DOE

ROADWAY LIGHTING GUIDELINES

EC Energy Efficiency and Conservation

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MESSAGE

DOE

Republic of the Philippines
DEPARTMENT OF ENERGY
Energy Center, Merritt Rd., Fort Bonifacio, Taguig

As the newly entrusted steward of the Department of Energy, I am favoured by lucky happenstance witness and be part of the official public release of these Roadway Lighting Guidelines.

But I must give credit where it is due; I thank all those who have collaborated to produce this great effort, from the Department, most especially my predecessors, and from our ever-dependable key stakeholders.

I cannot emphasize further the importance of this effort. But as a manager by training and career, I could not help but make a simple cost-benefit analysis of the matter at hand.

Currently, we have an overall road network of close to 200,000 kilometers. If we follow the recommended streetlights spacing of one for every 10 to 50 meters, depending on the road type, we will yield about 20 to 100 streetlights per kilometre. By rough computation, this means that we will have to install and maintain between 4.4 million to 22 million streetlights all over the country!

With this Astounding number, we can just imagine the enormity of the energy consumption of our streetlight alone! And this is not to factor in the immense carbon emissions of producing cement and asphalt, which combine to make up 90% of our roads!

These guidelines form part of the multifarious contributions of the DOE to the global movement of energy efficiency and conservation.

Through these, we are able to promote resource efficiency and environment preservation, facilitate human mobility, safety and economic growth.

To maximize the benefits effects, the challenge is upon in the Department to be constantly vigilant in our mandate to the Filipino people.

We must always be proactive and vigorous not only us in implementing these guidelines, but in heightening even further public awareness in this all-important cause, with the indispensable cooperation of other concerned agencies, local governments and the private sector.

Kudos! Maraming salamat at mabuhay!

ALFONSO G. CUSI
Secretary

MESSAGE

DOE

Republic of the Philippines
DEPARTMENT OF ENERGY
Energy Center, Merritt Rd., Fort Bonifacio, Taguig

Much of our roadway lighting system, by today's standards, consumes a high amount of electricity. As lighting technology continues to evolve, more alternatives present themselves. These alternatives present us with the opportunity of realizing significant electricity savings should we choose to upgrade it. New lighting systems such as Light Emitting Diode (LED) lamps that consume a lot less electricity than previous lighting models can make those improvements possible and as well as financially attractive.

The social cost of inefficient roadway lighting will lead to environmental costs. Inefficient lighting wastes energy. When energy is inefficiently used, we simply add greenhouse gas emissions (GHGs) to the atmosphere, emissions that can be prevented. GHGs are pinpointed to be the main culprit for climate change. It is high time for us to be conscious of our environment.

The purpose of this guideline is to revise the old Roadway Lighting Guidelines to cope up with the latest technology on lighting system. We aim not only for road visibility and safety, but also sustaining energy efficiency and environmental care.

Zenaida Y. Monsada
Secretary

"Energy Conservation is not doing without energy, but doing more with it"

PREFACE

Consistent with the *DOE 2014–2030 Energy Efficiency Roadmap for the Philippines,* this Roadway Lighting Guideline was developed to provide technical and safety information aspect in the design and installation of lighting system while at the same time promote the use of energy efficient lighting technology for roadway installation.

Keeping an energy efficient roadway lighting system in cities, municipalities and major provincial roads help contributes in ensuring energy security resulting to increase power grid integrity.

The development of this Guideline was facilitated by the Department of Energy (DOE) in cooperation with the Institute of Integrated Electrical Engineers of the Philippines, Inc. (IIEEP), Department of Public Works and Highways-Road Board (DPWH-RB), Lighting Industry association, and other energy efficiency stakeholders.

It is important to note that some of the national agencies that may have direct use of this Guideline are the DPWH-RB, Local Government Units (LGUs), and Metro Manila Development Authority (MMDA). Likewise, other users include the lighting industry associations, professional practitioners, engineering students, and researchers among others.

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Section 1. Purpose

These guidelines are aimed at providing policies and strategies for designing, operating and maintaining road lighting for use by administrators, contractors, designers, engineers and others involved in similar activities, with the view of achieving energy efficiency and savings while ensuring road visibility and safety.

Section 2. Scope and Applicability

2.1 These guidelines cover lighting systems used to illuminate expressways, major roads, collector roads, minor roads and rural highways, classified as follows:

a. Expressways. These are roads reserved for motor traffic which are accessible only from interchanges and with no crossings at grade.

b. Major Roads. These are roads which are part of roadway system that serves as the principal network for through traffic flows. The routes connect areas of principal traffic generation from different cities or municipalities.

c. Collector Road. These are distribution and collector roadways servicing traffic between major and minor roadways. They are used mainly for traffic movements within residential, commercial, and industrial center in the urban areas.

d. Minor Roads. These roads include subdivision roads and local roadways that are used primarily as an access road to residential areas, commercial buildings and industrial plants and where there is minimal through traffic most of the time.

e. Rural Highways. These are provincial roads which serve as the principal network for through traffic in the rural areas.

2.2 These guidelines does not cover special categories such as landscape lighting (structure, hardscape and softscape), plaza and park lighting, outdoor lighting (sports, retail, etc.) and specialty area lighting.

2.3 All new national, local or barangay road lighting shall be constructed in accordance with these guidelines.

2.4 All roadway lighting being modified, extended, expanded or added to the existing roadway installations shall conform to these guidelines.

Section 3. Lighting Luminaire

3.1 All roadway lighting in private, residential, commercial, industrial, municipal, recreational or institutional property shall be aimed, located and designed in accordance with Table 6.5.1 such that it will not produce high discomfort glare to motorists and pedestrians.

3.2 For special applications where there would be regular maintenance on the lighting facility to be installed, the following shall apply:

a. For narrow barangay roads measuring one to three (1-3) meters and pedestrian walkways in provincial areas and for urban alleys, the use of outdoor type of luminaire with high efficiency linear/compact fluorescent/LED may be allowed provided that the lighting requirements in Table 6.5.1 are met.

b. Aesthetic lighting may be additionally installed provided that the basic requirements of roadway lighting based on Table 6.5.1 are first met.

Table 3.1 General Characteristics for Roadway Lamps

Type of Light	Initial Light Output (lumens x 10^3)	Approximate Efficacy (lumens/ watt)	Approximate Lamp Life (hours x 10^3)[2]
Metal Halide	34-100	85-100[1]	10-15
High Pressure Sodium	9.5-140	95-140[1]	15-28
Low Pressure Sodium	1.8-33	100-183[1]	10-18
Induction Lighting	3.5-12	67-74(based on 100 h)	100
Light Emitting Diode (LED)[3]	16-20	71	50

Notes:

1. These values exclude wattage losses due to ballast.
2. Number of hours for a group of lamps at which 50% will remain in operation; based on 10 hours since start of operation.
3. Estimated values

Section 4. Electrical System

4.1 Lamps and Drivers

4.1.1 Lamps and drivers to be used shall be designed and manufactured according to the requirements in Section 9 and Section 10.

4.1.2 They shall operate within the range of voltage-current characteristic parameters that are compatible with each other.

4.1.3 Retrofit control gear shall have a power factor of 0.90 and above, and a total harmonic distortion (THD) of 15% and below.

4.2 Grounding

4.2.1 Equipment and grounding conductor shall be in accordance with the latest edition of the Philippine Electrical Code Part 1 and 2 (PEC 1 and 2).

4.2.2 All metal parts of the raceway should be connected to the grounding conductor, these includes the metal ground box lids, exposed metal conduit, metal poles, and supplemental ground rods at pole foundations (and other locations).

4.3 Voltage Drop

4.3.1 The roadway lighting shall be designed so that the farthest luminaire in the branch circuit shall operate within the voltage supply level of 230+/-10%. Voltage drop is of concern in order to assure that the voltage at all luminaires will be sufficient for the luminaires to operate properly, and also to avoid inefficient operation of the lighting system due to a large amount of power being dissipated in electrical distribution system.

4.3.2 Corollary to the preceding requirement, typical computations showing the voltage profile of the lighting circuit shall be shown in the design plan and shall be approved by a duly licensed electrical engineer/s.

4.3.3 In determining the voltage drop in a lighting branch circuit, the equation known as Ohm's Law will be used:

$$E = I*R$$

where:

E = voltage drop along a segment of wire

I = current through the same length of wire

R = resistance of the length of wire

Notes regarding the use of Ohm's Law are as follows:

i. This equation is only completely accurate for direct current systems. With the current in the branch circuits limited to 20 amperes by the circuit breakers, and the frequency of the power at 60Hz, the equation is fairly accurate for the lighting branch circuits also.

ii. E is the unknown value that is sought.

iii. I for any segment of wire is calculated by adding the currents for each luminaire the particular segment of wire feeds (i.e. all the luminaires downstream on that wire).

iv. R for a particular segment of wire is calculated by multiplying the length of wire (in three hundred meters) in that segment by the resistance per 300meters of wire for that particular size and material of wire.

v. The total voltage drop to the farthest luminaire is calculated by adding the voltage drops for each segment of wire from the service cabinet to that luminaire.

4.3.4 Voltage drop must be calculated for the phase wire and for the neutral wire, and these voltages must be added together to arrive at the total voltage drop.

4.4 Controls. Roadway lighting system shall be provided with the means of controlling lighting facilities efficiently. Provisions 4.4.1 through 4.4.3 shall apply. Remote network controls may be considered for important thorough fares depending on the operation and maintenance needs.

4.4.1 Roadway lighting should be provided with reliable photoelectric controls either internal/ external to keep lights turned ON/OFF automatically.

4.4.2 Group controlled lighting systems shall be provided with NEMA Type 3R service cabinet, Philippine National Standard (PNS) compliant control breakers, and phototransistor or photodiode type fail-off electronic photoelectric control or timer.

4.4.3 Individually controlled lighting system shall make use of internal/external phototransistor or photodiode type electronic photoelectric control with the appropriate receptacle*.

4.5 Metering. Meter and meter-socket shall be provided for lighting systems not owned by the distribution utility (DU)/electric cooperative (EC) and shall be installed in accordance with the standards set by the DU/EC having franchise ownership over that area. Nevertheless, the end user may request for the installation of a meter and meter-socket if the lighting system is owned by the DU/EC.

Remote Metering solutions would be provided in installations with Remote Network Controls

** Note: for detailed requirement of photoelectric control, refer to Section 12.*

4.6 Electrical Works and Materials

4.6.1 All electrical works and materials shall comply with the latest edition of the Philippine Electrical Code Part 1 and PEC 2.

4.6.2 All materials (equipment and devices) to be installed by the contractor shall be new and shall bear the Certification Mark(Philippine Standard Quality Mark or Import Commodity Clearance) issued by the Department of Trade and Industry-Bureau of Product Standards (DTI-BPS) for specific purposes.

All equipment shall comply with the product particular requirement of the DOE Philippine Energy Standard and Labeling Program to be installed by the contractor shall be new and shall bear the Certification Mark (Philippine Standard Quality Mark or Import Commodity Clearance) issued by the Department of Trade and Industry-Bureau of Product Standards (DTI-BPS) for specific purposes.

Section 5. Structural System

5.1 General. The components of the structural system shall be compatible with each other including that of the luminaires and the accessories to be used. Items not covered by the following specifications shall conform with standards and/or regulations under the Department of Public Works and Highways Bureau of Standards.

5.2 Poles

5.2.1 Pole Height. The pole height specified shall result to the following:

a. Illumination intensity & uniform brightness of area covered must conform withTable 6.5.1.For height and illumination guideline, refer to Table 6.5.3.

b. Reduced glare. Refer to Table 6.5.3 for height and guideline. The maximum height of lighting poles to be installed near an airport or flight path shall be coordinated with the airport authority.

5.2.2 Pole Placement. Pole placement shall be based on the geometry, character of the roadway, physical features, environment, maintenance policy, economics, aesthetics, and overall lighting objectives. For pole configuration, refer to Section 6. Pole placement must contribute to the attainment of limits under Table 6.5.1.

5.2.3 Type of Pole.

For most installation of streetlights, poles owned by the distribution utility are used for mounting streetlights. These distribution poles (concrete, steel, wood) which are primarily installed to support distribution and/or service wires, are either concrete or steel. Each pole adequately supports the additional load imposed on by the lighting equipment. Structurally, these poles can accommodate additional loads allowing lighting equipment/ luminaires to be installed on them. In case dedicated (or independent) lighting poles are used, they shall be made of hot-dip galvanized iron and steel products. Pole surface shall be matte or dull finished to prevent glare.

The poles have an average luminaire mounting height of 8-12 meters for the single and double arm post. High mast poles have an average luminaire mounting height of 20 meters. Pole height affects the illumination intensity, uniformity of brightness, area covered, and relative glare of theunit. Higher mounted units provide greater coverage, more uniformity, and a reduction of glare, but a lower footcandle level. The pole height to be specified shall result the recommended values for average luminance and uniformity for the target area. Power lines, nearby airports, and nearby residential neighborhoods may limit the height of poles used for street lighting. This shall be coordinated with local officials.

5.2.4 Material and Finish

a. Independent lighting poles shall have minimum thickness of 3.0 mm and shall be hot-dipped galvanized in accordance with material and finish. Generally, pole shaft shall be made in accordance with ASTM A53/A53M Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.

b. All lighting poles, made of steel, shall be hot-dip galvanized based on ASTM A 123/A 123M Standard Specification for Zinc (hot-dip galvanized) Coating on Iron and Steel Products.

c. The zinc coating shall be relatively smooth and reasonably uniform in thickness. The parts shall be free from uncoated areas, blisters, flux deposits, block spots, dross inclusions, and other defects not consistent with good galvanizing practice.

d. Pole surface shall be matte or dull finished to prevent glare.

5.2.5 Strength Requirement. Pole shall be so designed to adequately bear the additional load imposed by the lighting equipment/facilities on the distribution poles and shall meet the strength requirements specified in the latest edition of PEC 2 and NSCP.

5.3 Mast Arm (Mounting Bracket). The mast arm which is the same as horizontal bracket that is used to support the luminaire shall have a length that is coordinated with the proper photometric distribution.

5.3.1 Material and Finish

5.3.1.1 The mast arm shall be fabricated using galvanized iron (GI) pipe and to be fully hot-dipped galvanized after fabrication that are manufactured in accordance with PNS 26:1992, Steel - Black and hot-dipped zinc coated (galvanized) longitudinally welded steel pipes or ASTM A123- Black and Hot- Dipped Zinc Coated (galvanized) Longitudinally Welded Steel Pipes (for ordinary use) - Specification.

5.3.1.2 It shall be provided with mounting plate and stiffener to supplement its load bearing capacity.

5.3.1.3 It shall be designed in accordance with the strength requirements of the latest edition of PEC 2 and NSCP.

5.4 Foundations and Pads. The foundations and pads shall be designed in accordance with NSCP to adequately support the luminaire and pole structure as well as resist wind blows and vibrations inherent in the area where the poles are going to be located.

Section 6. Lighting Parameters

6.1 Lighting Arrangement

6.1.1 Single sided arrangement, in which all luminaires are located on one side of the road, shall be used when the road width is less than or equal to the mounting height.

Figure 6.1 Single Sided Lighting Arrangements

6.1.2 Staggered arrangement, in which the luminaires are placed alternately on each side of the road in a “zig-zag” or staggered fashion shall be used when the road width is equal to 1 to 1.5 times the mounting height.

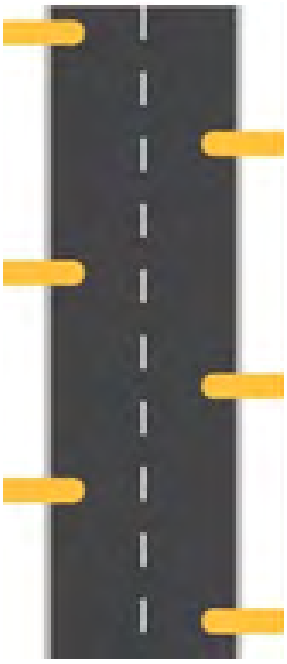

Figure 6.2 Staggered Lighting Arrangements

6.1.3 Opposite arrangement, in which the luminaires are placed directly opposite and facing each other along the road, shall be used when the road width is more than 1.5 times the mounting height.

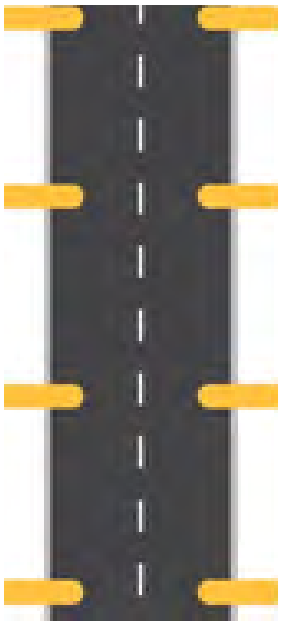

Figure 6.3 Opposite Lighting Arrangement

6.1.4 Twin central arrangement, in which the luminaires are mounted on a T-shaped like masts in the middle of the center island of the road, shall be used when the road width is less than or equal to the mounting height.

Figure 6.4 Twin Central Lighting Arrangement

6.1.5 For existing condition, twin central in combination with Opposite Arrangement, in certain application where adequate illumination cannot be met, a single sided arrangement is integrated with twin central arrangement, or if possible an opposite or staggered arrangement.

Typically, streetlights for major thoroughfares are installed on single sided, opposite and staggered of the roadway. Pole mounted street lighting are typically installed 30 to 40 meters apart and almost 100 meters apart for high mast in secondary streets and major thoroughfares.

Physical roadside conditions may require adjustment of the pole spacing determined from the base levels of illumination, as indicated in the guidelines. Higher levels of illumination are justified when overhead structures, safety, and object clearances restrict the placement of poles. It is advisable to provide higher illumination levels at diverging and merging areas.

To further illustrate the above design parameters, below is the street lighting geometry:

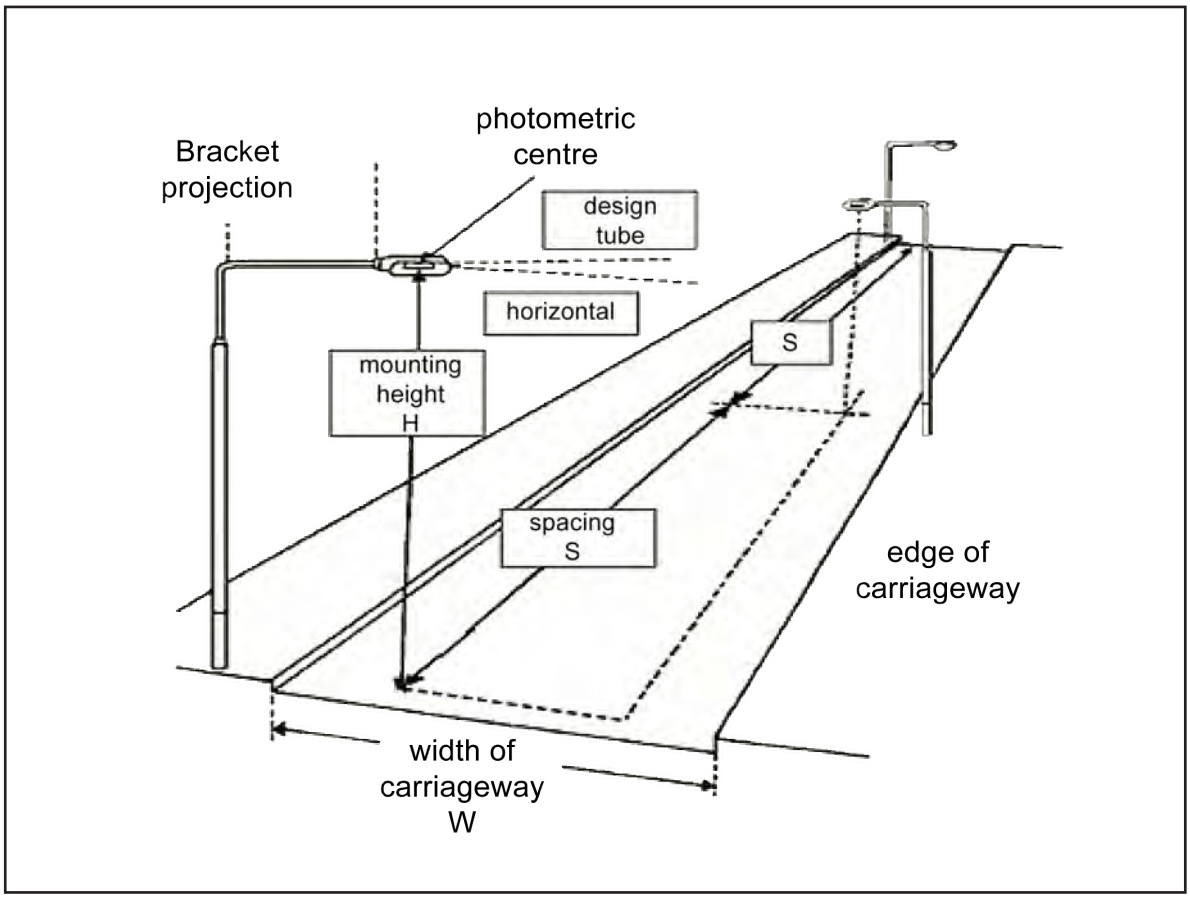

Figure 6.5 Street Lighting Parameters

6.2 Mounting Height

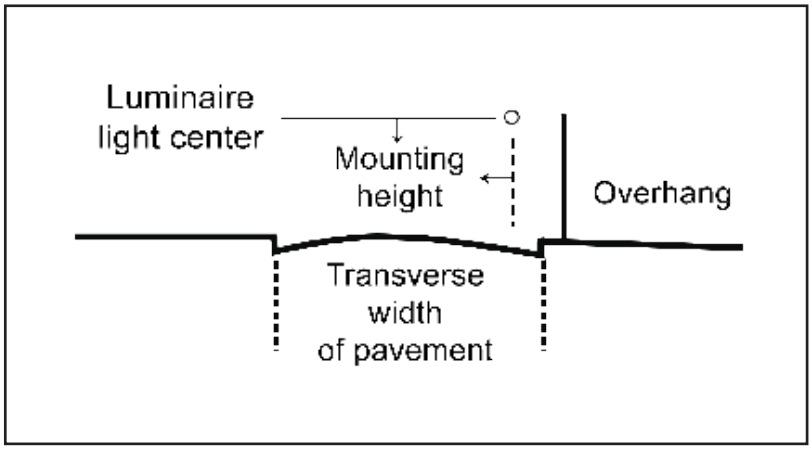

Figure 6.6 Mounting Height

6.2.1 **The** mounting height shall be the perpendicular distance from the center of the lamp to the ground surface.

6.2.2 Where the luminaire overhangs the road surface, the minimum mounting height shall be generally 8.0 m-12m. However, a luminaire that does not overhang the roadway may have a minimum mounting height of 3.0 m provided that the installed luminaire used would not result into disability glare to the motorist and the pole is installed in accordance with the latest edition of PEC 2 and NSCP.

6.3 Spacing

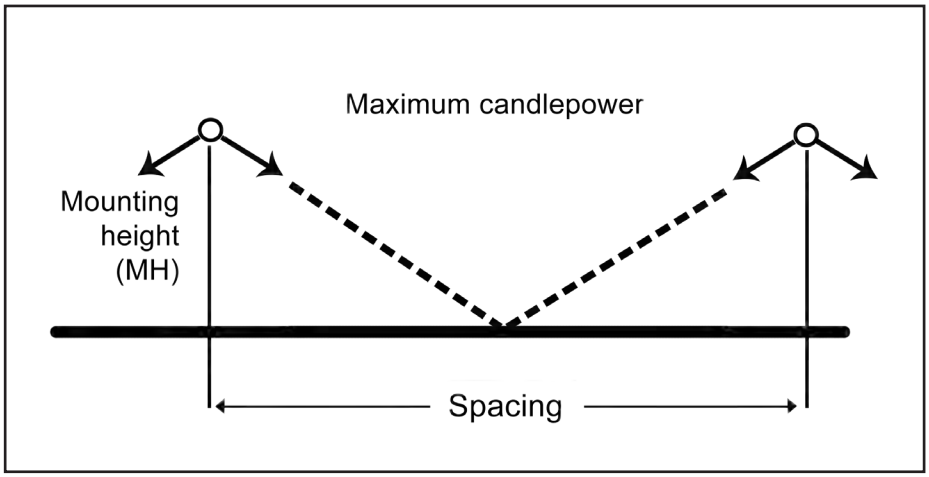

Figure 6.7 Spacing

6.3.1 Spacing shall be defined as the horizontal distance between poles supporting the luminaire.

6.3.2 The minimum allowable spacing shall be in accordance with the values set in Table 6.5.3.

6.3.3 The spacing of luminaires for a curved road shall be reduced by 25% to 50% for a similar stretch of a straight road. A curved road that has a radius of 1000 m and above may be treated as a straight road.

6.4 Overhang

6.4.1 The luminaire overhang shall be defined as the projected horizontal distance from the luminaire to the road curb.

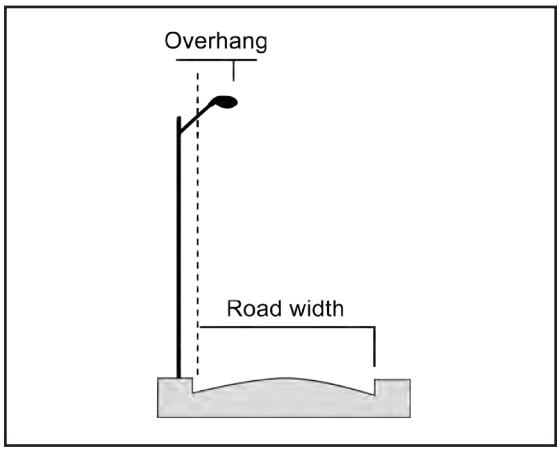

Figure 6.8 Overhang

6.4.2 Where the luminaire does not overhang the road curb, the new road width to be used in the following manner:

a. For single sided and central roadway lighting arrangements, the new road width (R_n) to be consideredshall be computed as follows:

$$^{1}R_n = R_a + (Ps - 1)$$

where:

R_n = new road width

R_a = actual road width

Ps = pole setback

b. For opposite side and staggered roadway lighting arrangements, the new road width (R_n) to be considered shall be computed as follows:

$$R_n = R_a + (Ps_1 + Ps_2 - 2)$$

where:

R_n = new road width

R_a = actual road width

Ps_1 = pole setback of one side of the street

Ps_2 = pole setback of the other side of the street

Values for R_n may be rounded off to the nearest fives and tens when practical.

1 Note: All units are in meters

6.5 Design Consideration for Road Lighting

6.5.1 Design Consideration with Motorized Traffic

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 limitations of Disability and Discomfort Glare and the requirements for the direct visual guidance.

The lighting criteria used are the maintained average road surface Luminance (Lav), the Overall (Uo) and Longitudinal (Ul) uniformity of the Luminance, the surround ratio (Rs) and the threshold increment (TI).

These values apply to roads, which are sufficiently long, so that the luminance concept can be used. The surround ratio is considered for roads with adjacent footpath/cycle path only when no specific requirements are given.

For all Roads carrying Motorized traffic, design shall conform to the set criteria as prescribed in Table 6.5.1.

A wide variety of computer programs are available from lighting manufacturers to perform exterior lighting calculations. Some programs are very simple, while others are complex and can even interface with computer-aided design (CAD).

These software packages are not intended as a substitute for creating design but as an aid to the design process. One should exercise prudence in the use of software for lighting calculation since some of them cater mainly to a particular brand of luminaire and therefore would be applicable to a specific type of luminaire only including their light distribution characteristics.

Table 6.5.1 Minimum Values for Roadway Lighting Parameters (Roads for Motorized Traffic)

Road Classification	[1]Luminance	Uniformity Ratios		Glare	Surrounding Ratio
	Average Road Surface, Cd/m^2	Overall Uniformity (U_o)		Threshold Increment (T_1)	R_s
Express	1.0	0.40	0.70	10.0	0.5
Major	1.2	0.40	0.60	15.0	0.5
Rural Highway	1.2	0.40	0.60	15.0	0.5
Collector	0.8	0.40	0.60	15.0	0.5
Minor (Local)	0.6	0.35	0.40	15.0	0.5

6.5.2 Measuring and Calculating Average Illuminance

Evaluating roadway illuminance, a measure of the amount of luminous flux falling per unit area – lumens/m^2, or lux (lx), is a simple comparative basis for roadway lighting systems used in this Guideline. Measurement and calculation of average illuminance delivered by existing installation (for retrofitting purpose), and new installation (to verify the actual values against the designed values) will be determined in accordance with CIE 140:2000.

CIE 140:2000 provides the basis for determining fields of calculation, the location of measurement or simulation points for lighting calculations, and calculation methods for average illuminance values, as well as uniformity and glare values across the field of calculation as described below.

(a) The field of calculation should be typical of the area of the road or intersection which is of interest to the driver and pedestrian, and may include the walkway, bikeway, and verges. According to CIE 140:2000, it should be bounded by the edges of the roadway and by transverse lines through two consecutive luminaires;

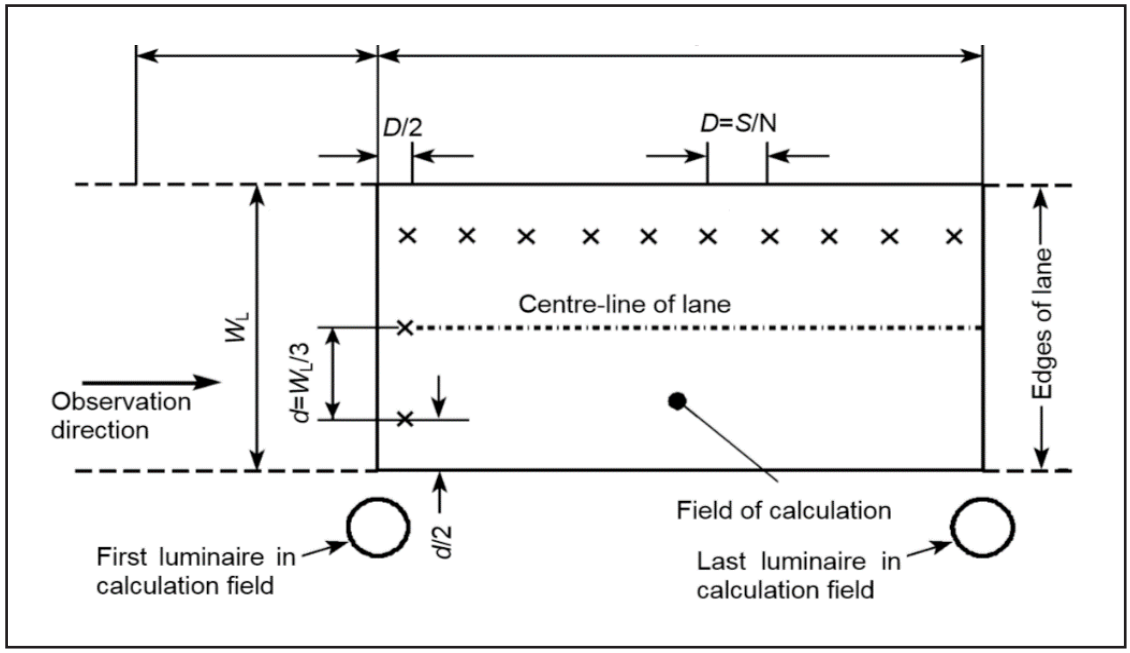

Figure 6.9 Illustration of Illuminance Field of Calculation and Measurement

(b) For staggered installations, consecutive luminaires will be on opposite sides of the road;

(c) The calculation points should be evenly spaced in the field of calculation (see Figure 6.9) and their number should be chosen as follows:

(d) In the longitudinal direction, the spacing in the longitudinal direction should be determined from the equation:

$$D = S/N$$

Where: D is the spacing between points in the longitudinal direction (m);

S is the spacing between luminaires (m);

N is the number of calculation points in the longitudinal direction with the following values:

For $S \leq 30$ m, $N = 10$

For $S > 30$ m, the smallest integer giving $D \leq 3$ m.

The first row of calculation points is spaced at a distance D/2 beyond the first luminaire (m).

(e) In the transverse direction

$d = W_r/3$ for single lane

$d = W_r/3x2$ for two lanes

$d = W_r/3x3$ for three lanes

Where: d is the spacing between points in the transverse direction (m);

Wr is the width of the carriageway or relevant area (m).

The spacing of points from the edges of the relevant area is D/2 in the longitudinal direction, and d/2 in the transverse direction, as indicated in Figure 6.9.

(f) Luminaire which are situated within five times the mounting height from the calculation point should be included in the calculation.

Calculation of average illuminance based on the measurement data can be performed using any spreadsheet tools. Illustrated in Figure 6.10 is calculation of lighting quality parameters (average maximum, and minimum illuminance, and uniformity) of measurement data using Excel.

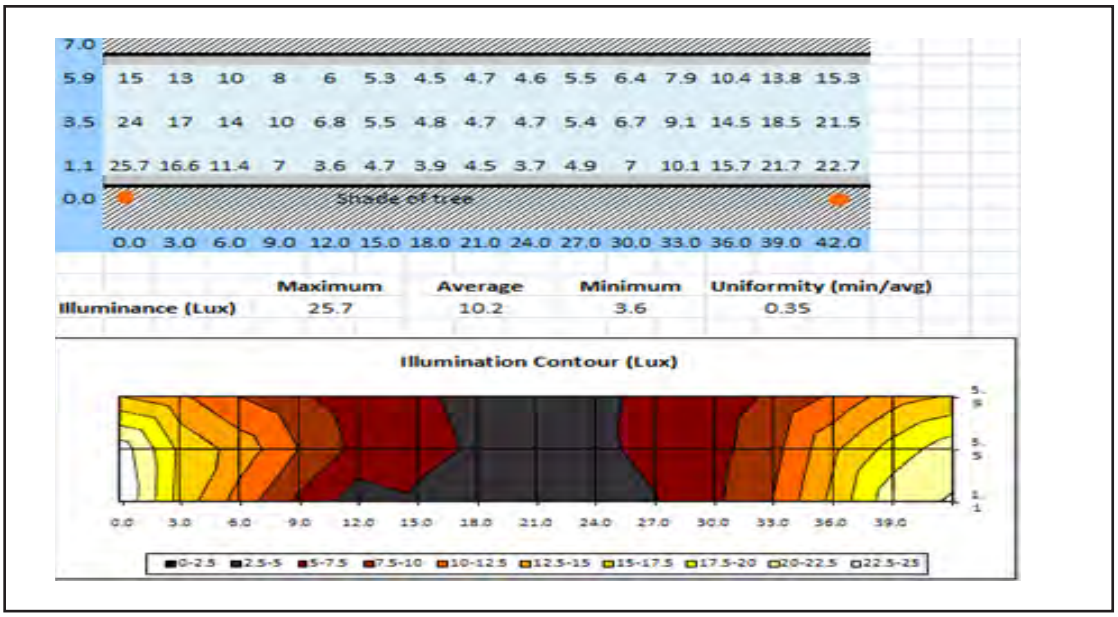

Figure 6.10 Calculation of Lighting Quality Parameters using an Excel Spreadsheet

6.5.3 Table 6.5.3 is provided as a guideline for specifying roadway lighting parameters for uniformity and safety.

Table 6.5.3 Placement Guide for Roadway Lighting

Road	Road Width, meters	Arrange-ment	Lamp Wattage, Watts	Luminaire Spacing, Meters	Mounting Height, meters	Mast Arm Length, meters
Expressway	10	Twin Central	250	25-35	12	1.5
	15		250	20-35	12	3.0
	20	Opposite	250	20-45	12	1.5
	25		250	20-40	12	1.5
	30		250	20-30	12	1.5
	36		250	20-25	12	1.5
	40		250	20-22	12	1.5
Major	10	One-side	250	10-40	10	1.5
	15		250	10-45	12	3.0
	10	Twin Central	150	20-37	10	1.5
	15		250	20-43	12	3.0
	20	Opposite	150	20-40	10	3.0
	25		250	20-45	10	1.5
	30		250	20-45	10	1.5
	36		250	20-45	12	3.0
	40		250	20-45	12	3.0
Collector	10	One-side	150	10-40	10	1.5
	15		250	10-50	12	3.0
	10	Twin Central	150	20-40	10	1.5
	15		150	20-37	12	3.0

Table 6.5.3 (Continued)

Road	Road Width, meters	Arrange-ment	Lamp Wattage, Watts	Luminaire Spacing, meters	Mounting Height, meters	Mast Arm Length, Meters
Collector	20	Opposite	150	20-47	10	1.5
	25		250	20-48	10	1.5
Rural Highway	8	One-side	150	10-38	8	1.5
	10		150	10-37	8	3.0
	15		150	15-38	10	3.0
	10	Twin Central	150	20-45	10	3.0
	15		150	20-39	12	3.0
	20	Opposite	150	20-45	8	1.5
Minor	4	One-side	70	10-40	8	1.5
	6		70	10-40	8	1.5
	8		70	10-40	8	1.5
	10		70	10-39	8	1.5
	10	Twin Central	70	20-35	8	1.5
	15	Staggered	70	10-20	8	1.5
	15	Opposite	70	20-40	8	1.5

Notes:

1. Assumed setback of pole from street curb is 1.0 m. In case where the pole setback is more than 1.0 m, a new road width shall be computed using the formula in Section 6.4. This computed new road width shall be the one that will be used in referring to Table 6.5.3.

2. Luminaire spacing for curved roads shall be reduced by 25% to 50% of that indicated in the table.

3. In situation where distribution poles with a spanning of more than the above and are being used to mount Roadway Lighting fixtures or luminaires, additional investment to install intermediate pole shall be provided.

6.5.4 Retrofitting using LED

The requirements for Table 6.7.1 are applicable for High Intensive Discharge (HID) lamps. Moreover, the same may be applied as a reference guide for retrofitting using LED. In so doing, the lumen output should be properly increased to cover for the limitation of LED luminaires in terms of the photometric distribution.

6.5.5 New Installation Using LED

At present, manufacturers of LEDs have not established a common standard for luminaire classification (such as type and distribution category) that they could collaboratively comply

with. Hence, the designer should provide the necessary computation and illumination result specific to the particular LED luminaire to be installed. Moreover, the requirements given in Table 6.5.1 (Minimum Values for Roadway Lighting Parameters) shall still be complied with. To aid in determination on the type and classification of LED luminaire to be installed, manufacturers may consult with the Department of Energy-Lighting and Appliance Testing Laboratory (DOE-LATL) for testing and certification.

6.6 Maintenance Factor (MF)

Luminaire maintenance factors vary according to the intervals between cleaning, the amount of atmospheric pollution and the IP rating of the luminaire.

Lamp flux maintenance factors vary according to lamp type and power. Values are usually available from lamp manufacturers.

However, it is proposed to consider maintenance factor of not less than 0.5for LED Road lighting installations for IP66 rated luminaires. These maintenance factor values shall be adopted for the purposes of producing the lighting simulation design

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6.7 Dimming of Road Lighting

Dimming of road lighting may be considered only for minor roads of private subdivisions after midnight, provided the cost benefit analysis value and safety issues are fully justified**.**

Section 7: Lighting Configuration

7.1 The lighting configuration shall set up as to provide the following:

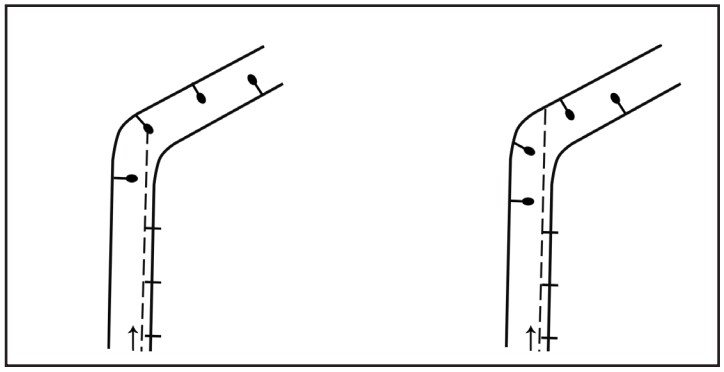
7.1.1 Visual Alertness and Guidance. The roadway lighting configuration shall be able to provide visual alertness towards an approaching road junction and visual guidance at the junction itself and on curves (see Fig. 7.1). To meet the objective, the roadway lighting configuration shall possess at least one of the following:

a. Difference in lighting arrangement

b. Difference in luminaire height

c. Use of different types of lamp

d. Increased luminance at road junction



(a) (b)

Improper installation Proper installation

Figure 7.1 Illustrative Guide on the Proper and Improper Way of Locating Luminaires in Curved Roads.

7.1.1.1 The relative positions of the luminaires at the junction shall not be closer than the minimum distance givenin Table 6.7.1.

7.1.1.2 For curved roads, visual guidance is enhanced by reducing the luminaire spacing by 25% to 50% of that normally applied for straight roads. Curves with a radius of 1000 m or more may be treated as straight roads

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7.1.1.3 For inclined roads, the roadway lights shall be so located such that the driver of a vehicle going uphill would not experience excessive glare discomfort.

7.1.2 Safety Clearance. The roadway lighting facilities shall conform to the latest edition of the PEC 2.

Section 8: Luminaire Requirements

8.1 Luminaire. For purposes of this section on the luminaire requirements, the term luminaire shall be defined as a complete lighting apparatus consisting of the housing and all integral parts necessary for its mounting, optical assembly, control gears and wiring assembly. Lamps are excluded in the luminaire specification. The requirements for lamp are listed in a separate section.

8.2 Standards. All luminaires shall meet applicable design and testing requirements of the latest edition of the applicable standards (see 9.10). If other equivalent internationally accepted standards are used, these standards and other supplementary standards, if applicable, shall be explicitly stated in the design proposal.

8.3 Design and Construction Features.

8.3.1 The housing of the luminaire shall be made of heat-treated, high pressure die-cast aluminum or aluminum alloy with <1% copper content and shall be painted with an electro-coated gray paint finish.

8.3.2 Hardware such as hinges, latches, springs, nuts, screws, washers, pins, etc. shall be made of materials compatible to the housing material and shall be inherently corrosion-proof or have been protected by finishes approved for corrosion-resistance. However, those exposed to the elements shall be made of high-grade stainless steel (SUS304 or better).

8.3.3 The luminaire shall be used for horizontal mounting on a mast arm. The mounting shall be designed using a clamping plate, if applicable,with at least two (2)-9.5mm minimum diameter hexagonal head clamping bolts to mechanically clamp the luminaire to a 48-60mm nominal diameter metal pipe end of the mast arm and adjust it to the required position. Luminaire shall meet vibrations test stipulated in IEC 60598.

8.3.4 A shoulder or stop shall be provided to limit the insertion of the pipe end of the mast arm during installation.

8.3.5 The luminaire housing shall bear a nameplate or other type of indelible marking that shall identify it as to type, rating, manufacturer, date manufactured, catalog number, etc. The marking shall comply to the requirements of IEC 60598-2-3.

8.3.6 A wattage marking in accordance with the latest edition of the PNS shall be provided on the underside of the housing using black-colored numerals 50.8mm minimum height with yellow gold-colored square background 76.2mm minimum dimension on the side. The marking shall be visible from an observer on the ground and shall be designed to endure the life of the luminaire.

8.3.7 The luminaire housing shall have an option to provide for a receptacle for a three-prong, twist-lock type photoelectric control (NEMA Type) or if not available, a separate box with the receptacle outside the luminaire is to be provided.

8.3.8 The luminaire surfaces, joints, and rim shall be smooth and free of burrs and sharp edges that could cause injury to the workman.

8.4 Electrical Rating

8.4.1 The luminaire shall be designed to operate at+/- 230volts AC 60hertz, single-phase.

8.5 Optical Assembly for LED Roadway Luminaire

8.5.1 The optical assembly shall be made from approved material and shall be capable of efficiently directing the light in the required directions while reducing it in directions where it might cause glare discomfort.

8.5.2 There fractor shall be prismatic or clear type made from heat-tempered glass. It shall be held in place in such a manner as to allow for its expansion and contraction.

8.5.3 The design of the optical system shall be based on the use of a clear, tubular or ovoid/ elliptical lamp.

8.5.4 The refractor-housing and socket-reflector junctions or optical chamber shall be adequately sealed against entry of moisture, rainwater, dust or insects, with provisions for thermal breathing and air filtering. It shall be rated for IP 66 or better. No special tools shall be required for the insertion and withdrawal of the lamp and control gear. A lamp fully inserted shall be rigidly held with its axis substantially coincident with that of the pole under normal conditions of wind, vibration and mechanical shock.

8.5.5 The lighting design and calculation method shall be in accordance with the following documents:

Item	Description	Reference document
1	Lighting Design	CIE 115 : 2010 2nd Edition
2	Calculation Methods	CIE 30.2 : 1982

When calculating luminance and illuminance values a maintenance factor (MF) of not less than 0.5 shall be used. R- Table used in the calculation shall be CIE type R3.

8.6 Control Gears and Wirings

8.6.1 The photoelectric control receptacle, when provided, shall conform to ANSI C136.10, latest revision or equivalent.

8.6.2 All components shall be mounted on a suitable module unit and shall be easily removed and replaced as a unit without the use of any special tools. Electrical connection and disconnection of the electrical control gear unit from the luminaire shall be easily done and terminals easily accessible.

8.6.3 All circuitry wirings shall be insulated to a minimum temperature rating of 125°C. Electrical terminations and connection shall have provisions that ensure good electrical and mechanical integrity and ease of replacement. Terminals of supply conductor shall be connected to the terminal block by means of screw-on type connections.

8.7 Tests and Inspection. All tests on the luminaire and its components shall be performed in accordance with applicable testing procedures and acceptance criteria of applicable PNS. Certified test reports for all types of test conducted shall be submitted prior to shipment of the luminaires.

Section 9: Requirements for LED Road Luminaires

9.1 General

The luminaire shall be designed and constructed so that it is capable of providing the service for which it is intended. Sound engineering principles shall be adopted throughout and the lantern shall be designed to enable ease of maintenance and replacement of LED lamps, driver and glass cover without the use of special tools on site. The contractor does not need to open the luminaire during installation.

9.1.1 Luminaire Housing

The luminaire shall be constructed from corrosion resistant materials such that no undue deterioration occurs in its safety, performance or appearance during normal life when operating under all local conditions. It shall be robustly constructed to withstand vibration innormal use.

The luminaire shall be designed so that condensation shall not fall on any operating part, which may fail or deteriorate as a result.

All die casting parts shall not have sharp edges for safety of installers and to prevent defects of the painting (not holding well enough on sharp edges).

Minimum salt spray paint test requirement shall be at least 500 hours in accordance with IEC standard.

Mechanical resistance level of the housing shall be IK06 minimum and Degrees of Protection shall be IP 66 to prevent any risk to get water or dust inside the luminaire. The IP 66 level shall be reached without using glue to make the luminaire fully recyclable.

Hinges and catches of the luminaire cover shall be robust and simple to operate and shall not be liable to accidental detachment during installation or maintenance. It shall be made of stainless steel of SUS 304 or better.

The luminaire cover or other component giving access to the interior of the lantern shall, in the closed position, be firmly attached to the fixed portion of the lantern. In the open position, it shall be attached in such a way that there is no likelihood of it becoming accidentally detached or damaging any part of the luminaire, the bracket or thecolumn.

The glass cover shall be tempered glass or a more superior material and shall form part of the lighting cover.

During opening, a stainless steel mechanism falls into position/ or other acceptable ways to keep the canopy open.

Figure 9.1 Ingress Protection (IP)

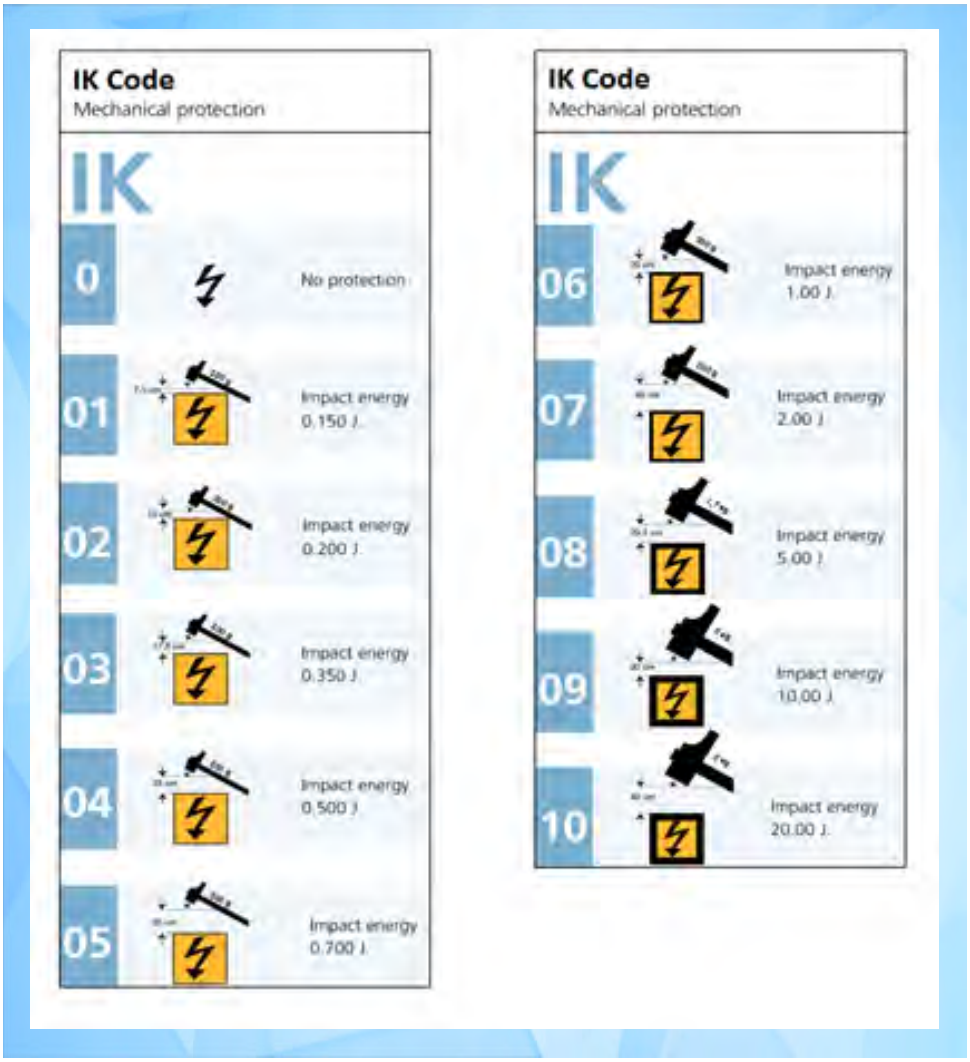

Figure 9.2: Mechanical or Impact Protection

All components (such as LED Drivers, Surge Protection Devices, Terminal Blocks, etc.) shall be mounted on a suitable module unit and shall be easily removed and replaced as a unit without the use of any special tools. Electrical connection and disconnection of the electrical control gear unit from the luminaire shall be easily done and terminals easily accessible.

The luminaire shall have an in built surge protection to protect the electronic driver and module with minimum surge protection rating of 10 KV.

The mounting of the luminaire will be in axial orientation through Ø 48-60mm sidearm.

9.1.2 Optics

The luminaire shall use high efficiency LED system that will cover higher road widths that will result to maximum allowable spacing between poles. Optic design must ensure luminance and illumination uniformity is consistent with Table 6.5.1.

9.1.3 Thermal Management

Managing thermal properties in LED luminaires are most critical to ensure optimum performance of LEDs and reliability of the system.The housing shell under the circuit board should be specially designed to ensure perfect contact between the board and the luminaire housing for efficient heat dissipation.

9.1.4 Useful Life Hours

The LED luminaire shall be designed for lumen maintenance of L70 or 70% at the end of useful life at ambient temperature of not less than45 deg C (L70 at 10,000 hours). The complete luminaire shall have a useful life of at least 50,000 burning hours.

9.1.5 Ambient Temperature

The luminaire shall be suitable for ambient temperature range of up to 45 degrees Celsius. 3rd party IEC 60598 Test Report shall be measured/corrected for Ta = 45 Degrees Celsius.

9.2 Driver

The LED driver shall be designed to operate large array of high power LED's through current controlled output. The driver shall be suitable for nominal 230V+/- 10% 60Hz mains supply.

9.2.1 Driver shall be either integrated or separated from the luminaire.

9.2.2 Driver can be Class 1 insulation.

9.2.3 Driver shall have a Power Factor (PF) not less than 0.90 and Total Harmonic Distortion (THD) not higher than 15% at maximum load.

9.2.4 Driver shall have a mains dimming option to allow dimming the light output when main voltage is dimmed down at electrical cabinet level.

9.2.5 Driver shall be rated for at least 50,000hours lifetime at maximum case temperature of 70°C or higher.

9.2.6 The operating temperature shall be up to 85°C.

9.2.7 Driver shall be designed with adequate surge protection features.

9.2.8 For driver separated from the luminaire, XLPE/PVC sheath cable, 3-core, 2.5mm2 rated at 600 / 1,000 Volts, shall be provided for the connection to the fuse cut-out unit and to the luminaire.

9.3 Controls

The luminaire or LED driver may be provided with dimming function as an option to enhance energy savings. The LED driver may incorporate multiple control interfaces for dimming capability. It may enable DALI, & 1-10V DC interface dimming control. It may also have a programmable feature to allow pre-programming of step dimming lighting levels based on the ON time.

9.4 Upgradeability

The LED module maybe upgradeable on site for possible future upgrading / maintenance after warranty period and further energy savings to ensure the lowest cost of ownership.

The luminaire may be provided with space available inside for communications antenna or equipment to be integrated into the luminaire for future tele-management control system implementation.

9.5 Wiring

9.5.1 Earthing Terminal

A separate terminal for the connection of an earth continuity conductor, clearly and indelibly marked shall be provided.

9.5.2 All exposed metal parts and other parts accessible when the luminaire is opened for maintenance and liable to become 'live' in the event of an insulation fault shall be permanently and reliably connected to this earthing terminal.

9.5.3 Internal Wiring

All internal/external wiring shall conform with the latest edition of PEC 1 & 2.

9.5.4 The luminaire shall be completely pre-wired, requiring only the connection of the electrical power supply cables to the terminal block and the earth continuity conductor to the earthing terminal.

9.5.5 The wiring used shall be heat resistant type with a temperature rating of minimum 105°C. Samples of the heat resistant cable and cable manufacturer specification shall be submitted.

9.6 Warranty

The luminaire supplier / manufacturer shall provide a warranty against all defective materials and workmanship-based on claimed life. The Deed of extended warranty shall be submitted upon the acceptance of the LED luminaire.

9.7 Test for Luminaire

9.7.1 The tests are as follows:

(a) Type Test for Luminaire

(i) A full type test shall be carried out for compliance with the latest edition of IEC 60598-2-3.

(ii) For the humidity test, the test shall be carried out at a relative humidity around 95% and at an ambient temperature of 28°C.

(b) Quality Control Tests

(i) A quality assurance scheme shall be established during the manufacture of the luminaires to ensure the quality of the product leaving the factory.

(ii) The scheme shall cover the assurance of the quality of incoming materials, methods of welding, casting, molding, forging, fabrication, assembly and final testing and inspection of the finished product.

9.8 Photometric and Electrical Data Measurements and Tests

The following tests and measurements shall be conducted to verify the luminaire photometric and electrical data including but not limited to the following:

(a) Isolux Diagram
(b) Coefficient of Utilization curves
(c) Polar Lighting Distribution Diagrams
(d) Electrical Parameters
(e) Power (W);
(f) luminous flux (lm);
(g) luminaire efficacy (lm/W);
(h) Correlated Color Temperature (CCT);
(i) Color Rendering Index (CRI)

9.9 LED Sources Technical Requirements. The LEDs shall be from a reputable manufacturer of LEDs with LM80-08 and LM79-08. Test report from ISO/IEC 17025 and qualified for pertinent testing of LED products particularly LED for roadway lighting.

9.9.1 The colour temperature of the light source shall be cool white (4000K- 5000K). The colour rendering index of the light source shall not be less than be 70+/- 5.

9.9.2 The LED module shall have the following information distinctly and durably marked:

(a) Trademark or mark of origin (Brand & model used);
(b) Weight;
(c) Marking requirements in accordance to relevant local or international standards

9.9.3 The LED Module shall have the following features:

(a) Heat sink with high thermal dissipation properties;
(b) Provisions to prevent unauthorized removal;
(c) Corrosion resistant;
(d) Diffuser/lenses shall be UV coated
(e) Operate in relative humidity of greater than 90%

Table 9.1. Sample of Technical Specifications for LED Luminaire

Item	Specification	Requirements
1.0	Luminaire Physical Characteristics	
1.1	Housing	High pressure die-cast aluminum with heat management system in light gray color, powder coated and rust resistant
1.2	Dimension	Length not more than 1200 mm Height not more than 200 mm Width not more than 400 mm
1.3	Weight	Maximum of 16 kilograms
1.4	Ingress Protection (IP)	Shall be rated a minimum of IP66
1.5	Minimum Vibration Resistance	Conforms to ANSI C136.31 for 2G Vibration
1.6	Mechanical Impact Protection (IK)	Minimum of IK06 or equivalent to 1 joule (drop of 500 gram object from 20 cm height)
1.7	Modularity	LED arrays, drivers, and surge protection device should by modularly replaceable, without need to dismantle.
1.8	Lighting Controls	Provisions for compatibility to wireless lighting control protocols.
1.9	Mounting Arm Connection	Luminaire shall mount on standard 2.375” O.D. horizontal tenon with no more than four 9/16-inches hex bolts and two piece clamp with vertical tilt adjustment range of +/- 5%.

1.10	PE Cell Receptacle	Luminaires shall have a 3-prong twist-lock photo-control receptacle in accordance with ANSI C136.10. The PE socket needs to be able to rotate, so that the PE window can always be positioned to face the North direction.
1.11	House Shield	Shall provide option for house side light control
1.12	Optics	Built-in sensor aluminum with satin or mirrorize finish
1.13	Cover	Tempered glass cover
1.14	Miscellaneous hardware	All screws shall be stainless steel. Captive screws or use of latches are needed on any components that require maintenance after installation.

Item	Specifications	Requirements
1.15	Bar Code (Marking)	Each Luminaire must have a Bar Code identifying its Catalog number, wattage and current settings (e. g., 700 mA, 525mA, or 350mA). The bar code shall be attached on the inside of housing door and must be easily visible once door is opened.
2.0	Luminaire Electrical Characteristic	
2.1	Applicable Electrical Code	Complies with the latest edition of AS/NZS 3000:2007 – Electrical Installations – known as the Australia/New Zealand Wiring Rules.
2.2	Operating Voltage	230 volts AC, 60 Hz with fluctuation tolerance of ±10%
2.3	Operating Current	Maximum amperage at LED must not exceed driver current to meet Lumen Depreciation value described above
2.4	Wire Type	Not smaller than 2.0mm^2 THHN stranded copper wire(supply connecting points) using terminal blocks for connections
2.5	Wire Electrical Insulation	Complies with NEC Class 1
2.6	Grounding	Grounding in accordance in NEC 2
2.7	Energy Efficiency	Minimum 50% savings compared with existing or installed lamps
2.8	System Power Tolerance	Not more +/- 10W
2.9	High Capability Surge Protection (separate device installed in the luminaire)	Minimum of 6kV level
2.10	Total Harmonic Distortion	≤15%

Item	Specifications	Requirements
2.11	Power Factor	Should have a minimum power factor of 0.90
2.12	Operating Temperature	Operating ambient temperature between 10° C and 50° C
3.0	Luminaire Driver	Dimmable and Design to operate maintenance free for 50,000 hours. The Driver and LED arrays shall be designed for multi-current input operation, with switchable ratings at 350 mA, 525 mA and 700 mA. Multi-current (dimming) driver output must be within the operating limits. Dimming functionality must be controllable via wireless networked control system. Provisions for compatibility to wireless lighting control protocols.
3.1	Off-state Power Consumption	The power draw of the luminaire (including PE or remote monitoring unit) shall not exceed 2.50 watts when in the off state.
3.2	On-State Power Consumption	Luminaire shall not consume more than 175 watts (not including optional monitoring/control device).
3.3	Cooling System (heat transfer)	Shall consist of heat sink with no fans, pumps, or liquids, and shall be resistant to debris buildup that does not degrade heat dissipation performance.
3.4	Frequency	Input operating frequency of 60 Hz.
3.5	Voltage Fluctuation Tolerance	+/- 10%
3.6	Electrical Insulation	Class I
3.7	Efficiency	Shall have an efficiency of at least 85%
3.8	Input voltage	The driver should be suitable for nominal 230 volts, 60 Hzmains supply
3.9	Luminaire LED Performance	Should be designed to operate large array high power LED's through current controlled output.
4.0	Minimum Luminaire Efficacy	100 lm/W
4.1	Correlated Colour Temperature (CCT)	≥4000K

4.2	Minimum Colour Rendering Index (CRI)	80 +/-10
4.3	Lumen Maintenance of LED source after 6,000 hours of operation	≥95.0% or 0.95
4.4	Minimum Operating Life of luminaireL70 at 50,000 hours	LED Module(s)/array(s) shall deliver at least 70% of initial lumens when installed for a minimum of 50,000 hours
5.0	Luminaire Photometry	
5.1	Average Road Surface Luminance, Cd/m^2	≥ 1.0
5.2	Overall Uniformity Ratio	≥ 0.40
5.3	Minimum Total Lumen Output	Integrated total flux (lux) 30% above level required to maintain compliance with recommended illumination level parameters indicated in the guidelines
5.4	Photometric Distribution (Light Distribution)	Should be in accordance in IESNA Type 3 Lighting Distribution.
5.5	IESNA Luminaire Classification	Cutoff or TM-15: B3 U3 G3
6.0	Warranty	
6.1	Period of Warranty	A warranty must be provided for the full replacement of the luminaire due to any failure for six (6) years. The warranty shall provide for the repair or replacement of defective electrical parts (including light source and power supplies/ drivers chip, and other accessory) for a minimum of eight (8) years from the date of purchase. Warranty covers luminaire integrity and functionality: Luminaire housing, wiring and connections; LED light source(s)-negligible light output from more than 10% of the LED sources constitutes luminaire failure; LED driver(s)

6.2	Lamp Lumen Depreciation (LLD) not to exceed annualized depreciation of 3.1% after 20,000 hours of operation, measurement period to begin after 1,000 hour burn-in period, net of Luminaire Dirt Depreciation (LDD).	Randomized selection of luminaires to be tested at periodic intervals by independent third party laboratory, testing protocol to be determined by the Purchaser.
6.3	Maintenance	Replaceable/upgradable LED module on the pole
6.4	3rd Party Test Report	Laboratory facility must be accredited according to ISO/IEC 17025 and qualified for pertinent testing of LED products particularly LED for roadway lighting by a recognized national or regional accreditation body (ILAC/APLAC). Certification or Accreditation document must be provided to the Purchaser.

9.10 Applicable Standards

The luminaires shall be in accordance with the applicable requirements of standard specifications listed as follows:

(a) ASTM A123: Specification for Black and Hot- Dipped Zinc Coated (galvanized) Longitudinally Welded Steel Pipes

(b) IEC EN 60598-1: Luminaires - General requirements and tests

(c) IEC EN 60598-2-3: Particular requirements - Luminaires for Road & Street Lighting

(d) IEC EN 62031: LED modules for general lighting – Safety specifications

(e) EN 55015: Limits & methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment

(f) EN 61547: Equipment for general lighting purposes – EMC immunity requirements

(g) EN 61000-3-2: Limits for Harmonic emissions (<16A per phase)

(h) EN 61000-3-3: Limitation of voltage fluctuation and flicker in Low-voltage supply systems for equipment with rated current 16A

(i) EN 61347-1: General and Safety requirements for the driver

(j) EN 61347-2-13: Particular requirements for DC or AC supplied electronic driver for LED modules

(k) EN 62471: Photo biological safety of Lamps and lamp systems

(l) LM-79-08: Approved Method: Electrical and Photometric Testing of Solid-State Lighting Devices Describes the procedures for performing standardized measurements of the power, light output, and color characteristics of SSL products.

(m) LM-80-08: Approved Method: Measuring Lumen Depreciation of LED Light Sources Specifies conditions for long-term testing of LED packages, arrays, and modules

(n) IEC 62384: DC or AC supplied electronic control gear for LED modules - Performance requirements

(o) BS5489-1:2013: Code of practice for the design of road lighting

(p) PNS 26:1992: Specification for Steel - Black and hot-dipped zinc coated (galvanized) longitudinally welded steel pipes

Section 10. Typical Light Sources for Roadway Lighting

There is a wide range of light sources that are suitable for lighting roads and public amenity areas. The following factors, which will influence the choice of light source for a particular application, or type of application, should be taken into account.

a) **Energy efficiency.** The energy efficiency of road lighting is not only a matter of light source efficacy in terms of lumens per watt (lm/W). The efficiency of the complete lighting installation should also be taken into account, including the effectiveness of the light source, control gear and luminaire optic combination in providing the lighting on the road, with the desired degree of colour rendering.

b) **Colour rendering.** The colour rendering attributes of the light source should be appropriate to the task. In general terms, higher colour rendering index values should be used where there is a high level of pedestrian activity or where the appearance of an area is important.

c) **Colour appearance.** Light sources can be of a warm, intermediate or cool colour appearance.

d) **Mesopic vision and scotopic/photophic (S/P) ratio.** Human vision is a highly complicated process, and the spectral luminous efficiency of the eye is influenced by a large number of factors. At lower lighting levels refer to Table 6.5.1.

Section 11. Tunnels / Underpasses

11.1 All roadways below the normal thoroughfare level, whether classified as tunnel or underpass shall be adequately and efficiently lighted.

11.2 Photoelectric controls shall be strategically designed and located along tunnel/underpass to activate roadway lights as necessary especially during night time and during adverse weather condition.

11.3 The entrance, interior, and exit portion of the tunnel shall be provided with separate control system.

11.4 Ceiling and wall surfaces shall be of a light color, easily maintained finish and highly reflective with an initial reflectance of 50%.

11.5 Uniformity of roadway lighting is critical to visibility and safe adaptation in tunnel lighting. A tunnel lighting layout should be designed based on luminance values to insure the average to minimum uniformity ratio do not exceed 2 to 1 and a maximum to minimum ratio of 2.5 to l.

11.6 Construction material to be used shall be of the type that would reduce the luminance contrast between the outside and the inside of the tunnel, which in turn reduce entrance zone luminance and illuminance requirements.

11.7 The luminance level shall be designed to provide direct illumination ranging from the adaptable daylight brightness to minimum night time lighting requirement with minimal or no glare.

11.8 Warrants for Tunnel Lighting

11.8.1 The design of tunnel lighting shall take into consideration the physiological limitation of the human eye to adapt from a bright environment to a relatively darker environment to avoid the “black hole effect”.

11.8.2 Lighting shall be extended up to the level where the motorist could distinguish lane markings. Lane markings should be easily recognized in order to provide safe driving condition.

11.8.3 Prior to establishment of a lighting design, an evaluation of brightness conditions (pavement, adjacent landscape, sky, and others) must be made for the actual roadway and tunnel.

11.8.4 The optimization conditions of the tunnel lights shall produce an adequate visibility level of not less than 3 cd/m2.

11.9.5 Tunnel lighting control systems shall be designed to have the least probability of a total tunnel outage in the event of a circuit failure or other breakdown.

Section 12. Maintenance of EE Street Lighting

A huge amount of money is invested for the design, procurement, installation, operation and maintenance of street lighting. To sustain its value, there shall be a periodic maintenance program to ensure the effectiveness of EE street lighting over time. Scope of the maintenance program includes cleaning of the luminaire inclusive of the refractor/lens, reflector, lamp, and control gear components, and replacement of the luminaire and/or the lamp and component of the control system e.g. the photoelectric control, electrical wiring inspection, and measurement of input voltage. The frequency of the maintenance activities shall be based on the extent of pollution in which the roadway lighting facilities are subjected to. It shall also take into consideration pedestrian/traffic safety, security, and economics.

12.1 Cleaning luminaires

The extent to which air-borne dirt and pollution reduce light output depends on the effectiveness of the luminaire's sealing (its IP rating) and the quality of the environment. The likely loss from dirt and pollution should also be allowed for in the initial design.

12.2 Lamp Replacement

Lamps gradually give less light output also known as "lamp light depreciation" as they age. In any large number or sample of lamps installed there will be a fraction which fails prematurely. There are two (2) major approaches to lamp replacement, *spot relamping* **and** *group relamping.*

12.2.1 In spot relamping or replacing individual lamps as and when they fail, and only when they fail. Intuitive appeal to developing countries but it can, especially if manpower costs are high, be a more expensive option.

12.2.2 In group relamping or replacing all lamps in a group with new lamps after a fixed period. This is usually the most cost-effective approach, but should be modified to exclude lamps which have been recently replaced as a result of random failure.

12.3 Electrical Wiring Inspection

All internal and external wiring installations shall be inspected to check for broken or cracked terminal lugs, frayed or deteriorated conductor insulations, and tightness of screws and loose connections. Loose electrical connection may cause overheating and damaged to the lighting system.

12.4 Measurement of Voltage Input

Measurement should be conducted to determine input voltage to the luminaire. The required voltage input is necessary for all the electrical components of the luminaires (e. g., ballast, driver, and ignitor) to operate properly. Lower voltage input may damage the luminaire prematurely (shorter lifetime).

Section 13. Requirements for Transition of Lighting Technology and Compliance to Standard

Not with standing the advent of Light Emitting Diode (LED) light sources and the use of S/P ratios, it is deemed necessary that Table 6.5.1 shall remain in effect a requirement and the sole basis for the acceptability of a particular roadway lighting system including the appurtenant light sources and luminaires used.

This is to ensure that the luminance of a particularly lighted area remains within acceptable limit of visibility and the use of LEDs would still result to an acceptable sharpness of perception of roadusers during night time especially during inclement weather condition. It should be furtheremphasized that with the variety of LED available in the market with theirdifferent specifications and reduction in actual lumen output over the rated lumen output, LEDs shall be required to have a lumen maintenance factorthat will enable it to comply(in conjunction with the luminaire used)with Table 6.5.1 over the claimed life span of the luminaire.

Adherence to a CRI level of not less than 70 shall be maintained during the entire installation duration of the aforementioned roadway lighting facility.

(Footnotes)

1 Reference: IESNA, Figure 22-8. Recommended Maintained Luminance and Illuminance Values for Roadways

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