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# ROAD LIGHTING STANDARDIZATION USING DIFFERENT LIGHT SOURCES

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## ABSTRACT

This paper investigates the optimization of LED lamps and luminaires lighting in Motorized traffic (M), Conflict (C), and Pedestrian (P) areas to enhance safety and efficiency. These areas present unique challenges regarding visual clarity, spatial awareness, and risk management. LED lamps offer a promising solution due to their energy efficiency and flexibility. This research explores the specific lighting requirements in M, P, and C areas by combining theoretical analysis, empirical measurements, and practical case studies. It proposes strategies for effectively implementing LED lamp lighting and luminaires to improve visibility, mitigate conflicts, and ensure a secure environment for all users by studies the glare in all cases.

**Keywords:** LED lamps, motorized traffic (m), conflict (c), pedestrian (p),

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## INTRODUCTION

According to CIE [(1)] criteria for road lighting the lighting areas have the following categories;

a) Motorized traffic, i.e. fast area, M,

(For drivers of motorized vehicles)

b) Conflict area, i.e. mixed area, C, (where traffic streams intersect or run into areas with peds, cyclists, or there is a change in geometry or parking areas).

c) Pedestrian i.e. low-speed areas, P, (for needs of pedestrians).

Also, the road width and the pole distance corresponding to the three categories of road areas concluded from the expert inquiry are represented in Table-1 the optimization of LED lamp lighting in these areas to enhance safety and efficiency. These areas present unique challenges in terms of visual clarity, spatial awareness, and risk management. LED lamps offer a promising solution due to their energy efficiency and flexibility. By combining theoretical analysis, empirical measurements, and practical case studies, this research explores the specific lighting requirements in M, P, and C areas and proposes strategies for effectively implementing LED lamp lighting to improve visibility, mitigate conflicts, and ensure a secure environment for all users. (1, 2, 3, 4).

**Table-1.** The road width and the pole distance.

| Category | Fast road M | Mixed road or Conflict area C | Slow road or Pedestrian areas P |
|---|---|---|---|
| Average width of road (m) | 20 | 10 | 8 |
| Average Pole distance (m) | 45 | 30 | 20 |

Also, CIE recommended that the lighting design must be based on illuminance for the cases of P and C categories and luminance for the M category.

**Table-2.** The CIE standard value of illuminance.

| Lighting Category | $E_{ave}$ | | Lighting Category | $E_{ave}$ |
|---|---|---|---|---|
| C0 | 50 | | P1 | 15 |
| C1 | 30 | | P2 | 10 |
| C2 | 20 | | P3 | 7.5 |
| C3 | 15 | | P4 | 5.0 |
| C4 | 10 | | P5 | 3.0 |
| C5 | 7.5 | | P6 | 2.0 |

**Table-3.** The CIE standard value of Luminance L.

| Lighting class M | M1 | M2 | M3 | M4 | M5 | M6 |
|---|---|---|---|---|---|---|
| Average Lin cd/m$^2$ | 2.0 | 1.5 | 1.0 | 0.75 | 0.50 | 0.30 |

**Theoretical:**

For the lighting comparison for the three LED lamp systems (9-12-15) watts, we have to determine the basic data needed for illumination calculation.

**First Illumination Calculation**

For their lumen calculation, exterior lighting designers use a formula very similar to that used in interior lighting. As the utilization factor diagram of the luminaire in use is given, the formula is

$$E= N \times \Phi_o \times MF \times UF / A \qquad \text{---------- (1)}$$

Where E is the Average maintained illuminance
N is the number of lamps used in the installation = 5
$\Phi_o$ is the initial value of the lamp's luminous flux (usually after burning for 100 hours).
MF has a maintenance factor (in this work we take MF= 0.8
UF is the utilization factor (in this work we take UF= 0.69)
A is the area (m) to be lit. (5, 6, 7)

**III - Experimental**

As usual, we use the integrating sphere to obtain the values of flux

**Figure-1.** Integrating sphere to measure the flux.

To obtain the data needed for the investigated study which we are dealing with, we classify the available lamps into three groups. Group I (T1, V1, and E1) for 9-watt LED, group II for 12-watt LED, and group III for 15-watt LED lamps where T, V, and E represent three different lighting companies. It is obvious that the investigated lamps are sensitive to the burning position. The three types of lamps are always operated at the base-up vertical position. (8, 9).

**Table-4.** The average values of the first type 9 watts LED lamps.

| Lamps 9 watts | Flux $\Phi_o$ after 100 h |
|---|---|
| T1 | 835 |
| V1 | 884 |
| E1 | 959 |
| Average | 893 |

**Table-5.** The average values of the first type 12 watts LED lamps.

| Lamps 12 watts | Flux $\Phi_o$ after 100 h |
|---|---|
| T4 | 1003 |
| V4 | 1201 |
| E4 | 1224 |
| Average | 1143 |

**Table-6.** The average values of the first type 15 watts LED lamps.

| Lamps 15 watts | Flux $\Phi_o$ after 100 h |
|---|---|
| T7 | 1355 |
| V7 | 1440 |
| E7 | 1636 |
| Average | 1477 |

**The Glare**

Glare is a visual sensation caused by excessive and uncontrolled brightness in the field of view. It is produced by brightness in the visual field that is so much greater than the brightness to which the eyes can handle. Glare ends up limiting a person's ability to distinguish details and objects. Also, sensitivity varies between people and older people are usually more sensitive to glare due to ageing characteristics of the eye. It is a common issue that can occur in various environments, including indoor spaces, outdoor areas, and while using electronic screens
There are two forms of glare. The most common are disability glare and discomfort glare. Disability glare and discomfort glare can be caused by two types of glare; they are direct and indirect glare

Disability glare is the reduction in visibility caused by intense light sources in the field of view. How it works is that it causes a loss of visibility from stray light being scattered within the optical system of the eye. This results in a uniform brightness/luminous veil being drawn over the retina. This veil reduces the apparent contrast in the visual scene to impair visibility.

Discomfort glare is the discomfort of annoyance or pain induced by an overly bright source. Discomfort glare also referred to as "psychological glare" as a physiological test can't measure it. Thus, discomfort glare is measured and evaluated exclusively based on the individual. The main physical parameters that determine

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discomfort glare are the brightness of the glare source and background, the size of the glare, and the position of the source.

Disability glare refers to the glare that significantly impairs vision, making it difficult to see objects or perform tasks.

Discomfort Glare refers to the sensation of visual discomfort or annoyance caused by excessive brightness or contrast.

It may not necessarily impair vision but can still cause discomfort, leading to eye strain, squinting, or headaches.

**There are several methods commonly used to calculate glare, including the following**

**a) Unified Glare Rating (UGR):** The UGR method is widely used in indoor lighting design. It takes into account the luminance values of the task area, background, and surrounding areas, as well as the observer's position. UGR values are assigned to different lighting installations and the lower the UGR value, the lower the perceived glare. The UGR method is primarily intended for indoor lighting scenarios and may not be suitable for evaluating glare in outdoor or daylighting conditions.

**b) Daylight Glare Probability (DGP):** DGP is commonly used in daylighting design to assess the potential for glare caused by natural light. It considers factors such as the luminance distribution of the sky, window geometry, and the view out of the window. DGP values range from 0% (no glare) to 100% (glare highly likely).

**c) Direct Calculation Methods:** In some cases, glare can be calculated directly by considering the luminance values of the light source, the background, and the observer's position. This approach involves using complex equations or software simulations to determine the glare level accurately.

**d) Disability Glare Index (DGI):** The DGI method focuses on evaluating glare specifically for people with disabilities. It considers the luminance values of the glare source, the background, and the observer's position. The DGI provides a numerical value indicating the potential disability glare experienced by individuals.

The Disability Glare Index (DGI) is a metric used to assess the disability glare caused by luminaires in outdoor lighting situations. Disability glare occurs when there is a significant difference in brightness between the glare source and the background, leading to visual discomfort and a potential decrease in visibility and we use this method in this paper.

The DGI (glare rating) is calculated using the following formula:

$GR= 27+24 \log (L_{vl}/L_{ve}{}^{0.9})$ -------- (2)

$L_{Vl}$ the veiling luminance produced by the luminaires.
$L_{ve}$ the veiling luminance produced by the environment.

**Measurements of illuminance E, luminance L and the glare**

For M classes valid for CIE road surface reflectance of CIE publication 144:2001, with $q_o$=0.07cd/m$^2$/lx where $L = q_o \bullet E$

And glare rating by applying $GR= 27+24 \log (L_{vl}/L_{ve}{}^{0.9})$
$L_{Vl}$ the veiling luminance produced by the luminaires.
$L_{ve}$ the veiling luminance produced by the environment.
From equation (1) E= 5x893x0.8x0.69/900 =2.73 lux for M class road and 9 watts lamps and Luminance L=0.07x1.64=0.19 cd/m$^2$
Then from eq. (2) GR = 9.69
E= 5x 1143x0.8 0.69/900 = 3.5 lux for M class road and 12 watts lamps and Luminance
L = 0.07x 3.5= 0.25 cd/m$^2$
Then GR = 12.55
E=5x 1477x0.8x 0.69/900 =4.5 lux for M class road and 15 watts lamps and Luminance
L= 0.07x 2.72= 0.32 cd/m$^2$
GR= 15.12
only lamps of 15 watts and number of 5 are suitable for road lighting class M6
also lamps 12 watts and 15 watts are suitable for Pedestrian lighting class P4, P5, and P6. (10, 11, 12)

**For luminaires**

We selected some luminaires such as Astra 100, 150, and 200 watts and panel-led luminaires. The measurements are achieved by Goniophotometer.

**Figure-2.** Goniophotometer to measure the luminaire flux.

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**Figure-3.** Led luminaire Astra 100W where the luminous flux is 12735 lumens.

N=1 where we deal with the luminaire
E= 1x12735x0.8x 0.69/900 = 7.8 Lux for M and L= 0. 07x 7.8=0.55 cd/m$^2$
E= 1x12735x0.8x 0.69/300 = 23.4Lux for C and L= 0.07x 23.4=1.64 cd/m$^2$
E= 1x12735x0.8x 0.69/160 = 43.9Lux for P and L= 0.07x 43.9=3.07 cd/m$^2$

This luminaire is suitable for C2 and all P and also for M5 and M6

**Figure-4.** Led luminaire Astra 150W where the luminous flux is 19204 lumens.

N=1 where we deal with the luminaire
E= 1x19204x0.8x 0.69/900 = 11.77 Lux for M and L= 0. 07x 11.77=0.82 cd/m$^2$
E= 1x19204x0.8x 0.69/300 = 35.33Lux for C and L= 0.07x 35.33=2.47 cd/m$^2$
E= 1x19204x0.8x 0.69/160 = 66.25 Lux for P and L= 0.07x 66.25=4.63 cd/m$^2$
This luminaire suitable for C1 and all P and also M4, M5 and M6

**Figure-5.** Led luminaire astra 200 W where the luminous flux is 25553lumen.

N=1 where we deal with the luminaire
E= 1x25553x0.8x 0.69/900 = 15.67 Lux for M and L= 0. 07x 15.67=1.09 cd/m$^2$
E= 1x25553x0.8x 0.69/300 = 47.01Lux for C and L= 0.07x 47.01=3.29 cd/m$^2$
E= 1x25553x0.8x 0.69/160 = 88.15 Lux for P and L= 0.07x 88.15=6.17 cd/m$^2$

This luminaire suitable for C1 and all P and alsoM4, M5 and M6

**Figure-6.** Led backlight panel 60x60 cm 55 W where the luminous flux is 4540 lumens.

N=1 where we deal with the luminaire
E= 1x4540x0.8x 0.69/900 = 2.78 Lux for M and L= 0. 07x 2.78=0.19 cd/m$^2$
E= 1x4540x0.8x 0.69/300 = 8.35 Lux for C and L= 0.07x 8.35=0.58 cd/m$^2$
E= 1x4540x0.8x 0.69/160 = 15.66 Lux for P and L= 0.07x 15.66=1.09 cd/m$^2$

This luminaire suitable for C1 and all P and also M4, M5 and M6
Not M and suitable for C5 and P1

By applying E= N x $\Phi_o$ x MF x UF / A Led luminaire Astra 100W where the luminous flux is 12735 lumens.
E= 1x 12735 x 0.8 x 0.69 /900 = 7.81 cd/m$^2$ for M
E = 1x12735 x0.8 x0.69/300 = 23.43 cd/m$^2$ for C
E = 1x 1735 x 0.8x 0.69/160 = 43.93 cd/m$^2$ for P
LVl = 0.07 x 7.81 = 0.55 for M

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LVl = 0.07 x 23.43 =1.64 for C
$L_{Vl}$ = 0.07x 43.93= 3.07 for P
Lve = 1 cd/m2
Hence GR= 27+24 log ($L_{vl}/L_{ve}^{0.9}$) = 20.77 for M
= 32.15 for C
= 38.69 for P

By applying E= N x $\Phi_o$ x MF x UF / A Led luminaire Astra 150W where the luminous flux is 19204 lumen
E = 11.77 Lux $L_{Vl}$ = 0.82 cd/m2 for M
E= 35.33 $L_{Vl}$ = 2.47 cd/m2 for C
E=66.25 $L_{Vl}$ = 4.63 cd/m2 for P
$L_{ve = 1}$ cd/m$^2$
GR = 24.93 for M
GR = 36.42 for C
GR = 42.97 for P

By applying E= N x $\Phi_o$ x MF x UF / A Led luminaire Astra 200W where the luminous flux is 25553 lumen
E = 15.67 Lux $L_{Vl}$ = 1.09 cd/m2 for M
E= 47.01 $L_{Vl}$ = 3.29 cd/m2 for C
E=88.15 $L_{Vl}$ = 6.17 cd/m2 for P
GR = 27.90 for M
GR = 39.41 for C
GR = 45.97 for P

By applying E= N x $\Phi_o$ x MF x UF / A for Led backlight panel 60x60 cm 55 W where the luminous flux is 4540 lumen.
E = 2.78 Lux $L_{Vl}$ = 0.19 cd/m2 for M
E= 8.35 $L_{Vl}$ = 0.58 cd/m2 for C
E=15.66 $L_{Vl}$ = 1.09 cd/m2 for P
GR = 9.69 for M
GR = 21.32 for C
GR = 27.90 for P

The outdoor glare rating (GR) is used for assessment. According to the International Commission on Illumination CIE 112-1994, the GR represents the glare level, the GR lower than 50 means the glare is acceptable, that higher than 50 means the glare is unacceptable. Therefore, the lower the glare rating is, the lower the glare degree, unlikely to discomfort vision as in the table.

**Table-7.** Glare rating evaluation relationships (CIE 112-1994).

| **GR** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** |
|---|---|---|---|---|---|---|---|---|---|
| Glare degree | Unnoticeable | Noticeable | Slightly sensible | Acceptable | Slight discomfort | Disturbing | Glaring | Intolerable | severely glaring |

## CONCLUSIONS

In conclusion, based on the given information, it can be determined that for road lighting class M6, only lamps with a wattage of 15 watts and a number of 5 are suitable. On the other hand, for pedestrian lighting classes P4, P5, and P6, both 12-watt and 15-watt lamps are suitable. These findings highlight the specific requirements for different lighting classes and emphasize the importance of selecting the appropriate wattage and number of lamps to ensure optimal lighting conditions for roads and pedestrians. It is important to note that these recommendations are specific to the mentioned lighting classes and wattages. Other lighting classes or different wattage requirements may require different lamp specifications.

M6 class roads typically have moderate traffic volume and lower speed limits when compared to highways or major roads.

Pedestrian lighting classes are used to define the lighting requirements for different types of pedestrian areas, such as sidewalks, pathways, or pedestrian zones.

Classes P4, P5, and P6 represent specific categories within the pedestrian lighting classification system, each with its own characteristics and lighting needs.

Lamps with wattages of both 12 and 15 are considered suitable for meeting the lighting requirements of these pedestrian lighting classes.

The specific choice between the 12-watt and 15-watt lamps may depend on factors such as the size of the area, desired illumination level, and energy efficiency considerations.

For the luminaires:

The luminaire astra 100 watts is suitable for C2 and all P and also for M5 and M6

The luminaire astra 150 watts is suitable for C1 and all P and also M4, M5 and M6

The luminaire astra 200 watts is suitable for C1 and all P and alsoM4, M5 and M6

The luminaire backlight panel is suitable for C1 and all P and also M4, M5 and M6

Not M and suitable for C5 and P1

For the glare measurements, no glare for lamps but for luminaires high watts gives Acceptable GR.

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