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Energy efficiency functionality and labelling requirements for lighting products – Part 3: Street lighting

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Foreword

Saudi Standards, Metrology and Quality Organization (SASO) has prepared " Energy efficiency functionality and labelling requirements for lighting products – Part 3: Street lighting " based on relevant ADMO, International and National Foreign Standards and references.

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Energy efficiency functionality and labelling requirements for lighting products – Part 3: Street lighting

1 Scope

- This Standard cover **requirement** for **street and road lighting applications**, covering:
    - Classification of street/road lighting
    - Tunnel lighting
    - Technical requirements of lighting products

1.1 Classification of street/road lighting

This standard covers three type of lighting classification (M, C and P)

1.2 Tunnel lighting

This standard cover daylight and night for Tunnel

1.3 Technical requirements of lighting products

Table 1 illustrates all lighting products included in the scope of standards.

Table 1: List of products covered

Regulatory Parameters	Metal Halide	High Intensity Discharge (HID)	Control Gear	Luminaires
Energy efficiency	✓	✓	X	✓
Functionality / performance	✓	✓ *	X	✓ *
Electrical requirements	✓	✓	✓	✓
Mechanical requirements	✓	✓	✓	✓
Energy efficiency labelling	✓	✓	X	✓

* Information is required based on self-declaration
✓ Included in this Standard
✘ Excluded from this Standard

2 Reference Standards

The following list of reference standards applies. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

• **SASO 2902**	Energy efficiency, functionality and labelling requirements for lighting products (part 2)
• **CIE 115-2010**	Lighting of roads for motor and pedestrain traffic
• **CIE 88-2004**	Guied for the lighting of road tunnels and underpasses
• **IEC 60598-1/2017**	Luminaires - Part 1: General requirements and tests
• **IEC 61547:2009**	Equipment for general lighting purposes - EMC immunity requirements
• **IEC 61643-11:2011**	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods
• **IES LM-79-08**	Electrical and photometric measurements of Solid State lighting products
• **IES LM-80-08**	Measuring lumen maintenance of LED Light sources
• **IES LM-82-12**	Method for characterisation of LED light Engines and Integrated LED lamps for Electrical properties as a function of the temperature
• **IES LM-84-14**	Measuring Luminous Flux and Color Maintenance of LED Lamps, Light Engines, and Luminaires
• **ISTMT**	In-SITU Temperature Measurement Testing
• **IES TM21-11**	Projecting long term lumen maintenance of LED light sources
• **IES TM28-14**	Projecting long-term luminous flux maintenance of LED lamps and luminaires
• **IEC 60529:2013**	Degrees of protection provided by enclosures (IP Code)
• **ISO 9227:2017**	Corrosion tests in artificial atmospheres — Salt spray tests
• **ISO 4628-2:2016**	Paints and varnishes -- Evaluation of degradation of coatings -- Designation of quantity and size of defects, and of intensity

	of uniform changes in appearance -- Part 2: Assessment of degree of blistering
• **ISO 4628-4:2016**	Paints and varnishes -- Evaluation of degradation of coatings -- Designation of quantity and size of defects, and of intensity of uniform changes in appearance -- Part 4: Assessment of degree of cracking
• **ANSI C136.31-2001**	Roadway and area Lighting Equipment - Luminaire Vibration
• **ANSI C136.3-2001**	Roadway and area lighting equipment - luminaire attachments
• **ANSI C78.377-2011**	Specifications for the Chromaticity of Solid State Lighting Products
• **IEC 62384:2006**	DC or AC supplied electronic control gear for LED modules - Performance requirements

3 Terms and Definitions

For the purpose of this document, the following terms and definitions shall apply.

3.1 General

End-user: Average person buying or expected to buy a lamp or a luminaire for purposes which are outside his trade, business, craft or profession.

General Lighting: The full or partial illumination of an area, by replacing or complementing natural light with artificial light in order to enhance visibility in that area.

Manufacturer: Means the natural or legal person who manufactures products covered by this Standard and is responsible for their conformity with this Standard in view of their being placed on the market and/or put into service under the manufacturer’s own name or trademark or for the manufacturer’s own use. In the absence of a manufacturer as defined in the first sentence of this point or of an importer, any natural or legal person who places on the market and/or puts into service products covered by this Standard shall be considered a manufacturer.

Point of sale: Physical location where the product is displayed or offered for sale to the end-user.

Product: An equipment, system or part of a system, which is included in the list of regulated products under this Standard.

Registration system: The SASO e-application is used by manufacturers or importers to register products before the products is displayed or offered for sale to the end-user.

Shall: Where “shall” or “shall not” is used for a provision, that provision is mandatory if compliance with the standard is claimed.

Should: “Should” is used to indicate provisions which are desirable as good practice, but which are not mandatory.

3.2 Technical

Average Luminance of the Road Surface (Lav): The values Of Lav Are the minimum values to be maintained throughout the life of the installation for the specified lighting classes. They are dependent on the light distribution of the luminaires, the luminous flux of the lamps, the geometry of the installation, and on the reflection properties of the road surface. Higher levels are acceptable when they can be environmentally or economically justified.

The calculation of the average luminance of the road surface shall be carried out in accordance with CIE 140-2000.Calculated values shall consider the luminaire and tamp maintenance factors. Luminaire maintenance factors vary according to the intervals between cleaning, the amount of atmospheric pollution, the quality of the sealing of the lamp housing of the luminaire, and the age of the materials.

Their values may be established by field measurements. Lamp flux maintenance factors vary according to lamp type and power. Values are usually available from lamp manufacturers.

Ballast: Means lamp control gear inserted between the supply and one or more discharge lamps which by means of inductance, capacitance or a combination of inductance and capacitance, serves mainly to limit the current of the lamp(s) to the required value.

Beam angle: Means the angle between two imaginary lines in a plane through the optical beam axis, such that these lines pass through the center of the front face of the lamp and through points at which the luminous intensity is 50% of the center beam intensity, where the center beam intensity is the value of luminous intensity measured on the optical beam axis.

Chromaticity: Means the property of a color stimulus defined by its chromaticity coordinates, or by its dominant or complementary wavelength and purity taken together.

Clear lamp: Lamp (excluding compact fluorescent lamps) with a luminance above 25,000 cd/m^2 for lamps having a luminous flux below 2,000 lm and above 100,000 cd/m^2 for lamps having more luminous flux, equipped with only transparent envelopes in which the light producing filament, LED or discharge tube is clearly visible.

Color consistency: Means the maximum deviation of chromaticity coordinates (x and y) of a single lamp from a chromaticity center point (cx and cy), expressed as the size (in steps) of the MacAdam ellipse formed around the chromaticity center point (cx and cy). MacAdam ellipses refer to the regions (in the form of an ellipse) on a chromaticity diagram which contain all colors that are indistinguishable to the average human eye from the color at the center of the ellipse.

Color rendering (CRI / Ra): Means the effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant.

Control device: Means an electronic or mechanical device controlling or monitoring the luminous flux of the lamp by other means than power conversion for the lamp, such as timer switches, occupancy sensors and daylight standard devices. In addition, phase cut dimmers shall also be considered as control devices.

Counter-beam lighting (CBL): The lighting where the light falls on objects from an opposite Direction to the traffic. Counter-beam lighting is characterized by using luminaires that show a luminous intensity distribution that is asymmetric in relation to the plane normal to the Direction of the traffic, where the maximum luminous intensity is aimed against the direction of the traffic. The term refers only to the direction of normal travel.

Control gear: Means a device located between the electrical supply and one or more lamps, which provides a functionality related to the operation of the lamp(s), such as transforming the supply voltage, limiting the current of the lamp(s) to the required value, providing starting voltage and preheating current, preventing cold starting, correcting the displacement factor or reducing radio interference. The device may be designed to connect to other lamp control gear to perform these functions. The term does not include control devices or power supplies.

Correlated color temperature (CCT / Tc [K]): a specification of the color appearance of the light emitted by a lamp, relating its color to the color of light from a reference source when heated to a particular temperature, measured in degrees Kelvin (K). More specifically, it is the absolute temperature of a blackbody whose chromaticity most nearly resembles that of the light source. A black body is an idealized physical body that absorbs all incident electromagnetic radiation, regardless of frequency or angle of incidence.

Directional (direct) Lamp or Luminaire: a lamp or a luminaire having at least 80% light output within a solid angle of πSr corresponding to a cone with an angle of 120˚.

Discharge lamp: means a lamp in which the light is produced, directly or indirectly, by an electric discharge through a gas, a metal vapor or a mixture of several gases and vapors.

External lamp control gear: means non-integrated lamp control gear designed to be installed outside the enclosure of a lamp or luminaire, or to be removed from the enclosure without permanently damaging the lamp or the luminaire

Family of product (or Model Group): group of light sources or luminaires that have the same characteristics, distinguished by common features of materials, components and/or method of processing.

Luminaire: means integrated luminaire which is a complete unit consisting of non-replaceable/ replaceable light emitting elements and a matched driver together with part to distribute light, to position and protect the light emitting elements and to connect directly the unit to a branch circuit. Integrated luminaire might be provided with or without control gear.

Lamp: means a unit whose performance can be assessed independently, and which consists of one or more light sources. It may include additional components necessary for starting, power supply or stable operation of the unit or for distributing, filtering or transforming the optical radiation, in cases where those components cannot be removed without permanently damaging the unit

Lamp cap: means that part of a lamp which provides connection to the electrical supply by means of a lamp holder or lamp connector and may also serve to retain the lamp in the lamp holder

Lamp holder or 'socket': means a device which holds the lamp in position, usually by having the cap inserted in it, in which case it also provides the means of connecting the lamp to the electric supply

Lamp lifetime: For LED lamps, lamp lifetime means the operating time between the start of their use and the moment when only 50% of the total number of lamps survive or when the average lumen maintenance of the batch falls below 70%, whichever occurs first. For all other lamps, lamp lifetime means the period of operating time after which the fraction of the total number of lamps which continues to operate corresponds to the lamp survival factor of the lamp under defined conditions and switching frequency

Lamp lumen maintenance factor (LLMF): means the ratio of the luminous flux emitted by the lamp at a given time in its life to the initial luminous flux

Lamp mercury content: means the mercury contained in the lamp (weight usually specified in mg)

Lamp start time: means the time needed, after the supply voltage is switched on, for the lamp to start fully and remain alight

Lamp survival factor (LSF): means the defined fraction of the total number of lamps that continue to operate at a given time under defined conditions and switching frequency

Lamp warm-up time: means the time needed after start-up for the lamp to emit a defined proportion of its stabilized luminous flux

LED Light-emitting diode: means a light source which consists of a solid-state device embodying a P-N junction. The junction emits optical radiation when excited by an electric current

LED lamp: means a lamp incorporating one or more LED modules. The lamp may be equipped with a cap.

LED package: means an assembly having one or more LED(s). The assembly may include an optical element and thermal, mechanical and electrical interfaces.

Lighting: means the application of light to a scene, objects or their surroundings so that they may be seen by humans.

Light source: means a surface or object designed to emit mainly visible optical radiation produced by a transformation of energy. The term 'visible' refers to a wavelength of 380-780 nm.

Luminaire: means an apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes all the parts necessary for supporting, fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electric supply.

Luminous flux (Φ): means the quantity derived from radiant flux (radiant power) by evaluating the radiation in accordance with the spectral sensitivity of the human eye. Without further specification, it refers to the initial luminous flux. Radiant flux is the measure of the total power of electromagnetic radiation (including infrared, ultraviolet, and visible light).

Luminous intensity (candela or cd): means the quotient of the luminous flux leaving the source and propagated in the element of solid angle containing the given direction, by the element of solid angle.

Longitudinal uniformity of Road Surface Luminance [Ul]: Ul is the ratio of the minimum to the maximum luminance along a line or lines parallel to the run of the road and shall be calculated in accordance with CIE 140-2000. It is mainly a Criterion rerating to comfort and its purpose is to prevent the repeated pattern of high and low luminance values on a lit run of road becoming too pronounced. It only applies to long uninterrupted sections of road.

Materials: means all materials used during the life cycle of a product.

Nominal value: means the value of a quantity used to designate and identify a product.

Non clear lamp: is a lamp that does not comply with the specifications of the definition of “Clear lamp”, including compact fluorescent lamps

Non-directional (indirect) lamp or luminaire: means a lamp or a luminaire that is not a directional lamp or luminaire.

Overall uniformity of Road Luminance [Uo]: Uo is the ratio of the minimum luminance at a point to the average road surface luminance and shall be calculated according to CIE 140-2000. This criterion is important as regards the control of minimum visibility on the road.

Power factor: means the ratio of the absolute value of the real power (also known as active power) to the apparent power under periodic conditions.

Premature failure: means when a lamp reaches the end of its life after a period in operation which is less than the rated life time stated in the technical documentation.

Rated value: means the value of a quantity used for specification purposes, established for a specified set of operating conditions of a product. Unless stated otherwise, all requirements are set in rated values.

Retrofit lamp: means a lamp which can replace another lamp with similar performances and different technology using the same cap.

Pro-beam lighting: The lighting where the light falls on objects in the same direction as the Traffic. Pro-beam lighting is characterized by using luminaires that show a luminous intensity Distribution that is asymmetric in relation to the 90/270 C-plane (the plane normal to the Direction of the traffic), where the maximum luminous intensity is aimed in the same direction As the direction of the traffic.

Second lamp envelope: second outer lamp envelope which is not required for the production of light, such as an external sleeve for preventing mercury and glass release into the environment in case of lamp breakage, for protecting from ultraviolet radiation or for serving as a light diffuser.

Surround Ratio: SR [Rs]: One of the principal aims in road lighting is to create a bright road surface against which objects can be seen. However, the upper parts of tall objects on the road and objects toward the side of the road, particularly on curved sections, are seen against the surrounds of the road. Thus, adequate lighting on surrounds helps the motorist to perceive more of the environment and make speed adjustment in time.
The function of the surround ratio is to ensure that light directed on the surrounds is Sufficient for objects to be revealed. In situations where Lighting is already provided on the Surrounds the use of surround ratio is rendered unnecessary.

Symmetric lighting: The lighting where the light equally falls on objects in directions with and against the traffic. Symmetric lighting is characterized by using luminaires that show a luminous intensity distribution that is symmetric in relation to the plane normal to the direction of the traffic.

Switching cycle: means the sequence of switching the lamp on and off at set intervals.

Threshold Increment TI: Disability glare results from the scattering of light within the eye. So reducing contrasts of the Retinal image. The effect may be explained by the superimposition of a uniform luminance veil over the scene, which is quantified as the equivalent veiling luminance. The magnitude of this Depends on the illuminance on the driver's eye from the luminaires and the angles at which they are seen. While the degree of disability glare increases with the equivalent veiling Luminance. It decreases as a function of the average road luminance.
Tl is a measure of the loss of visibility caused by the disability glare form the road Lighting luminaires. The formula from which it is calculated is based on the percentage Increase in the luminance difference needed to make the object visible in the presence of Glare when it is just visible in the absence of glare. That is, when the luminaires are screened from the view of the observer. The mathematical procedure is given in CIE 140-2000. (See Annex C of this report for additional remarks) and the calculation is made for a clean Luminaire equipped with a lamp emitting.

Useful luminous flux ($\boldsymbol{\Phi_{use}}$): means the part of the luminous flux of a lamp falling within the beam angle used for calculating the lamp's energy efficiency.

Warm-start: feature that is performed to reset a previously running system after an unintentional shutdown or limited interruption of the lighting emission.

4 Requirements for Lighting of Roads for Motor and Pedestrian Traffic

4.1 Requirements for motorized traffic

The M lighting classes are intended for drivers of motorize vehicle on traffic route, and in some countries also on residential roads, allowing medium to high driving speeds. The lighting Classes M1 to M6 are defined by the lighting criteria given for each class in Table 3. The application of these classes depends on the geometry of the relevant area and on the traffic and time dependent circumstances. The appropriate class has to be selected according to the function of the road, the design speed, the overall layout, the traffic volume and composition, and the environmental conditions.

For the determination of the M lighting class to be applied the appropriate weighting values for the different parameters have to be selected and added to find the sum of the Weighting values (V_{WS}). The number of the lighting class M is then calculated as:

Number of lighting class M: $6 – V_{WS}$
Careful selection of appropriate weighting values in Table 2 will yield class numbers between 1 and 6. If the result is not a whole number, use the next lower whole number.

Table 2 : Parameter for the selection of M lighting class

Parameter	Option	Description	Weighting factor	V_w selected
Speed.	Very High	≥ 90 km/h	1	
	high	70 < v < 90 km/h	0.5	
	Moderate	v ≤ 70 km/h	0	
Traffic Volume.	Very High	> 25,000 vehicles per day	1	
	high	≥ 15,000 ≤ 25,000 vehicles per day	0.5	
	moderate	≥ 7,000 ≤ 14,999 vehicles per day	0	
	Low	≥ 3,000 ≤ 6,999 vehicles per day	- 0.5	
	Very Low	< 3,000 vehicles per day	-1	
Traffic Composition.	Mixed with High percentage of non-motorized		2	
	Mixed		1	
	Motorized only		0	
Separation of carriageway.	Yes		0	
	No		1	

Intersection density.	High	More than 3 intersection per km	1	
	Moderate	Less than 3 intersection per km	0	
Parked vehicles.	Present		0.5	
	Not present		0	
Ambient Luminance.	High		1	
	Moderate		0	
	Low		-1	
Visual Guidance.	Poor		0.5	
	Moderate to good		0	
Equation	**$M = 6 - V_{ws}$**		Sum of weighting values	V_{ws}

The controlling criteria for the lighting of roads for motorized traffic are the luminance Level and uniformity of the carriageway, the illuminance level of the surrounds of the road, the limitation of disability and discomfort glare, and the requirements for direct visual guidance. For the other criteria recommended values are given in Table 3 for the lighting classes MI M6, reflecting various traffic situations.
The lighting criteria used are the maintained average road surface luminance (Lav), the Overall (Uo) and longitudinal (U0) uniformity of the luminance. The surround ratio (Rs) and the Threshold increment (Fn)

These values apply to roads. Which are sufficiently long so that the luminance concept can be used, outside conflict areas and/or outside areas with measures of traffic calming. The Surround ratio is considered for roads with adjacent footpath/cycle path only when Requirements are given (see P lighting classes).

Table 3: Lighting classes for traffic, based on road surface luminance.

Lighting Class	Road surface				Threshold increment	Surround ratio
	Dry			Wet *		
	L (cd/m2)	Uo	U1	Uo	Fn in %	Rs
M1	2.0	0.40	0.70	0.15	10	0.50
M2	1.5	0.40	0.70	0.15	10	0.50
M3	1.0	0.40	0.60	0.15	15	0.50
M4	0.75	0.40	0.60	0.15	15	0.50
M5	0.50	0.35	0.40	0.15	15	0.50
M6	0.30	0.35	0.40	0.15	20	0.50

***** Applicable in addition to dry condition, where road surfaces are wet for a substantial part of the hours of darkness and appropriate road surface reflectance data are available.

NOTE the use of luminance concept requires the knowledge of the properties of the road surface. They are taken into account either through the real properties (measurements) or through a reference r-table such as the C and R Standards defined by the CIE (CIE 132-1999 and CIE 144:2001). However, recent measurements have shown that the current pavements used on roads very largely with time and are very different from the CIE standards (which were defined decades ago), frequently to errors between 30% and 100% in terms of average luminance (CHAIN et al., 2007).

When designing a lighting installation using the luminance concept it is thus important to have an accurate representation of the photometric characteristics of the road surface at its stabilized situation. If the measurement of the r-table in laboratory is not possible, real road reflectance properties may be measured on site with portable devices. If not possible, the current CIE standards remain the latest recommended r tables to use for the calculation. In all cases, it is to systematically a representative value of the luminance coefficient q0.

4.2 The lighting of conflict areas

Conflict areas occur whenever vehicle streams intersect each other or run into areas frequented by pedestrians, cyclists, or other road users, or when there is a change in road geometry, such as a reduced number of lanes or a reduced lane or carriageway width. Their existence results in an increased potential for collisions between vehicles, between vehicles and pedestrians, cyclists, or other road users, or between vehicles and fixed objects. Parking areas and toll-stations are also regarded as conflict areas. General circulation areas at outdoor working places are covered by CIE S 0151E:20C5.

The lighting shall reveal the existence of the conflict area, the position of the kerbs and road markings, the directions of the roads, the presence of pedestrians, other road users, and obstructions, and the movement of vehicles in the vicinity of the conflict area. Where no lighting is otherwise provided on a road leading to or leaving the conflict area, the selected lighting class shall be installed for a stretch long enough to provide about 5 seconds of driving distance at the expected traffic speed.
The lighting classes C0 to C5 are defined by the lighting criteria given for each class in Table 4.

Table 4: parameters for the selection of C lighting class.

Parameter	option	Description	Weighting factor	V_w selected
Speed.	Very High	v ≥ 90 km/h	3	
	High	70 < v < 90 km/h	2	
	Moderate	60 < v ≤ 70 km/h	1	
	Low	v ≤ 60	0	
Traffic Volume.	Very High	> 25,000 vehicles per day	1	
	High	≥ 15,000 ≤ 25,000 vehicles per day	0.5	
	Moderate	≥ 7,000 < 15,000 vehicles per day	0	
	Low	≥ 3,000 <7,000 vehicles per day	-0.5	
	Very Low	< 3,000 vehicles per day	-1	
Traffic Composition.	Mixed with High percentage of non-motorized		2	
	Mixed		1	
	Motorized only		0	
Separation of carriageway	Yes		0	
	No		1	
Ambient Luminance.	High		1	
	Moderate		0	
	Low		-1	
Visual Guidance.	Poor		0.5	
	Moderate to good		0	
equation	**$C = 6 - V_{ws}$**			

For the determination of the C lighting class to be applied the appropriate weighting values in Table 4 for the different parameters have to be selected and added to find the sum of the weighting values (V_{ws}).

The number of the lighting class C is then calculated as:
Number of lighting class C = 6 – Vws
Careful selection of appropriate weighting values will yield class numbers between 0 and 5. If the result is not a whole number, use the next lower whole number.

For conflict areas, luminance is the recommended design criterion. However, where viewing distances are short and other factors prevent the use of luminance criteria, illuminance shall be used on a part of the conflict area, or the entire area if the luminance criteria cannot be applied to the whole area. The correspondence between luminance and average horizontal illuminance depends on the lightness of the road surface, as represented by the q0 value of that surface. Table 5 gives the relationship between the M and C class for three examples of q0 values.

Table 5: M and C lighting classes of comparable lighting level for different values of q0 for the Road surface

Lighting class M			**M1**	**M2**	**M3**	**M4**	**M5**	**M6**
Average luminance L in cd/m2			2.0	1.5	1	0.75	0.50	0.30
Lighting class C If q0 =0.05cd/m2			C0	C1	C2	C3	C4	C5
Average illuminance E in lux			50	30	20	15	10	7.5
Lighting class C If q0 =0.07cd/m2		C0	C1	C2	C3	C4	C5	
Average illuminance E in lux		50	30	20	15	10	7.5	
Lighting class C If q0 =0.09cd/m2	C0	C1	C2	C3	C4	C5		
Average illuminance E in lux	50	30	20	15	10	7.5		

The conflict area shall as a minimum have a lighting level no lower than that of the connecting roads. However, it is recommended that the lighting class used for the conflict area shall normally be one step higher than the highest lighting class used for the road or roads leading to the conflict area (e.g. M2 instead of M3). This will not be possible where the entrance roads are lit to Class M1. In this case. The conflict area shall also be lit to class M1.

Where illuminance is used as a criterion for the conflict area lighting. It is necessary to consider comparable luminance and illuminance classes (M and C classes respectively from Tables 2 and 6).

Table 5 gives comparable M and C classes for various values of q0 for the road surface. Raw 1 gives the M classes from which the luminance class used for the most important road leading to the conflict area is selected. The equivalent illuminance C class is then taken from column 1, depending on the q0 value. The actual C class to be used in the conflict area is recommended to be one step higher than the equivalent class so determined.

(E.g. if the most important road leading to the conflict area is M4 and q0 = 0.07 cd/m^2·lx, the equivalent class is C4 and the conflict area is recommended to be lit to class C3.)
Where luminance is used as a criterion for the conflict area lighting, it is necessary to calculate threshold increment TI (symbol f_{TI}), for relevant observer positions and viewing directions in the conflict area, which requires knowledge of veiling luminance and adaption luminance for the particular observer positions and viewing directions.

Table 6: Lighting classes for conflicts area

Lighting Class	Average illuminance over whole of used surface E in lux.	Uniformity of Iluminance U0 (E)	threshold increment f_{TI} in % *	
			High and moderate speed	Low and very low speed
C0	50	0.40	10	15
C1	30	0.40	10	15
C2	20	0.40	10	15
C3	15	0.40	15	20
C4	10	0.40	15	20
C5	7.5	0.40	15	25

* Applicable where visual tasks usually considered for the lighting of roads for motorized traffic (M classes) are of importance.

4.3 The Lighting of Pedestrian Areas

4.3.1 Control of Glare

The control of discomfort and disability glare is not as critical as for the motorist. Because speed of movement is much lower, giving a greater reaction time. No method of quantifying glare has been agreed to intentionality, but several methods are in current use on a national basis. Methods for quantifying and controlling glare in pedestrian and low speed traffic areas are given in CIE 115-2010.

4.3.2 Lighting Levels for Pedestrian and Low Speed Traffic Areas

The parameters relevant for the selection of an appropriate P lighting for a given Pedestrian or low speed traffic area are summarized in Table 7. The lighting classes P1 to P6 are defined by the lighting criteria given for each class in Table 8. They are intended for pedestrians and pedal cyclists on footways, cycle ways, and other road areas lying separately or along the carriageway of a traffic route, and for residential roads, pedestrian streets, etc.

Table 7: Parameters for the selection of P lighting class.

Parameter	option	Description	Weighting factor	V_w selected
Speed.	low	> 5 and ≤ 30 km/h	1	
	Very low (walking peed)	≤ 5 km/h	0	
Traffic Volume.	Very high	5000< traffic volume ≤ 7000 vehicles per day	1	
	high	3000< traffic volume ≤ 5000 vehicles per day	0.5	
	Moderate	1000< traffic volume ≤ 3000 vehicles per day	0	
	low	500< traffic volume ≤1000 vehicles per day	-0.5	
	Very low	traffic volume ≤ 500 vehicles per day	-1	

Traffic Composition.	Pedestrians, cyclists and motorized traffic	2	
	Pedestrians and motorized traffic	1	
	Pedestrians and Cyclist only	1	
	Pedestrians only	0	
	Cyclist only	0	
Parked vehicles.	Present	0.5	
	Not present	0	
Ambient Luminance.	High	1	
	Moderate	0	
	Low	-1	
Equation	**$P = 6 – V_{sw}$**	Sum of Weighting Values	V_{ws}

The application of these classes depends on the geometry of the relevant area and the Traffic and time dependent circumstances.

For the determination of the P lighting class to be applied, the appropriate and weighting values in Table 7 for the different parameters have to be selected and added to find the sum of the weighting values (V_{ws}). The number of the lighting class p is then calculated as:

Number of lighting class $P = 6 — V_{ws}$

Careful selection of appropriate weighting values will yield class numbers between 1 and 6. If the result is not a whole number. Use the next lower whole number.

Table 8: Lighting classes for pedestrian and low speed traffic areas.

Lighting Class	Average horizontal illuminance $E_{h,av}$, in lux	Minimum horizontal illuminance $E_{h,min}$, in lux	Additional requirement if facial recognition is necessary	
			Minimum vertical illuminance $E_{v,min}$, in lux	Minimum semi-cylindrical illuminance $E_{sc,min}$, in lux
P1	15	3	5	3
P2	10	2	3	2
P3	7.5	1.5	2.5	1.5
P4	5	1	1.5	1
P5	3	0.6	1	0.6
P6	2	0.4	0.6	0.4

5 Requirements for Lighting of Road Tunnels and Underpasses

5.1 Tunnel related zones

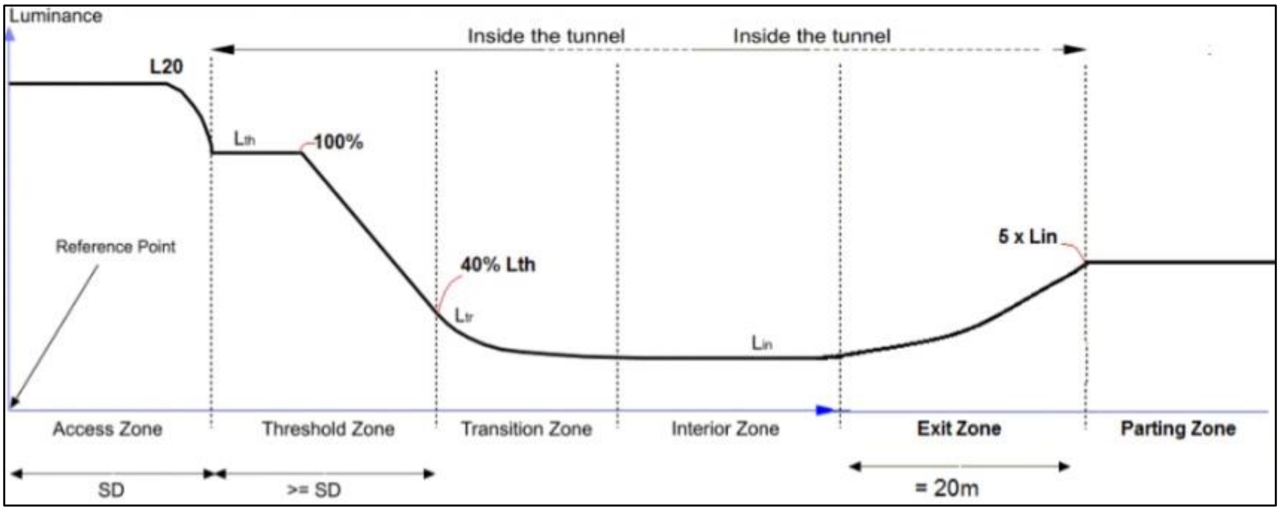

Figure 9: Zones in a tunnel. (Typical longitudinal section of a one way tunnel)

5.1.1 Tunnel

A structure over a roadway that restricts the normal daytime illumination of a roadway section such that the driver's capability to see is substantially diminished. In the context of this guide, other constructions that do not restrict visibility are not relevant.

It is practical to distinguish different zones in the tunnel in order to determine the longitudinal lighting level at daytime lighting: the access zone, the threshold zone, the transition zone, the interior zone and the exit zone.

5.1.2 Access zone

The part of the open road immediately outside (in front of) the tunnel portal, covering the distance over which an approaching driver must be able to see into the tunnel.
The access zone begins at the stopping distance point ahead of the portal and it ends at the portal.

5.1.3 Threshold zone

The first part of the tunnel, directly after the portal. The threshold zone starts either at the beginning of the tunnel or at the beginning of the daylight sunscreens when occurring. The length of the threshold zone is at least equal to the stopping distance.

5.1.4 Transition zone

The part of the tunnel following directly after the threshold zone. The transition zone begins at the end of the threshold zone. It ends at the beginning of the interior zone. In the transition zone, the lighting level is decreasing from the level at the end of the threshold zone to the level of the interior zone.

5.1.5 Interior zone

The part of the tunnel following directly after the transition zone. It stretches from the end of the transition zone to the beginning of the exit zone.

5.1.6 Exit zone

The part of the tunnel where, during the day-time, the vision of a driver approaching the exit is predominantly influenced by the brightness outside the tunnel. The exit zone begins at the end of the interior zone. It ends at the exit portal of the tunnel.

5.1.7 Parting zone

The first part of the open road directly after the exit portal of the tunnel. The parting zone is not a part of the tunnel, but it is closely related to the tunnel lighting. The parting zone begins at the exit portal. It is advised that the length of the parting zone equals two times the stopping distance. A length of more than 200 m is not necessary.

5.1.8 Entrance portal

The part of the tunnel construction that corresponds to the beginning of the covered part of the tunnel, or - when open sun-screens are used - to the beginning of the sun-screens.

5.1.9 Exit portal

The part of the tunnel construction that corresponds to the end of the covered part of the tunnel, or- when open sun-screens are used - to the end of the sun-screens.

6 Distinction Between Long and Short Tunnels

A tunnel is a covering over the road. The lighting requirements for long and short tunnels differ according to the degree to which the approaching motorist can see through the tunnel. The ability to see through the tunnel depends primarily on the length of the tunnel but also on other design parameters (width, height, horizontal and/or vertical curvatures of the tunnel, etc.).

Tunnels are usually subdivided in " long tunnels " and "short tunnels". This designation Refers primarily to the length of the tunnels (typically measured along the tunnel axis). Some tunnels - where the drivers cannot see the exit from a point in front of the tunnel - need to be illuminated like a long tunnel, even if their lengths would seem to make them a "short" one.
These tunnels are designated as "optically long tunnels", contrary to those where approaching motorists can see through the tunnel ("optically short tunnels"). With regard to the lighting, tunnels are subdivided into three classes :

- Geometrically long tunnels.
- Optically long tunnels.
- Short tunnels.

The distinction can be made on the basis of the diagram given in Figure 2

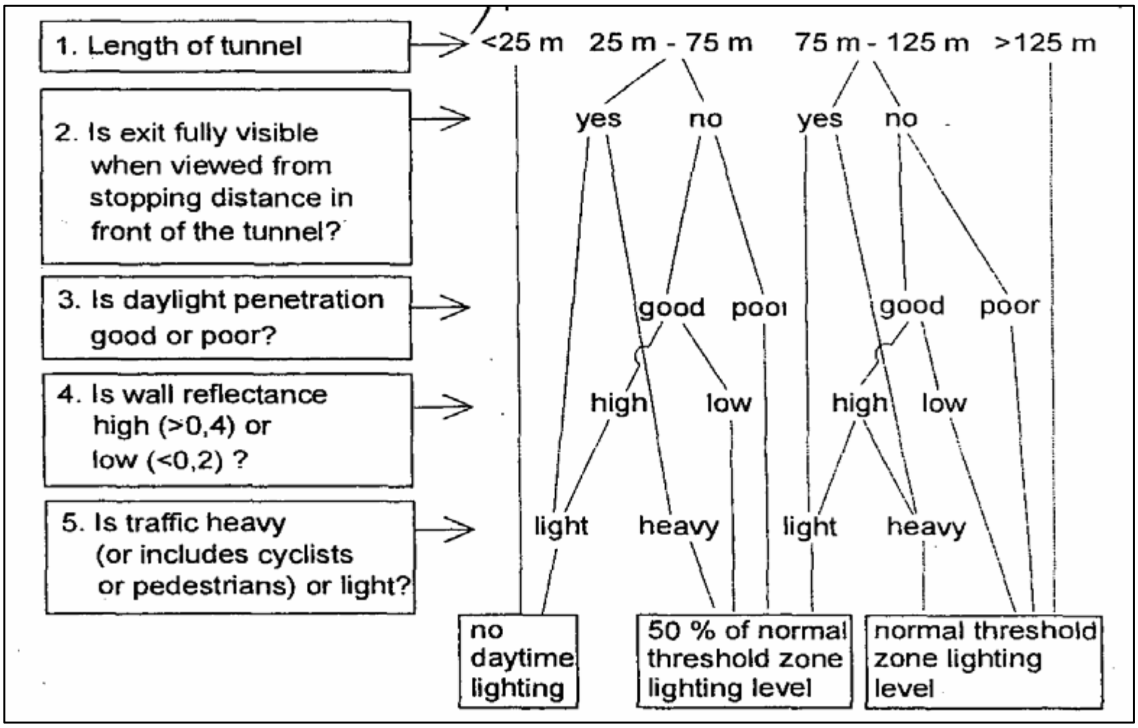

Figure 10: Daytime lighting of tunnels for different tunnel lengths

Note For tunnel lengths up to 75 m where no daytime lighting is recommended in Figure 2, it is to be noted that at least one hour before sunset and one hour after sunrise a lighting level equal to the recommended values for the interior zone of a long tunnel shall be achieved (see luminance in the interior zone). At night only the recommended value for night-time lighting is needed.

6.1 Design speed

The design speed to be taken into consideration for the design of a lighting system of a tunnel must be specified by the prime contractor.
The design speed is in principle the speed for which the tunnel is laid out. It is generally accepted that this speed is the maximum speed allowed on the access roads to the tunnel. However, some people consider that a reduction of speed on the approach and passing through the tunnel is acceptable. In this case the reduction must of course be indicated ahead of the tunnel.

6.2 Reference point

The reference point is in principle the point located in the center of the approaching lanes, at a height of 1, 5 m and at a distance from the entrance of the tunnel equal to the stopping distance (SD) at the design speed. This stopping distance is the distance necessary to stop the vehicle moving at the speed in question in total safety. It comprises the distance covered during the reaction time and during the braking time.

The stopping distance is extremely variable and depends on the driver, his vehicle, the speed of the latter, on the gradient of the road and on the atmospheric conditions.
Reference shall be made to national standards.

6.3 Tunnel lighting related terms

6.3.1 Symmetric lighting

The lighting where the light equally falls on objects in directions with and against the traffic. Symmetric lighting is characterized by using luminaires that show a luminous intensity distribution that is symmetric in relation to the plane normal to the direction of the traffic.

6.3.2 Counter-beam lighting (CBL)

The lighting where the light falls on objects from an opposite Direction to the traffic. Counter-beam lighting is characterized by using luminaires that show a luminous intensity distribution that is asymmetric in relation to the plane normal to the Direction of the traffic, where the maximum luminous intensity is aimed against the direction of the traffic. The term refers only to the direction of normal travel.

6.3.3 Pro-beam lighting

The lighting where the light falls on objects in the same direction as the Traffic. Pro-beam lighting is characterized by using luminaires that show a luminous intensity Distribution that is asymmetric in relation to the 90/270 C-plane (the plane normal to the Direction of the traffic), where the maximum luminous intensity is aimed in the same direction as the direction of the traffic.

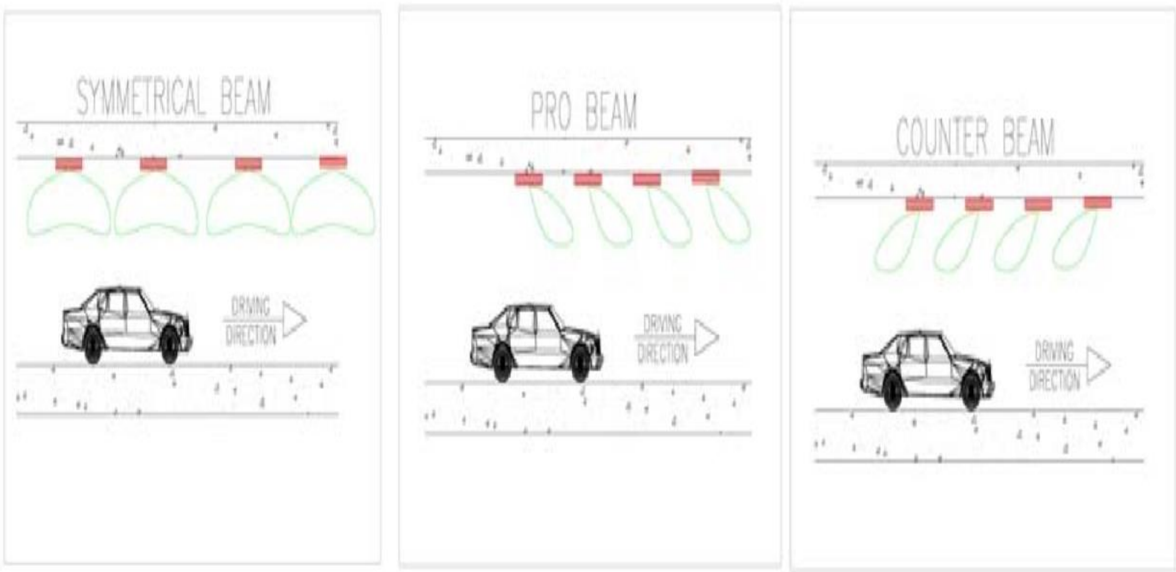

Figure 11: Lighting styles (distribution beam)

7 Daytime Lighting for Long Tunnels

7.1 Lighting in the threshold zone

As noted above, the necessary lighting level in the threshold zone is determined by visibility criteria or, in other words, by enough contrast. A driver can identify other road users or objects in the threshold zone from the stopping distance if the perceived contrast is equal to or higher than the minimum required contrast.

The driver's task is to determine the presence of other road users or objects in the relatively dark threshold zone while he is driving in a relatively light environment at a distance equal to the stopping distance corresponding to the tunnel design speed. This implies that the perceived contrast by a driver is different from the intrinsic contrast as can be measured from a very short distance from the object. The perceived contrast differs from the intrinsic contrast due to at least three main influences:

1. The light veil due to light scattered in the atmosphere in the line of sight;
2. The light veil due to the scattering in the windscreen (including light reflected from the dashboard) and
3. The light veil due to the scattering in the eye (from sources outside of the line of sight scattered into the fovea).

The minimum required contrast perceived at the stopping distance is not only the minimum required contrast in laboratory conditions, but also depends on the level of attention of the driver. Approaching a tunnel requires not only attention for its entrance but also for driving the car, for the road itself, for other road users at short distance, for lane changing, and so on.

7.2 Length of the threshold zone

The total length of the threshold zone must be at least equal to the stopping distance. Over the first half of the distance, the luminance level must be equal to L_{th} (the value at the beginning of the threshold zone). It is recommended that from half the stopping distance onwards, the lighting level may gradually and linearly decrease (linear scale) to a value, at the end of the threshold zone, equal to 0,4 L_{th}. See Figure 4. The gradual reduction over the last half of the threshold zone may also be in steps. However, the luminance levels shall not fall below the values corresponding to a gradual decrease.

7.3 Luminance in the transition zone

The reduction of the luminance of the road in the transition zone follows, in principle, the Curve shown in Figure 4. The transition zone starts at the end of the threshold zone (t = 0). This curve can be replaced by a stepped curve with levels that shall never fall below the continuous curve. The maximum luminance ratio permitted on passing from one step to another is 3. The last step shall not be greater than 2 times the interior zone luminance.
As the field of view of the driver is made up by the tunnel interior, a longer transition zone may be advisable in order to counteract a second black hole effect.
For additional driving comfort, in the case of the stepped curve, the length of the transition zone may, at its end, be extended for 1 to 2 seconds over the length that follows from the CIE-curve.

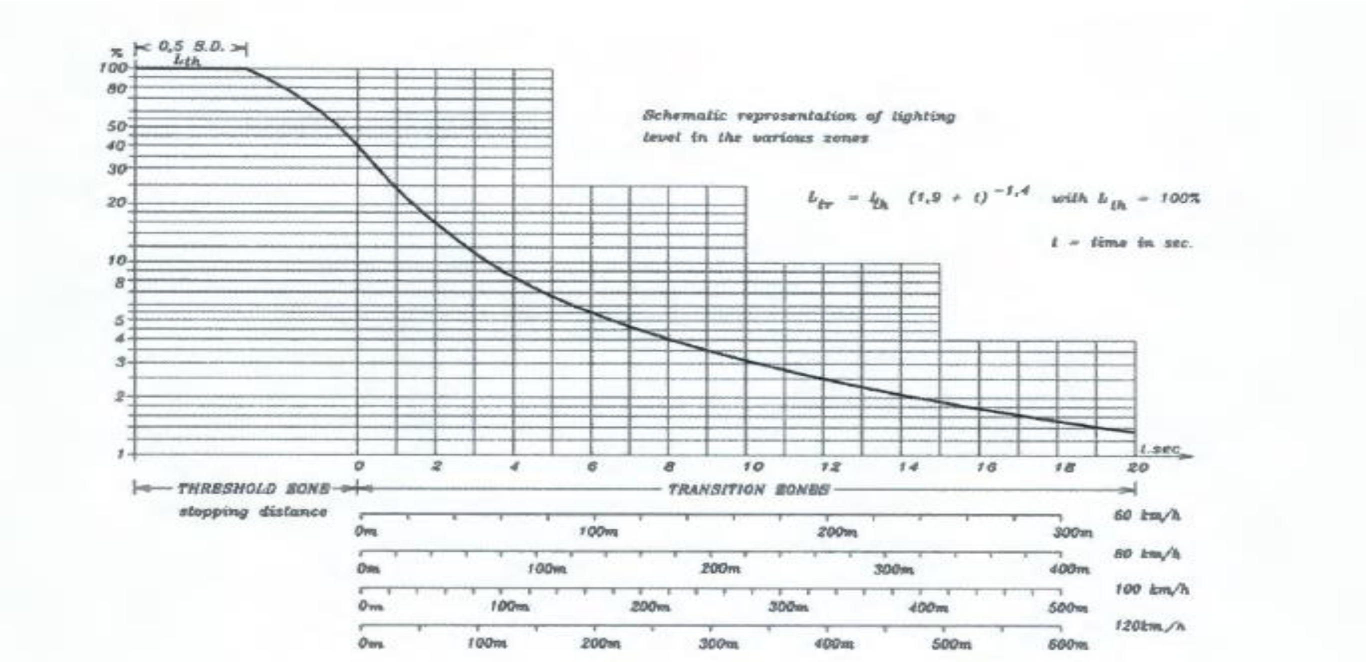

Figure 12: Luminance evolution along the tunnel.

7.4 Daytime luminance in the interior zone

The average luminance of the road in the interior zone of the tunnel is given below as a function of the stopping distance SD and of the traffic flow. Very long tunnel's interior zone consists of two different sub zones. The first sub zone corresponds to the length which is covered in 30 seconds and shall be illuminated with the "long tunnels" levels. The second sub zone corresponds to the remaining length and shall be illuminated with the "very long tunnels" levels.

7.5 Traffic flow

Traffic flow is the number of vehicles passing a specific point in a stated time in stated Direction. In tunnel design, peak hour traffic, vehicles per hour per lane, will be used.

Table 9: Luminance values in cd/m2 in the interior zone (long tunnels).

Stopping Distance (m)	LONG TUNNELS Traffic flow [vehicles / hour / lane]	
	Low	**Heavy**
160	6	10
60	3	6

Table 10: Luminance values in cd/m2 in the second part of the interior zone (very long tunnels).

Stopping Distance (m)	VERY LONG TUNNELS Traffic flow [vehicles / hour / lane]	
	Low	**Heavy**
160	2.5	4.5
60	1	2

For stopping distances lying between the stated figures and intermediate traffic flows (between low and heavy), linear interpolation may be used.
Traffic flow used in the previous tables may be defined as follows:

Table 11: Traffic flow classification.

Traffic flow (see definition in section 7.5)	One way traffic	Two way traffic
High	> 1500	> 400
Low	< 500	< 100

7.6 Luminance in the exit zone

In order to ensure adequate direct illumination of small vehicles and sufficient rear vision via mirrors, the exit zone shall be illuminated in the same way as the interior zone of the tunnel. In situations where additional hazards are expected near the exit of the tunnel and in tunnels where the interior zone is long, it is recommended that the daytime luminance in the exit zone increases linearly over a length equal to the SD (before the exit portal), from the level of the interior zone to a level five times that of the interior zone at a distance of 20 m from the exit portal.

7.8 Parting zone lighting

In case the tunnel is part of an unlit road and the speed of driving is higher than 50 km/h, night-time lighting of the parting zone is recommended:

- If the night-time lighting level in the tunnel is more than 1 cd/m^2
- If different weather conditions are likely to appear at the entrance and at the exit of the tunnel.

Road lighting in the parting zone shall be provided over the length of two stopping distances with road luminance not lower than 1/3 of the night-time luminance in the interior zone of the tunnel.

7.9 Uniformity of luminance

Good uniformity of luminance must be provided on the road surface and on the walls up to a height of 2 m. The lower parts of the walls act as a background for traffic, as does the road.So both must be considered in the same way. A ratio of 0,4 for the minimum to the average value of luminance on the road surface and on the walls up to 2 m in height in clean conditions of the tunnel is recommended. A longitudinal uniformity of 0, 6 along the center of each lane is recommended for the road. Such values of uniformity must be verified for all dimming steps of the lighting installation. Moreover, in the transition zone, as well as in the second half of the threshold zone (and in the exit zone if existing), the luminance uniformity shall be calculated and measured in the central part of each step replacing the continuous variation curve. It is recommended that the above values shall be reached, independently, on the length of the step.

Note The values of 0, 4 and 0, 6 are those corresponding to the values for normal road Lighting given in CIE 115-1995.

8 Night-Time Lighting

(a) If the tunnel is on a section of an illuminated road, the quality of the lighting inside the tunnel shall be at least equal to the level, uniformities and glare of the access road. The uniformity at night of tunnels shall fulfil the same requirements as the daytime lighting.

(b) If the tunnel is a part of an unlit road, the average road surface luminance inside must not be less than 1 cd/m^2, the overall uniformity at least 40% and the longitudinal uniformity at least 60%.

8.1 Emergency Lighting

In the event of a failure in the normal power source that supplies the lighting system, it is recommended that an emergency non interruptible power supply is employed to energize sufficient system luminaires.
Conventionally the "emergency" luminaires form a part of stage 1 being the normal night-time level throughout the tunnel. The emergency configuration by example could consist of: one lamp from a selection of the system luminaires, forming a linear symmetrical and inter spaced series of emergency luminaires, being energized from the non-interruptible power supply source. It is recommended that the average illuminance level of the emergency lighting shall be at least 10 lux with 2 lux being the minimum level at any location within the tunnel.
For recommendations relating to escape lighting in the event of a fire, appropriate references and standards shall be sought by the reader (e.g. EN 1838), as it is not intended for this document to cover the specific demands required by such circumstances.

9 L20 Method

The luminance L20 in the access zone is defined as the average of the luminance values measured in a conical field of view, subtending an angle of 20° (2 x 10°), by an observer located at the reference point and looking towards a centered point at a height equal to one quarter of the height of the tunnel opening. See Figure 6.
This average luminance is conventionally considered as representative of the state of adaptation of the eye of a driver approaching the entrance of the tunnel when he finds himself at the reference point and is used as a basis for computing the luminance in the entrance zone.
Preferably, it can be calculated or it can be measured by means of a luminance meter having a 20° angle of aperture.
This method can be used if one has an image taken at the stopping distance from the portal of the tunnel. In this method, the evaluation of L20, is obtained from a sketch of the environment of the entrance of the tunnel and is calculated by means of the following formula:

$$L_{20} = \gamma \cdot L_c + \rho \cdot L_r + \varepsilon \cdot L_e + \tau \cdot L_{Th} \qquad \textbf{(Eq.9.1)}$$

Where:

L_c = luminance of the sky. γ = % of sky in the 20° field
L_r = *luminance of the road.* ρ = *%of road*
L_e = *luminance of the surroundings*. ε = *% of surroundings*
L_{Th} = *luminance of the threshold zone.* τ = *% of tunnel entrance*

And

$$\gamma + \rho + \varepsilon + \tau = 1 \quad \textbf{(Eq.9.2)}$$

In this formula the value of L_{th} is the unknown to be determined. For stopping distances longer than 100 m, the value of τ is low (below 10%) and given that L_{th} is already low with respect to the other values of luminance, the L_{th} term is negligible.
For a stopping distance of 60 m the following expression can apply:

$$L_{20} = (\gamma \cdot L_c + \rho \cdot L_r + \varepsilon \cdot L_e + \tau \cdot L_{Th}) / (1- k) \quad \textbf{(Eq.9.3)}$$

Ask (see Section 9.1 and Eq.9.5) can never be greater than 0,1, the product $\tau \cdot k$ is negligible, and the expression can be written as follows:

$$L_{20} = \gamma \cdot L_c + \rho \cdot L_r + \varepsilon \cdot L_e \quad \textbf{(Eq.9.4)}$$

Where:

$$\gamma + \rho + \varepsilon < 1$$

If no L values of the surroundings are available, the data for L_c. L_r and L_e (expressed in kcd/m^2) are given in table 12.

Table 12: Examples of luminance's at tunnel portals.

Driving direction (Northern hemisphere)	L_c (sky) kcd/m^2	L_r (road) kcd/m^2	L_e (environment) kcd/m^2			
			Rocks	**Buildings**	**Snow**	**Meadows**
N	8	3	3	8	15 (v) 15 (h)	2
E-W	12	4	2	6	10 (v) 15 (h)	2
s	16	5	1	4	05 (v) 15 (h)	2

(V) Mountainous country with mainly steep surfaces facing drivers
(H) Flat, more or less horizontal, country

NOTE In the southern hemisphere N and S shall be interchanged.

In order to estimate the percentages of the components of L_{20}, it is appropriate to take a photograph of the entrance of the tunnel from the reference point, the axis of the line of sight being oriented towards a point in the center of the entrance at a height equal to one quarter of the height of the tunnel opening.
The circle of intersection of the cone of observation with the vertical plane of the portal is then marked on the photograph and the zones of the components are delineated, their luminance being calculated as a percentage of the area of the circle. The radius of the circle can be calculated, at the scale of the photograph, on the basis of a known dimension of the picture, for example the height of the portal of the tunnel.

Example: (see Figure 6)

Stopping distance: SD = 100 m
Portal height= 5 m (13,7 mm on the photograph)
The sought radius R = SD · tg · 10° = 0,176 · SD
On the scale of the plane of the portal, SD = 100 x 13,7/5 = 274 mm
Therefore R = 0,176 x 27 4 = 48,3mm
In this case, the skyline must not be modified during the construction. Otherwise it will be appropriate to make use of a scale drawing. The photograph or the drawing can be compared with the most similar sketch in Figure 5, whose specific sky percentage is known.

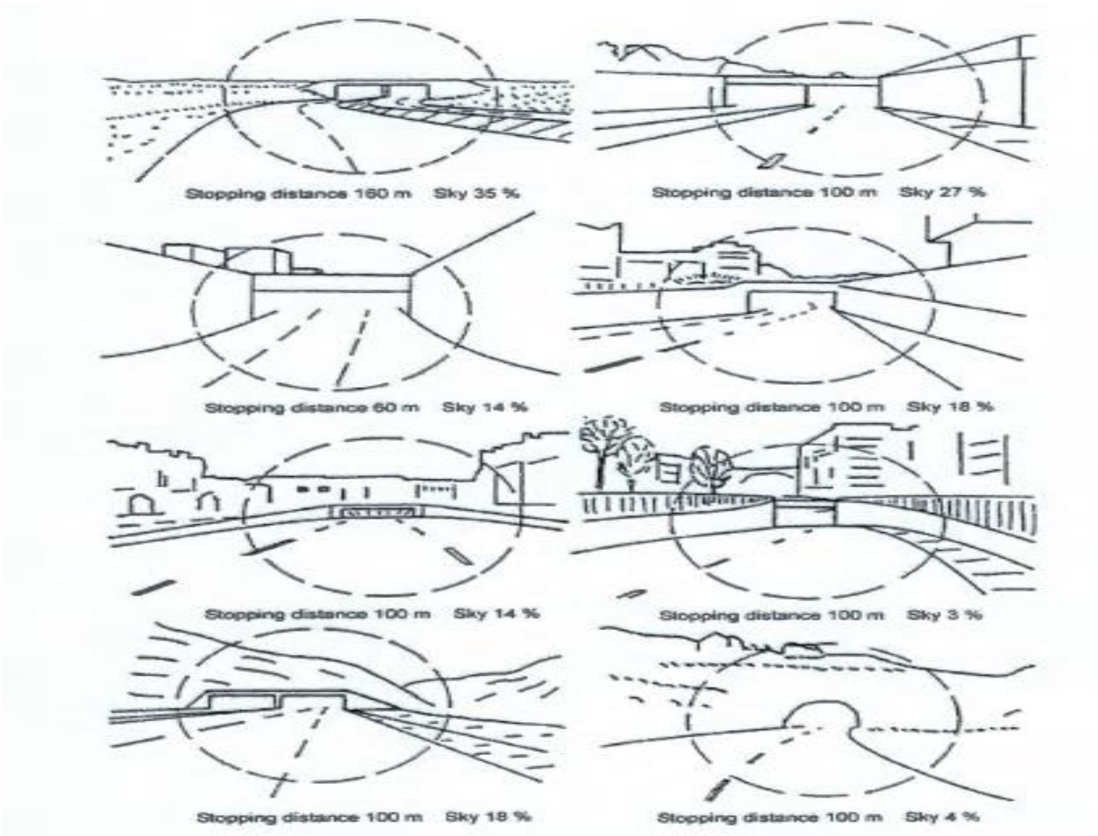

Figure 13: Sky percentages for several configurations.

9.1 Evaluation of the luminance in the threshold zone with the L20 method

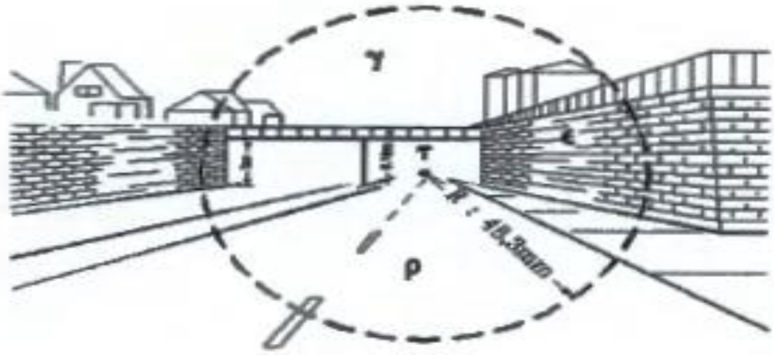

Figure 14: Perspective view of tunnel entrance with superimposed 20° subtended circle.

In order to prevent the sensation of a black hole and to create minimum luminance conditions to obtain sufficient visibility of objects in the threshold zone, the luminance of the road in the threshold zone must reach certain minimum values. These depend on the luminance in the access zone. In practice it is necessary to distinguish a first half within the threshold zone where the luminance of the road is constant and called the threshold luminance (L_{th}) ·

L_{th} can be expressed as a fraction k of L_{20}

$L_{th} = k \cdot L_{20}$ **(Eq.9.5)**

As the proportion taken by the view of the entrance is a function of the length of the access zone, the minimum value of k to be complied with also depends on the stopping distance according to the Table 13

Table 13: L_{th}/L_{20} ratio's for various speeds

Speed (km/h)	k = Lth I L2o
<= 60 km/h	0.05
80 km/h	0.06
120 km/h	0.10

9.2 Stopping Distance

Important parameters for the design of tunnel lighting installations include the speed, volume and composition of traffic flow entering, and passing through the tunnel.
There is a strong, but non-linear relationship between the traffic flow and the accident risk: higher volumes show a higher accident risk (with the exception of very low or very high traffic flows). The extra risk can be counteracted, at least in part, by increasing the light level.
This relationship is established for many types of open roads, and it is assumed that it also holds for tunnels.

One of the most important factors is speed. In practice, road and tunnel designs are such that speed and flow usually are interrelated, as a high design speed is selected for roads for which a high flow is expected. High speeds require better visibility and therefore generally a higher luminance level.

The stopping distance SD that often has to be evaluated for the correct design of the lighting is the sum of two stretches of road:

- the X_0 distance covered during the reaction time;
- The x distance covered during the braking time.

If u is the travelling speed, constant at the beginning of the stopping action,

$X_0 = u \cdot t_0$ **(Eq.9.6)**

Where:

u = vehicle speed limit (u, m/s)

t_0 = the reaction time in seconds.

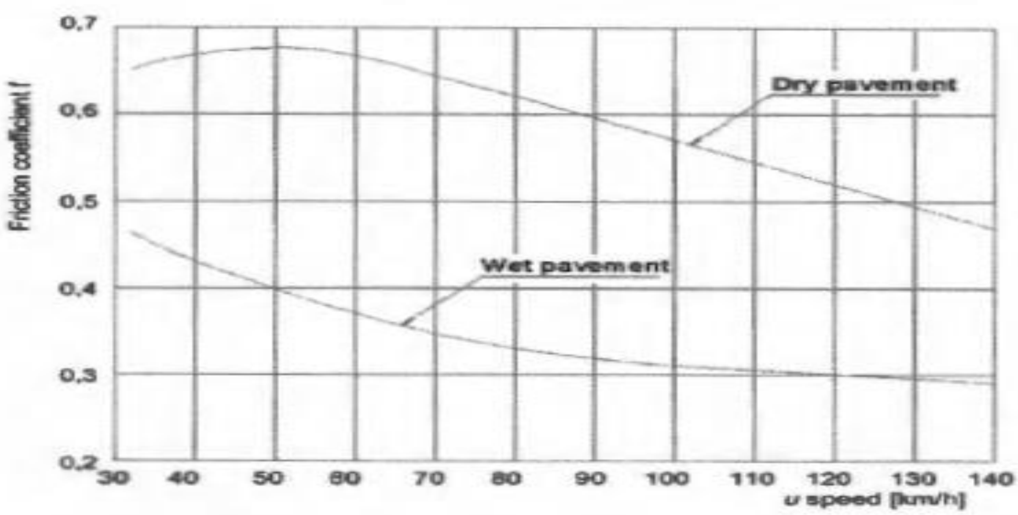

Figure 15: Typical diagrams of the friction coefficient as a function of the speed for dry and wet pavement.

the general formula of the safe stopping distance is given as:

$$SD = X_0 + \frac{u^2}{2.g.(f \pm s)}$$ **(Eq.9.7)**

Where:

f = friction coefficient tire-pavement

g = gravity acceleration (g, m/s^2)

s = road gradient (upward or down ward; ± s, %)

u = vehicle speed limit (u, m/s)

Without any particular value, t_0 can be assumed equal to 1 s and f taken from the curve of Figure 7 for wet pavement as a function of the design speed.

10 Requirements for Street Lighting Lamps, Control Gears and Non-integrated Luminaires / Luminaires

10.1 Energy Efficiency Requirements

- Integrated luminaire and led chips shall comply with energy efficiency requirements specified in table 14

Table 14: Efficacy requirements integrated luminaire and LED chips

Type	Efficacy [lm / W]
Integrated luminaire	≥ 120 and ≥ 85% of LED chips Efficacy
LED chips	≥ 140 at 25 °C

- High pressure sodium shall comply with energy efficiency requirements specified in table 15 and table 16

Table 15: Rated minimum efficacy values for high pressure sodium lamps with Ra ≤ 60

Nominal Lamp Wattage [W]	Rated Lamp Efficacy [Lm/W] - Clear Lamps	Rated Lamp Efficacy [Lm/W] - Not Clear Lamps
W ≤ 45	≥ 60	≥ 60
45 < W ≤ 55	≥ 80	≥ 70
55 < W ≤ 75	≥ 90	≥ 80
55 < W ≤ 75	≥ 100	≥ 95
105 < W ≤ 155	≥ 110	≥ 105
155 < W ≤ 255	≥ 125	≥ 115
255 < W ≤ 605	≥ 135	≥ 130

Table 16: Rated minimum efficacy values for high pressure sodium lamps with Ra > 60

Nominal Lamp Wattage [W]	Rated Lamp Efficacy [Lm/W] - Clear Lamps	Rated Lamp Efficacy [Lm/W] - Not Clear Lamps
W ≤ 55	≥ 60	≥ 60
55 < W ≤ 75	≥ 75	≥ 70
75 < W ≤ 105	≥ 80	≥ 75
105 < W ≤ 155	≥ 80	≥ 75
155 < W ≤ 255	≥ 80	≥ 75
255 < W ≤ 405	≥ 85	≥ 75

- Metal halide lamps shall comply with energy efficiency requirements specified in table 17

Table 17: Rated minimum efficacy values for metal halide lamps

Nominal Lamp Wattage [W]	Rated Lamp Efficacy [Lm/W] - Clear Lamps	Rated Lamp Efficacy [Lm/W] - Not Clear Lamps
W ≤ 55	≥ 70	≥ 65
55 < W ≤ 75	≥ 80	≥ 75
75 < W ≤ 105	≥ 85	≥ 80
105 < W ≤ 155	≥ 85	≥ 80
155 < W ≤ 255	≥ 85	≥ 80
255 < W ≤ 405	≥ 90	≥ 85

- All other High Intensity Discharge lamps shall comply with energy efficiency requirements specified in table 18

Table 18: Rated minimum efficacy values for other high intensity discharge lamps

Nominal Lamp wattage [W]	Rated Lamp Efficacy [lm/W]
W ≤ 40	50
40 < W ≤ 50	55
50 < W ≤ 70	65
70 < W ≤ 125	70
125 < W	75

- For efficiency of ballasts and control gears refer to SASO 2902/2018 ENERGY EFFICIENCY, FUNCTIONALITY AND LABELLING REQUIREMENTS FOR LIGHTING PRODUCTS (PART 2)

10.2 Functionality/Performance LEDs requirements

- The lighting unit shall be designed to operate continuously at external temperature and humidity, taking into account the effects of direct exposure to sunlight and dust storms.
- Life span of LED ships and Luminaire shall be greater than or equal to 70% (L70) after 50,000 hours
- Color rendering (Ra) shall be greater than Ra 70 (Ra ≥ 70)
- Color temperature must be between 3000 - 6000 K
- Vendor shall present ISTMT test results for the luminaire at 50°C which displays the recorded temp within each part of the luminary (LED chips, Lenses, Driver, SPD)
- The color consistency of the light source or luminaire at the time the system is put into operation shall be within a 5 step MacAdam ellipse.
- The value of the **maintenance factor (MF)** shall be set during the design as follows:

  Maintenance factor (MF) equal Lamp Lumen Depreciation for Led chips **(LLD)** × Luminaire Dirt Depreciation **(LDD)** where:

  Lighting unit dirt factor (LDD)

  - Lighting unit dirt factor shall be chosen according to the specification:

Table 19: Lighting unit dirt factor

Environmental zone	Mount-ing height	Maintenance factor					
		Cleaning frequency 12 months	Cleaning frequency 24 months	Cleaning frequency 36 months	Cleaning frequency 48 months	Cleaning frequency 60 months	Cleaning frequency 72 months
E1/E2	≤ 6 m	0.96	0.96	0.95	0.94	0.93	0.92
E1/E2	> 6 m	0.96	0.96	0.95	0.94	0.93	0.92
E3/E4	≤ 6 m	0.92	0.92	0.90	0.88	0.86	0.84
E3/E4	> 6 m	0.96	0.96	0.95	0.94	0.93	0.92

Table 20: Lighting Zone

LIGHTING ZONE	DESCRIPTION
1	Developed areas of national parks, forest land and rural areas.
2	Areas predominately consisting of residential zoning neighborhood business districts with limited nighttime use and residential mixed-use areas.
3	All other areas.
4	High-activity commercial districts in major metropolitan areas as designed by the local land use planning authority.

10.3 Electrical Requirements

- The installation shall have overvoltage protection of 10 kV.
- All luminaires shall have Class I electrical protection.
- The control unit shall be equipped with internal protection to withstand charges and lightning of not less than 4 kV
- Constant Voltage Drivers are not allowed to be used; drivers shall be programmable whether DALI (preferable) or 0-10V dimmable
- Fixture shall include a base for Receptacle 7-pin NEMA Socket capped (short-circuited) to enable future use in smart city application
- The control units (Driver) must operates with voltage (120-277) Vac at 60 Hz
- If the temperature exceeds the permissible limits, the control unit shall reduce the intensity of the lantern lighting gradually until the temperature returns to normal rates; it is not allowed to use control units that turn the lantern fully off when the temperature rises.
- The Power factor value for driver and integrated luminaire shall be ≥ 0.9
- Total Harmonic Distortion of the driver individually < 15%

10.4 Mechanical Requirements

- The luminaire / integrated luminaire units shall have IP66
- The control gear in the lighting fixtures shall have IP66 protection levels
- The luminaire shall have an impact protection rating greater than IK08
- The control unit enclosure shall be designed to withstand a temperature between -10 and +85.

- The painted parts of the lighting unit are exposed to the external environment and shall exceed the fifth classification after 2,500 hours
- The vibration test of roads and bridges (3 Axis vibration test) is performed in accordance with ANSI C136.31-2001, ANSI C136.3-2001. The test shall be in the case of road installation at least 1.5G and in the case of installation on bridges or tunnels at least 3G
- The luminaire shall be built in such a way that it can withstand wind speed of 150 KMph.
- The Surge Protection Device (SPD) shall be able to work normally at a temperature of 80°C (inside the fixture)

10.5 Requirements

- Lamps and integrated luminaires in the scope of this standard shall comply with the marking requirement according to SASO 2902/2018 ENERGY EFFICIENCY, FUNCTIONALITY AND LABELLING REQUIREMENTS FOR LIGHTING PRODUCTS (PART 2)

10.6 Energy Efficiency Label

- Lamps and integrated luminaires in the scope of this standard shall have a label printed directly on the individual packaging of the product) as in Annex B.
- Ballasts/control gears are excluded from the energy labelling requirements.

10.7 Hazardous Materials

- Lamps and integrated luminaires in the scope of this standard shall comply with the maximum hazardous substances limits according to SASO 2902/2018 ENERGY EFFICIENCY, FUNCTIONALITY AND LABELLING REQUIREMENTS FOR LIGHTING PRODUCTS (PART 2)

11 Registration Requirements

11.1 General

Product registration is mandatory, whereby information about registration requirements will be available in the information center of the Saudi Standards, Metrology, and Quality Organization (SASO), and reference shall be made to the separate SASO registration forms and requirements.
The product's information shall be submitted through the registration system electronically via SASO website. The applicant shall fulfill all updated requirements of the electronic registration system and any new requirements, procedures, and regulations required by SASO.
Labels will be automatically published by SASO website after the final registration of a product.

11.2 Type of documents needed for registration under the scope of this standard

To confirm the claims of the applicant, the following documents shall be submitted to SASO during registration from a third party accredited laboratory (ISO 17025) and accepted by SASO:

• datasheets for the Fixture
• datasheets for the Driver
• datasheets for the LED units
• datasheets for the SPD
• LM-79-08 test report accredit
• LM - 80 -08 and TM - 21 - 11 reports
• LM - 82 - 12 report
• LM – 84-14 and TM – 28-14 reports at temperature (50°C) at 2000 hr. or 6000 hr.
• ISTMT test for the luminaire at 50°C which displays the recorded temp within each part of the luminary (LED chips, Driver)
• IP test according to IEC/EN 60598 -1
• IK test according to IEC/EN 62262
• THD test according to IEC 610000-3-2
• Corrosion test according to ISO 9227 for 2500 hours and should obtain Class 5 or above
• 3-axis vibration test according to ANSI CI136.3-2001, ANSI CI136.31-2001 Minimum 1.5G for road and 3G for bridges and tunnels
• Photobiological safety test

ANNEX A
(normative)

– Energy label and classes for lamps and integrated luminaires

A.1 - Determining the energy efficiency class

Lamps and integrated luminaires in the scope of this standard shall comply with the Energy efficiency classes and calculation according to SASO 2902/2018 ENERGY EFFICIENCY, FUNCTIONALITY AND LABELLING REQUIREMENTS FOR LIGHTING PRODUCTS (PART 2).

A.2 - Design and placement of the label

The label is issued automatically by SASO application at the end of the registration process.

Energy efficiency classes shall each be represented as follows with a fixed number of color-coded bars as outlined in Table 21 and illustrated in Figure 8.

Table 21 Energy efficiency class representation

Bar color	Energy efficiency class (Arabic)	Equivalent energy efficiency class (English)
Dark green	أ	A
Green	ب	B
Light green	ج	C
Yellow	د	D
Orange	هـ	E
Red	و	F
Dark red	ز	G
Note For labelling purposes, the Arabic letters shall be used. The equivalent English version is only provided for informational purposes.		

The label shall be printed directly on one side of the individual packaging of the product. The label shall be (43 mm wide and 75 mm high) as in figure 8 without alteration.

A.3 - Information and values contained on the label

The fields (a), (b), (c), (d), (e), (f), (g), (h) and (i) outlined in Figure 8 (given for illustration) shall comply with the following requirements:

- **Field (a):** This field shall display the logo of the Saudi Standards, Metrology and Quality Organization (SASO).

- **Field (b):** This field shall reflect the energy efficiency class, which the product attained, based on its energy efficiency index (EEI).

- **Field (c):** This field shall have a QR code representing the main characteristics of the lamp or integrated luminaire, this may include the following items as a minimum requirements:
  - Manufacturer name
  - Model number
  - Country of origin
  - Luminous flux (lumens)
  - Beam angle (for directional lamps only)
  - Lifetime (h)
  - Rated power (W)
  - EEI (unit-less)
  - Efficacy (lumens/W)
  - Color Rendering Index (Ra)
  - Color temperature (K)
  - Annual electricity consumption (kWh/year)

- **Field (d):** this field identifies the brand name of the product.
- **Field (e):** this field identifies the country of origin
- **Field (f) :** this field identifies the model number
- **Field (g):** this field identifies the lighting type
- **Field (h):** this field identifies the registration number and the standard reference number
- **Field (i):** this field identifies the legal statement

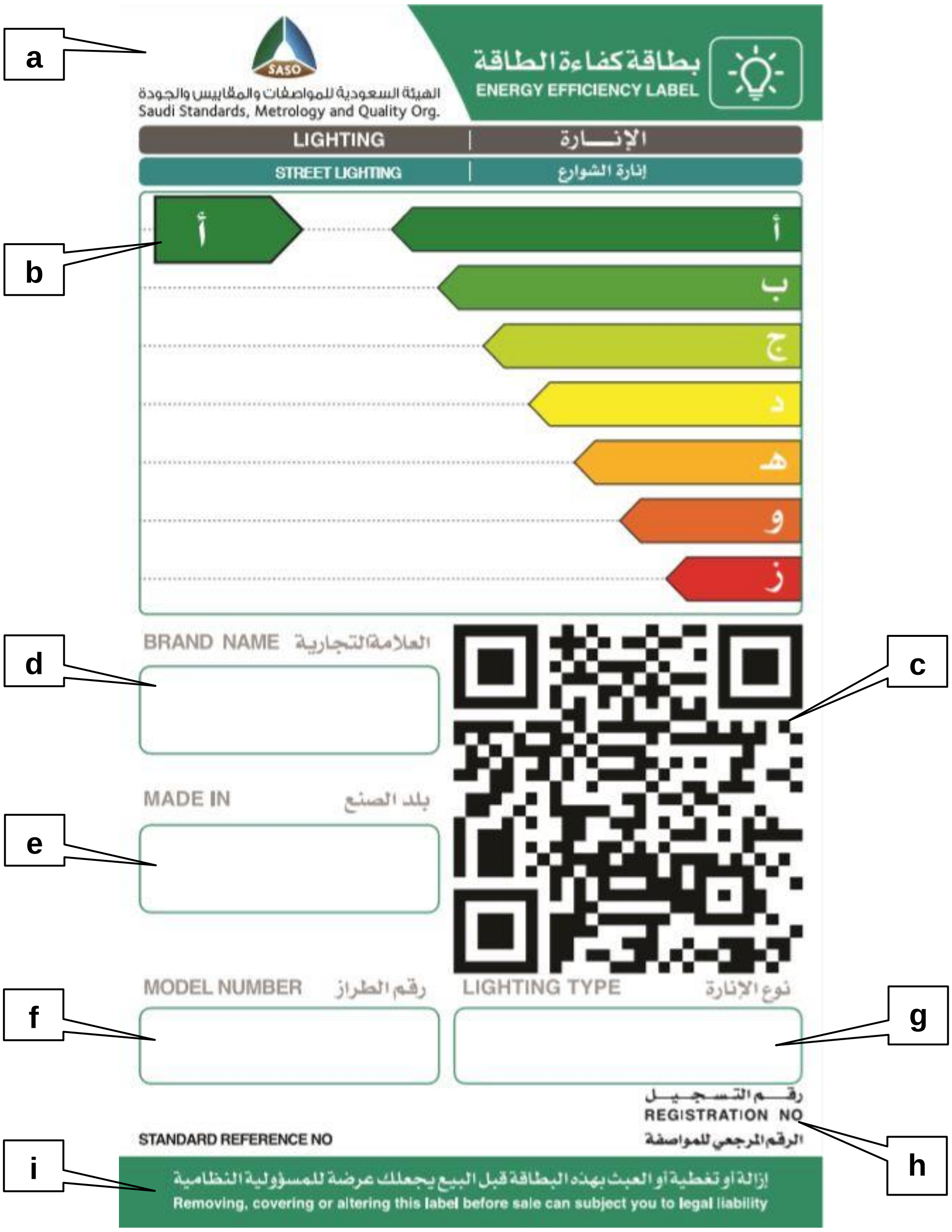

Figure 16: Label for lighting products

ANNEX B

(normative)

– Criteria for market surveillance

The enforcer may draw a sample of batch of a minimum of twenty (20) lamps or ten (10) luminaires of the same model from the same manufacturer, where possible obtained in equal proportion from four randomly selected sources, unless specified otherwise in Table 22.
The model shall be considered to comply with the requirements laid down in this Standard if:

- The lamps in the batch are accompanied by the required and correct product information,
- All parameters listed in Table 22 are met.

Table 22: Criteria applying for market surveillance

Parameter	Procedure
Energy efficiency index[1]	Compliance: The Energy Efficiency Index (EEI) value for lamps in the scope of this Standard shall be less than or equal to the specified values in Tables 2 and 8, when calculated at both rated and average tested power and luminous flux. Furthermore, the average EEI of the sample tested shall be not higher than 10% of the rated EEI, and each lamp in the sample shall have an EEI value within 10% of the sample's average EEI. For Luminaires the MEPS for Energy Efficacy shall be respected for each product; furthermore, the average efficacy of the sample tested shall not be lower 10% of the rated efficacy (in Lumen/W), and each luminaire in the sample shall have an efficacy value within 10% of the sample's average efficacy. Non-compliance: otherwise
Lamp survival factor at 2000h or 6000 h (for LED lamps only)	The test shall end • when the required number of hours is met, or • when more than two lamps fail, whichever occurs first Compliance: a maximum of two out of every 20 lamps in the test batch may fail before the required number of hours Non-compliance: otherwise

[1] The tolerances for variation indicated above relate only to the verification of the measured parameters by the authorities and shall not be used by the supplier as an allowed tolerance on the values in the technical documentation to achieve a more efficient energy class. The declared values shall not be more favorable for the supplier than the values reported in the technical documentation.

Number of switching cycles before failure	The test shall end when the required number of switching cycles is reached, or when more than one out of every 20 lamps in the test batch have reached the end of their life, whichever occurs first Compliance: at least 19 of every 20 lamps in the batch have no failure after the required number of switching cycles is reached Non-compliance: otherwise
Starting time	Compliance: the average starting time of the lamps in the test batch is not higher than the required starting time plus 10 %, and no lamp in the sample batch has a starting time longer than two times the required starting time Non-compliance: otherwise
Lamp warm-up time to 60 % Φ	Compliance: the average warm-up time of the lamps in the test batch is not higher than the required warm-up time plus 10%, and no lamp in the sample batch has a warm-up time that exceeds the required warm-up time multiplied by 1.5 Non-compliance: otherwise
Premature failure rate	The test shall end • when the required number of hours is met, or • when more than one lamp fails, whichever occurs first. Compliance: a maximum of one out of every 20 lamps in the test batch fails before the required number of hours Non-compliance: otherwise
Color rendering (Ra)	Compliance: the average Ra of the lamps in the test batch is not lower than three points below the required value, and no lamp in the test batch has a Ra value that is more than 3,9 points below the required value Non-compliance: otherwise
Lumen maintenance at end of life and rated lifetime (for LED lamps only)	For these purposes, ‘end of life’ shall mean the point in time when only 50 % of the lamps are projected to survive or when the average lumen maintenance of the batch is projected to fall below 70 %, whichever is projected to occur first Compliance: the lumen maintenance at end of life and the lifetime values obtained by extrapolation from the lamp survival factor and from the average lumen maintenance of the lamps in the test batch at 6000 h are not lower than respectively the lumen maintenance and the rated lifetime values declared in the product information minus 10 % Non-compliance: otherwise

Beam angle	Compliance: the average results of the lamps in the test batch do not vary from the declared beam angle by more than 25 % and the beam angle value of each individual lamp in the test batch does not deviate by more than 25 % of the rated value Non-compliance: otherwise
Peak intensity	Compliance: the peak intensity of each individual lamp in the test batch is not less than 75 % of the rated intensity of the model Non-compliance: otherwise
Other parameters	Compliance: the average results of the lamps in the test batch do not vary from the limit, threshold or declared values by more than 10 %. Non-compliance: otherwise

If a model within the registered family of product fails, the registration of all models under the same family of product will be automatically canceled.

ANNEX C

(normative)

– Tests methods for lamp, luminaire and control gears

Table 23: Type of Test Required

Organization	Reference	Title	Measured parameters
IEC	62722-2-1	Luminaire performance - Part 2-1: Particular requirements for LED luminaires	Power Luminous flux CRI, CCT, chromaticity coordinates Beam angle Lumen maintenance Endurance
IEC	IEC 60598-2-3	Luminaires - Part 2-3: Particular requirements - Luminaires for road and street lighting	
IEC	60598-1	Luminaires - Part 1: General requirements and tests	IP
IEC	60529	Degrees of protection provided by enclosures (IP Code)	IP
IEC	62262	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)	IK

IES	LM-79-08	Electrical and photometric measurements of Solid State lighting products	Total Luminous Flux Luminous Intensity Distribution Electrical Power Characteristics Luminous Efficacy (calculated) Color Characteristics (CRI, CCT…)
IES	LM-82-12	Method for characterisation of LED light Engines and Integrated LED lamps for Electrical properties as a function of the temperature	Light output Efficacy Color temperature
IES	LM-84	Measuring Luminous Flux and Color Maintenance of LED Lamps, Light Engines, and Luminaires	
IEC	61000-3-2	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)	Total Harmonic Distortion
IEC	61643-11	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods	Surge protection
IEC	61140	Protection against electric shock - Common aspects for installation and equipment	electric shock classes

ISO	9227	Corrosion tests in artificial atmospheres -- Salt spray tests	Corrosion tests
ISO	10289	Methods for corrosion testing of metallic and other inorganic coatings on metallic substrates — Rating of test specimens and manufactured articles subjected to corrosion tests	Corrosion tests
ISO	4628-2	Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 2: Assessment of degree of blistering	
ISO	4628-4	Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 2: Assessment of degree of blistering	
IEC	62471	Photobiological safety test	