TECHNICAL SPECIFICATION

NMF01:2024 LED luminaires – requirements

DRAFT

Edition 5.0 10.6.2024

NMF – Nordic co-operation group in the field of road equipment

NMF – Nordiskt Möte för Förbättrad vägutrustning

Contents

Foreword

This Technical Specification presents the requirements for outdoor LED luminaires. This publication has been drafted in accordance with the ISO/IEC Directives, Part 2 with the following supplement:

- notes concerning only a certain road authority or authorities may also contain requirements.

This document supersedes *NMF01:2023 LED luminaires – requirements, Edition 4.1, 27.6.2023.*

LED luminaires shall meet the requirements set out in this Technical Specification at the latest by 31.12.2024.

In this Technical Specification, the following print types are used:

- requirements: Arial type.
- references: *italic type*.
- notes: smaller Arial type.

This publication was prepared by a working group:

Petter Hafdell	Swedish Transport Administration
Joakim Frank	Swedish Transport Administration
Arne Jørgensen	Norwegian Public Roads Administration
Thomas Lind Hansen	Danish Road Directorate
Aleksanteri Ekrias	A-Insinöörit Suunnittelu Oy (representing the Finnish Transport Infrastructure Agency)

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Introduction

This Technical Specification has been prepared to achieve consistency, clarity and increased quality in all types of procurements for lighting on roads and in railway areas. The Specification has four main aims:

- to create a basis for improvement of national guidelines by harmonizing requirements for LED luminaires in the Nordic countries,
- to have a greater effect on the market as harmonised requirements for LED luminaires,
- to ease and increase the interaction with the manufacturers and
- to enforce a level of quality consistency of products available on the market in Nordic countries.

This Technical Specification is based on the previous edition of this document *NMF01:2023 LED luminaires – requirements, Edition 4.1, 27.6.2023* and current national guidelines of four road authorities: the Swedish Transport Administration, the Norwegian Public Roads Administration, the Danish Road Directorate and the Finnish Transport Infrastructure Agency. Furthermore, the publication is based on ongoing CIE technical committee work, current ISO, IEC and CEN standards and standard drafts, Zhaga Consortium publications as well as experiences from different outdoor lighting procurements. The purchasers, tenderers, lighting designers, manufacturers and contractors have been heard during the preparation stage of this document.

1 Scope

This Technical Specification presents the technical requirements for LED luminaires used on roads and in railway areas in Sweden, Norway, Denmark and Finland. This includes road lighting, tunnel lighting, lighting under bridges, underpass lighting, decorative lighting and railway lighting. Escape route direction signs are not in the scope of this document.

The requirements for LED luminaires presented in this publication shall be followed in all forms of contracts in design, new construction, rehabilitation and maintenance of lighting on roads and in railway areas.

Target groups for this Technical Specification are purchasers, tenderers, lighting designers, manufacturers and contractors.

2 Normative references

The documents introduced in Bibliography, in whole or in part, are normatively referenced in this document and are indispensable for its application.

For dated references, only the edition (or revision) cited applies. The dated reference includes all amendments to the referenced document made after the publication of the edition (or revision).

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the standards *CIE S 017/E:2020*, *EN 60529:1992, EN IEC 60598-1:2021, EN 62262:2011, IEC 62717:2014*, *IEC 62722-1:2022* and *IEC 62722-2-1:2023* as well as the following apply.

NOTE 1: The terms and definitions given in the *CIE S 017/E:2020* are published on https://cie.co.at/e-ilv.

3.1
road lighting
functional lighting for roads, streets, footways and cycleways

Note 1 to entry: If a floodlight is used to illuminate a road section, it is considered to be a road luminaire.

3.2
tunnel lighting
functional lighting for tunnels. Tunnel lighting includes normal lighting, ~~standby~~ safety lighting and evacuation lighting.

3.3
railway lighting
functional lighting for railway platforms (open parts and covered parts) and railway yards

3.4
lighting under bridges
lighting of a road section under bridge intended for drivers of motorized vehicles

3.5
underpass lighting
lighting of a footway or a cycleway section under road intended for pedestrians and pedal cyclists

3.6
decorative lighting
lighting that is purely ornamental and installed for aesthetic effect. Decorative lighting shall not

include functional lighting.

Note 1 to entry: Usually means lighting fixtures ~~provided~~ primarily intended to enhance the appearance of public areas ~~with a public use or pedestrian orientation,~~ and navigation within those areas, or to highlight important ~~key~~ architectural elements, landscaping, and similar design elements.

3.7
rated maximum ambient temperature
***t*$_a$**
temperature assigned to a luminaire by the manufacturer to indicate the highest sustained temperature in which the luminaire may be operated under normal conditions

3.8
external wiring
wiring generally outside a luminaire

Note 1 to entry: In outdoor lighting, usually a cable between the luminaire's and the column's wiring blocks.

Note 2 to entry: External wiring is not necessarily outside a luminaire for its full length.

~~**3.9**~~
~~**rated useful lifetime**~~
~~time over which the luminaire is expected to function as designed~~

~~Note 1 to entry: Generally defined by a client.~~

~~**3.9**~~
~~**maximum expected control gear failure rate**~~
~~maximum value for the expected control gear failure rate for the given rated useful lifetime of the luminaire~~

3.9
group replacement
replacement of many components at one chosen time in an installation

3.10
spot replacement
replacement of a single component at one chosen time in an installation

3.11
luminaire group replacement interval
planned time between group replacement of luminaires

3.12
constant light output
functionality to constantly adjust the luminous flux of the light source based on the known or predicted depreciation behavior of the light source to enable a constant luminous flux over time

Note 1 to entry: Generally abbreviated to CLO.

3.13
CLO lifetime
time over which the CLO control ensures a constant luminous flux

3.14
luminaire cleaning interval
planned time between cleaning of (parts of) luminaires

Note 1 to entry: In outdoor lighting cleaning usually indicates cleaning of the luminaire's optics e.g. luminaire's

flat glass.

3.15
luminaire extension module (Z-LEX-M)
separate device defined by the *Zhaga Book 18:2021, Edition 3.0*, that provides an interface between the electronic control gear of a luminaire and the lighting control system, other system or other modules

Note 1 to entry: Can be installed to the luminaire extension receptacle (Z-LEX-R) by means of a twist-lock.

3.16
luminaire extension receptacle (Z-LEX-R)
socketed device defined by the *Zhaga Book 18:2021*, *Edition 3.0,* that enables an installation or replacement of the luminaire extension module (Z-LEX-M) without tools, and enables communication between the luminaire extension module (Z-LEX-M) and the luminaire electronic control gear

3.17
luminaire extension cap (Z-LEX-C)
separate unit defined by the *Zhaga Book 18:2021*, *Edition 3.0,* which can be attached to the luminaire extension receptacle (Z-LEX-R)

Note 1 to entry: luminaire extension cap does not hold any functionality and is used to cover the luminaire extension receptacle (Z-LEX-R) in case no luminaire extension module (Z-LEX-M) is used.

3.18
Annual Average Daily Traffic (AADT)
term used to provide the projected future average traffic volume in both directions on a section of road

3.19
DALI (Digital addressable lighting interface)
DALI is an industry-standardized protocol defined by the standard *EN IEC 62386*

Note 1 to entry: The standard *EN IEC 62386* is published in multiple parts, with several new parts in development.

Note 2 to entry: DALI-2 is based on the second edition of the standard *EN IEC 62386*, which also includes control devices.

3.20
stand-alone dimming
lighting control that is integrated into the electronic control gear of a luminaire and does not require any external command

Note 1 to entry: Is usually preprogrammed.

3.21
flat glass
an even surface, which protects LEDs and optics of a luminaire

3.22
curved glass
a gently curving surface, which protects LEDs and optics of a luminaire

Note 1 to entry: Is usually made of glass and created by bending.

3.23
LED strip
a non-integrated LED light source which needs a separate electronic control gear to operate

Note 1 to entry: Is usually a circuit board on top of which LED chips are mounted. The circuit board provides a structural base of the LED strip, a path for heat dissipation and an electricity supply through its circuitry.

Note 2 to entry: In outdoor environments an LED strip is usually sealed to protect the circuit board against intrusion from foreign matter (dirt etc.) and moisture. The LED strip can also be used with different range of profiles for installation, protection and heat dissipation.

3.24
Flicker $\boldsymbol{P_{st}^{LM}}$
the metric for flicker, where *st* stands for short-term flicker indicator and *LM* for light flickermeter method

Note 1 to entry: Unless otherwise specified, the P_{st} evaluation time is 10 min in accordance with *EN 61000-4-15:2013.*

Note 2 to entry: The light flickermeter is based on the *EN 61000-4-15:2013* specifications.

3.25
DiiA (Digital Illumination Interface Alliance)
The Digital Illumination Interface Alliance (DiiA) is an open, global consortium of lighting companies

3.26
Zhaga Consortium
a global lighting-industry organization that aims to standardize interfaces of components of LED luminaires

3.27
D4i
an extension of the DALI-2 certification program that brings standardization to small DALI networks inside luminaires

3.28
evacuation lighting
lighting whose function is to guide tunnel users to evacuate the tunnel on foot in case of emergency circumstances such as fire

3.29
evacuation route lighting
lighting provided to ensure that the means of evacuation can be identified and safely used when the location is occupied

Note 1 to entry: Evacuation route marker lights or LED strips, which are used to guide pedestrians and delineate an evacuation route to an emergency exit.

3.30
emergency exit lighting
lighting to make emergency exits visible and identifiable

Note 1 to entry: Emergency exit marker lights or LED strips, which are used to delineate the frame of an emergency exit.

4 Symbols, units and abbreviations

The symbols, units and abbreviations in Table 1 apply.

Table 1. Symbols, units and abbreviations.

Symbol/ abbreviation	Description	Unit
CLO	constant light output (see 3.12 and 7.6)	-
t_a	rated maximum ambient temperature (see 3.7)	°C
t_q	rated ambient performance temperature value (see *IEC 62722-2-1:2023*)	°C
R_a	~~rated~~ general colour rendering index (see *CIE S 017/E:2020*)	-
T_{cp}	~~rated~~ correlated colour temperature (see *CIE S 017/E:2020*)	K
L_x	median useful life (see *IEC 62722-2-1:2023*) for *x* % remaining luminous flux	h
x	luminous flux maintenance factor (see *IEC 62722-2-1:2023*)	-
AFV	abrupt failure value at median useful life L_x (see *IEC 62722-2-1:2023*)	%
η_l	luminaire luminous efficacy (see *IEC 62722-2-1:2023*)	lm/W
f_m	maintenance factor (see 7.4)	1
f_{LF}	luminous flux factor (see 7.5 and 7.6)	1
f_{LM}	luminaire maintenance factor (see 7.7)	1
Φ_L	luminaire luminous flux	lm
Φ_{CLO}	CLO-corrected luminaire luminous flux (see 7.6)	lm
Φ_e	luminaire luminous flux at the end of ~~rated~~ median useful~~useful~~ life~~time~~ (see 7.6)	lm
Φ_i	initial luminaire luminous flux (see 7.6)	lm
H_M	luminaire mounting height (*CIE S 017/E:2020*)	m
DALI	Digital Addressable Lighting Interface (see 3.19)	-
DiiA	Digital Illumination Interface Alliance (see 3.25)	-
λ	circuit power factor (see *IEC 62384:2020*)	1
AADT	Annual Average Daily Traffic (see 3.18)	veh/d
P_{st}^{LM}	metric for flicker (see 3.24)	-

5 Light sources in lighting installations

In this publication, light sources used in luminaires are considered to contribute to the performance of the luminaire as a system. No individual requirements for the light sources as such are stated.

When constructing new lighting and in the rehabilitation of current lighting installations only the LED luminaires shall be used.

For general road, tunnel and railway lighting, only phosphor-converted inorganic LED packages producing white light shall be used.

6 Safety requirements

6.1 Low Voltage Directive

A luminaire shall comply with the *Low Voltage Directive 2014/35/EU*, and it shall fulfil the luminaire safety requirements specified in the Directive in accordance with the standards mentioned in Table 2. Standards other than those mentioned in Table 2 can also be used to demonstrate compliance with the Directive. In that case, sufficient background for demonstrating compliance with the Directive shall be presented.

Fulfilment of the luminaire safety requirements shall be evidenced with a manufacturer's declaration of conformity (DoC) related to the CE marking and its technical documents, or with test results by a conformity assessment body. The conformity assessment body shall comply with the *Regulation (EC) No 765/2008*.

Table 2. Safety standards specified in the Low Voltage Directive 2014/35/EU.

Standard Number	Description	General purpose luminaires [a]	Road and tunnel lighting [b]	Flood-lighting [c]	Evacuation lighting [d]
EN IEC 60598-1:2021	Luminaires - Part 1: General requirements and tests	X	X	X	X
EN IEC 60598-2-1:2021	Luminaires - Part 2-1: Particular requirements – Fixed general purpose luminaires	X			
EN 60598-2-3:2003	Luminaires - Part 2-3: Particular requirements - Luminaires for road and street lighting		X		
EN 60598-2-5:2015	Luminaires - Part 2-5: Particular requirements - Floodlights			X	
EN IEC 60598-2-22:2022	Luminaires - Part 2-22: Particular requirements - Luminaires for emergency lighting				X
EN 62493:2015	Assessment of lighting equipment related to human exposure to electromagnetic fields	X	X	X	X

[a] *Includes LED strips.*

[b] *Also includes street lighting, lighting for pedestrian and cycle areas, ~~standby~~ safety lighting in tunnels etc.*

[c] *Includes areas and objects illuminated by floodlights, for example interchange area lighting, parking area lighting, railway yard lighting, decorative lighting, etc.*

[d] *Includes evacuation route marker lights and emergency exit marker lights in tunnels but does not include LED strips.*

A luminaire shall be equipped with marking in accordance with the standard *EN IEC 60598-1:2021*. The durability of the marking shall fulfil the test requirements defined in the standard *EN IEC 60598-1:2021*.

NOTE 1: Markings to be observed during maintenance should be visible on the outside of a luminaire or behind a cover that is removed during control gear or other component replacement.

A luminaire shall be assessed for blue light hazard according to the technical report *IEC/TR 62778:2014*. The requirement is included in the standard *EN IEC 60598-1:2021*.

The luminaire electronic control gear voltage is 230 V. The luminaire control gear circuit power factor shall be $\lambda \geq 0.90$ for luminaires with a rated input power of ≤ 50 W and $\lambda \geq 0.95$ for luminaires with a rated input power of > 50 W (100 % power, initial luminaire luminous flux Φ_i). The electronic control gear circuit power factor of a dimmed luminaire (dimmed to 20 % of the initial luminous flux Φ_i) shall be $\lambda \geq 0.5$~~6~~0~~.~~ for luminaires with a rated input power of ≤ 50 W and $\lambda \geq 0.60$ for luminaires with a rated input power of > 50 W (100 % power).

A luminaire including all electronics shall operate without malfunctioning at an ambient temperature of -35 ≤ t_a ≤ +25 °C.

NOTE 2: In Danish Road Directorate projects, a luminaire including all electronics shall operate without malfunctioning at an ambient temperature of -20 ≤ t_a ≤ +25 °C.

Road and railway luminaires shall have protection class II in accordance with the standard EN IEC 60598-1:2021.

NOTE 3: In Finnish Transport Infrastructure Agency and the Norwegian Public Roads Administration projects road luminaires shall have protection class I or II in accordance with the standard EN IEC 60598-1:2021.

Tunnel luminaires shall have protection class I or II in accordance with the standard EN IEC 60598-1:2021. Road tunnel evacuation route lighting luminaires and emergency exit lighting luminaires shall have protection class II or III (SELV/PELV) in accordance with the standard EN IEC 60598-1:2021.

The external wiring shall be suitable for use outdoors.

NOTE 4: If the external wiring (see 3.8) is exposed to direct sunlight (for example overhead wiring), the cable sheath should be made of UV resistant material.

For the external wiring of all road lighting installations, the nominal cross-sectional areas of the cable's wires shall be ≥ 1.5 mm^2. The wires shall have stranded conductors according to the standard *EN 60228:2005*.

NOTE 5: Longer external cables may require a higher nominal cross-sectional area due to mechanical strength or electrotechnical requirements, for example 2.5 mm^2. This is also dependent on the cable type used.

NOTE 6: In Finnish Transport Infrastructure Agency projects also wires with solid conductors according to the standard *EN 60228:2005* can be used.

The external cable type shall be such that it remains undamaged when pulled through a normal column and bracket or when it is bent permanently with a bending radius of at least three times the cable diameter. For the requirements above, the lowest permitted handling ambient temperature is t_a = -15 °C.

In road lighting installations the external cable between the luminaire's and the column's wiring blocks shall not be equipped with a cable connector.

NOTE 7: In Danish Road Directorate catenary lighting projects the external cable can be equipped with a cable connector.

6.2 Electromagnetic Compatibility Directive

A luminaire shall comply with the *Electromagnetic Compatibility (EMC) Directive 2014/30/EU*, and it shall fulfil the EMC requirements specified in the Directive in accordance with the standards mentioned in Table 3. Standards other than those mentioned in Table 3 can also be used to demonstrate compliance with the Directive. In that case, sufficient background for demonstrating compliance with the Directive shall be presented.

Fulfilment of the EMC requirements shall be evidenced with a manufacturer's declaration of conformity (DoC) related to the CE marking and its technical documents, or with test results by a conformity assessment body. The conformity assessment body shall comply with the *Regulation (EC) No 765/2008*.

Table 3. EMC standards specified in the Electromagnetic Compatibility (EMC) Directive 2014/30/EU.

Standard Number	Description	General purpose luminaires [a]	Road and tunnel lighting [b]	Flood-lighting [c]	Evacuation lighting [d]
EN IEC 55015:2019	Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment	X	X	X	X
EN IEC 61000-3-2: 2019	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)	X	X	X	X
EN 61000-3-3:2013	Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection	X	X	X	X
EN IEC 61547:2023	Equipment for general lighting purposes. EMC immunity requirements.	X	X	X	X

[a] *Includes LED strips.*

[b] *Also includes street lighting, lighting for pedestrian and cycle areas, safety ~~standby~~ lighting etc.*

[c] *Includes areas and objects illuminated by floodlights, for example interchange area lighting, parking area lighting, railway yard lighting, decorative lighting, etc.*

[d] *Includes tunnel evacuation lighting, railway tunnel evacuation lighting, etc.*

The surge immunity of a luminaire shall be at least 6 kV in differential mode and 10~~8~~ kV in common mode according to the standard *EN IEC 61547:2023*. ~~The test shall be performed according to the standard *EN 61000-4-5:2014* using a 1.2/50 µs – 8/20 µs combination wave with a 2 Ω source impedance in differential mode and a 12 Ω source impedance in common mode.~~

For installations with ~~overhead cabling or~~ high masts (H_M > 20 m), the surge immunity of a luminaire shall be at least 10 kV in differential mode and 10 kV in common mode according to the standard *EN IEC 61547:2023*.

NOTE 1: To obtain the ~~this~~ requirements above, a separate surge protective device can be applied.

If a separate surge protective device is used to meet the surge immunity requirements, it shall be tested in accordance with the standard EN 61643-11:2013. ~~In that case the test shall be performed according to the standard EN 61643-11:2013, test class III, using a 1.2/50 µs – 8/20 µs combination wave with a 2 Ω generator impedance and the surge immunity requirement shall correspond to the open source voltage.~~

NOTE 2: For luminaires with external control gear, the overvoltage protection should be located before the external control gear.

~~NOTE 3: The overvoltage protection in tunnel lighting, railway tunnel lighting, ceiling lighting (e.g. covered part of railway platforms), lighting under bridges and underpass lighting can be in a technical room or operation room and should protect the lighting system in general.~~

The surge immunity requirements stated above do not apply to tunnel lighting, railway tunnel lighting, ceiling lighting (e.g. covered part of railway platforms) and decorative lighting. The minimum surge immunity requirements for these lighting systems are in accordance with the

standard *EN IEC 61547:2023*.

NOTE 3: In 230 V IT system maximum continuous operating voltage *U*c of a surge protection device should be:

- type 2: ≥ 350 V and
- type 3: ≥ 440 V between L – PE and ≥ 275 V between L – L (phase to phase).

Tunnel luminaires (including safety ~~standby~~ lighting and evacuation lighting) shall not cause radiated disturbance in the Tetra frequency band (380…500 MHz, private Tetra frequency included). The radiated disturbance generated shall not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended.

NOTE 4: Conformity related to the relevant harmonised standards does not guarantee that luminaire is not able to cause radiated disturbance in the Tetra frequency band, and thereby violate the essential requirements stated in *Electromagnetic Compatibility (EMC) Directive 2014/30/EU* Annex I.

NOTE 5: Further guidance on the EMC assessment where harmonised standards do not exist or are not fully applied is given in the Annex 3 of the publication *Guide for the EMCD:2018*.

NOTE 6: This is especially valid in, but not limited to, road tunnels with Tetra coverage.

NOTE 7: It should be noted that Tetra emergency communications are not a specific Nordic phenomenon, as Tetra emergency communication in the same frequency band is used in almost all countries in Europe.

6.3 RoHS 2 Directive

A luminaire shall comply with the *Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS 2)* and it shall fulfil the requirements specified in the Directive in accordance with the standard *EN IEC 63000:2018*. Standards other than *EN IEC 63000:2018* can also be used to demonstrate compliance with the Directive. In that case, sufficient background for demonstrating compliance with the Directive shall be presented.

Fulfilment of the RoHS 2 requirements shall be evidenced with a manufacturer's declaration of conformity (DoC) related to the CE marking and its technical documents, or with test results by a conformity assessment body. The conformity assessment body shall comply with the *Regulation (EC) No 765/2008*.

7 Performance requirements

7.1 Photometric data and initial luminous flux of a luminaire

A luminaire shall have the light distribution characteristics in the *C* - *γ* - system measured in accordance with the standards *EN 13032-1:2004* and *EN 13032-4:2015.*

For all luminaires, the angular intervals in vertical planes (*γ*) and photometric azimuth (*C*) shall be according to the standard *EN 13201-3:2015*.

The light distribution files shall be delivered in EULUMDAT file format.

The initial luminous flux Φ_i of a luminaire shall not be lower than -10 % of the initial luminous flux Φ_i of the light distribution file representing the luminaire. The requirement includes all measurement uncertainties described in the standard *EN 13032-4:2015*.

NOTE 1: If the light distribution file representing the luminaire is not requested, the initial luminous flux Φ_i of a luminaire should not be lower than -10 % of the value provided in the technical specifications.

7.2 Performance requirements for luminaires

A luminaire shall comply with the *Commission Regulations (EU) 2019/2020* and *(EU) 2021/341*.

The technical specifications and the performance of a luminaire shall be presented in accordance with the standards *IEC 62722-1:2022*, *IEC 62722-2-1:2023* and *IEC 62717:2014,* taking the specifications of this document into account. A recommendation for the format used in presenting the technical specifications and the performance of a luminaire can be found in Annex A.

7.3 Median~~Rated~~ useful life~~time~~ of a luminaire

The median~~rated~~ useful life L_x~~time~~ (h) of a luminaire is defined by the client. If no value is given by the client, the median ~~rated~~ useful life~~time~~ of the luminaire is the value presented in Table 4.

NOTE 1: The luminaire group replacement interval of an installation should follow the median ~~rated~~ useful life~~time~~ of the luminaire.

~~The *h* value of the median useful life L_x shall follow the given rated useful lifetime of the luminaire.~~ The manufacturer shall provide the rated luminous flux maintenance factor ~~*value x*~~ at the rated ambient temperature t_q = 25 °C for the ~~given~~ required median ~~rated~~ useful life~~time~~ of the luminaire according to the standards *IEC 62722-2-1:2023* and *IEC 62717:2014*. The manufacturer shall also provide the rated abrupt~~expected control gear~~ failure value AFV (%) of the luminaire at ~~rate for the given~~ median ~~rated~~ useful life~~time of the luminaire~~. The rated luminous flux maintenance factor ~~*value x*~~ and the rated ~~maximum expected control gear failure rate~~ abrupt failure value AFV (%) shall fulfil the requirements presented in Table 4.

Table 4. Requirements for a luminaire's median ~~rated~~ useful life (h)~~time~~, ~~maximum~~ luminous flux maintenance factor x ~~degradation~~ and abrupt failure value AFV (%) at median useful life~~maximum expected control gear failure rate~~.

Luminaire type	**Median useful life L_x (h)~~Rated useful lifetime~~**	**~~Maximum~~ Luminous flux maintenance factor *x* (%) at median useful life~~ degradation~~**	**~~Maximum expected control gear~~ Abrupt failure value AFV (%) at median useful life~~rate~~**
Road luminaire, tunnel luminaire, railway yard luminaire, luminaires on open parts of platforms	100 000~~ h~~	≥ 90~~L_{90}~~	≤ 10~~ %~~
Luminaire under bridge, underpass luminaire	100 000~~ h~~	≥ 80~~L_{80}~~	≤ 10~~ %~~
Floodlight, decorative lighting luminaire, ceiling luminaire (e.g. covered parts of railway platforms), evacuation route lighting luminaire and emergency exit lighting luminaire [a]	50 000~~ h~~	≥ 80~~L_{80}~~	≤ 10~~ %~~
[a] *If evacuation route lighting luminaires and emergency exit lighting luminaires are on during normal conditions, the minimum requirements shall be 100 000 h, ≥ ~~L~~80~~$_{80}$~~ and ≤ 10 %.*			

7.4 Maintenance factor

The maintenance factor f_m shall be employed in lighting designs to ensure that the target requirements are met throughout the median ~~rated~~ useful life~~time~~ of a luminaire when the luminaire is maintained according to the defined maintenance schedule.

The maintenance factor f_m is determined using the following formula:

$$f_m = f_{LF} \cdot f_{LM} \qquad (1)$$

where

f_m is the maintenance factor,
f_{LF} is the luminous flux factor (see 7.5 and 7.6), and
f_{LM} is the luminaire maintenance factor (see 7.7).

EXAMPLE 1: Road lighting. The given median ~~rated~~ useful life~~time~~ of a luminaire = 100 000 h, the received luminous flux maintenance factor ~~x degradation value~~ = 90 ~~L_{90}~~, no CLO, the luminaire cleaning interval every 6 years.

$f_M = 0.90 \cdot 0.90 = 0.81$

In outdoor lighting, the survival factor and the surface maintenance factor are not considered in the determination of the overall maintenance factor.

NOTE 1: In outdoor lighting, it is usually not possible to compensate for the failed luminaire by increasing the initial luminous flux of other luminaires due to the survival factor. For that reason, the survival factor is not considered in the determination of the maintenance factor f_m (or set to 1.0). For failed luminaires, a spot replacement regime is applied with agreed response times.

NOTE 2: In outdoor lighting the surface maintenance factor is not considered (or set to 1.0) because depreciations of surface reflections of the area of interest are usually not known (for example, road surface and surroundings of a carriageway). In tunnels and underpasses, the effects of the surface maintenance factor are compensated for by the use of a lower luminaire maintenance factor; see Table 5.

7.5 Luminous flux factor

The luminous flux factor f_{LF} describes the depreciation of the luminous flux over time due to the ageing of a luminaire during regular operation (this excludes external factors such as for example dirt, optics and flat glass). This is defined as the ratio of depreciated luminous flux to the initial luminous flux Φ_i.

For outdoor lighting, the luminous flux factor f_{LF} shall be determined at luminaire level.

The f_{LF} shall be determined based on the median ~~rated~~ useful life~~time~~ of a luminaire (see 7.3) and shall be provided by the manufacturer according to the standard *IEC 62722-2-1:2023* and section 7.3 of this document. In this case *x* of the the median useful life L_x equals f_{LF}.

EXAMPLE 1: The median useful life L_{90} = 100 000 h translates to 90 % remaining luminous flux at 100 000 h, which results in f_{LF} = 0.90.

NOTE 1: If constant light output control is used, the luminous flux factor f_{LF} should be determined based on section 7.6.

7.6 Determination of the luminous flux factor in case of constant light output control

A constant light output (CLO) control of a luminaire shall always be used, if available, for the selected luminaire type.

The CLO lifetime shall be the same as the median ~~rated~~ useful life~~time~~ of a luminaire, see 7.3.

NOTE 1: In CLO installations, light source behaviour and electronic control gear behaviour are interlinked. In the case of premature control gear failure, the replaced components should match the performance and behaviour of the original part prior to failure.

Luminaires utilising a constant light output control adjust the luminous flux based on the known or predicted depreciation behaviour of the light source to enable a constant luminous flux over time. This is realised by initially dimming the light source to the predicted end-of-life flux and increasing the current (and as such the power consumption) over time to compensate for the depreciation in luminous flux due to ageing of the light source.

NOTE 2: If CLO control is used, the manufacturer should provide the average rated input power of the luminaire (W) for the median ~~rated~~ useful life~~time~~ of the luminaire and the rated input power of the luminaire (W) at the end of median~~rated~~ useful life~~time~~.

NOTE 3: The increasing power consumption over time should be considered in the electrical design and energy calculations for the installation, but also when comparing different luminaires with and without CLO.

NOTE 4: In the context of this TS, CLO refers to the standalone feature based on known or predicted depreciation and does not include external input such as sensors. As such, it only applies to the luminous flux factor f_{LF}.

Figure 1 shows a simplified representation of a luminaire not using CLO, based on L_{90} = 100 000 h (i.e. 10 % depreciation after 100 000 hours). Both power and luminous flux are set to their maximum value (point A). Over time, power remains the same (line between point A and B) whereas the luminous flux depreciates to the luminaire luminous flux at the end of the median ~~rated~~ useful life~~time~~ Φ_e (line between point A and C, 90 % of initial luminaire luminous flux Φ_i).

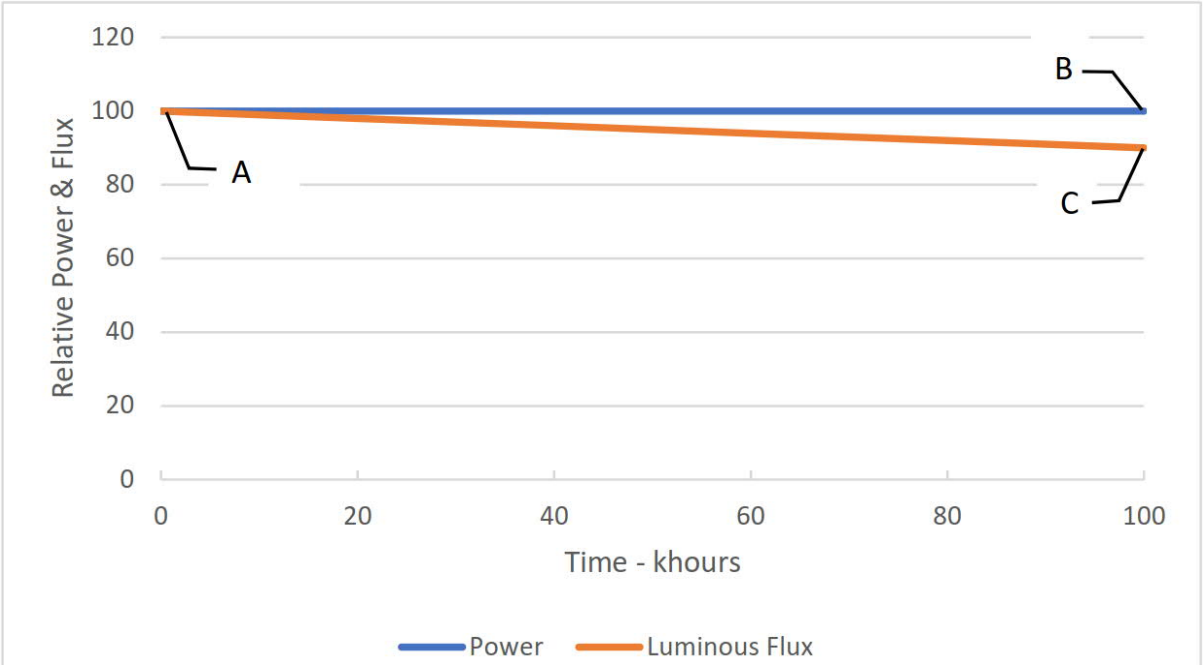

Figure 1. Illustration of CLO principle using simplified graph representation. A luminaire without CLO control.

Figure 2 shows a simplified representation of the same luminaire, but with CLO control. Both power and luminous flux start at 10 % below their maximum value at 0 h (point D – as in the operation of the luminaire without CLO the total flux depreciation is 10 % at the end of the median ~~rated~~ useful life~~e~~~~etime~~). Over time, luminous flux is kept constant (line between point D and F) by increasing the power (line between point D and E). Note that at the end of median ~~rated~~ useful life~~time~~, both luminaires have the same power consumption (B versus E) and the same luminous flux (C versus F).

In practice, there are two ways CLO luminaire specifications are provided by manufacturers. Depending on which of the two options is used, the luminous flux factor f_{LF} shall be determined differently. The current known options are:

1. the initial (without CLO control) specifications are specified, Figure 1 – point A (in which case the CLO correction needs to be done by using the luminous flux factor f_{LF}, as there was no CLO control),
2. the corrected luminous flux is given, Figure 2 – point D (in which case no correction is needed as this is already represented in the corrected luminous flux, f_{LF} = 1.00).

For CLO luminaires, the luminous flux factor f_{LF} shall be determined as follows:

If $\Phi_L = \Phi_{CLO}$, then $f_{LF} = 1.00$, (2)

If $\Phi_L = \Phi_i$, then $f_{LF} = \Phi_e / \Phi_i$,

where

Φ_L is the specified luminaire luminous flux,
Φ_{CLO} is the CLO-corrected luminaire luminous flux (i.e. Figure 2 – point D),
Φ_e is the luminaire luminous flux at the end of the median ~~rated~~ useful life~~time~~ without CLO control (i.e. Figure 1 – point C),
Φ_i is the initial luminaire luminous flux without CLO control (i.e. Figure 1 – point A).

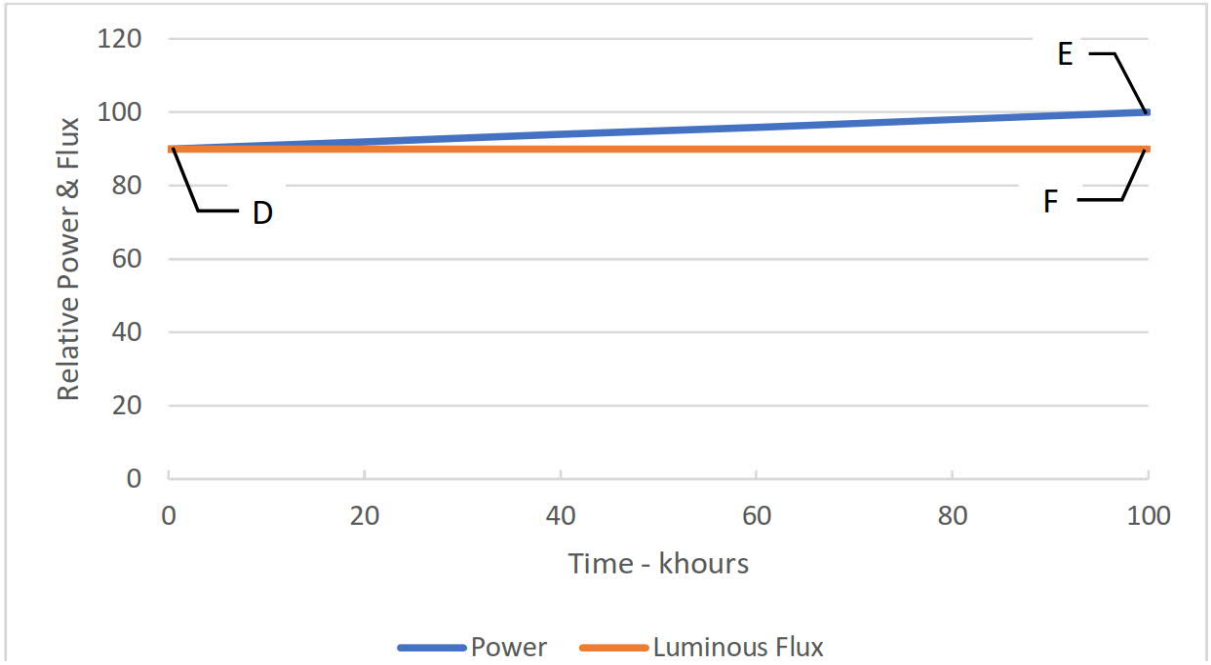

Figure 2. Illustration of CLO principle using simplified graph representation. A luminaire with CLO control.

7.7 Luminaire maintenance factor

The luminaire maintenance factor f_{LM} describes the relative output of a luminaire due to dirt deposited on light sources, optical components or other external factors influencing the luminaire output. The luminaire maintenance factor f_{LM} shall be based upon a luminaire's characteristics and environmental conditions.

The luminaire maintenance factor f_{LM} for outdoor luminaires shall be based upon the combination of luminaire design (rated according to IP code), the environmental pollution category and the luminaire cleaning interval.

The luminaire cleaning interval has a significant impact on the maintenance factor. The minimum requirements for luminaire cleaning intervals for various locations are shown in Table 5. Based on these minimum requirements, the f_{LM} values for different applications are defined in Table 5. The luminaire cleaning interval of the road tunnel is dependent on the annual average daily traffic volume (AADT), tunnel type and tunnel location.

The luminaire cleaning interval and the luminaire maintenance factor f_{LM} shall be defined on the national level or given by the client. If no values are given or defined, the maximum luminaire cleaning interval and the luminaire maintenance factor f_{LM} are the values presented in Table 5.

Table 5. The minimum requirements for luminaire cleaning intervals for various locations and corresponding f_{LM} values.

Location	Luminaire cleaning interval, max	Luminaire maintenance factor f_{LM}
Roads, railway areas, ~~decorative lighting,~~ luminaire mounting height $H_A \geq 4.0$ m	every 6 years	0.90
Roads, railway areas, ~~decorative lighting,~~ luminaire mounting height $H_A < 4.0$ m	every 6 years	0.85
Road tunnels	dependent on the AADT, tunnel type and tunnel location	0.85
Railway tunnels with a brake curve	every 3 years	0.50
Railway tunnels without a brake curve	every 3 years	0.70

7.8 Colour rendering index and colour temperature

The rated values of the luminaire's general colour rendering index R_a and the correlated colour temperature T_{cp} shall be according to Table 6.

~~NOTE 1: Luminaire luminous efficacy increases with increasing correlated colour temperature and decreasing general colour rendering index. Therefore, it is recommended to use 4 000 K correlated colour temperature and $R_a \geq 70$ where no other specific requirements are set.~~

Table 6. The general colour rendering index R_a and the ~~rated~~ correlated colour temperature T_{cp} requirements in various locations.

Location	Correlated colour temperature T_{cp}	Colour rendering index R_a
~~Roads [a,b],~~ Ttunnels	4 000 K	$R_a \geq 70$
Roads [a,b], oOpen parts of railway platforms, railway yards [c]	3 000 K	$R_a \geq 70$
Public areas and covered parts of railway platforms	3 000 K	$R_a \geq 80$

[a] *~~In Swedish Transport Administration and Norwegian Public Roads Administration~~ In Finnish Transport Infrastructure Agency ~~road~~ projects $T_{cp} = 4\,000$ K ~~values 3 000 K and $R_a \geq 70$~~ shall be used.*
[b] *In Danish Road Directorate ~~road~~ projects, values 3 000 K or 4 000 K are specified at the project level.*
[c] *In Finnish Transport Infrastructure Agency projects values 3 000 K and $R_a \geq 80$ shall be used for open parts of railway platforms and values 4 000 K and $R_a \geq 70$ for railway yards.*

The performance requirements specified in Table 6 do not apply to tunnel evacuation lighting, and decorative lighting.

7.9 Chromaticity coordinate values

For luminaires of the same type within a lighting installation, rated chromaticity coordinate values, both initial and maintained, shall fulfil the tolerance requirements presented in Table 7.

Table 7. Tolerance (category) requirements on ~~rated~~ chromaticity coordinate values.

Distance between luminaires within a lighting installation	Colour variation tolerance, size of MacAdam ellipse, centred on the rated colour target	
	Initial	Maintained
< 5 m	5	5
≥ 5 m	7	7

7.10 Luminaire luminous efficacy

The luminaire luminous efficacy shall be according to Table 8.

Table 8. The minimum requirements for luminaire luminous efficacy η_l.

Correlated colour temperature T_{cp}	Colour rendering index R_a	Initial luminaire luminous flux Φ_i (100 % power)	Luminaire luminous efficacy η_l
3 000 K	$R_a \geq 80$	< 2 000 lm	≥ 1050 lm / W
		≥ 2 000 lm	≥ 1150 lm / W
	$R_a \geq 70$	< 2 000 lm	≥ 12015 lm / W
		≥ 2 000 lm	≥ 13025 lm / W
4 000 K	$R_a \geq 70$	< 2 000 lm	≥ 13020 lm / W
		≥ 2 000 lm	≥ 14030 lm / W

The luminaire luminous efficacy requirements shown in Table 8 do not apply to tunnel evacuation lighting and decorative lighting.

7.11 Flicker

The flicker for a luminaire at full load (100 % power, initial luminaire luminous flux Φ_i) and dimmed to 40 % of the initial luminous flux Φ_i shall be $P_{st}^{LM} \leq 0{,}5$. The flicker shall be measured in accordanceing to the technical report *IEC/TR 61547-1:2020*.

7.12 Road tunnel evacuation lighting requirements

The performance requirements for evacuation route marker lights and emergency exit marker lights in tunnels shall be in accordance with the standard *EN 16276:2013.*

If an LED strip is used for an evacuation route lighting, it shall fulfil the following performance requirements:

- the minimum opening of 120 degrees for vertical plane
- the average initial luminaire luminous flux of $200 \leq \Phi_i \leq 250$ lm/m
- the minimum initial luminaire luminous flux of $\Phi_i = 180$ lm/m
- the rated correlated colour temperature $T_{cp} = 4\,000$ K.

NOTE 1: The minimum initial luminaire luminous flux is intended for LED strip sections with connectors.

If an LED strip is used to delineate the frame of an emergency exit and the emergency exit lighting is permanently illuminated, the LED strip shall fulfil the following performance requirements:

- the minimum opening of 120 degrees for vertical plane
- the average initial luminaire luminous flux of $200 \leq \Phi_i \leq 250$ lm/m
- the minimum initial luminaire luminous flux of $\Phi_i = 180$ lm/m
- green colour according to the standard *ISO 3864-4:2011*.

In emergency circumstances if an LED strip is used to delineate the frame of an emergency exit, the LED strip shall fulfil the following performance requirements:

- the minimum opening of 120 degrees for vertical plane
- the average initial luminaire luminous flux of $400 \leq \Phi_i \leq 500$ lm/m
- the minimum initial luminaire luminous flux of $\Phi_i = 360$ lm/m
- green colour according to the standard *ISO 3864-4:2011*.

NOTE 2: The same LED strip can be used for permanent emergency exit lighting and lighting in emergency circumstances by controlling the initial luminaire luminous flux.

During an emergency the emergency exit lighting shall flash (from 0 % to 100 %) to attract the attention of fleeing pedestrians. A frequency of flashing shall be within a range of 1 Hz to 4 Hz with a duty cycle of 50 %.

8 Structural requirements

8.1 General structural requirements

All electronics of a luminaire shall be protected against moisture, condensation and corrosion for the whole median ~~rated~~ useful life~~time~~ of the luminaire.

NOTE 1: Protection against moisture and condensation can usually be achieved by an adequate IP code of enclosures, good luminaire design, and the adequate pressure equalisation of a luminaire housing.

NOTE 2: Adequate pressure equalisation can be achieved by using vents, for example.

The ingress protection rating of a luminaire shall be IP66 in accordance with the standards *EN IEC 60598-1:2021* and *EN 60529:1992*.

NOTE 3: In decorative lighting and on covered parts of railway platforms (ceiling luminaire), luminaires with the ingress protection rating of IP65 can also be used.

The ingress protection rating of a luminaire shall remain IP66 for the whole median ~~rated~~ useful life~~time~~ of the luminaire, including appropriate maintenance.

NOTE 4: This can be achieved by using an elastic material that maintains its characteristics throughout the median ~~rated~~ useful life~~time~~ of the luminaire as the luminaire's seal, for example.

NOTE 5: If glue is required to attach the seal, the glue should not become brittle and cause the luminaire's IP code to deteriorate during use.

Cable entries shall provide the degree of protection against dust or moisture in accordance with the ingress protection rating of the luminaire, when an appropriate external cable is installed.

NOTE 6: For cable entries the degree of protection against dust and moisture can be ensured by using cable glands with adequate IP code or weather and temperature resistant cable TET grommets, for example.

Cable entries shall have rounded edges with a minimum radius of 0.5 mm.

An ~~luminaire~~ electronic control gear within a luminaire shall be protected against moisture and condensation. This protection shall be achieved by either applying conformal coating or potting which entails ~~(~~filling the ~~housing of the~~ control gear housing with a homogeneous and dense mass.~~)~~ The electronic control gear shall operate without malfunctioning at an ambient temperature of -35 ≤ t_a ≤ +25 °C. ~~intended for the operation of the control gear at an ambient temperature of -35 ≤ t_a ≤ +25 °C.~~

A luminaire housing (not including flat glass, seals, vents, nuts, screws, latches etc.) shall be made from die cast aluminium, extruded aluminium or stainless steel.

NOTE 7: A luminaire housing or parts of a luminaire housing, that are not exposed to direct sunlight can also be made from materials other than die cast aluminium, extruded aluminium or stainless steel.

NOTE 8: In Danish Road Directorate projects, a luminaire housing can also be made from other materials. In this case, sufficient background for choosing that material instead of die cast aluminium, extruded aluminium or stainless steel should be provided.

If a luminaire housing is made from stainless steel, the exterior nuts, screws, latches and other fasteners of a luminaire shall be made from stainless steel A4 according to the standard *EN ISO 3506-1:2020*.

The service life of the luminaire housing, post top or side entry fixing equipment, seals, vents, nuts, screws, latches etc. shall be at least the same as the median ~~rated~~ useful life~~time~~ of the luminaire.

The corrosion resistance of a luminaire shall fulfil the requirements of the corrosivity categories of Table 9. The test procedures and duration shall be as specified in Table 9.

Metal components in contact with one another shall be made from metals which lie close to each other in the galvanic series to avoid electrolytic corrosion. If metals do not lie close enough to each other in the galvanic series, a galvanic separation shall be established between the materials to ensure a corresponding corrosion protection.

EXAMPLE 1: Brass or other copper alloys should not be used in contact with aluminium or aluminium alloys.

The cord anchorage of a luminaire shall fulfil the requirements of the standard *EN IEC 60598-1:2021* so that the external cable and wires are relieved from strain, including twisting, when they are connected to the wiring block of the luminaire.

NOTE 9: Cable tie should not be used as the cord anchorage of a luminaire.

Table 9. Corrosivity category requirements for corrosion resistance in different environments and test procedures applied based on the standard EN ISO 12944-6:2018.

Environment	Corrosivity category as defined in EN ISO 12944-2:2017	Durability ranges according to EN ISO 12944-1:2017	Test according to EN ISO 9227:2022 (neutral salt spray test)
Tunnels [a], coastal areas with high salt content [b]	C5	high (H)	1 440 h
Industrial areas and coastal areas with moderate salt content [b]	C4	high (H)	720 h
Other environments	C3	high (H)	480 h

[a] *Corrosivity category requirements do not apply to luminaires with housing made from stainless steel.*
[b] *Distances to the sea are defined at the national level.*

A luminaire shall not be disposable, in other words it shall be possible to easily replace the electronic control gear, LED modules and optics of the luminaire on-site or indoors.

A luminaire shall have no electromechanical parts e.g. motors, ventilators, conventional relays.

8.2 Additional road luminaire requirements

The protection rating of a road luminaire against external mechanical impacts shall be at least IK08 in accordance with the standard *EN 62262:2011*.

NOTE 1: IK code requirements do not include external components, such as luminaire extension module (Z-LEX-M).

A road luminaire shall be equipped with flat glass. The flat glass material shall be glass. The service life of the flat glass shall be at least the same as the median ~~rated~~ useful life~~time~~ of the luminaire. Curved glass luminaires and luminaires with lens modules as the flat glass are not permitted. The lens module refers to a module put in the place of flat glass, with several lenses on the module surface.

NOTE 2: Flat glass is required to ensure a high luminaire maintenance factor f_{LM} value, to ease and to enhance the cleaning of the luminaire, and to reduce glare and obtrusive light produced by the luminaire.

NOTE 3: Glass protects lenses from ultraviolet radiation to some extent.

NOTE 4: The light distribution properties of a luminaire with curved glass or with lens modules as the flat glass change more than those of a luminaire with flat glass, due to dirt.

The flat glass of a road luminaire shall be a part of the sealed luminaire housing.

A luminaire post top or side entry fixing equipment shall be made from die cast aluminium, extruded aluminium or stainless steel. The fixing equipment shall be a closed structure when installed on the lantern fixing.

NOTE 5: A closed structure is required to prevent birds and other external objects from entering the bracket and the column from the luminaire side.

A luminaire shall be mountable on post top lantern fixings of Ø 60 mm and Ø 76 mm and on side entry lantern fixings of Ø 42 mm and Ø 60 mm. The luminaire post top or side entry fixing equipment shall be compatible with the standard *EN 40-2:2005*. The luminaire tilt angle shall be at least 0° and 5° for the post top lantern fixing and at least 0° and -5° for the side entry lantern fixing. The adjustment of the tilting angle shall be done in steps of 2,5° or 5°. The adjustment of the tilt angles shall be instructed by means of the installation instructions and markings made on the luminaire.

NOTE 6: In Danish Road Directorate projects, the luminaire tilt angle can be fixed at 0°.

A control gear of a luminaire shall be placed inside the sealed luminaire housing.

The direction of the catenary luminaire's optics shall be clearly marked on the luminaire and indicated in the installation instructions. The marking shall be visible from the outside of the luminaire when viewed from below.

8.3 Additional requirements for underpass luminaires and luminaires under bridges

If the mounting height of an underpass luminaire or a luminaire under bridge is H_M < 4.0 m, the protection rating of the luminaire against external mechanical impacts shall be at least IK10 in accordance with the standard *EN 62262:2011*. If the mounting height is H_M ≥ 4.0 m, the protection rating of the luminaire against external mechanical impacts shall be at least IK08 in accordance with the standard *EN 62262:2011*.

If the mounting height of a luminaire ~~under bridge~~ is H_M < 4.0 m, the luminaire shall not be openable without tools.

NOTE 1: The usage of anti-vandal fasteners is recommended.

8.4 Additional road tunnel luminaire requirements

A luminaire housing (not including flat glass, seals, vents, nuts, screws, latches etc.) of a tunnel luminaire shall be made from stainless steel type 1.4404 according to the standard *EN 10088-1:2021*~~4~~, die cast aluminium or extruded aluminium. If a tunnel luminaire housing is made from stainless steel, all exterior nuts, screws, latches and other fasteners of a luminaire shall be made from stainless steel A4 according to the standard *EN ISO 3506-1:2020*. If a tunnel luminaire housing is made from aluminium, the aluminium alloy shall contain copper *Cu* < 0,1 %.

The protection rating of a road tunnel luminaire against external mechanical impacts shall be at least IK08 in accordance with the standard *EN 62262:2011*.

A road tunnel luminaire shall be equipped with tempered flat glass. The service life of the flat glass shall be at least the same as the median ~~rated~~ useful life~~time~~ of the luminaire. Curved glass luminaires and luminaires with lens modules as the flat glass are not permitted. The lens module refers to a module put in the place of flat glass, with several lenses on the module surface.

NOTE 1: Flat glass is required to ensure a high luminaire maintenance factor f_{LM} value, to ease and to enhance the cleaning of the luminaire, and to reduce glare produced by the luminaire.

The flat glass of a road tunnel luminaire shall be a part of the sealed luminaire housing.

The requirements above apply also for safety ~~standby~~ lighting luminaire.

For asymmetrical counter-beam and pro-beam luminaires the direction of the luminaire's optics shall be clearly marked on the luminaire and indicated in the installation instructions. The marking shall be visible from the outside of the luminaire when viewed from below.

8.5 Additional railway luminaire requirements

8.5.1 Covered parts of platforms

The protection rating of a railway luminaire against external mechanical impacts shall be at least IK08 in accordance with the standard *EN 62262:2011*.

If the mounting height of a railway luminaire is H_M < 4.0 m, the luminaire shall not be openable without tools.

NOTE 1: The usage of anti-vandal fasteners is recommended.

8.5.2 Open parts of platforms

The provisions of Clause 8.2 apply.

NOTE 1: In Swedish Transport Administration projects, the luminaire tilt angle can be fixed at 0°.

8.5.3 Yards

For installations with high masts (H_M > 20 m), a control gear of a floodlight can be placed outside the floodlight and lantern fixing requirements can be defined on the project level. Otherwise, the provisions of Clause 8.2 apply.

8.6 Additional railway tunnel luminaire requirements

Luminaires in railway tunnels shall be able to withstand the estimated pressure and suction loads, which occur when a train passes a tunnel.

8.7 Additional decorative lighting luminaire requirements

If the mounting height of a decorative lighting luminaire is H_M < 4.0 m, the protection rating of the luminaire against external mechanical impacts shall be at least IK10 in accordance with the standard *EN 62262:2011*. If the mounting height is 4.0 m ≤ H_M ≤ 10.0 m, the protection rating of the luminaire against external mechanical impacts shall be at least IK08 in accordance with the standard *EN 62262:2011*.

If the mounting height of a decorative lighting luminaire is H_M < 3.0 m, the luminaire shall not be openable without tools.

NOTE 1: The usage of anti-vandal fasteners is recommended.

The aforementioned requirements do not apply to decorative lighting in tunnels.

8.8 Additional road tunnel evacuation lighting luminaire requirements

The protection rating of a road tunnel evacuation route lighting luminaire and emergency exit lighting luminaire against external mechanical impacts shall be at least IK08 in accordance with the standard *EN 62262:2011*.

For shielding the LEDs, clear polycarbonate or equivalent material shall be used. Materials used in the LED strip shall fulfil the class V-0 requirements for self-extinguishing in accordance with the standard *UL 94:2013*.

In tunnels, where high pressure cleaning equipment is used, the ingress protection rating of a evacuation route lighting luminaire and emergency exit lighting luminaire shall be IP69 in accordance with the standards *EN IEC 60598-1:2021* and *EN 60529:1992*.

9 Road lighting control requirements

9.1 General requirements

A road luminaire shall enable the luminaire luminous flux to be controlled using one of the following options:

~~1. preprogrammed stand-alone dimming~~
~~2.~~1. preprogrammed stand-alone dimming or mains voltage amplitude modulation
~~3.~~2. preprogrammed stand-alone dimming or~~and~~ luminaire extension receptacle (external control).

~~4. preprogrammed stand-alone dimming and mains voltage amplitude modulation.~~

NOTE 1: ~~The options 1 and 3 are used in Norwegian Public Roads Administration projects.~~ The option~~s~~ 1~~2~~ ~~and 4~~ is~~are~~ used in Swedish Transport Administration projects. The option 2~~3~~ is used in Danish Road Directorate~~,~~ ~~and~~ Finnish Transport Infrastructure Agency and Norwegian Public Roads Administration projects ~~projects~~.

An underpass luminaire and a luminaire under bridge shall enable the luminaire luminous flux to be controlled using at least preprogrammed stand-alone dimming ~~(option 1)~~.

9.2 Preprogrammed stand-alone dimming

In preprogrammed stand-alone dimming, the luminaire control gear shall enable a preprogrammed dimming schedule with three lighting levels and five time intervals to be used during 24 hours. An example of a dimming schedule for the preprogrammed stand-alone luminaire control used on roads is shown in Figure 4.

NOTE 1: In Danish Road Directorate projects, dimming of conflict area lighting is not allowed.

NOTE 2: In Danish Road Directorate projects, the dimming schedule shown in Figure 4 is amended with the Danish designations of lighting classes M~L and HS~E.

Preprogrammed stand-alone dimming shall operate together with the constant light output control.

NOTE 3: CLO control can be considered as a “dimming” factor following line D – E in Figure 2 of this document.

	Time, the starting hour																		
	15	16	17	18	19	20	21	22	23	00	01	02	03	04	05	06	07	08	09
Lighting class	**Residual average luminance percentage**																		
Lighting classes M	100	100	100	100	100	60	60	40	40	40	40	40	40	40	60	100	100	100	100
	Residual average illuminance percentage																		
Lighting classes P, C and HS	100	100	100	100	100	60	60	40	40	40	40	40	40	40	60	100	100	100	100

Figure 4. Example of a dimming schedule for a preprogrammed stand-alone luminaire control.

NOTE 4: The times in the schedule are indicative - in preprogrammed stand-alone dimming the times are usually determined by the median point of the period of darkness, which varies by location and the time of year, including any use of daylight saving time.

NOTE 5: The times of the dimming schedule are always programmed for winter time.

A preprogrammed stand-alone luminaire shall enable the inspection or the exchange of the dimming schedule by using RFID (radio frequency identification) readers such as high frequency (HF) RFID NFC (Near-field communication) readers. ~~If option 1 of Clause 9.1 is required, a preprogrammed stand-alone luminaire shall enable the inspection or the exchange of the dimming schedule also by using the external and the internal wiring.~~

~~NOTE 6: The latter can be achieved by connecting wires DA+ and DA- between the wiring block of a luminaire and the electronic control gear of the luminaire and by using an external cable with four or five wires between the luminaire's and the column's wiring blocks.~~

9.3 Luminaire extension receptacle

If option 2~~3~~ of Clause 9.1 is required, a road luminaire shall be equipped with at least one luminaire extension receptacle (Z-LEX-R). The extension interface of the luminaire shall:

- be Zhaga-D4i certified or
- meet the requirements of mechanical, electrical and communication interface and luminaire compliance tests given in the *Zhaga Book 18:2021, Edition 3.0*.

In addition, the electronic control gear shall have the addresses 0x03 – 0x77 of Memory bank 1 stored according to *DALI Part 251:2019*.

Placing the luminaire extension receptacle (Z-LEX-R) completely inside the luminaire housing is not permitted.

NOTE 1: In Danish Road Directorate projects, one luminaire extension receptacle (Z-LEX-R) shall be positioned downwards. If an additional luminaire extension receptacle is provided, it shall be positioned sideways, upwards, or placed inside the luminaire (in the latter case, provided that the luminaire housing does not obstruct sufficient radio communication).

The luminaire extension receptacle shall be built into a luminaire. The placing of the luminaire extension receptacle shall be performed by the luminaire manufacturer at the luminaire assembly stage. The luminaire with the receptacle shall always be equipped with a luminaire extension cap (Z-LEX-C). The luminaire extension cap shall be according to the *Zhaga Book 18:2021, Edition 3.0*. The receptacle, together with the luminaire extension cap, shall provide a degree of protection against dust or moisture (IP code) in accordance with the classification of the luminaire.

If a road luminaire is equipped with the luminaire extension receptacle, the luminaire shall enable the selection of the control method between the preprogrammed stand-alone dimming and the external control by using the luminaire extension module (Z-LEX-M).

9.4 Additional requirements on mains voltage amplitude modulation

When mains voltage amplitude modulation is in use, a road luminaire shall enable the luminous flux to be controlled using amplitude of the mains voltage. The luminaire electronic control gear shall enable a preprogrammed dimming using at least four different lighting levels. The lighting levels of the luminaire shall be reprogrammable using amplitude of the mains voltage.

To avoid an unintended change in lighting levels due to small fluctuations in the main voltage amplitude, a minimum difference of 5 V shall be used to trigger the change of the preprogrammed lighting level.

A luminaire shall enable the selection of the control method between the preprogrammed stand-alone dimming and the mains voltage amplitude modulation. This selection shall be facilitated through the use ~~by~~ of an ~~using~~ RFID (radio frequency identification) reader such as high frequency (HF) RFID NFC (Near-field communication) reader or a reader that utilizes both ~~-~~the external and the internal wiring of the luminaire.

NOTE 1: The latter can be achieved by connecting wires DA+ and DA- between the wiring block of a luminaire and the electronic control gear of the luminaire and by using an external cable with four or five wires between the luminaire's and the column's wiring blocks.

NOTE 2: A luminaire manufacturer should provide recommendations for an appropriate reader.

10 Other requirements

Luminaire technical specifications described in Annex A, except the declaration of conformity (DoC), shall be published and made publicly available.

NOTE 1: Available and downloadable without registration.

The declaration of conformity (DoC) of a luminaire shall be provided on request.

Installation instructions for a luminaire shall be delivered together with the luminaire. The instructions shall correspond to the product delivered. The instructions shall not contradict with the requirements of this document.

NOTE 2: It is recommended to deliver at least two QR code stickers with the luminaire. The QR code should provide access to the luminaire's technical specifications and production details without registration.

Annex A (informative) Technical specifications of an LED luminaire

Red fields should be filled by the client, if necessary
Green fields should be filled by the manufacturer

Luminaire manufacturer	
Luminaire type and product code	

Parameters	**Requirement**	**Rated vValue**
Rated input power of the luminaire (W)		
Average rated input power of the luminaire (W) for the median rated useful lifetime of the luminaire, if CLO control is used		
Rated input power of the luminaire (W) at the end of the median rated useful lifetime, if CLO control is used		
Rated lLuminaire electronic control gear circuit power factor λ (100 % power) (see 6.1)		
Rated lLuminaire electronic control gear circuit power factor λ of a dimmed luminaire (dimmed to 20 % of the initial luminous flux Φ_i) (see 6.1)		
Rated iInitial luminaire luminous flux Φ_i (lm) (see 7.6)		
Rated CLO-corrected luminaire luminous flux Φ_{CLO} (see 7.6), if CLO control is used		
Rated luminaire luminous efficacy (lm/W) (see Table 8)		
Rated correlated colour temperature T_{cp} (K) (see Table 6)		
Rated general colour rendering index R_a (see Table 6)		
Rated chromaticity co-ordinate values, initial and maintained, size of the MacAdam ellipse (see Table 7)		
Rated median Rated useful lifetime of a luminaire (h) (see Table 4)		
Rated lLuminous flux maintenance *factor x*degradation at the ambient temperature of t_q = 25 °C at for the median rated useful lifetime of a luminaire (%), *L_x, x* value (see Table 4)		
Rated Maximum expected control gear abrupt failure value AFV (%) rate at the ambient temperature of t_q = 25 °C at for the median rated useful lifetime of a luminaire, % (see Table 4)		
Ingress protection rating of a luminaire, IP code (see 8.1 and 8.8)		
Protection against mechanical impacts, IK code (see 8.1 - 8.8)		
Protection class (I, or II or III) (see 6.1)		
Overvoltage protection (kV) of an electronic control gear, differential mode / common mode (see 6.2)	/	/
Overvoltage protection (kV) of a separate surge protective device, differential mode / common mode (see 6.2)	/	/
Luminaire weight (kg)		
Luminaire's effective projected wind surface area		
Luminaire colour (default RAL colour)		
Number of luminaire extension receptacles and their mounting position (U = upwards, D = downwards and S = sideways, e.g., U + D)		
Luminaire's guarantee period (years)		
Other information, documents and files to be delivered		
Description of the luminaire's materials (housing, reflectors, optical cover, lenses, heat sinks etc.)		
Description of the luminaire's control options		
Luminaire's dimensions and a luminaire post top or side entry fixing equipment information		
Installation instructions for a luminaire		
Luminaire's photometric files in EULUMDAT file format, or information on where they can be acquired (on		
At least two QR code stickers (recommendation)		

Declaration of conformity (DoC) (on request)

Bibliography

Regulations and Directives

Commission Regulation (EU) 2019/2020 laying down ecodesign requirements for light sources and separate control gears pursuant to Directive 2009/125/EC of the European Parliament and of the Council and repealing Commission Regulations (EC) No 244/2009, (EC) No 245/2009 and (EU) No 1194/2012

Commission Regulation (EU) 2021/341 amending Regulations (EU) 2019/424, (EU) 2019/1781, (EU) 2019/2019, (EU) 2019/2020, (EU) 2019/2021, (EU) 2019/2022, (EU) 2019/2023 and (EU) 2019/2024 with regard to ecodesign requirements for servers and data storage products, electric motors and variable speed drives, refrigerating appliances, light sources and separate control gears, electronic displays, household dishwashers, household washing machines and household washer-dryers and refrigerating appliances with a direct sales function

Regulation (EC) No 765/2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93

Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment

Directive 2014/30/EU on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (EMC)

Guide for the EMCD:2018 (Directive 2014/30/EU) ANNEX 3 - EMC assessment where harmonised standards do not exist or are not fully (applied)

Low Voltage Directive 2014/35/EU on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits

Standards

EN 10088-1:2021~~4~~ Stainless steels. Part 1: List of stainless steels

EN ISO 12944-1:2017 Paints and varnishes – Corrosion protection of steel structures by protective paint systems - Part 1: General introduction

EN ISO 12944-2:2017 Paints and varnishes – Corrosion protection of steel structures by protective paint systems - Part 2: Classification of environments

EN ISO 12944-6:2018 Paints and varnishes – Corrosion protection of steel structures by protective paint systems - Part 6: Laboratory performance test methods

EN 13032-1:2004 + A1:2012 Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 1: Measurement and file format

EN 13032-4:2015 + A1:2019 Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 4: LED lamps, modules and luminaires

EN 13201-3:2015 Road lighting - Part 3: Calculation of performance

EN 16276:2013 Evacuation Lighting in Road Tunnels

EN ISO 3506-1:2020 Mechanical properties of corrosion-resistant stainless steel fasteners – Part 1: Bolts, screws and studs with specified grades and property classes

EN 40-2:2005 Lighting columns. General requirements and dimensions

EN IEC 55015:2019 / A11:2020 Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment

EN 60228:2005 Conductors of insulated cables

EN 60529:1992 / A1:2000 / A2:2013 / AC:2019 Degrees of protection provided by enclosures (IP Code)

EN IEC 60598-1:2021 / A11:2022 Luminaires - Part 1: General requirements and tests

EN IEC 60598-2-1:2021 Luminaires - Part 2-1: Particular requirements - Fixed general purpose luminaires

EN 60598-2-3:2003 / A1:2011 Luminaires - Part 2-3: Particular requirements - Luminaires for road and street lighting

EN 60598-2-5:2015 Luminaires - Part 2-5: Particular requirements – Floodlights

EN IEC 60598-2-22:2022 Luminaires - Part 2-22: Particular requirements - Luminaires for emergency lighting

EN IEC 61000-3-2:2019 / A21:2024 Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)

EN 61000-3-3:2013 / A2:2021 / AC:2022 Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection

EN 61000-4-5:2014 / A1:2017 Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test

EN 61000-4-15:2013 Electromagnetic compatibility (EMC) - Part 4-15: Testing and measurement techniques - Flickermeter - Functional and design specifications

EN IEC 61547:2023 Equipment for general lighting purposes - EMC immunity requirements

EN 61643-11:2013 / A11:2018 Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods

EN 62262:2011 / A1:2021 Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)

EN IEC 62386, the international standard for the Digital Addressable Lighting Interface, is published in multiple Parts

EN 62493:2015 / A1:2022 Assessment of lighting equipment related to human exposure to electromagnetic fields

EN IEC 63000:2018 Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

EN ISO 9227:2022 Corrosion tests in artificial atmospheres - Salt spray tests

IEC 62384:2020 DC or AC supplied electronic control gear for LED modules – Performance requirements

IEC 62717:2014 / AMD1:2015 / AMD2:2019 LED modules for general lighting - Performance

requirements

IEC 62722-1:2022 Luminaire performance - Part 1: General requirements

IEC 62722-2-1:2023 Luminaire performance - Part 2-1: Particular requirements for LED luminaires

IEC/TR 61547-1:2020 Equipment for general lighting purposes - EMC immunity requirements - Part 1: Objective light flickermeter and voltage fluctuation immunity test method, Edition 3.0

IEC/TR 62778:2014 Application of IEC 62471 for the assessment of blue light hazard to light sources and luminaires

ISO 3864-4:2011 Graphical symbols - Safety colours and safety signs - Part 4: Colorimetric and photometric properties of safety sign materials

UL 94:2013, Edition 6, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

Other references

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DiiA Specification, DALI Part 251:2019 – Memory Bank 1 Extension, version 1.1

NMF01:2023 LED luminaires – requirements, Edition 4.1, 27.6.2023

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