Location*—The standard sign locations are such that the center point of the sign coincides with the three locations shown as “LS,” “OV,” and “RS” in Fig. 1, for left shoulder, overhead, and right shoulder sign locations, respectively. The distances from the sign center with respect to the vehicle’s projected view on the plane formed by the sign centers are shown in Fig. 1.

6.5.6 *Vehicle Dimensions*—Vehicle dimensions and driver eye locations are used in calculating the  $R_A$  multipliers for the analysis are given in Table 2. The definitions of the dimensions in Table 2 are given in Fig. 2. The vehicle reference point is the

TABLE 2 Headlight and Driver Eye Positions for Three Vehicle Types

Vehicle Type	Vehicle Dimensions and Relative Driver Eye Positions ft [m]				
	$h_1$	$h_2$	$s_1$	$s_2$	$s_3$
Passenger Car <sup>A</sup>	2.13 [0.65]	3.93 [1.20]	3.27 [1.00]	0.66 [0.20]	6.55 [2.00]
SUV/Minivan/LT <sup>A</sup>	2.72 [0.83]	4.66 [1.42]	4.26 [1.30]	0.75 [0.23]	6.82 [2.08]
Large Truck <sup>B</sup>	3.57 [1.09]	7.68 [2.34]	6.17 [1.88]	1.35 [0.41]	7.22 [2.20]

<sup>A</sup> BS 8408.

<sup>B</sup> Sivak et al. (4).

point on the road surface on the vertical plane consisting the headlights, at an equal distance to the two headlights.

6.6 *Demand Luminance (Drivers’ Need for Luminance)*—Demand luminance is the luminance of the brighter portion of the sign needed to successfully read the sign by a given performance index as a function of legibility index and scene complexity. A detailed expansion of the demand luminance for each scenario, with the legibility indices converted to sign viewing distances, is provided in Table A1.12 through Table A1.15. Demand luminance generally follows a linear relationship as a function of legibility index within the legibility range. Therefore, linear interpolation is used to determine the demand luminance for legibility indices between 20 ft/in. [2.4 m/cm] and 40 ft/in. [4.8 m/cm] in calculating the required luminance values provided in Table A1.12 through Table A1.15.

7. Procedure

7.1 *Sampling*—A minimum of nine specimens shall be used to determine coefficients of retroreflection for a sheeting.

7.1.1 The specimens shall be cut from three different rolls or sheets of retroreflective sheeting in new (unexposed) condition at least 1 yd [0.914 m] long,

7.1.2 Each roll should be taken from a different, commercially available lot. A full width by 1 yd [0.914 m] long sample is selected at random to represent the entire sheet, roll, or lot.

<sup>4</sup> The boldface numbers in parentheses refer to a list of references at the end of this standard.

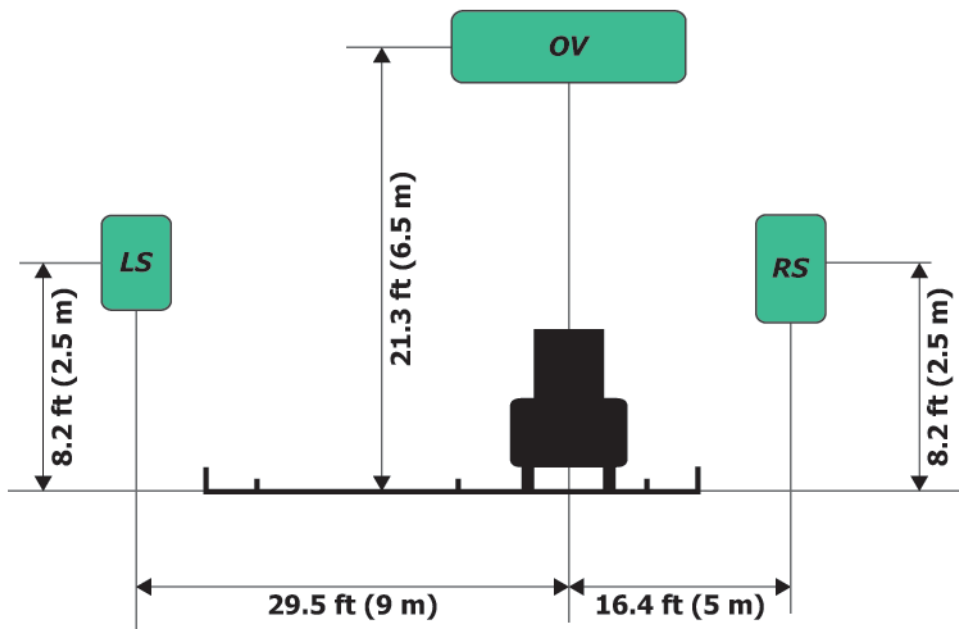


FIG. 1 Standard Sign Locations Designating the Center of the Sign (Carlson (3))



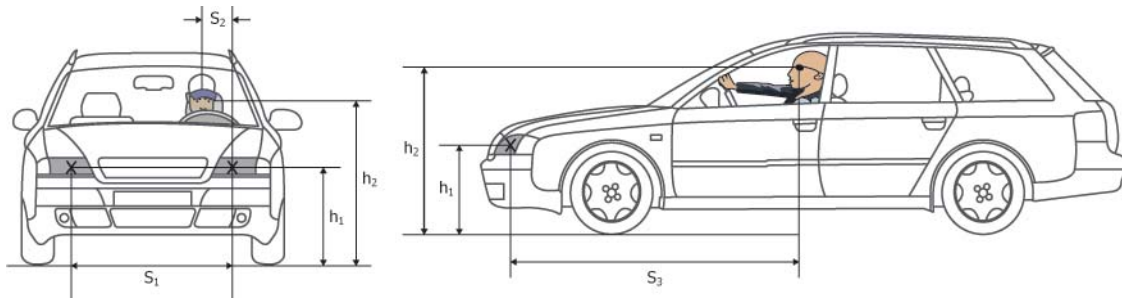


FIG. 2 Vehicle Dimensions (definitions of dimensions in Table 2)

7.1.3 Three specimens are taken from the selected sample. The three specimens shall be spaced evenly across (left, center, right) and spaced evenly down the specimen as shown in the examples in Fig. 3.

7.1.4 *Panel Preparations*—Unless otherwise specified, apply the specimens of retroreflective material to smooth aluminum cut from Alloy 6061-T6 or 5052-H38, in accordance with Specification B209/B209M. The sheets shall be 0.020 in. [0.508 mm], 0.040 in. [1.016 mm], or 0.063 in. [1.600 mm] in thickness, and a minimum of 8 by 8 in. [200 by 200 mm]. Prepare the aluminum in accordance with Specification B449, Class 2, or degrease and lightly acid etch before the specimens are applied. Apply the specimens to the panels in accordance with the manufacturer’s recommendations.

7.2 *Measure Sheeting Coefficients of Retroreflection:*

7.2.1 Measure the coefficients of retroreflection  $R_A$  ( $cd \cdot lx^{-1} \cdot m^{-2}$ ) as per Practice E809 for each of the nine specimens at each of the  $\alpha$ ,  $\beta_1$ ,  $\beta_2$ ,  $\epsilon$  angles corresponding to the chosen scenario.

7.2.2 The coefficients of retroreflection shall be determined for the CIE goniometric angle sets ( $\alpha$ ,  $\beta_1$ ,  $\beta_2$ ,  $\epsilon$ ) given in Table A1.3 through Table A1.11.

7.2.2.1 The datum axis on the goniometer, as defined in Practice E808, represents the vertical axis on the sign, and as such, the orientation of the sheeting on the goniometer (the angle between the datum mark on the sheeting and the datum axis on the goniometer) represents the orientation of the sheeting on the sign. Therefore, if the sheeting’s performance at 0° orientation on the sign is of interest (datum mark on the sheeting parallel to the vertical sign axis), the sheeting sample shall be mounted such that datum mark on the sheeting is aligned with the datum axis of the goniometer. For other orientations, such as 45° or 90°, sheeting shall be mounted accordingly.

7.3 Report the coefficients of retroreflection as the average of all nine specimen at each of the  $\alpha$ ,  $\beta_1$ ,  $\beta_2$ ,  $\epsilon$  angles. Determine the luminance observed by the driver:

7.3.1 The luminance as observed by the driver in each scenario shall be obtained by multiplying the coefficients of retroreflection for the angle sets given in Table A1.3 through Table A1.11, with the corresponding  $R_A$  multipliers in the same tables for each of the 25<sup>th</sup>, 50<sup>th</sup>, and the 75<sup>th</sup> percentile headlights. At a given distance, add the luminance provided by the right headlight to the luminance provided by the left headlight, and note the total luminance at that distance.

7.3.2 For 16 in. [40.64 cm] letter height scenarios, only the distance range of 640 ft to 320 ft [192.07 m to 97.54 m] shall be used. For the 12 in. [30.48 cm] letter height, only the 480 ft to 240 ft [146.3 m to 73.15 m] range shall be used.

NOTE 3—At the end of this step, for each scenario, the user will have three sets of luminances (one for each percentile headlights) for the applicable distance range.

7.4 *Calculate Performance Index:*

7.4.1 Compare the total luminance observed by the driver to the luminance required for different percentile drivers at each distance to determine the performance index at that distance. Determine the applicable performance index table for the selected scenario (Table A1.12 through Table A1.15). To find the correct performance index table, see Table A1.1. At each distance index, determine the two cells, which the total observed luminance from 7.3 falls in between.

7.4.2 Determine the benchmark performance index given in the column headers for these two cells (in the top row). Calculate the performance index, which will be between these two benchmark performance indexes, by linear interpolation. An example calculation is provided in Annex A1.

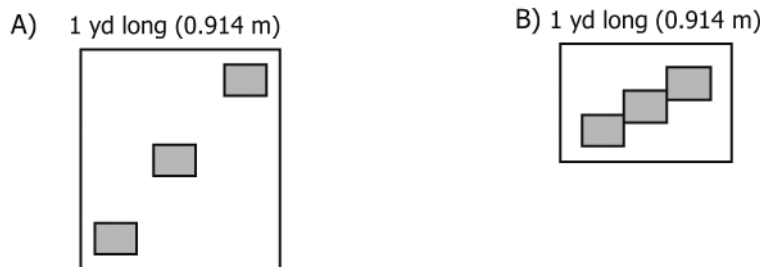


FIG. 3 Examples of Proper Spacing for Samples

7.4.3 If the total luminance from 7.3 exceeds the highest value on the right-most column, the performance index shall be noted as “98.”

7.4.4 The lowest limit for PI is 10. If the total luminance from 7.3 falls below the lowest value on the left-most column, the PI shall be below 10 without a definite value.

7.4.5 Repeat the above steps 7.4.1 and 7.4.2 for each headlight percentile.

7.4.6 The interpolation yields an individual performance index at each of the distances for each of the three headlight percentiles (99 total for 16 in. letter heights: 33 distances × 3 headlight percentiles, and 75 total for 12 in. letters: 25

distances × 3 headlight percentiles). To calculate overall performance index, compute the average of these 99 individual performance indexes (or 75 in the case of 12 in. letter heights), which will be the single and final performance index for the scenario.

## 8. Report

8.1 Report the following:

8.1.1 The evaluated retroreflective sheeting,

8.1.2 Scenario number(s) evaluated, and

8.1.3 The performance index for the scenario(s).

## ANNEXES

### (Mandatory Information)

#### A1. PARAMETERS

A1.1 Data:

A1.1.1 Scenario Numbers—See Table A1.1.

A1.1.2 Headlamp Luminous Intensity Data – UMTRI 2011—See Table A1.2.

A1.1.3 CIE Goniometric System Angles  $\alpha$ ,  $\beta_1$ ,  $\beta_2$ ,  $\epsilon$ , and  $R_A$  Multipliers for Each Sign Scenario—See Tables A1.3-A1.11.

A1.1.4 Performance Index Luminance Requirement Tables—See Tables A1.12-A1.15.

**TABLE A1.1 Scenario Numbers and Corresponding Data Tables for Each of the 36 Scenarios**

Scenario No.	Sign Location	Vehicle Type	Letter Height	Scenario No.	Visual Complexity	Measurement Angles and RA Multiplier Table	Performance Index Table	
1	Right Shoulder	Passenger Car	12 in.	1	Low/Medium	Table A1.3	Table A1.12	
2				2	High	Table A1.3	Table A1.13	
3				3	Low/Medium	Table A1.3	Table A1.14	
4			Light Truck/ SUV/ Minivan	12 in.	4	High	Table A1.3	Table A1.15
5				5	Low/Medium	Table A1.6	Table A1.13	
6				6	High	Table A1.6	Table A1.13	
7				16 in.	7	Low/Medium	Table A1.6	Table A1.14
8					8	High	Table A1.6	Table A1.15
9			Heavy Vehicle	12 in.	9	Low/Medium	Table A1.9	Table A1.12
10				10	High	Table A1.9	Table A1.13	
11				11	Low/Medium	Table A1.9	Table A1.14	
12				16 in.	12	High	Table A1.9	Table A1.15
13	Overhead	Passenger Car	12 in.	13	Low/Medium	Table A1.4	Table A1.12	
14				14	High	Table A1.4	Table A1.13	
15				15	Low/Medium	Table A1.4	Table A1.14	
16			Light Truck/ SUV/ Minivan	12 in.	16	High	Table A1.4	Table A1.15
17				17	Low/Medium	Table A1.7	Table A1.12	
18				18	High	Table A1.7	Table A1.13	
19				16 in.	19	Low/Medium	Table A1.7	Table A1.14
20					20	High	Table A1.7	Table A1.15
21			Heavy Vehicle	12 in.	21	Low/Medium	Table A1.10	Table A1.12
22				22	High	Table A1.10	Table A1.13	
23				23	Low/Medium	Table A1.10	Table A1.14	
24				16 in.	24	High	Table A1.10	Table A1.15
25	Left Shoulder	Passenger Car	12 in.	25	Low/Medium	Table A1.5	Table A1.12	
26				26	High	Table A1.5	Table A1.13	
27				27	Low/Medium	Table A1.5	Table A1.14	
28			Light Truck/ SUV/ Minivan	12 in.	28	High	Table A1.5	Table A1.15
29				29	Low/Medium	Table A1.8	Table A1.12	
30				30	High	Table A1.8	Table A1.13	
31				16 in.	31	Low/Medium	Table A1.8	Table A1.14
32					32	High	Table A1.8	Table A1.15
33			Heavy Vehicle	12 in.	33	Low/Medium	Table A1.11	Table A1.12
34				34	High	Table A1.11	Table A1.13	
35				35	Low/Medium	Table A1.11	Table A1.14	
36				16 in.	36	High	Table A1.11	Table A1.15

**TABLE A1.2 Luminous Intensities (cd) for Sales-Weighted Sample Representing the Low-Beam Headlamps (Schoettle et al. (1))<sup>a</sup>**

	8L	7.5L	7L	6.5L	6L	5.5L	5L	4.5L	4L	3.5L	3L	2.5L	2L	1.5L	1L	0.5L
5U	134.78	135.19	129.26	126.53	129.75	141.31	157.36	157.81	158.11	156.86	152.4	146.71	144.16	145.53	149.94	147.67
	156.44	160.05	161.96	163.02	167.64	168.7	172.33	177.44	194	201.22	207.94	212.85	204.45	205.38	205.33	213.63
	182	186.18	193.07	197.95	205.65	208.37	210.21	211.42	213.62	213.95	216.69	220.85	225.09	227.94	234.16	239.01
4.5U	164.81	168.52	170.43	170.37	166.45	170.55	173.05	172.44	173.78	173.81	175.75	180.28	185.1	187.04	195.05	197.31
	208.03	213.11	219.2	223.28	229.79	231.99	231.43	232.39	238.15	239.81	238.13	242.71	247.17	247.2	247.33	248.01
	256.76	258.66	254.51	254.62	255.07	265.33	268.92	269.58	272.23	268.75	270.85	259.15	276.73	280.08	273.95	279.58
4U	174.81	180.11	184.38	189.51	194.98	198.97	203.12	198.32	199.72	202.01	206.74	210.85	214.44	218.17	210.4	224.77
	214.06	222.2	242.63	236.69	243.66	243.23	243.88	246.15	244.63	248.02	248.4	252.81	255.6	260.49	264.46	
	275.87	275.99	276.37	277.94	279.49	281.48	284.62	285.31	287.8	289.1	289.73	290.08	295.38	296.75	300.77	302.14
3.5U	193.17	197.43	212.92	208.42	216.77	226.99	226.27	227.43	226.96	224.2	228.73	232.27	256.46	264.62	253.19	248.99
	258.51	267.17	278.03	285.38	292.74	289.06	282.13	282.11	289.99	292.64	290.31	298.71	283.59	288.76	297.33	302.04
	281.12	288.18	304.32	315.74	310.45	313.83	321.03	327.36	338.08	342	341.24	343.53	346.91	352.22	369.27	388.56
3U	204.08	211.14	220.15	220.83	227.15	246.25	256.45	257.5	257.77	256.78	252.93	251.44	284.44	276.87	281.92	287.18
	249.05	260.48	273.11	282.54	294.64	302.93	303.51	306.57	311.4	316.74	316.43	315.11	315.63	318.11	322.12	322.67
	304.2	320.51	335.36	337.21	337.99	338.13	350.65	358.15	372.53	379.93	387.38	385.75	386.69	391.57	400.88	418
2.5U	208.48	216.28	234.33	241.67	262.77	272.08	281.69	285.75	292.29	294.66	314.49	312.77	336.51	322.4	317.88	320.51
	241.54	246.14	255.82	266.77	288.66	299.62	316.39	326.4	336.23	358.1	351.66	355.65	357.6	361.93	376.85	386.27
	325	357.09	366.66	375.05	389.09	393.91	403.63	411.48	428.01	438.4	453.64	467.29	481.26	489.82	451.2	470.8
2U	234.41	246.96	257.09	267.11	283.56	293.81	308.9	316.37	329.33	338.8	334.38	355.04	362.24	359.86	365.96	363.61
	251.73	268.98	286.73	292.59	302	320.41	329.55	332.76	350.71	364.84	388.26	385.06	390.02	410.14	430.33	441.59
	354.19	363.33	376.54	382.19	392.97	401.99	438.08	453.45	466.6	482.16	508.52	537.43	541.23	554.99	519.66	534.19
1.5U	250.85	262.44	282.61	297.35	319.12	327.26	344.11	358.09	375.14	378.47	395.7	397.53	401.72	405.99	414.35	416.49
	269.31	280.81	301.16	312.72	329.9	342.39	360.66	371.17	416.96	412.45	414.86	450.9	470.57	510.52	523.37	541.8
	367.59	383.39	382.84	393.69	411.32	423.84	443.41	481.83	499.32	529.69	542.83	550.19	550.05	548.33	584.88	593.91
1U	252.63	260.08	281.57	295.46	317.93	330.91	356.66	365.99	386.51	397.64	409.95	417.11	423.68	430.66	459.41	474.27
	323.57	338.02	359.57	369.42	384.87	397.35	421.57	433.96	490.82	486.66	494.6	518.33	543.24	556.39	570.4	585.94
	395.84	406.08	416.07	429.66	453.65	460.69	479.84	491.85	511.74	522.31	528.34	543.72	575.57	594.84	634.21	650.5
0.5U	269.96	282.33	306.32	320.58	343.15	357.84	375.9	389.48	408.34	416.33	433.01	446.49	470.44	488.77	547.1	602.61
	392.03	407.47	423.11	436.79	472.96	518.42	555.79	600.27	655.74	665.56	669.95	681.17	767.24	831.02	896.35	936.72
	714.24	722.7	735.47	744.46	768.55	785.4	794.47	814.86	861.11	880.19	919.65	979.5	998.53	1018.48	1003.04	1037.03
0	494.38	508.08	521.61	532.73	552.91	525.39	596.08	620.41	617.55	648.27	662.83	681.2	745.8	827.46	1048.35	1331.84
	636.15	681.94	701.03	710.46	764.17	870.27	940.67	1091.67	1143.88	1207.79	1349.88	1380.68	1557.24	1821.9	2259.83	2461.44
	1321.73	1379.34	1381.47	1405.99	1523.15	1622.43	1671.83	1708.28	1820.88	1820.88	2092.43	2136.9	2333.6	2429.22	2547.32	2856.78
	0	0.5R	1R	1.5R	2R	2.5R	3R	3.5R	4R	4.5R	5R					
5U	147.41	145.64	153.5	150.11	146.57	146.57	145.7	143.52	141.7	135.81	140.31					
	213.07	214.79	229.73	212.03	232	227.21	210.94	209.76	208.96	206.63	205.81					
	244.94	248.55	252.48	255.13	253.32	247.72	241.82	241.55	240.02	237.6	233.85					
4.5U	198.45	195.34	196.85	198.05	197.97	194.94	192.66	190.13	185.49	192.08	185.41					
	247.87	248.58	252.66	261.73	263.77	262.69	261.68	256.06	254.65	254.35	251.72					
	281.05	282.38	286.48	287.8	284.8	284.37	289.42	290.66	299.28	291.89	283.45					
4U	226.7	234.05	226.4	224.65	228.61	234.88	221.3	219.56	213.3	210.59	214.82					
	271.71	275.76	278.28	283.33	289.47	296.23	296.37	292.83	291.93	281.64	279.05					
	299.56	304.47	307.97	308.98	306.67	303	312.29	315.64	310.59	316.5	294.15					
3.5U	253.16	254.4	251.69	249.55	246.65	244.24	245.88	249.27	242.91	238.23	240.48					
	301.12	300.05	300.45	299.72	307.92	312.53	319.47	324.67	317.72	312.99	295.75					
	391.44	393.75	386.19	384	380.16	370.54	355.86	349.11	358.32	355.75	341.79					
3U	290.63	279.96	280.95	279.61	277.25	277.48	275.69	284.65	281.74	283.55	294.55					
	324.86	325.12	324.92	324.92	335.2	341.44	350.02	344.35	346.09	334.43	334.97					
	416.84	429.25	415.95	416.47	408.78	415.04	413.61	390.28	385.28	384.85	372.04					
2.5U	321.66	324.48	333.65	328.08	340.03	347.62	342.33	362.44	320.12	314.24	311.76					
	378.07	380.84	386.49	397.19	422.66	434.41	455.49	415.71	432.87	396.5	398.38					
	479.06	486	477.59	475.81	464.38	463.36	464.07	461.91	445.3	450.05	436.77					
2U	353.22	356.45	367.16	385.21	380.22	376.73	369.02	382.86	355.85	347.59	343.41					
	461.24	463.1	464.2	478.84	490.16	492.33	499	489.49	472.69	435.27	395.61					
	537.74	538.71	526.3	522.22	517.23	516.31	522.7	518.04	492.14	492.55	476.54					
1.5U	413.49	414.27	433.77	459.59	452.26	441.05	420.13	409.98	404.82	387.11	389.08					
	578.88	603	596.12	582	566.65	557.6	544.53	541.42	536.62	532.63	493.81					
	623.75	617.84	626.7	641.21	641.52	654.31	656.91	624.64	586.45	560.27	535.83					
1U	481.55	499.72	522.27	550.1	530.08	501.14	454.18	432.51	417.79	411.78	394.71					
	582.41	581.81	573.75	613.31	665.87	666.72	686.23	663.94	601.03	588.8	569.45					
	706.05	749.39	768.07	782.51	801.9	798.53	790.29	762.62	703.88	700.91	672.27					
0.5U	697.4	820.9	944.75	949.74	899.63	826.67	699.69	659.37	615.59	596.56	592.68					
	1080.8	1126.06	1159.87	1215.91	1260.17	1218.75	1202.63	1116.59	1043.35	994.71	974.72					
	1152.14	1248.21	1339.02	1350.33	1355.3	1340.17	1294.67	1250	1120.97	1045.02	1017.38					
0	2345.83	3214.88	3633.49	3661.13	3577.71	3486.11	2998.84	2728.16	2408.25	2241.42	2135.89					
	3092.23	3612.98	4164.56	4175.91	3945.28	4142.89	4001.46	3942.72	3460.95	3132.11	2840.49					
	3328.71	3919.65	4399.75	4493.22	4533.93	4572.18	4370.71	4205.19	3928.92	3789.8	3265.03					

<sup>a</sup> Each cell contains 25<sup>th</sup>, 50<sup>th</sup>, and 75<sup>th</sup> percentile, from top to bottom, respectively.

**TABLE A1.3  $\alpha$ ,  $\beta_1$ ,  $\beta_2$ ,  $\epsilon$  Angles (deg) and  $R_A$  Multipliers for Passenger Car, Right Shoulder (PC-RS) Sign Scenarios (Scenarios 1–4)**

Dist. to Sign (ft)	Dist. to Sign (m)	LEFT HEADLIGHT							RIGHT HEADLIGHT						
		Obs. Angle $\alpha$	Ent. Angle $\beta_1$	Ent. Angle $\beta_2$	Rot. Angle $\epsilon$	$R_A$ Mult. (25 %)	$R_A$ Mult. (50 %)	$R_A$ Mult. (75 %)	Obs. Angle $\alpha$	Ent. Angle $\beta_1$	Ent. Angle $\beta_2$	Rot. Angle $\epsilon$	$R_A$ Mult. (25 %)	$R_A$ Mult. (50 %)	$R_A$ Mult. (75 %)
640	195.07	0.18	2.81	4.90	24.35	0.0170	0.0220	0.0245	0.27	-3.93	3.64	-53.09	0.0172	0.0214	0.0244
630	192.02	0.18	2.83	4.91	24.41	0.0173	0.0225	0.0251	0.28	-3.93	3.66	-53.05	0.0175	0.0219	0.0249
620	188.98	0.19	2.86	4.93	24.48	0.0177	0.0230	0.0256	0.28	-3.94	3.68	-53.01	0.0179	0.0223	0.0255
610	185.93	0.19	2.88	4.95	24.54	0.0180	0.0235	0.0262	0.29	-3.95	3.71	-52.97	0.0184	0.0228	0.0261
600	182.88	0.19	2.91	4.97	24.61	0.0184	0.0240	0.0268	0.29	-3.96	3.73	-52.92	0.0188	0.0234	0.0267
590	179.83	0.20	2.93	4.98	24.69	0.0188	0.0246	0.0275	0.30	-3.97	3.76	-52.88	0.0192	0.0239	0.0274
580	176.78	0.20	2.96	5.00	24.76	0.0192	0.0252	0.0281	0.30	-3.98	3.78	-52.83	0.0197	0.0244	0.0280
570	173.74	0.20	2.99	5.02	24.84	0.0195	0.0258	0.0288	0.31	-3.99	3.81	-52.78	0.0202	0.0250	0.0287
560	170.69	0.21	3.02	5.04	24.92	0.0200	0.0264	0.0295	0.31	-4.01	3.84	-52.73	0.0206	0.0256	0.0294
550	167.64	0.21	3.05	5.07	25.00	0.0204	0.0271	0.0303	0.32	-4.02	3.87	-52.68	0.0211	0.0262	0.0301
540	164.59	0.22	3.09	5.09	25.09	0.0208	0.0278	0.0311	0.32	-4.03	3.90	-52.62	0.0215	0.0268	0.0309
530	161.54	0.22	3.12	5.11	25.18	0.0212	0.0285	0.0318	0.33	-4.04	3.93	-52.56	0.0220	0.0275	0.0316
520	158.50	0.23	3.16	5.13	25.27	0.0217	0.0292	0.0327	0.33	-4.05	3.96	-52.50	0.0225	0.0282	0.0324
510	155.45	0.23	3.19	5.16	25.36	0.0221	0.0299	0.0335	0.34	-4.07	4.00	-52.44	0.0230	0.0289	0.0333
500	152.40	0.24	3.23	5.18	25.46	0.0226	0.0305	0.0343	0.35	-4.08	4.03	-52.38	0.0235	0.0296	0.0341
490	149.35	0.24	3.27	5.21	25.56	0.0230	0.0311	0.0352	0.35	-4.09	4.07	-52.31	0.0240	0.0303	0.0350
480	146.30	0.25	3.31	5.24	25.67	0.0235	0.0318	0.0361	0.36	-4.11	4.11	-52.24	0.0245	0.0311	0.0360
470	143.26	0.25	3.36	5.27	25.78	0.0239	0.0325	0.0370	0.37	-4.12	4.15	-52.17	0.0251	0.0320	0.0369
460	140.21	0.26	3.40	5.29	25.89	0.0244	0.0332	0.0380	0.38	-4.14	4.19	-52.09	0.0256	0.0328	0.0380
450	137.16	0.26	3.45	5.33	26.01	0.0249	0.0339	0.0390	0.38	-4.15	4.24	-52.01	0.0262	0.0337	0.0390
440	134.11	0.27	3.50	5.36	26.13	0.0254	0.0347	0.0400	0.39	-4.17	4.28	-51.93	0.0268	0.0347	0.0401
430	131.06	0.28	3.55	5.39	26.26	0.0259	0.0355	0.0411	0.40	-4.19	4.33	-51.84	0.0274	0.0357	0.0413
420	128.02	0.28	3.61	5.42	26.40	0.0264	0.0363	0.0422	0.41	-4.20	4.38	-51.75	0.0280	0.0366	0.0424
410	124.97	0.29	3.67	5.46	26.54	0.0269	0.0371	0.0433	0.42	-4.22	4.44	-51.65	0.0286	0.0374	0.0436
400	121.92	0.30	3.73	5.50	26.69	0.0273	0.0381	0.0444	0.43	-4.24	4.49	-51.55	0.0292	0.0382	0.0447
390	118.87	0.31	3.79	5.54	26.84	0.0277	0.0392	0.0455	0.44	-4.26	4.55	-51.44	0.0298	0.0391	0.0459
380	115.82	0.32	3.86	5.58	27.00	0.0281	0.0402	0.0467	0.45	-4.28	4.61	-51.33	0.0305	0.0400	0.0472
370	112.78	0.33	3.93	5.62	27.17	0.0285	0.0414	0.0480	0.46	-4.30	4.68	-51.21	0.0311	0.0409	0.0485
360	109.73	0.34	4.01	5.67	27.34	0.0289	0.0426	0.0493	0.47	-4.33	4.75	-51.08	0.0317	0.0418	0.0498
350	106.68	0.35	4.09	5.71	27.53	0.0293	0.0439	0.0506	0.49	-4.35	4.82	-50.94	0.0324	0.0428	0.0512
340	103.63	0.36	4.17	5.76	27.73	0.0304	0.0456	0.0526	0.50	-4.37	4.90	-50.80	0.0336	0.0446	0.0533
330	100.58	0.37	4.26	5.82	27.93	0.0318	0.0475	0.0549	0.51	-4.40	4.99	-50.65	0.0350	0.0469	0.0559
320	97.54	0.38	4.36	5.87	28.15	0.0334	0.0495	0.0572	0.53	-4.43	5.07	-50.49	0.0364	0.0495	0.0586
310	94.49	0.40	4.46	5.93	28.38	0.0351	0.0517	0.0597	0.54	-4.45	5.17	-50.31	0.0379	0.0522	0.0615
300	91.44	0.41	4.57	5.99	28.62	0.0370	0.0540	0.0622	0.56	-4.48	5.27	-50.13	0.0395	0.0550	0.0647
290	88.39	0.43	4.69	6.05	28.88	0.0391	0.0563	0.0647	0.58	-4.51	5.38	-49.93	0.0414	0.0579	0.0681
280	85.34	0.44	4.82	6.12	29.15	0.0415	0.0585	0.0670	0.60	-4.54	5.50	-49.72	0.0434	0.0610	0.0718
270	82.30	0.46	4.96	6.19	29.44	0.0441	0.0612	0.0694	0.62	-4.57	5.62	-49.49	0.0460	0.0640	0.0751
260	79.25	0.48	5.11	6.27	29.75	0.0471	0.0643	0.0720	0.64	-4.61	5.76	-49.24	0.0489	0.0672	0.0787
250	76.20	0.50	5.27	6.35	30.07	0.0503	0.0683	0.0754	0.66	-4.64	5.91	-48.97	0.0521	0.0709	0.0824
240	73.15	0.53	5.44	6.44	30.43	0.0535	0.0730	0.0789	0.69	-4.68	6.07	-48.67	0.0558	0.0748	0.0861



**TABLE A1.4  $\alpha$ ,  $\beta_1$ ,  $\beta_2$ ,  $\epsilon$  Angles for Passenger Car, Overhead (PC-OH) Sign Scenarios (Scenarios 13–16)**

Dist. to Sign (ft)	Dist. to Sign (m)	LEFT HEADLIGHT							RIGHT HEADLIGHT						
		Obs. Angle $\alpha$	Ent. Angle $\beta_1$	Ent. Angle $\beta_2$	Rot. Angle $\epsilon$	R <sub>A</sub> Mult. (25 %) (lx)	R <sub>A</sub> Mult. (50 %) (lx)	R <sub>A</sub> Mult. (75 %) (lx)	Obs. Angle $\alpha$	Ent. Angle $\beta_1$	Ent. Angle $\beta_2$	Rot. Angle $\epsilon$	R <sub>A</sub> Mult. (25 %) (lx)	R <sub>A</sub> Mult. (50 %) (lx)	R <sub>A</sub> Mult. (75 %) (lx)
640	195.07	0.19	5.47	-1.68	18.52	0.0073	0.0100	0.0111	0.29	3.58	4.47	-52.73	0.0074	0.0098	0.0110
630	192.02	0.19	5.49	-1.69	18.50	0.0075	0.0102	0.0114	0.30	3.60	4.48	-52.69	0.0075	0.0099	0.0113
620	188.98	0.19	5.52	-1.69	18.48	0.0077	0.0104	0.0116	0.30	3.62	4.50	-52.65	0.0077	0.0101	0.0116
610	185.93	0.20	5.55	-1.70	18.45	0.0079	0.0106	0.0119	0.31	3.64	4.52	-52.60	0.0079	0.0103	0.0118
600	182.88	0.20	5.58	-1.70	18.43	0.0081	0.0108	0.0122	0.31	3.67	4.54	-52.56	0.0081	0.0105	0.0121
590	179.83	0.20	5.61	-1.71	18.41	0.0083	0.0110	0.0125	0.32	3.69	4.56	-52.51	0.0083	0.0108	0.0124
580	176.78	0.21	5.64	-1.71	18.39	0.0085	0.0112	0.0128	0.32	3.72	4.58	-52.46	0.0085	0.0111	0.0128
570	173.74	0.21	5.68	-1.72	18.36	0.0087	0.0115	0.0132	0.33	3.74	4.60	-52.41	0.0087	0.0113	0.0131
560	170.69	0.22	5.71	-1.72	18.34	0.0089	0.0117	0.0135	0.34	3.77	4.63	-52.36	0.0089	0.0115	0.0134
550	167.64	0.22	5.75	-1.73	18.31	0.0091	0.0119	0.0138	0.34	3.80	4.65	-52.31	0.0092	0.0117	0.0138
540	164.59	0.22	5.78	-1.73	18.28	0.0094	0.0122	0.0142	0.35	3.83	4.67	-52.25	0.0094	0.0120	0.0142
530	161.54	0.23	5.82	-1.74	18.25	0.0097	0.0125	0.0147	0.36	3.86	4.70	-52.20	0.0097	0.0123	0.0146
520	158.50	0.23	5.86	-1.75	18.23	0.0100	0.0127	0.0151	0.36	3.89	4.72	-52.14	0.0100	0.0126	0.0150
510	155.45	0.24	5.90	-1.75	18.20	0.0103	0.0129	0.0156	0.37	3.92	4.75	-52.08	0.0103	0.0129	0.0155
500	152.40	0.24	5.95	-1.76	18.17	0.0106	0.0133	0.0160	0.38	3.96	4.78	-52.01	0.0107	0.0132	0.0159
490	149.35	0.25	5.99	-1.77	18.13	0.0110	0.0136	0.0165	0.39	3.99	4.81	-51.95	0.0110	0.0135	0.0164
480	146.30	0.26	6.04	-1.77	18.10	0.0113	0.0139	0.0170	0.40	4.03	4.84	-51.88	0.0113	0.0138	0.0169
470	143.26	0.26	6.09	-1.78	18.07	0.0117	0.0142	0.0176	0.40	4.07	4.87	-51.81	0.0117	0.0143	0.0174
460	140.21	0.27	6.14	-1.79	18.03	0.0121	0.0145	0.0182	0.41	4.11	4.90	-51.73	0.0121	0.0146	0.0180
450	137.16	0.27	6.19	-1.80	17.99	0.0125	0.0149	0.0188	0.42	4.16	4.93	-51.65	0.0125	0.0150	0.0185
440	134.11	0.28	6.25	-1.81	17.95	0.0130	0.0153	0.0194	0.43	4.20	4.97	-51.57	0.0129	0.0153	0.0191
430	131.06	0.29	6.30	-1.82	17.91	0.0134	0.0157	0.0200	0.44	4.25	5.00	-51.49	0.0134	0.0158	0.0197
420	128.02	0.30	6.36	-1.82	17.87	0.0138	0.0162	0.0206	0.45	4.30	5.04	-51.40	0.0138	0.0162	0.0203
410	124.97	0.30	6.43	-1.83	17.83	0.0143	0.0167	0.0213	0.47	4.35	5.08	-51.31	0.0143	0.0166	0.0210
400	121.92	0.31	6.50	-1.84	17.78	0.0148	0.0170	0.0220	0.48	4.40	5.12	-51.21	0.0148	0.0171	0.0217
390	118.87	0.32	6.57	-1.86	17.74	0.0153	0.0176	0.0227	0.49	4.46	5.17	-51.11	0.0154	0.0176	0.0224
380	115.82	0.33	6.64	-1.87	17.69	0.0158	0.0182	0.0235	0.50	4.52	5.21	-51.00	0.0159	0.0181	0.0231
370	112.78	0.34	6.72	-1.88	17.63	0.0163	0.0187	0.0242	0.52	4.59	5.26	-50.89	0.0165	0.0186	0.0239
360	109.73	0.35	6.80	-1.89	17.58	0.0169	0.0194	0.0252	0.53	4.66	5.31	-50.77	0.0171	0.0193	0.0249
350	106.68	0.36	6.89	-1.90	17.52	0.0175	0.0202	0.0263	0.55	4.73	5.36	-50.65	0.0176	0.0202	0.0260
340	103.63	0.38	6.98	-1.92	17.46	0.0182	0.0211	0.0275	0.57	4.80	5.42	-50.52	0.0182	0.0211	0.0272
330	100.58	0.39	7.08	-1.93	17.40	0.0189	0.0221	0.0288	0.58	4.89	5.48	-50.38	0.0188	0.0221	0.0285
320	97.54	0.40	7.18	-1.94	17.33	0.0196	0.0231	0.0302	0.60	4.97	5.54	-50.24	0.0194	0.0231	0.0299
310	94.49	0.42	7.29	-1.96	17.26	0.0204	0.0241	0.0311	0.62	5.06	5.60	-50.08	0.0201	0.0242	0.0309
300	91.44	0.43	7.41	-1.98	17.19	0.0213	0.0252	0.0312	0.65	5.16	5.67	-49.92	0.0209	0.0251	0.0310
290	88.39	0.45	7.54	-1.99	17.11	0.0223	0.0264	0.0313	0.67	5.27	5.75	-49.74	0.0218	0.0261	0.0311
280	85.34	0.47	7.67	-2.01	17.03	0.0233	0.0276	0.0313	0.70	5.38	5.83	-49.56	0.0227	0.0270	0.0311
270	82.30	0.49	7.82	-2.03	16.94	0.0242	0.0289	0.0320	0.72	5.51	5.91	-49.36	0.0236	0.0282	0.0318
260	79.25	0.51	7.97	-2.05	16.85	0.0248	0.0303	0.0338	0.75	5.64	6.00	-49.15	0.0245	0.0297	0.0336
250	76.20	0.54	8.14	-2.07	16.75	0.0253	0.0316	0.0357	0.78	5.79	6.10	-48.92	0.0253	0.0314	0.0354
240	73.15	0.56	8.32	-2.10	16.65	0.0254	0.0329	0.0374	0.82	5.94	6.20	-48.68	0.0256	0.0328	0.0370

**TABLE A1.5  $\alpha$ ,  $\beta_1$ ,  $\beta_2$ ,  $\epsilon$  Angles (deg) and  $R_A$  Multipliers for Passenger Car, Left Shoulder (PC-LS) Sign Scenarios (Scenarios 25–28)**

Dist. to Sign (ft)	Dist. to Sign (m)	LEFT HEADLIGHT							RIGHT HEADLIGHT						
		Obs. Angle $\alpha$	Ent. Angle $\beta_1$	Ent. Angle $\beta_2$	Rot. Angle $\epsilon$	$R_A$ Mult. (25 %) (lx)	$R_A$ Mult. (50 %) (lx)	$R_A$ Mult. (75 %) (lx)	Obs. Angle $\alpha$	Ent. Angle $\beta_1$	Ent. Angle $\beta_2$	Rot. Angle $\epsilon$	$R_A$ Mult. (25 %) (lx)	$R_A$ Mult. (50 %) (lx)	$R_A$ Mult. (75 %) (lx)
640	195.07	0.17	-0.74	-6.48	11.28	0.0084	0.0127	0.0177	0.31	6.03	-3.17	-57.75	0.0083	0.0125	0.0171
630	192.02	0.17	-0.72	-6.52	11.14	0.0087	0.0130	0.0180	0.31	6.07	-3.19	-57.78	0.0085	0.0128	0.0174
620	188.98	0.17	-0.70	-6.56	11.00	0.0089	0.0133	0.0183	0.32	6.12	-3.20	-57.81	0.0088	0.0131	0.0177
610	185.93	0.18	-0.68	-6.61	10.85	0.0092	0.0137	0.0186	0.32	6.16	-3.21	-57.85	0.0090	0.0135	0.0180
600	182.88	0.18	-0.66	-6.65	10.69	0.0095	0.0140	0.0189	0.33	6.21	-3.23	-57.88	0.0093	0.0138	0.0183
590	179.83	0.18	-0.64	-6.70	10.53	0.0098	0.0144	0.0193	0.34	6.26	-3.24	-57.92	0.0096	0.0142	0.0186
580	176.78	0.19	-0.62	-6.75	10.37	0.0101	0.0148	0.0196	0.34	6.31	-3.26	-57.95	0.0099	0.0146	0.0190
570	173.74	0.19	-0.60	-6.80	10.20	0.0104	0.0152	0.0200	0.35	6.37	-3.27	-57.99	0.0101	0.0150	0.0193
560	170.69	0.19	-0.58	-6.85	10.02	0.0107	0.0156	0.0203	0.36	6.42	-3.29	-58.03	0.0105	0.0154	0.0197
550	167.64	0.20	-0.55	-6.91	9.84	0.0110	0.0160	0.0207	0.36	6.48	-3.31	-58.07	0.0108	0.0158	0.0201
540	164.59	0.20	-0.53	-6.97	9.65	0.0114	0.0164	0.0211	0.37	6.54	-3.32	-58.11	0.0111	0.0163	0.0205
530	161.54	0.20	-0.50	-7.02	9.45	0.0118	0.0169	0.0214	0.38	6.60	-3.34	-58.16	0.0115	0.0168	0.0209
520	158.50	0.21	-0.47	-7.09	9.25	0.0122	0.0174	0.0219	0.39	6.66	-3.36	-58.20	0.0119	0.0173	0.0214
510	155.45	0.21	-0.44	-7.15	9.03	0.0126	0.0179	0.0223	0.39	6.73	-3.38	-58.25	0.0123	0.0178	0.0218
500	152.40	0.22	-0.41	-7.21	8.81	0.0130	0.0185	0.0228	0.40	6.80	-3.40	-58.30	0.0127	0.0183	0.0223
490	149.35	0.22	-0.38	-7.28	8.58	0.0135	0.0190	0.0233	0.41	6.87	-3.42	-58.35	0.0132	0.0189	0.0228
480	146.30	0.22	-0.34	-7.35	8.34	0.0140	0.0196	0.0238	0.42	6.95	-3.44	-58.40	0.0136	0.0195	0.0233
470	143.26	0.23	-0.31	-7.43	8.09	0.0145	0.0203	0.0243	0.43	7.02	-3.46	-58.45	0.0141	0.0201	0.0239
460	140.21	0.23	-0.27	-7.50	7.83	0.0150	0.0209	0.0249	0.44	7.11	-3.49	-58.51	0.0147	0.0208	0.0244
450	137.16	0.24	-0.23	-7.58	7.56	0.0156	0.0216	0.0255	0.45	7.19	-3.51	-58.57	0.0153	0.0215	0.0250
440	134.11	0.24	-0.18	-7.66	7.28	0.0162	0.0223	0.0261	0.46	7.28	-3.54	-58.63	0.0158	0.0220	0.0255
430	131.06	0.25	-0.13	-7.75	6.98	0.0169	0.0231	0.0267	0.47	7.37	-3.56	-58.69	0.0164	0.0224	0.0260
420	128.02	0.26	-0.08	-7.84	6.67	0.0176	0.0240	0.0273	0.49	7.47	-3.59	-58.75	0.0169	0.0227	0.0265
410	124.97	0.26	-0.03	-7.94	6.34	0.0183	0.0248	0.0279	0.50	7.58	-3.62	-58.82	0.0175	0.0230	0.0270
400	121.92	0.27	0.03	-8.03	6.00	0.0191	0.0258	0.0286	0.51	7.68	-3.65	-58.89	0.0182	0.0232	0.0275
390	118.87	0.28	0.09	-8.14	5.64	0.0198	0.0262	0.0292	0.53	7.80	-3.68	-58.97	0.0189	0.0237	0.0280
380	115.82	0.28	0.16	-8.25	5.27	0.0206	0.0266	0.0297	0.54	7.92	-3.71	-59.04	0.0197	0.0244	0.0287
370	112.78	0.29	0.23	-8.36	4.87	0.0214	0.0269	0.0303	0.56	8.04	-3.74	-59.12	0.0206	0.0251	0.0293
360	109.73	0.30	0.31	-8.48	4.45	0.0223	0.0272	0.0309	0.58	8.17	-3.78	-59.21	0.0215	0.0259	0.0300
350	106.68	0.31	0.39	-8.60	4.01	0.0232	0.0277	0.0315	0.60	8.32	-3.81	-59.30	0.0224	0.0266	0.0306
340	103.63	0.32	0.48	-8.73	3.54	0.0244	0.0287	0.0328	0.62	8.46	-3.85	-59.39	0.0231	0.0274	0.0316
330	100.58	0.33	0.58	-8.87	3.05	0.0256	0.0300	0.0344	0.64	8.62	-3.89	-59.49	0.0240	0.0283	0.0329
320	97.54	0.34	0.69	-9.02	2.52	0.0270	0.0313	0.0361	0.66	8.79	-3.93	-59.59	0.0249	0.0293	0.0344
310	94.49	0.35	0.80	-9.17	1.97	0.0281	0.0324	0.0377	0.68	8.97	-3.98	-59.70	0.0262	0.0305	0.0362
300	91.44	0.36	0.93	-9.34	1.38	0.0293	0.0335	0.0395	0.71	9.16	-4.03	-59.82	0.0276	0.0318	0.0381
290	88.39	0.37	1.07	-9.51	0.75	0.0305	0.0347	0.0413	0.74	9.36	-4.08	-59.94	0.0288	0.0331	0.0398
280	85.34	0.39	1.22	-9.69	0.08	0.0323	0.0363	0.0436	0.77	9.58	-4.13	-60.07	0.0300	0.0343	0.0414
270	82.30	0.40	1.39	-9.88	-0.64	0.0342	0.0379	0.0461	0.80	9.81	-4.18	-60.20	0.0313	0.0356	0.0433
260	79.25	0.42	1.58	-10.09	-1.41	0.0360	0.0395	0.0484	0.83	10.07	-4.24	-60.35	0.0329	0.0371	0.0457
250	76.20	0.44	1.78	-10.30	-2.23	0.0377	0.0410	0.0506	0.87	10.34	-4.31	-60.50	0.0345	0.0384	0.0484
240	73.15	0.46	2.01	-10.54	-3.12	0.0396	0.0427	0.0533	0.92	10.63	-4.37	-60.67	0.0358	0.0392	0.0520

**TABLE A1.6  $\alpha$ ,  $\beta_1$ ,  $\beta_2$ ,  $\epsilon$  Angles for Light Truck/SUV/Minivan, Right Shoulder (LT-RS) Sign Scenarios (Scenarios 5–8)**

Dist. to Sign (ft)	Dist. to Sign (m)	LEFT HEADLIGHT							RIGHT HEADLIGHT						
		Obs. Angle $\alpha$	Ent. Angle $\beta_1$	Ent. Angle $\beta_2$	Rot. Angle $\epsilon$	R <sub>A</sub> Mult. (25 %) (lx)	R <sub>A</sub> Mult. (50 %) (lx)	R <sub>A</sub> Mult. (75 %) (lx)	Obs. Angle $\alpha$	Ent. Angle $\beta_1$	Ent. Angle $\beta_2$	Rot. Angle $\epsilon$	R <sub>A</sub> Mult. (25 %) (lx)	R <sub>A</sub> Mult. (50 %) (lx)	R <sub>A</sub> Mult. (75 %) (lx)
640	195.07	0.20	2.89	4.89	25.62	0.0182	0.0239	0.0262	0.35	-4.29	3.11	-59.42	0.0185	0.0232	0.0262
630	192.02	0.20	2.91	4.91	25.68	0.0184	0.0243	0.0266	0.35	-4.30	3.13	-59.40	0.0187	0.0235	0.0265
620	188.98	0.20	2.93	4.93	25.75	0.0187	0.0247	0.0272	0.36	-4.32	3.15	-59.37	0.0191	0.0240	0.0271
610	185.93	0.21	2.96	4.95	25.82	0.0190	0.0254	0.0278	0.36	-4.33	3.17	-59.34	0.0195	0.0246	0.0277
600	182.88	0.21	2.99	4.97	25.89	0.0195	0.0260	0.0285	0.37	-4.34	3.19	-59.30	0.0200	0.0252	0.0284
590	179.83	0.21	3.01	4.99	25.96	0.0198	0.0266	0.0293	0.37	-4.35	3.22	-59.27	0.0204	0.0257	0.0291
580	176.78	0.22	3.04	5.01	26.03	0.0203	0.0273	0.0299	0.38	-4.37	3.24	-59.24	0.0210	0.0264	0.0298
570	173.74	0.22	3.07	5.03	26.11	0.0208	0.0279	0.0308	0.39	-4.38	3.26	-59.20	0.0215	0.0270	0.0305
560	170.69	0.23	3.10	5.05	26.19	0.0212	0.0287	0.0315	0.39	-4.40	3.29	-59.17	0.0221	0.0277	0.0314
550	167.64	0.23	3.13	5.07	26.27	0.0217	0.0295	0.0323	0.40	-4.41	3.31	-59.13	0.0226	0.0284	0.0322
540	164.59	0.23	3.17	5.09	26.36	0.0221	0.0303	0.0332	0.41	-4.43	3.34	-59.09	0.0232	0.0291	0.0330
530	161.54	0.24	3.20	5.12	26.44	0.0226	0.0311	0.0341	0.41	-4.45	3.37	-59.05	0.0237	0.0298	0.0338
520	158.50	0.24	3.24	5.14	26.53	0.0230	0.0318	0.0350	0.42	-4.46	3.39	-59.00	0.0243	0.0306	0.0347
510	155.45	0.25	3.27	5.17	26.63	0.0236	0.0325	0.0359	0.43	-4.48	3.42	-58.96	0.0248	0.0314	0.0358
500	152.40	0.25	3.31	5.19	26.73	0.0240	0.0332	0.0368	0.44	-4.50	3.45	-58.91	0.0253	0.0322	0.0367
490	149.35	0.26	3.35	5.22	26.83	0.0245	0.0339	0.0378	0.45	-4.52	3.49	-58.87	0.0260	0.0331	0.0377
480	146.30	0.27	3.39	5.25	26.93	0.0250	0.0347	0.0388	0.46	-4.54	3.52	-58.82	0.0266	0.0340	0.0388
470	143.26	0.27	3.44	5.28	27.04	0.0256	0.0355	0.0399	0.46	-4.56	3.56	-58.76	0.0273	0.0349	0.0399
460	140.21	0.28	3.48	5.31	27.15	0.0261	0.0363	0.0410	0.47	-4.58	3.59	-58.71	0.0279	0.0359	0.0410
450	137.16	0.28	3.53	5.34	27.27	0.0266	0.0371	0.0421	0.48	-4.60	3.63	-58.65	0.0285	0.0370	0.0422
440	134.11	0.29	3.58	5.37	27.40	0.0272	0.0380	0.0433	0.49	-4.62	3.67	-58.59	0.0293	0.0381	0.0434
430	131.06	0.30	3.63	5.41	27.52	0.0277	0.0389	0.0445	0.51	-4.65	3.71	-58.53	0.0299	0.0392	0.0448
420	128.02	0.31	3.69	5.44	27.66	0.0283	0.0400	0.0458	0.52	-4.67	3.76	-58.46	0.0307	0.0403	0.0461
410	124.97	0.31	3.74	5.48	27.80	0.0287	0.0410	0.0470	0.53	-4.70	3.80	-58.39	0.0315	0.0416	0.0475
400	121.92	0.32	3.81	5.52	27.94	0.0291	0.0422	0.0483	0.54	-4.73	3.85	-58.32	0.0323	0.0426	0.0489
390	118.87	0.33	3.87	5.56	28.10	0.0295	0.0434	0.0496	0.55	-4.76	3.90	-58.24	0.0330	0.0437	0.0504
380	115.82	0.34	3.94	5.60	28.26	0.0300	0.0448	0.0510	0.57	-4.79	3.96	-58.16	0.0337	0.0447	0.0519
370	112.78	0.35	4.01	5.64	28.42	0.0305	0.0461	0.0525	0.58	-4.82	4.01	-58.08	0.0345	0.0458	0.0534
360	109.73	0.36	4.09	5.69	28.60	0.0309	0.0476	0.0540	0.60	-4.85	4.07	-57.99	0.0353	0.0470	0.0550
350	106.68	0.37	4.17	5.74	28.79	0.0315	0.0489	0.0556	0.61	-4.88	4.14	-57.89	0.0361	0.0482	0.0567
340	103.63	0.38	4.25	5.79	28.98	0.0324	0.0499	0.0570	0.63	-4.92	4.21	-57.79	0.0369	0.0494	0.0584
330	100.58	0.40	4.34	5.85	29.19	0.0332	0.0511	0.0585	0.65	-4.96	4.28	-57.68	0.0378	0.0506	0.0602
320	97.54	0.41	4.44	5.90	29.40	0.0340	0.0522	0.0600	0.67	-5.00	4.35	-57.57	0.0385	0.0522	0.0619
310	94.49	0.43	4.54	5.96	29.63	0.0353	0.0538	0.0619	0.69	-5.04	4.44	-57.44	0.0395	0.0543	0.0643
300	91.44	0.44	4.65	6.03	29.87	0.0371	0.0560	0.0644	0.71	-5.09	4.52	-57.31	0.0411	0.0574	0.0676
290	88.39	0.46	4.77	6.09	30.13	0.0393	0.0579	0.0667	0.73	-5.13	4.62	-57.17	0.0429	0.0608	0.0713
280	85.34	0.48	4.90	6.16	30.40	0.0417	0.0600	0.0691	0.75	-5.19	4.72	-57.02	0.0449	0.0644	0.0753
270	82.30	0.50	5.04	6.24	30.69	0.0443	0.0625	0.0716	0.78	-5.24	4.83	-56.85	0.0473	0.0680	0.0795
260	79.25	0.52	5.18	6.32	31.00	0.0473	0.0659	0.0750	0.81	-5.30	4.95	-56.67	0.0502	0.0716	0.0835
250	76.20	0.54	5.35	6.40	31.32	0.0505	0.0702	0.0790	0.83	-5.36	5.08	-56.48	0.0535	0.0754	0.0878
240	73.15	0.57	5.52	6.49	31.68	0.0539	0.0750	0.0830	0.87	-5.42	5.21	-56.27	0.0571	0.0796	0.0922