Headlight Safety Performance Rating (HSPR) - Recommended Practice –

Foreword

This GTB recommended practice has been prepared by the Working Group Safety and Visual Performance (WG-SVP), is based on the work of CIE Technical Committee 4-45 “Performance Assessment Method for Vehicle Headlamps” and is derived from CIE S 021/E:2011. It is a primary source of internationally accepted and agreed data which can be taken, essentially unaltered, into universal standard systems.

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1 Scope

This Recommended Practice provides a rating system for modern headlights including adaptive driving-beam functionality (ADB).

Assessing the performance of headlighting systems is an important topic for car manufacturers and headlight suppliers for increasing nighttime traffic safety.
Statistics show that the risk of accidents at night increases by a factor of 2 to 4 in comparison to daytime. Good light not only creates a feeling of safety, but headlights are the main contributors to orientation and object detection in nighttime traffic.

The manufactures specify the headlighting system performance/requirements for their suppliers, for consumer organizations and car magazines, which try to evaluate the quality of automotive lighting in order to give the ordinary consumer assistance to select the appropriate lighting system when buying a car.

So far, a wide variety of assessment methods exist, which give different results, which are not seldom contradictory, arbitrary, hard to understand by the non-expert or do not include all modern lighting functions.

Therefore, the technical committee TC4-45 of the International Commission on Illumination (CIE) was found with the task, to find a standard assessment method. As a result of the work of the light expert group a CIE-Report and a CIE-Standard were published in 2011. In this assessment method the road illuminance in terms of lane guidance and recognition of obstacles as well as glare of oncoming traffic can be evaluated objectively.

However, new lighting technologies raise the demand of a further development of this assessment method:

- High complexity of individual data makes a simple and clear evaluation difficult. A single number to rate the individual lighting functions and the headlighting system is needed

- No adaptive driving-beam is considered because such systems spread to the market later.

Since 2011 the need of a single number, which rates the performance of a headlighting function and even the whole headlighting system, becomes evident when looking at the new technology developments.

The broad availability and the performance increase of the LED light source led to the start of a series of innovations mainly the full LED headlight and the adaptive driving-beam function.

For conventional lighting systems the car buyer and the car salesman know that headlighting systems with gas discharge bulbs (HID, high intensity discharge) have a significantly better performance than systems with H7 bulbs, which in turn outperform in most cases H4 systems. But, for an adaptive driving-beam system and even the simpler full LED systems, such a classification is not possible anymore. Different adaptive driving-beam technologies (dynamic bending swivelling, matrix or high-resolution system) and the type and number of LED lead to various results in road illumination.

A performance rating score would give the car buyer a valuable tool to select the appropriate lighting performance when buying a car.

For a full and fair rating modern headlights must be evaluated concerning a rating for the single lighting functions of the passing-beam, driving-beam and adaptive driving-beam and an overall score for the total headlighting system. Therefore, a group of lighting experts worked on an improved headlight rating system based on the TC4-45 CIE-Standard called Headlight Safety Performance Rating (HSPR) to address todays and oncoming challenges in road illumination by headlighting systems.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including amendments) applies.

CIE S 021/E:02011, Vehicle Headlighting Systems Photometric Performance – Method of Assessment, 2011.

CIE DS 017.2/E:2009, International Lighting Vocabulary, 2009.

Federal Motor Vehicle Safety Standard (FMVSS) No. 108, Lamps, reflective devices, and associated equipment, US Department of Transportation, National Highway Traffic Safety Administration, 2020.

GTB Working Group Photometry, Photometry Laboratory Accuracy Guidelines, Edition 3, 2005.

SAE J1383, Performance Requirements for Motor Vehicle Headlamps, 2010.

UN Regulation No. 37, Uniform Provisions Concerning the Approval of Filament Lamps for Use in Approved Lamp Units on Power-Driven Vehicles and of their Trailers, available at https://unece.org/trans/main/wp29/wp29regs.

UN Regulation No. 99, Uniform Provisions Concerning the Approval of Gas-Discharge Light Sources for Use in Approved Gas-Discharge Lamp Units of Power-Driven Vehicles, available at https://unece.org/trans/main/wp29/wp29regs.

UN Regulation No. 123, Uniform Provisions Concerning the Approval of Adaptive Front-Lighting Systems (AFS) for Motor Vehicles, available at https://unece.org/trans/main/wp29/wp29regs.

UN Regulation No. 149, Uniform Provisions Concerning the Approval of Road Illumination Devices (Lamps) and Systems for Power-Driven Vehicles, available at https://unece.org/trans/main/wp29/wp29regs.

Blanckenhagen et al. at, Headlight Performance Analysis Experience according to the CIE TC4-45 method, ISAL, 2011.

3 Terms and definitions

For the purposes of this document the terms and definitions given in the International Lighting Vocabulary (CIE DS 017.2/E:2009) and the following apply:

Headlighting system	a full set of headlights as installed to a vehicle
Lighting function	passing-beam, driving-beam or adaptive driving-beam (definition see UN Regulation No. 48)
Nearside	for traffic following the right-hand rule of the road, the right side of the vehicle
Offside	for traffic following the right-hand rule of the road, the left side of the vehicle
ADB	short for adaptive driving-beam (glare free driving beam)
EP	short for Effective Performance
MEP	short for Mean Effective Performance
Criterion	a single feature to evaluate the lighting functions performance (e.g. Zone A)

NOTE (1) With regard to the performance of the passing-beam and adaptive driving-beam it is necessary to define whether the traffic flow is for right-hand or left-hand rule of the road. For the purposes of this recommended practice, it is assumed that the traffic is following the right-hand rule of the road (as in mainland Europe and USA for example) and all reference to features of the beam pattern and photometric performance is related to this. In the case of traffic following the left-hand rule of the road (as in Japan and the UK for example) a reference to a feature on the right in this document should be transformed to refer to an identical feature translated to the left side.

NOTE (2) This recommended practice only refers to headlighting systems according to the UN regulations.

4 Performance of a headlighting system

4.1 General

The assessment method given in this recommended practice is a mean of evaluating passing-beam, driving-beam, adaptive driving-beam and the headlighting system performance, to enable the performance of different systems to be compared. It uses techniques that produce repeatable results and has been developed to give correspondence also with the subjective impressions of the driver.

When assessing the compliance of a headlighting system to safety regulations or standards with this method, it is solely the photometry of the passing-beam, driving-beam and adaptive driving that is evaluated using calibrated equipment in the photometric laboratory.

NOTE In service, the photometric performance of the headlight is influenced by several factors that will cause the actual performance to differ from that defined in regulations or standards. These include mounting height, supply voltage/operating current and beam alignment.

Vehicle headlights illuminate the road scene ahead of the vehicle in order to provide guidance for the driver to retain control of the vehicle through adequate illumination of road markings, the edges of the road and features such as verges, trees and road signs, and to provide early warning of the presence of obstacles including pedestrians and other road users. It is also necessary that headlighting system performance is such that glare to vehicles travelling in the opposite direction is controlled.

NOTE Reflected glare in rear view mirrors caused by the headlights of following vehicles is not considered, as technologies exist to reduce the reflectivity of the mirrors.

4.2 Assessment requirements

The vertical illuminance[1] provided by the headlighting system shall be determined at the road surface, at a horizontal plane located 250 mm and 1500 mm above the road surface, using the assessment procedure and measurement procedure described in section 6. To ensure repeatability of results and to avoid interpolation errors when transforming data between matrices, the measurements and calculations shall exactly follow the procedures set out in section 6 and the software suggestion for evaluating the light distributions from the TU-Darmstadt (see section 9.3) shall be used.

NOTE The height of 250 mm corresponds to the mid-point of the leg and the height of 1500 mm to the shoulder height of an average adult pedestrian.

[1] In the following, if not indicated elsewise, vertical illuminances are meant when speaking of illuminance.

5 Beam assessment parameters

The assessment of the passing-beam takes account of the following parameters:

- range for guidance;
- range for pedestrian detection;
- width for lane guidance;
- visibility on curves;
- width for pedestrian detection at intersections;
- opposing glare.

The assessment of the driving-beam takes account of the following parameters:

- range for pedestrian detection, lane guidance and visibility;
- width for pedestrian detection at intersections.

The assessment of the adaptive driving-beam takes account of the following parameters:

- range for guidance for oncoming and preceding traffic in 50m, 100m and 200m;
- range for pedestrian detection for oncoming and preceding traffic in 50m, 100m and 200m;
- visibility on curves for oncoming and preceding traffic in 50m, 100m and 200m;
- glare for oncoming and preceding traffic in the adaptive driving scenarios.

The assessment for all three beam functions includes the calculation of the total projected luminous flux, as an indication of the optical efficiency of the system.

6 Assessment procedure

6.1 Basis of the procedure

The procedure is based upon laboratory measurements of headlights under defined conditions regarding the light source operation (calibrated light source, vehicle operating voltage as defined in section 9.2 d) as well as regarding the headlight initial aim according to 9.2 c) by using a defined format for the data including the angular increments of the measurement points. Using these data, aspects of the headlight performance are evaluated as detailed in 6.2 to 6.3. In all cases, the illuminance and luminous intensity values being assessed are derived from a combination of the individual photometric data measured for each component of the headlighting system. These values are combined taking account of the mounting height, separation and aim specified for the vehicle to which the system is installed.

6.2 Passing-beam and driving-beam illumination

In section 6 of the CIE-Standard (CIE S 021/E:2011) the assessment method for the passing-beam and the driving-beam is described. No changes for the passing-beam and driving-beam assessment are made in the Headlight Safety Performance Rating.

Note: *For calculation of the driving beam performance, the real driving scenario with respect to passing-beam function is used, e.g. if the passing beam is always switched ON during driving beam activation, the driving beam may be evaluated with the passing-beam switched ON.*

6.3 Adaptive driving-beam illumination

6.3.1 Summary of the adaptive driving beam assessment procedure

Illuminance of the road scene by the adaptive driving-beam shall be assessed by evaluating the performance of the headlighting system as summarized in Table 1.

Table 1 – Aspects of adaptive driving-beam road scene illumination to be assessed

Zone	*Purpose*	*Assessment Method*
A’	Range for lane guidance	See explanations 6.3.4 and Figure 4
B’	Range for lane guidance and visibility on curves	See explanations 6.3.5 and Figure 5
C’	Range along the offside verge for pedestrian detection	See explanations 6.3.6 and Figure 6
Whole beam	Luminous flux	See explanations 6.3.7 Total luminous flux (lumen) within a vertical zone 10° up to 5° down, 45° left to 45° right

6.3.2 Oncoming and preceding traffic scenarios

Create the light distributions (size and position of the ADB tunnel area) of preceding and oncoming traffic for 50m, 100m and 200m. The traffic situations are based on UN Regulation No. 123 Table 7 (respectively UN Regulation No. 149-00 Table 15 respectively UN Regulation No. 149-01 Table 13), for the HSPR an additional safety tolerance of 0.5° for the ADB tunnel is considered (see Table 2).

NOTE The reference of all values is the vehicle axis and the headlights are placed on their mounting positions, i.e., the test lines cannot be applied directly and need to be corrected by the angle due to the parallax of both headlights.

a) The ADB light distribution for each driving situation must be generated in a way that the max. intensity limits shall not be exceeded in the enlarged ADB tunnel (e.g. switching on/off ADB segments).
b) For calculation of the ADB ranges the real driving scenario with respect to passing-beam function is used, e.g., passing-beam is always switched ON and the headlights are in the real mounting position.

Table 2 – Test lines for the adaptive driving-beam driving scenarios
Note, that the angular values need to be corrected by the parallax

HSPR-Shadows	*Left Edge*	*Right Edge*	*Vertical Angle*	*Max. Intensity*
50m preceding a)*	-2.20°	1.00°	0.30°	2475cd
50m preceding b)*	1.00°	2.20°	0.30°	4250cd
50m oncoming	-5.30°	-1.50°	0.57°	975cd
100m preceding a)*	-1.40°	0.50°	0.15°	5300cd
100m preceding b)*	0.50°	1.40°	0.15°	8750cd
100m oncoming	-2.90°	-0.50°	0.30°	1750cd
200m preceding	-0.95°	0.95°	0.10°	16000cd
200m oncoming	-1.70°	0.00°	0.15°	5450cd

**In case preceding traffic of 50 m and 100 m the test lines a) and b) both need to be fulfilled*

NOTE *Due to the parallax correction and the additional safety margin of +-0.5°, and to the half-sum requirement in homologation which is not available for HSPR, some today homologated light distributions require a larger maximum limit on the "50m preceding", "100m preceding" and "50m oncoming" test lines.*

Figure 1 – Driving scenarios for oncoming traffic

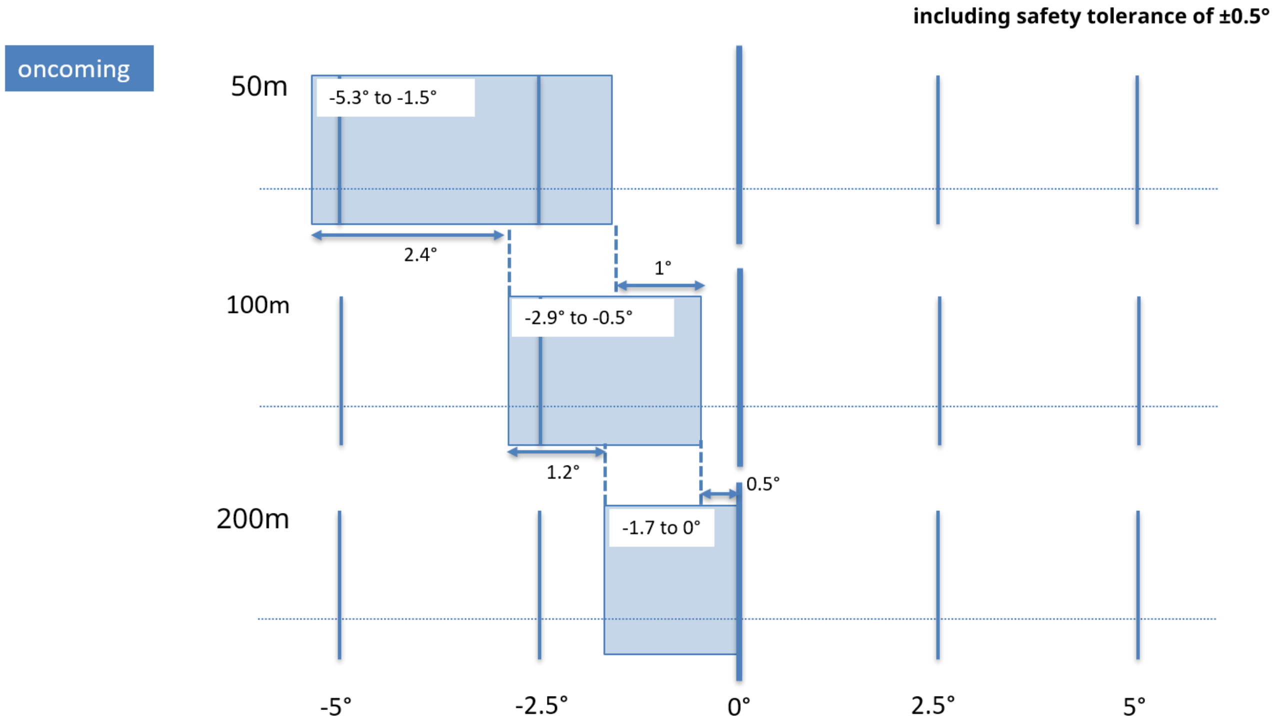
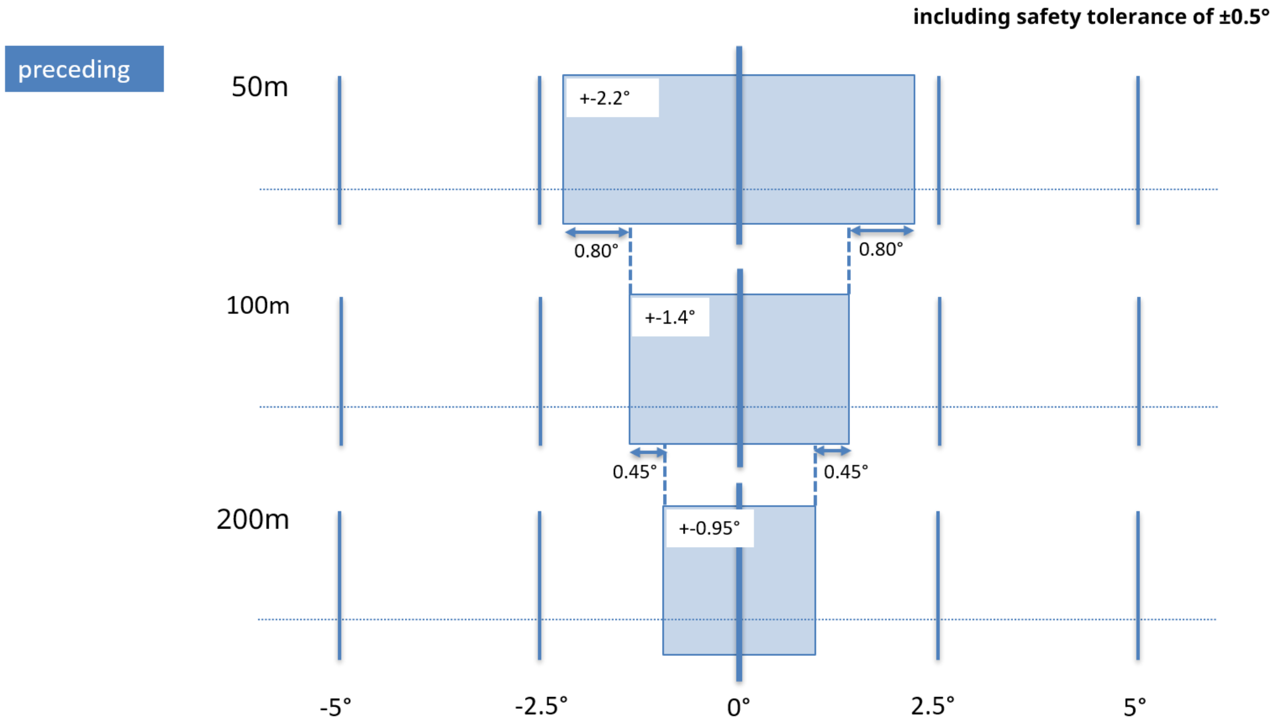


Figure 2 – Driving scenarios for preceding traffic



6.3.3 Parallax correction of the adaptive driving scenarios

The HSPR is evaluated with headlights in mounting position, therefore the parallax of the headlight must be considered. That means, the test lines (Table 2) cannot be applied directly and need to be corrected by the angle due to the parallax of both headlights. This results in new test lines for the left and right headlight depending on the mounting position. The maximum intensity limit needs to be fulfilled both by the left and the right headlight separately.

The parallax angle α_i can be calculated by the following equation:

$$\alpha_i = ArcSin\left(\frac{w}{di}\right) \quad (1)$$

<u>*Key*</u>

α_i *parallax angle for (i = 50m, 100m, 200m)*

w *lateral positions of the adaptive driving-beam headlights from the vertical plane through the longitudinal axis of the vehicle*

d_i *Distance to the oncoming or preceding vehicle (50m, 100m, 200m)*

Note, that the parallax angle changes for different distances of the oncoming or preceding traffic.

For the left headlight the parallax angle needs to be added to the angular value of the edges of the test lines in Table 2.

For the right headlight the parallax angle needs to be subtracted.

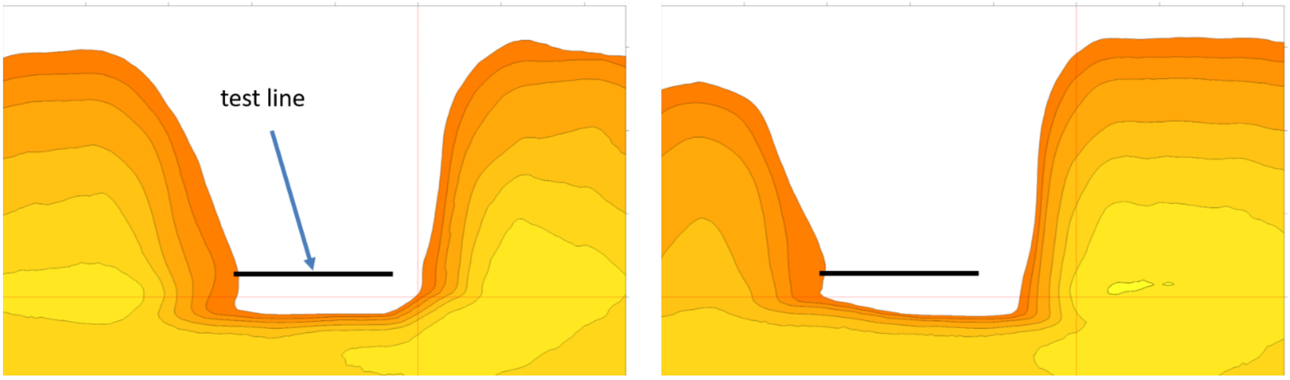
NOTE The parallax angle will only be added or subtracted to the edges of the test line. If a test line is segmented in two parts, the position of the transition point between segment a) and b) (see *table 2) will not be changed: For 50 m preceding the transition point will stay fixed at 1° horizontal (0.3° vertical) and for 100 m preceding at 0.5° horizontal (0.15° vertical).*

Example *Oncoming vehicle in 50 m distance. The distance w from the lateral position of the adaptive driving-beam headlights to the longitudinal axis of the vehicle is 0.675 m. With equation (1) the parallax angle can be determined to* $\alpha_{50m} = 0.77°$

Table 3 – Example 50m oncoming traffic, w = 0.675 m

HSPR-Shadows	*Left Edge*	*Right Edge*	*Vertical Angle*	*Max. Intensity*
50 m oncoming (Table 2)	-5.30°	-1.50°	0.57°	975 cd
Left headlight corrected	-4.53°	-0.73°	0.57°	975 cd
Right headlight corrected	-6.07°	-2.27°	0.57°	975 cd

Figure 3 – Example 50 m oncoming traffic, w = 0.675 m - left: left headlight – right: right headlight



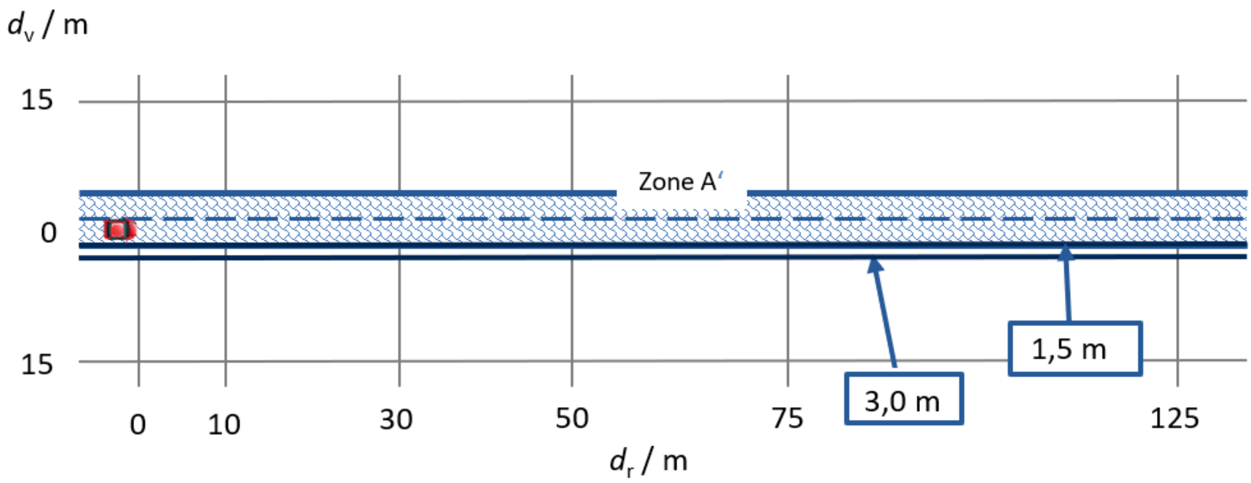
6.3.4 Range assessment procedure – Zones A'

Referring to Table 1 and Figure 4, the position of the intersection of the 1,0 lx, 3,0 lx and 5,0 lx isolux lines shall be calculated with each of the two longitudinal lines in Zone A'. The range (in meters) is the average of the values determined for the 1,0 lx, 3,0 lx and 5,0 lx intersection points with the two lines. The isolux lines shall be plotted 1500 mm above the road surface as vertical illuminance values.

NOTE (1) *In contrast to the Zone A of the CIE-Standard only two lines for the range assessment are used. The line closest to the vehicle is not evaluated because in this area an adaptive driving-beam system will create a light tunnel for a preceding car.*

NOTE (2) *The projection plane is positioned at 1500 mm above the road surface to assess the adaptive driving-beam mostly independent from the passing-beam.*

Figure 4 - Zone A' range assessment for straight road



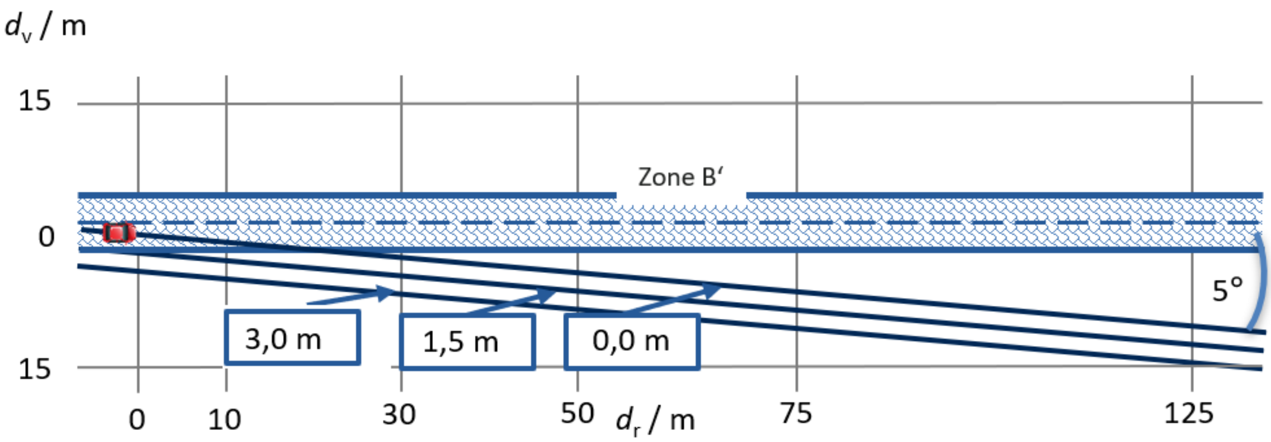
6.3.5 Range assessment procedure – Zones B'

A similar procedure shall be followed to calculate the range on the curved road shown in Figure 5.

Referring to Table 1 and Figure 5, the position of the intersection of the 1,0 lx, 3,0 lx and 5,0 lx isolux lines shall be determined along the three lines inclined at 5° in Zone B' (with respect to the Zone A' and C'). The range (in meters) is the average of the values determined for the 1,0 lx, 3,0 lx and 5,0 lx intersection points with the three lines. The isolux lines shall be plotted 1500 mm above the road surface as vertical illuminance values.

NOTE All three lines of Zone B of the CIE-Standard are used, because no oncoming or preceding traffic is expected in this evaluation area. However, like Zone A', the projection plane is changed to 1500 mm above the road surface to assess the adaptive driving-beam mostly independent from the passing-beam.

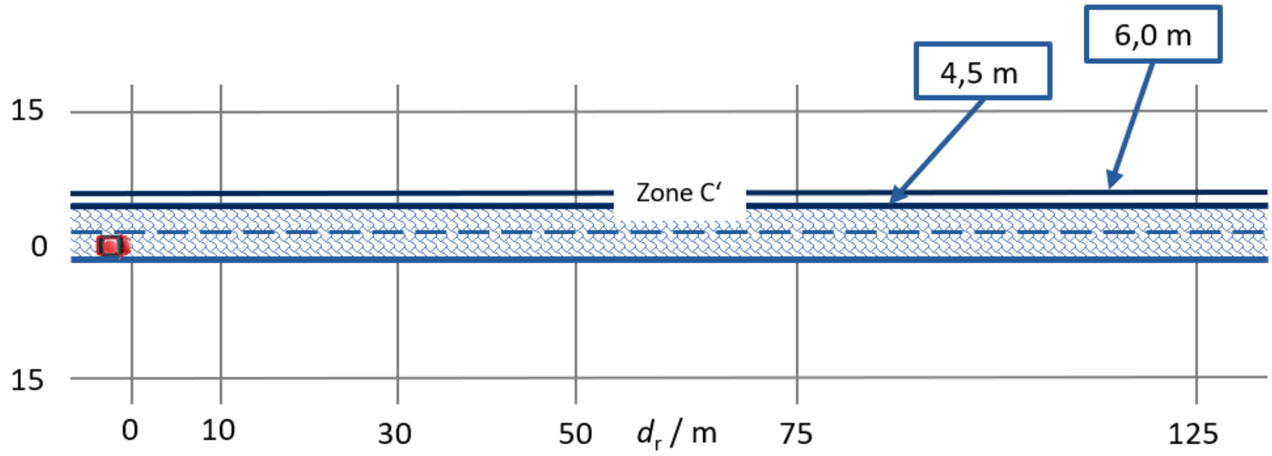
Figure 5 – Zone B' range assessment for lane guidance and visibility on curves



6.3.6 Range assessment procedure – Zones C'

Referring to Table 1 and Figure 6 the position of the intersection of the 1,0 lx, 3,0 lx and 5,0 lx isolux lines shall be calculated with each of the two longitudinal lines in Zone C' following a similar procedure to that shown in Figure 4. The range, in meters, is the average of the values determined for the 1,0 lx, 3,0 lx and 5,0 lx intersection points with the two lines. The isolux lines shall be plotted on a plane situated at 1500 mm above the road surface as vertical illuminance values.

Figure 6 – Zone C' range assessment for offside pedestrian visibility



NOTE 1 *In contrast to the Zone C of the CIE-Standard two lines for the range assessment are used. The line closest to the vehicle is not evaluated because in this area an adaptive driving-beam system will create a light tunnel for an oncoming car.*

NOTE 2 *The projection plane is at 1500 mm above the road surface to assess the adaptive driving-beam mostly independent from the passing-beam.*

6.3.7 Total luminous flux

Calculate the total luminous flux within a vertical zone 10° up to 5° down, 45° left and 45° right (the measurement procedure is described in chapter 9).

6.3.8 Adaptive driving-beam glare

Adaptive driving-beam glare shall be assessed by evaluating the performance of the headlighting system for oncoming and preceding vehicles in 50m. This performance indicates the glare in the adaptive driving-beam light tunnel, as summarized in Table 4.

The horizontal component of the Glare-Window is based on the test line “Line 1” and “Line 4” of the UN Regulation No. 123 Table 7 (respectively UN Regulation No. 149-00 Table 15 respectively UN Regulation No. 149-01 Table 13) projected an a 50m wall (see Table 7 and Table 8).

The vertical component of the Glare-Window is, comparable to the CIE-Standard.

Figure 7 and Figure 8 show the location of the glare zone relative to the vehicle axis (horizontal component) and a plane 0.75 m to the road surface (vertical component).

The weighted luminous flux value can be used as an indication of the potential glaring effect of the adaptive driving-beam system.

NOTE 1 *For the vertical component of the probability of the driver's eye position has been considered (compare CIE-Standard). The horizontal component is independent of the eyes position because the adaptive driving-beam window is much smaller, and the light shadow is following the vehicle position.*

NOTE 2 *The preceding drivers glare is separated horizontally in two areas according to the "Line 4" of UN Regulation No. 123 Table 7 (respectively UN Regulation No. 149-00 Table 15 respectively UN Regulation No. 149-01 Table 13)*

NOTE 3 *The glare assessment for the adaptive driving-beam is rated for 50m opposing traffic like CIE-Standard (passing-beam).*

Table 4 – Aspects to be assessed – opposing glare

Item to Assess (see Figure 7 and Figure 8)	*Assessment Method*
Opposing Glare of an oncoming vehicle in 50 m	Calculate the luminous flux (lm) in each zone of the grid shown in Figure 7 and multiply by the weighting factor shown in the chart. Sum all the values to obtain a single value for the weighted luminous flux in the complete zone.
Opposing Glare of a preceding vehicle in 50 m	Calculate the luminous flux (lm) in each zone of the grid shown in Figure 8 and multiply by the weighting factor shown in the chart. Sum all the values to obtain a single value for the weighted luminous flux in the complete zone.

Figure 7 – 50 m oncoming vehicle – Details of the weighting factor inside glare zone

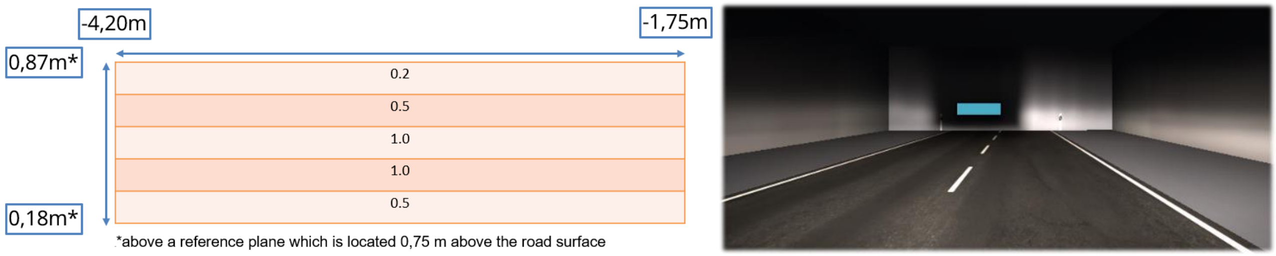
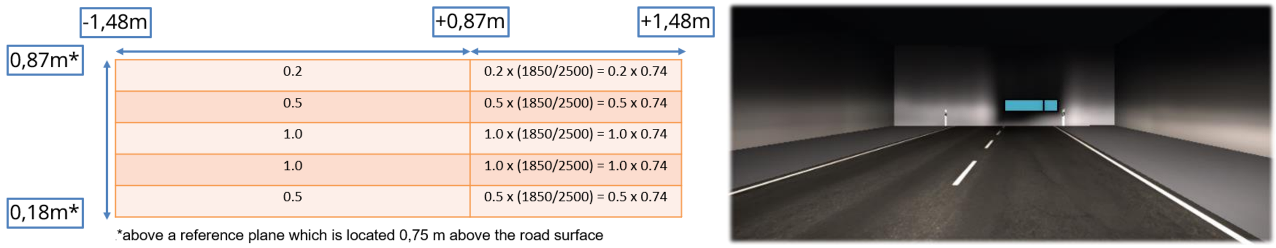


Figure 8 – 50 m preceding vehicle – Details of the weighting factor inside glare zone



7 Resulting score of passing-beam, driving-beam, and adaptive driving-beam assessment

7.1 Basis of the procedure

In the following step the assessment of the road illumination is combined to a single passing-beam, a single driving-beam, and a single adaptive driving-beam score. Therefore, the system to be tested is compared to a representative set of headlighting systems.

For passing-beam and driving-beam the 16 headlighting systems from the CIE-Standard are used, carefully chosen by light experts as a representative group for these lighting functions.

For the adaptive driving-beam rating, an ADB-database with 20 systems is chosen, that represents the technologies currently available on the market.

After comparison to a database each single criterion (e.g. Zone A) is applied a point value (section 7.2.1), whereas the sum of these points multiplied by a weighting factor indicates the lighting functions performance (section 7.2.2). The final rating score for a single lighting function is achieved by normalizing the weighted sum between 1 and 5 for easier access for the end-user (section 7.2.3).

7.2 Rating principle

7.2.1 Applying points to assessment criteria

Each single criterion of a lighting function is now compared to a headlighting system database to apply a point value.

The performance of a criterion can be considered above average if its value is better than the average of the representative test systems and below average if it is worse. To be more precise, the average and the standard deviation of the database are calculated for each criterion (Table 5 for passing-beam, Table 7 for driving-beam and Table 8 to Table 11 for adaptive driving-beam).

To define the linear mapping a headlight criterion is defined as "one criterion-point" if it reaches a value of the average minus the standard deviation and "two criterion-points" for the average plus the standard deviation.

Values in between or outside this area are interpolated or extrapolated according to:

$$P = \frac{1}{V_2 - V_1}(V - V_1) + 1 \quad (2)$$

where:
- is the actual value of the headlight to be assessed;
- is the two-points value of Table 5 to Table 11;
- is the one-point value of Table 5 to Table 11;
- is the resulting criterion points.

For the glare criterion (flux in the glare zone) a larger number implies higher glare and hence a reduction in headlight performance. Therefore, the one-point and two point values V_1 and V_2 of the glare are interchanged: V_2 is calculated as the average minus the standard deviation, V_1 as the average plus the standard deviation (see Table 6 for passing-beam Glare and Table 9 for ADB Glare), resulting in a linear interpolation with a negative slope.ù

7.2.2 Weighted sum of criterion points

In order to get a single rating number for each lighting function, the criterion points must be summed up for the passing-beam (9 criteria), the driving-beam (8 Criteria) and the adaptive driving-beam (10 criteria for each traffic distance in 50 m, 100 m and 200 m). The relative importance of a criterion is given by a weighting factor w_i, which is applied to the criterion-points P_i when calculating the total sum Σ:

$$\Sigma = \sum_i w_i \cdot P_i \quad (3)$$

The weighting factors for the passing-beam are given in Table 12, the ones for the driving-beam in Table 13, and the ones for the adaptive driving-beam in Table 14. They provide a balanced and performance oriented total rating number for each lighting function.

For a single rating number for the adaptive driving-beam lighting function, the weighted sums in 50m (Σ_{50m}), 100m (Σ_{100m}) and 200m (Σ_{200m}) distance are averaged by the following equation:

$$\Sigma = \frac{(\Sigma_{50m}+\Sigma_{100m}+\Sigma_{200m})}{3} \quad (4)$$

7.2.3 Normalizing weighted points

After evaluating the weighted sum of the criterion points as defined in the section 7.2.2, the resulting total sum would not be comparable between the lighting functions and would vary with the number of criteria. To have a descriptive rating number, a scaling of the sum must be done. For many rating systems (NCAP crash tests, customer ratings, hotel ratings...) a scale from one point for bad performance to five points for outstanding performance is used, which is also adopted here: a very well performing headlighting function, by modern light performance standards, should get a rating number of five, whereas a standard performing system should only get one point (so called benchmark systems).

To determine the linear mapping from one to five points two benchmark systems (see Table 15) are defined for each lighting function.

The scaling is performed according to the following equation:

$$N = \frac{(5-1)}{\Sigma_{5p} - \Sigma_{1p}} \cdot (\Sigma - \Sigma_{1P}) + 1 \quad (5)$$

Here N is the final rating number for the lighting function, Σ is the weighted sum of this system according to the equation (3,4), Σ_{5p} the weighted sum of the five-point-system and Σ_{1p} the weighted sum of the one-point-system.

7.3 Values for single lighting function rating

In the following chapter the values for the average and standard deviation for all criteria, the weighting factors and the two benchmark systems for all lighting functions are provided. Using the equations (2) – (4) the passing-beam-, driving-beam and adaptive driving-beam score can be evaluated.

7.3.1 Values for applying points

Table 5 – Passing-beam: Average and Standard Deviation for the 16 systems of the CIE-Standard

	Zone A [m]	*Zone B [m]*	*Zone C [m]*	*Zone D offside [m]*	*Zone D nearside [m]*	*Zone E offside [m]*	*Zone E nearside [m]*	*Flux [lm]*
Average	83.4	105.0	40.6	8.6	12.0	7.8	8.5	1266.4
Standard Deviation	11.8	33.5	7.9	3.9	4.3	1.8	2.0	518.7
1 point = Average - Standard Deviation	71.6	71.5	32.7	4.8	7.6	5.9	6.6	747.6
2 points = Average + Standard Deviation	95.1	138.4	48.4	12.5	16.3	9.6	10.5	1785.1

Table 6 - Passing-beam Glare: Average and Standard Deviation for the glare criterion

	passing-beam Glare [lm]
Average	0.50
Standard Deviation	0.23
2 points = Average - Standard deviation	0.27
1 point = Average + Standard deviation	0.73

NOTE In contrast to the other passing-beam criteria, the glare is derived from 39 modern headlighting systems plus all halogen headlighting systems of the CIE-Standard.

Table 7 – Driving-beam: average and Standard Deviation for the 16 systems of the CIE-Standard

	Point A [m]	*Point B [m]*	*Point C [m]*	*Point D [m]*	*Point E [m]*	*Zone E offside [m]*	*Zone E nearside [m]*	*Flux [lm]*
Average	184.2	45.1	47.4	61.7	170.9	8.0	8.4	2120.1
Standard Deviation	50.9	15.9	15.9	19.8	36.7	2.5	2.5	1006.0
1 point = Average - Standard Deviation	133.3	29.1	31.5	41.9	134.2	5.5	5.9	1114.1
2 points = Average + Standard Deviation	235.0	61.0	63.3	81.4	207.7	10.5	10.9	3126.1

Table 8 – Adaptive driving-beam at 50 m vehicle distance: Average and Standard Deviation for the ADB-Database

	Zone A' 50 m oncoming [m]	*Zone B' 50 m oncoming [m]*	*Zone C' 50 m oncoming [m]*	*Flux 50 m oncoming [m]*	*Zone A' 50 m preceding [m]*	*Zone B' 50 m preceding [m]*	*Zone C' 50 m preceding [m]*	*Flux 50 m preceding [lm]*
Average	170,6	151,0	56,8	2359,6	48,4	152,7	96,0	2296,2
Standard Deviation	57,6	31,1	29,5	470,3	8,6	28,6	21,5	452,4
1 point = Average - Standard Deviation	113,0	119,9	27,3	1889,3	39,8	124,1	74,6	1843,7
2 points = Average + Standard Deviation	228,2	182,0	86,3	2829,9	57,0	181,4	117,5	2748,6

Table 9 – Adaptive driving-beam Glare: average and Standard Deviation for the glare criterion for 50 m traffic

	ADB Glare 50 m oncoming [lm]	*ADB Glare 50 m preceding [lm]*
Average	0,20	0,25
Standard Deviation	0,08	0,09
2 points = Average - Standard deviation	0,28	0,35
1 point = Average + Standard deviation	0,11	0,16

Table 10 - Adaptive driving-beam at 100 m vehicle distance: Average and Standard Deviation for the ADB-Database

	Zone A' 100 m oncoming [m]	*Zone B' 100 m oncoming [m]*	*Zone C' 100 m oncoming [m]*	*Flux 100 m oncoming [lm]*	*Zone A' 100 m preceding [m]*	*Zone B' 100 m preceding [m]*	*Zone C' 100 m preceding [m]*	*Flux 100 m preceding [lm]*
Average	151,3	155,0	76,0	2456,2	67,8	159,4	122,4	2421,3
Standard Deviation	58,5	27,9	10,9	506,5	14,9	24,6	27,6	477,4
1 point = Average - Standard Deviation	92,8	127,1	65,0	1949,7	52,9	134,8	94,7	1943,9
2 points = Average + Standard Deviation	209,9	182,9	86,9	2962,7	82,7	184,0	150,0	2898,7

Table 11 - Adaptive driving-beam at 200 m vehicle distance: average and Standard Deviation for the ADB-Database

	Zone A' 200 m oncoming [m]	*Zone B' 200 m oncoming [m]*	*Zone C' 200 m oncoming [m]*	*Flux 200 m oncoming [lm]*	*Zone A' 200 m preceding [m]*	*Zone B' 200 m preceding [m]*	*Zone C' 200 m preceding [m]*	*Flux 200 m preceding [lm]*
Average	128,7	156,9	110,3	2516,1	89,7	158,1	144,2	2502,5
Standard Deviation	47,4	26,3	20,8	522,4	23,5	25,2	33,2	477,3
1 point = Average - Standard Deviation	81,3	130,6	89,4	1993,6	66,2	132,9	110,9	2025,2
2 points = Average + Standard Deviation	176,0	183,2	131,1	3038,5	113,2	183,3	177,4	2979,9

7.3.2 Values for weighted points

Table 12- Weighting factors for passing-beam

	Zone A	*Zone B*	*Zone C*	*Zone D offside*	*Zone D nearside*	*Zone E offside*	*Zone E nearside*	*Flux*	*Glare*
Weighting factor	1,5	1	1	0,75	0,75	0,5	0,5	1	1

Table 13 - Weighting factors for driving-beam

	Point A	*Point B*	*Point C*	*Point D*	*Point E*	*Zone E offside*	*Zone E nearside*	*Flux*
Weighting factor	2	0,8	0,4	0,8	1,0	1	1	1

Table 14 – Weighting factors for adaptive driving-beam criteria applied to the 50 m, 100 m and 200 m traffic situation

	Zone A' oncoming	*Zone B' oncoming*	*Zone C' oncoming*	*Flux oncoming*	*Glare oncoming*	*Zone A' preceding*	*Zone B' preceding*	*Zone C' preceding*	*Flux preceding*	*Glare preceding*
Weighting factor	1,5	1	1	0,5	0,5	1,5	1	1	0,5	0,5

7.3.3 Normalising weighted passing-beam points

Table 15 - Benchmark weighted sums

Lighting function	*Weighted sum of the 1-point benchmark*	*Weighted sum of the 5-point benchmark*
passing-beam	11.15	17.61
driving-beam	11.31	19.23
Adaptive driving-beam	9.35	20.81

8 Resulting score for the headlighting system

8.1 Calculating the Effective Performance

The passing-beam-, driving-beam- and adaptive driving-beam scores must be merged to a final headlighting system rating. The passing-beam range is smaller than adaptive driving-beam range and the driving-beam provides with the highest range the best safety level. For a fair safety rating the average switch-on time of each lighting function and the specific range must be considered.

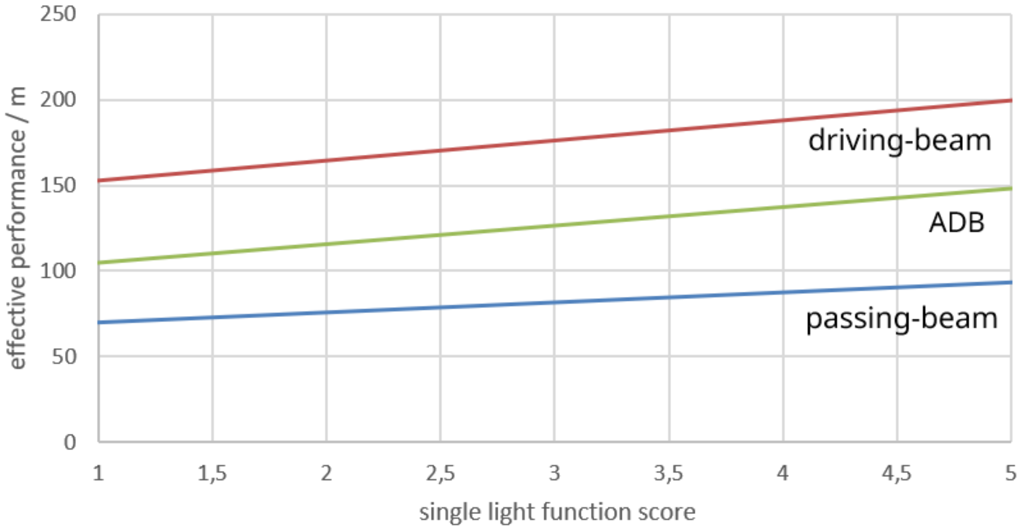
It´s not possible to take the mean value of the three ratings due to the fact that the total rating of a headlight with a high passing-beam and driving-beam rating would drop down by an additional (but rather low performance) adaptive driving-beam feature. However, the ADB feature would lead to additional safety and better visibility of pedestrians in comparison to a simple passing-beam, driving-beam system.

This leads to the Effective Performance based on the evaluation of the isolux lines for each lighting function taking physiological effects for object recognition into account (e.g. adaptation luminance, angular object size in different distances).

To come to a correlation between the achieved score for each lighting function and the corresponding Effective Performance all 16 headlights of the CIE-Standard and 20 ADB headlights have been evaluated. The result is shown Figure 9 and by equation (6) – (8):

$$EP_{Passing-Beam} = 5.80m \cdot score\ passing - beam + 64.17m \quad (6)$$
$$EP_{Driving-Beam} = 11.71m \cdot score\ driving - beam + 141.27m \quad (7)$$
$$EP_{ADB} = 10.87m \cdot score\ ADB + 94.13m \quad (8)$$

Figure 9 - Effective Performance as a function of the single lighting function scores of passing-beam, driving-beam, and adaptive driving-beam



8.2 Lighting function average switch-on-times

The Effective Performance is now weighted by it´s typical average switch-on times depending on three different driving-beam operation modes:

(i) manually operated driving-beam
(ii) automatically operated driving-beam
(iii) Adaptive driving-beam

Manually operated driving-beam describes the mode where the driving-beam is solely operated by the vehicle driver by hand, whereas the *automatically operated driving-beam* describes a driving-beam operated by e.g. camera system or sensor either being completely switched ON or off.

The *adaptive driving-beam* mode describes a system which reacts to the oncoming or preceding traffic either by a matrix beam (switching off single segments, not the whole driving-beam), or a swivelling-system.

This results in the Mean Effective Performance – a single value characterizing the performance of the whole headlighting system.

The typical average switch-on-times are derived from the literature in the footnote 1-6 and shown in Table 16:

Table 16 – Typical average switch-on-times of the lighting functions depending on the operation mode of the driving-beam

Driving mode	*passing-beam*	*driving-beam*	*Adaptive driving-beam*
Manually operated driving-beam	95%	5%	-
Automatically operated driving-beam	80%	20%	-
Adaptive driving-beam	30%	20%	50%

The Mean Effective Performance of the three driving-beam operation modes is therefore calculated by:

$$MEP_{manually} = 0.95 \cdot EP_{Passing\ Beam} + 0.05 \cdot EP_{Driving\ Beam} \quad (9)$$
$$MEP_{automatic} = 0.80 \cdot EP_{Passing\ Beam} + 0.20 \cdot EP_{Driving\ Beam} \quad (10)$$
$$MEP_{ADB} = 0.30 \cdot EP_{Passing\ Beam} + 0.20 \cdot EP_{Driving\ Beam} + 0.50 \cdot EP_{ADB} \quad (11)$$

8.3 Final score

By comparing the Mean Effective Performance, with two benchmark systems (see section 7.2.3) it´s possible to directly compare the overall performance of headlighting systems.

To differentiate between the single function score and the total headlighting system score a total score of 50 is applied to a typical premium+ system (instead of 5 points for the single function rating) and a score of 10 is applied to the best manually operated halogen system of the CIE-Standard (instead of 1 point for the single function rating). Both systems performances were selected by light experts of the GTB/WG-SVP and are displayed in Table 17.

Table 17 - Benchmark systems for total headlighting system score

Score	*Mean Effective Performance of the benchmark systems*
10	74.16m
50	138.07m

[2][1] Austerschulte, A., Vogt, H., Dreier B., Rosenhahn, E.-O. : "Driver perception aspects of LED-Matrix High Beams", VISION, Versailles, 2014.
[2] Dreier, B., Rosenhahn, E.-O.: "Camera Controlled Adaptive Cut-Off and Adaptive Partial High Beam Applications", ISAL Symposium, Darmstadt, 2009.
[3] Martoch, J., Ferbas, P., Büttgen S., Groner H. : "Opti-ADB-Study on Low Numerber of Segments", ISAL Symposium, Darmstadt, 2019.
[4] Böhm. M. : *"Efficacy of Adaptive Front-Lighting Systems -A Field Study Under Further Consideration of Drivers' Customary High Beam Usage Behaviour"*, ISAL Symposium, Darmstadt, 2009.
[5] Sprute. H. : *"Entwicklung lichttechnischer Kriterien zur Blendungsminimierung von adaptiven Fernlichtsystemen"*, Fachgebiet Lichttechnik, Darmstadt, 2012.
[6] Mefford. M. : *"Real-World Use of High-Beam Headlamps"*, Ann Arbor, Michigan, Research Report UMTRI-2006-11, 2006.

These benchmark systems lead to the equation relating the headlighting system score and the Mean Effective Performance:

$$headlighting\ system\ score = \frac{0.626}{m} \cdot Mean\ Effective\ Performance - 36.42 \quad (12)$$

In addition, each 10-score interval is applied by a different verbal rank: Standard, Good, Advanced, Excellent, Premium, Premium+ as shown in Table 18:

Table 18 - Verbal Rank of the total headlighting system score

Headlighting system score	*Verbal rank*
<10	Standard
10 - <20	Good
20 - <30	Advanced
30 - <40	Excellent
40 - <50	Premium
>=50	Premium+

NOTE *The same verbal ranks can also be applied for the single lighting function rating. In this case the verbal rank changes for every 1-point step: the standard rank corresponds to less than 1-point and the premium+ rank to 5-points or more.*

8.4 Evaluation of a test headlighting system

To comprehend the rating method as an example a test headlighting system will be evaluated by the Headlight Safety Performance Rating. The tested system is a premium headlight with an 84 segmented adaptive driving-beam. The mounting height of each headlight function is at 0.75m.

The headlight functions of the left and right headlight are separated by 1.5 m.

8.4.1 Test headlight: Single criteria points

The test headlights performance and the resulting single criteria points of the passing-beam, driving-beam and Adaptive driving-beam criteria is shown in Table 19 - Table 23:

Table 19 - Test headlight passing-beam result

	Zone A [m]	*Zone B [m]*	*Zone C [m]*	*Zone D offside [m]*	*Zone D nearside [m]*	*Zone E offside [m]*	*Zone E nearside [m]*	*Flux [lm]*	*Glare [lm]*
Test headlight	91.9	130.3	48.2	18.0	17.5	10.75	10.75	2357	0.54
Points	1.86	1.88	1.99	2.71	2.14	2.31	2.06	2.55	1.40

Table 20 - Test headlight driving-beam result

	Point A [m]	*Point B [m]*	*Point C [m]*	*Point D [m]*	*Point E [m]*	*Zone E offside [m]*	*Zone E nearside [m]*	*Flux [lm]*
Test headlight	354.5	58.5	33.0	68.5	200.5	10.75	10.75	3498
Points	3.17	1.92	1.05	1.67	1.90	2.06	1.97	2.19

Table 21- Test headlight 50m adaptive driving-beam result

	Zone A' oncoming [m]	*Zone B' oncoming [m]*	*Zone C' oncoming [m]*	*Flux oncoming [m]*	*ADB Glare oncoming [m]*	*Zone A' preceding [m]*	*Zone B' preceding [m]*	*Zone C' preceding [m]*	*Flux preceding [lm]*	*ADB Glare preceding [lm]*
Test headlight	205.6	150.4	45.33	2451.7	0.15	54.0	150.6	104.9	2455.7	0.17
Points	1.80	1.49	1.31	1.60	1.79	1.83	1.46	1.71	1.68	1.96

Table 22- Test headlight 100m adaptive driving-beam result

	Zone A' oncoming [m]	*Zone B' oncoming [m]*	*Zone C' oncoming [m]*	*Flux oncoming [lm]*	*Zone A' preceding [m]*	*Zone B' preceding [m]*	*Zone C' preceding [m]*	*Flux preceding [lm]*
Test headlight	198.3	150.4	74.3	2593.5	80.3	150.4	163.8	2695.6
Points	1.90	1.42	1.42	1.64	1.92	1.32	2.25	1.79

Table 23- Test headlight 200m adaptive driving-beam result

	Zone A' oncoming [m]	Zone B' oncoming [m]	Zone C' oncoming [m]	Flux oncoming [lm]	Zone A' preceding [m]	Zone B' preceding [m]	Zone C' preceding [m]	Flux preceding [lm]
Test headlight	146.8	150.6	133.8	2686.3	94.2	150.6	163.8	2690.5
Points	1.69	1.38	2.06	1.66	1.59	1.35	1.79	1.70

As an example, the points for the Zone A range of the passing-beam are calculated by inserting the Zone A range and the 1-point, 2-point value in equation (2):

$$P_{Zone\ A} = \frac{1}{95.1m - 71.6m}(91.9m - 71.6m) + 1 = 1.86\,points.$$

8.4.2 Test headlight: Weighted sum value

As a next step the single criteria points will be summed up and weighted by the corresponding factors (see equation (3)):

$$Weighted\ Sum_{Passing\ Beam} = 1.5 \cdot 1.86 + 1 \cdot 1.88 + 1 \cdot 1.99 + 0.75 \cdot 2.71 + 0.75 \cdot 2.14 + 0.5 \cdot 2.31 + 0.5 \cdot 2.06 + 1 \cdot 2.55 + 1 \cdot 1.40 = 16.44$$

$$Weighted\ Sum_{Driving\ Beam} = 2 \cdot 3.17 + 0.8 \cdot 1.92 + 0.4 \cdot 1.05 + 0.8 \cdot 1.67 + 1 \cdot 1.90 + 1 \cdot 2.06 + 1 \cdot 1.97 + 1 \cdot 2.19 = 17.75$$

$$Weighted\ Sum_{50m\ ADB} = 1.5 \cdot 1.80 + 1 \cdot 1.49 + 1 \cdot 1.31 + 0.5 \cdot 1.60 + 0.5 \cdot 1.79 + 1.5 \cdot 1.83 + 1 \cdot 1.46 + 1 \cdot 1.71 + 0.5 \cdot 1.68 + 0.5 \cdot 1.96 = \mathbf{14.92}$$

$$Weighted\ Sum_{100m\ ADB} = 1.5 \cdot 1.90 + 1 \cdot 1.42 + 1 \cdot 1.42 + 0.5 \cdot 1.64 + 0.5 \cdot 1.79 + 1.5 \cdot 1.92 + 1 \cdot 1.32 + 1 \cdot 2.25 + 0.5 \cdot 1.79 + 0.5 \cdot 1.96 = \mathbf{15.72}$$

$$Weighted\ Sum_{200m\ ADB} = 1.5 \cdot 1.69 + 1 \cdot 1.38 + 1 \cdot 2.06 + 0.5 \cdot 1.66 + 0.5 \cdot 1.79 + 1.5 \cdot 1.59 + 1 \cdot 1.35 + 1 \cdot 1.79 + 0.5 \cdot 1.70 + 0.5 \cdot 1.96 = \mathbf{15.07}$$

For getting the final ADB weighted sum, equation (4) must be applied:

$Weighted\ Sum_{ADB} = \frac{14.92+15.72+15.07}{3} = 15.24.$

8.4.3 Test headlight: Final single lighting function score

The final single lighting function rating can now by calculated with equation (5):

$$Passing\ Beam\ score = \frac{5-1}{17.61-11.15} \cdot (16.44 - 11.15) + 1 = 4.27$$

$$Driving\ Beam\ score = \frac{5-1}{19.23-11.31} \cdot (17.75 - 11.31) + 1 = 4.25$$

$$ADB\ score = \frac{5-1}{20.81-9.35} \cdot (15.24 - 9.35) + 1 = 3.06$$

That means the passing-beam and the driving-beam lighting function achieve the verbal rank **Premium** and the adaptive driving-beam lighting function achieves the verbal rank **Excellent**.

8.4.4 Test headlight: Calculating the Effective Performance

To calculate the Effective Performance the single lighting function scores are inserted into the equation (6) – (8):

$$EP_{Passing\ Beam} = 5.80m \cdot 4.27 + 64.17 = 88.9m$$

$$EP_{Driving\ Beam} = 11.71m \cdot 4.25 + 141.27 = 191.0m$$

$$EP_{ADB} = 10.87m \cdot 3.06 + 94.13 = 127.4m$$

8.4.5 Test headlight: Calculation the Mean Effective Performance

The Mean Effective Performance is evaluated by inserting the Effective Performance values in equation (11) because the headlight is operated in the adaptive driving-beam modus:

$$MEP_{ADB} = 0.30 \cdot 88.9m + 0.20 \cdot 191.0m \; + \; 0.50 \cdot 127.4m = 128.6m$$

8.4.6 Test headlight: Calculation the final headlighting system score

The final headlighting system score is then calculated by inserting the Mean Effective Performance in equation (12):

$$score_{Test\ Headlight} = 0.626 \cdot 128.6 - 36.42 = 44.1$$

The final headlighting system score is **44.1**, which corresponds to a verbal grade of **Premium**.

9 Measurement and calculation

9.1 Photometric measurement of each headlight

In order to perform the photometric measurement of the light distributions the following steps shall be performed:

a) In the case of headlights equipped with LED modules, the modules supplied with the headlight should be used and energized at the vehicle operating voltage as defined in 9.2 d).

   In the case of headlights equipped with filament or gas discharge light sources, use a standard (etalon) light source having dimensions according to the “Etalon” requirements as defined in UN Regulation No. 37 or 99 and energized at the vehicle operating voltage as defined in 9.2 d).

b) The passing-beam pattern should be measured without an active position lamp. If the passing-beam can only be measured with an active position lamp, measure the position lamp alone and subtract the pattern from the passing-beam pattern.

c) Measure passing-beam and driving-beam pattern of each headlight separately using a computer-controlled photometer in association with a photodetector located at a distance of 25 m from the headlight. For the adaptive driving-beam all 6 driving scenarios must be measured separately. The photodetector shall conform to the requirements defined in the GTB Working Group Photometry, “Photometry Laboratory Accuracy Guidelines” Edition 3, 2005.

Note: *For calculation of the driving beam performance, the real driving scenario with respect to passing-beam function is used, e.g. if the passing beam is always switched ON during driving beam activation, the driving beam may be evaluated with the passing-beam switched ON. For calculation of the ADB ranges, the real driving scenario with respect to passing-beam function is used, e.g., passing-beam is always switched ON and the headlights are in the real mounting position.*

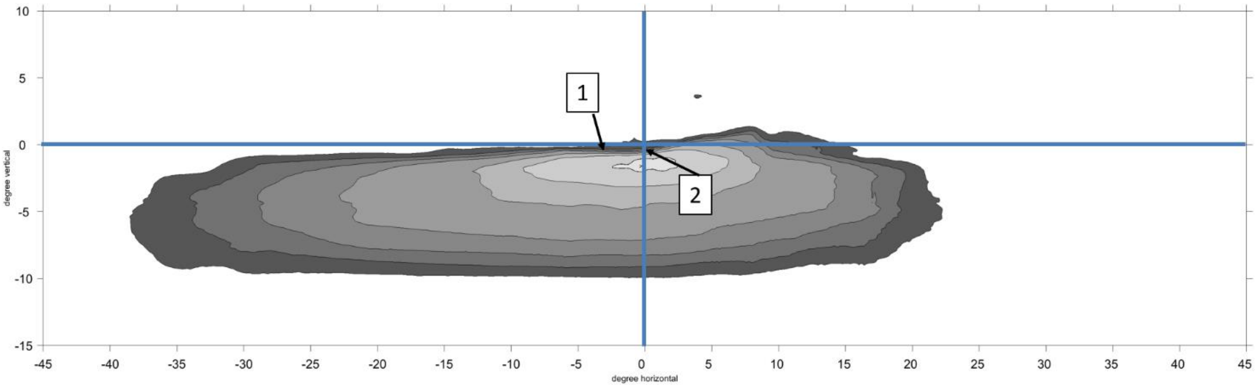
d) Aim the passing-beam cut-off with reference to Figure 13 as follows:

Vertically: Visually by means of positioning the horizontal cut-off as declared by the vehicle manufacture.

Horizontally: Visually by means of positioning the elbow of the cut-off at the V-V line.

NOTE The H-H and V-V lines pass through the H-V point which coincides with the optical axis of the passing or driving-beam being measured.

Figure 10 - Aiming method – vertical aim



Key
1 *horizontal cut-off positioned as declared by the vehicle manufacturer*
2 *the elbow of the cut-off positioned on the V-V line*

e) If the driving-beam or adaptive driving-beam does not have separate adjustment means, the same aim as used for the passing-beam shall apply. In the case where the driving-beam has separate adjustment means, the center of the beam shall be positioned at the intersection of the H-H and V-V lines.

f) Program the photometer to produce a matrix of luminous intensity readings at points for driving-beam and passing-beam as shown in Figure 11. The spacing of the test points in Zone 2 has a finer vertical resolution than in Zones 1 and 3 to ensure that the illuminance gradients are measured with sufficient accuracy. In Figure 12 the resolution for the adaptive driving-beam is shown. The Zone 5 has a finer resolution than Zone 4.

g) Store the photometric data in ies-Format according to the Software Manual of the TU Darmstadt.

Figure 11 - Zones for test point matrices for passing-beam and driving-beam

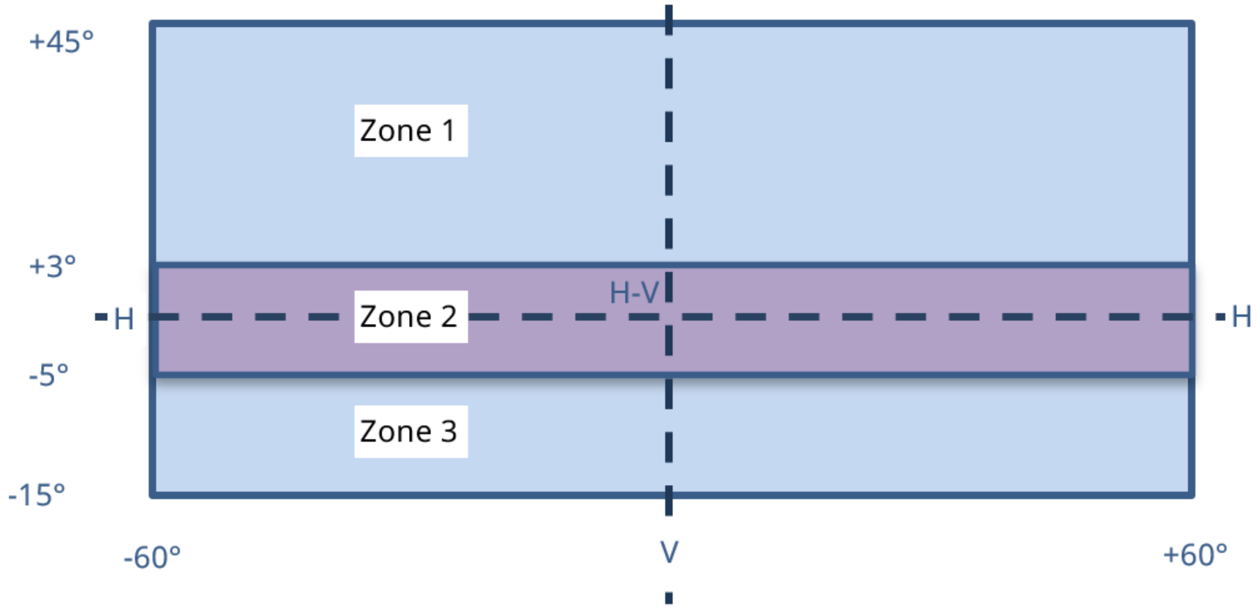
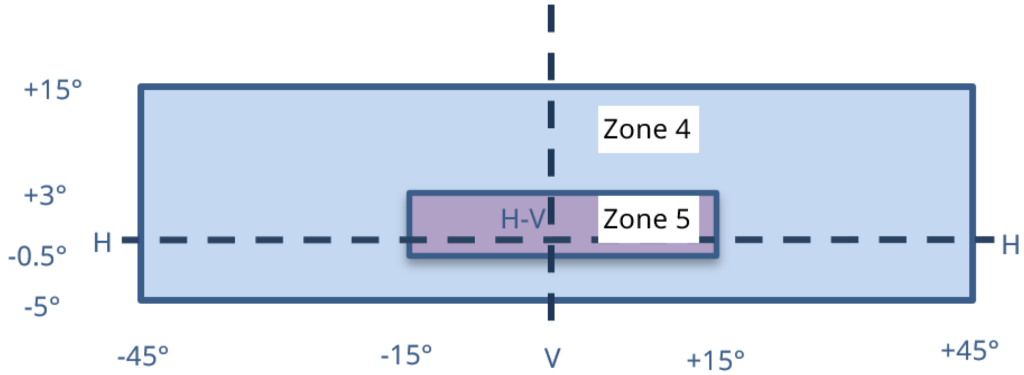


Figure 12 - Zones for test point matrices for adaptive driving-beam



NOTE (1) This diagram shows the zones of the matrices of test points referred to in 9.1 f) with the following spacing between the test points: in Zones 1, 3, 4: 0,2º horizontally, 0,5º vertically; in Zone 2: 0,2º horizontally, 0,1º vertically and in Zone 5: 0,1° horizontally/vertically.

NOTE (2) This diagram is NOT drawn to scale.

NOTE (3) The horizontal measuring area of Zone 5 can be extended from -45° to +45°.

9.2 Data relating to the installation of the headlighting system on the vehicle

The following data are required:

a) Mounting height of each headlighting function from the optical axis of the passing-beam, driving-beam and adaptive driving-beam to the road surface, see Figure 13.

b) Lateral position of each headlighting function measured from the longitudinal axis of the vehicle to the optical axis of each headlight, see Figure 13.

c) The initial aim as declared by the vehicle manufacturer.

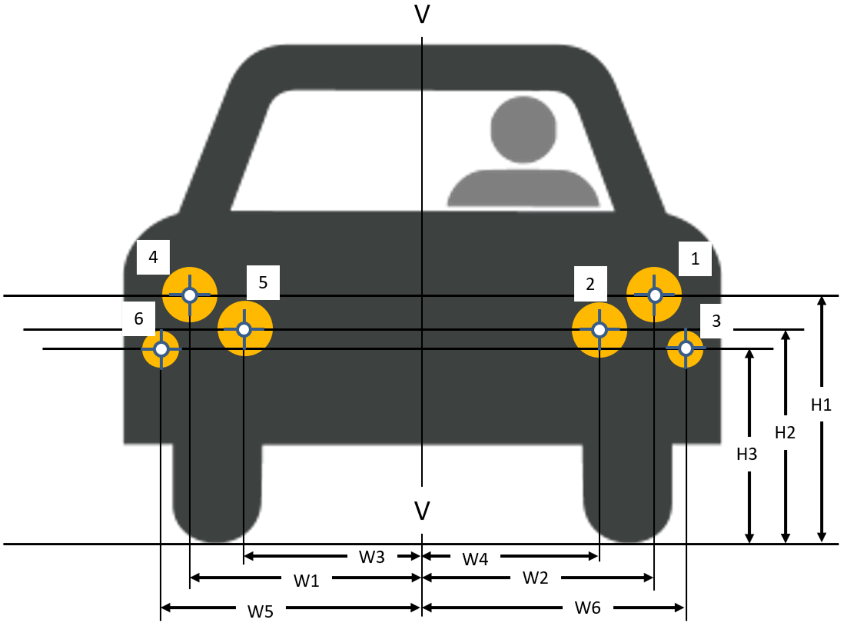
d) NOTE The initial aim is marked on the headlight or on the vehicle (for headlights approved to ECE regulations).

e) Operating voltage measured at the terminals of the light source or its electronic control gear with the engine of the vehicle operating at 2000 rpm and with the obligatory lighting equipment energized.

f) The operating modes of all headlights in the system, i.e. if driving-beams are operating separately or in conjunction with the passing-beam.

g) driving-beam operation mode: (i) manually operated driving-beam, (ii) automatically operated driving-beam, (iii) adaptive driving-beam.

Figure 13 - Measurement of headlighting system installation values



Key

1	*optical axis of left-hand passing-beam headlighting function*
2	*optical axis of left-hand driving-beam headlighting function*
3	*optical axis of left-hand adaptive driving-beam headlighting function*
4	*optical axis of right-hand passing-beam headlighting function*
5	*optical axis of right-hand driving-beam headlighting function*
6	*optical axis of right-hand adaptive driving-beam headlighting function*
V-V	*vertical plane through longitudinal axis of vehicle*
H1	*height from road surface to optical axis of the passing-beam headlighting function*
H2	*height from road surface to optical axis of the driving-beam headlighting function*

H3 height from road surface to optical axis of the adaptive driving-beam headlighting function
W1,W2 lateral positions of the passing-beam headlights from the vertical plane through the longitudinal axis of the vehicle
W3,W4 lateral positions of the driving-beam headlights from the vertical plane through the longitudinal axis of the vehicle
W5,W6 lateral positions of the adaptive driving-beam headlights from the vertical plane through the longitudinal axis of the vehicle

All dimensions shall be in mm.

NOTE Multiple headlight lighting functions may have the same mounting parameters.

9.3 HSPR-Software for the analysis of the headlight performance

For the analysis of the headlight data, you can follow the process of the Open-Source code from the TU Darmstadt. The HSPR source code is accessible via the GTB website at the following link:

https://www.gtb-lighting.org/publications/