A COMPARATIVE ANALYSIS OF LIGHTING PARAMETERS ON VARIOUS ROAD SURFACES AND DIFFERENT LAMPS

A thesis submitted towards partial fulfillment of the requirements of the degree of

Master of Technology

In

Illumination Technology and Design

SUBMITTED BY

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **“A Comparative Analysis of Lighting Parameters on Various Road Surfaces and Different Lamps”** submitted by **PROSHOMON KUMAR BHOWMICK** bearing Exam Roll No.: **M6ILT23010** under my supervision and guidance for partial fulfillment of the requirement of **Master of Technology** in **Illumination Technology and Design** in **School of Illumination Science, Engineering & Design** of **Jadavpur University** during the academic session **2022 - 2023**.

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This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented by **PROSHOMON KUMAR BHOWMICK** bearing **EXAM ROLL NO. M6ILT23010** in a manner satisfactorily to guarantee its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of his Master of Technology In Illumination Technology and Design studies during academic session 2022-2023.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by this rules and conduct, I have fully cited and referred to all material and results that are not original to this work.

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ABSTRACT

This dissertation is about the analysis of lighting parameters of three types of lamps namely ***high pressure sodium vapour (HPSV), Metal Halide (MH) and Solar-Efficient Light Emitting Diodes (LED)*** *using* ***DIALux 4.13 lighting design software.*** *These lamps are placed in three different arrangements i.e. zig-zag having dry road surface R1, opposite having wet road surface W2 and twin-central having concrete road surface C2. The traffic lighting class selected is* ***ME4a****. Lighting parameters such as* ***average luminance (L_{avg}), overall uniformity (U0), uniformity index (UI), threshold increment (TI) & surround ratio (SR)*** *have been calculated for these lamps in every arrangement. It has been found out that L_{avg} value is preferred for Solar-Efficient LED in zig-zag arrangement having dry road tarmac (R1). U0 value is preferred for HPSV & MH lamps in zig-zag arrangement having dry road tarmac (R1). UI value is preferred for HPSV lamps in twin-central arrangement having concrete road tarmac (C2). TI value is preferred for HPSV lamps in opposite arrangement having wet road tarmac (W2). SR value is preferred for Solar-Efficient LED in all arrangements for dry, wet and concrete roads R1, W2 and C2 respectively. Moreover, lighting parameters of the four observers were also analyzed. All the observers of Solar Efficient LED in the zig-zag pattern give the highest values. For U0, observer 1 and observer 4 of HPSV lamps in a zig-zag pattern gives the best value. For UI, observer 1 of HPSV lamp in opposite arrangement and for TI, best value is perceived by all observers of Solar Efficient LED in twin-central arrangement. The highest average illuminance (E_{avg}) yield is found to be 36 lux when Solar Efficient LED is arranged in a zig-zag pattern. The lowest E_{avg} is found to be 13 lux when HPSV lamps are arranged in a twin-central pattern. HPSV lamps give an average savings pay-back period of 13.03 years which is not viable. Solar Efficient LED lamps give an average savings pay-back period of 5.2 years which is viable.*

Keywords: *HIGH PRESSURE SODIUM VAPOUR, METAL HALIDE, SOLAR EFFICIENT LIGHT EMITTING DIODES, AVERAGE LUMINANCE, OVERALL UNIFORMITY, UNIFORMITY INDEX, SURROUND RATIO, THRESHOLD INCREMENT, ME4A TRAFFIC LIGHTING CLASS & AVERAGE ILLUMINANCE.*

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CHAPTER 1: INTRODUCTION

1.1. INTRODUCTION ABOUT STREET LIGHTING

Street lighting offers numerous significant advantages by artificially prolonging the hours of daylight so that activity can occur, it can be utilized to improve security in metropolitan areas and the quality of life. Additionally, street lighting increases pedestrian, cyclist, and vehicle safety. Driving at night is riskier since only 25% of all car traffic occurs between 7 p.m. and 8 a.m., but this time frame is responsible for 40% of fatalities and major injuries within the same population. In the dark, vision is further compromised for pedestrians and other vulnerable road users. These factors necessitate finding methods to lessen the danger that nighttime driving poses to all road users[1].

With the rapid enhancement in the lighting industry, street lighting has become more complex with the current availability of Light Emitting Diode (LED) products varying in their power and different lighting qualities. Street lighting has also become important due to the increased vehicles on the road. More emphasis is needed while designing a streetlight luminaire which will cover all the lighting parameters to ensure a safe driving in a motorized road with several lanes.

However, it is also essential to analyze the economic aspects of the streetlight and how much it benefits the metropolitan corporations of a given city in the coming years. There are various advantages and disadvantages for the different pole arrangements based on the pole arrangements and the different values it gives for several lighting parameters. The savings payback period is also taken into account for the streetlight luminaires nowadays to visualize whether the investment is going in the right direction or not.

1.2. LITERATURE SURVEY

To head this dissertation towards its final destination, several journal and conference papers had to be consulted. It resulted in giving a jest of the topic and helped me in getting various ideas to proceed deep and complete this dissertation.

An educational approach to a Lighting Design Simulation using DIALux evo Software
By A.F.C.V. D. Silva; A.O.Godinho; C.I.F.Agreira; M.M.T.Valdez Published in 2016 51st International Universities Power Engineering Conference (UPEC) received from ***IEEE XPLORE (2016)*****[2]**

This paper gave a general idea about lighting efficiency as simulated by the authors. Using a practical approach, it can be understood that the design of a lighting installation needs to take into account the satisfaction of three basic human needs: visual comfort, visual performance and safety. The main objective of this work was to propose a new lighting design solution and the corresponding economic study for *Calçada de Santa Isabel*. The present lighting system uses HPS (high-pressure sodium) lamps and the objective is to replace the HSP lamps with LED technology. This paper also gives us a view whether the LEds of different power and the HPS luminaires meet the lighting parameters such as L_{avg}(Average Luminance), U_o(Overall Uniformity), UI(Uniformity Index), TI(Threshold Increment) and SR(Surround Ratio) under the Illuminance class- ME4a.

Optimisation of lighting quality and energy efficiency of LED luminaires in roadway lighting systems on different road surfaces *By S. Yoomak, A. Ngaopitakkul*

Published in Sustainable Cities and Society received from ***ELSEVIER (2018)*****[3]**

This paper presents the analysis of lighting quality in different road surface conditions using the DIALux software. Dry and wet road surfaces are used to study lighting quality following the classifications of the International Commission on Illumination (CIE), where the lighting qualities of high-pressure sodium (HPS) and light-emitting diode (LED) luminaires are compared, based on a roadway without a traffic island. The lighting parameters taken for comparison are L_{avg}, E_{avg}, $U_{o,}$ UI, SR, TI and SL. In addition, it presents the design of a roadway lighting system with optimized LED luminaires, by adjusting pole spacing and mounting height, ensuring the best installation in each classification of road surface. Thereafter, energy evaluations of different input powers of LED luminaires are discussed and compared with the HPS luminaire. Results indicate that the HPS luminaire can provide better average illuminance and average luminance values than LED luminaires, resulting in positive visual performance. However, LED luminaires can achieve better overall visual and comfort performances, including energy saving, due to their light distribution efficiency. For lighting quality in different road surface conditions, the wetter the road surface, the higher the lighting quality; because wet road surfaces cause alternating bright and dark areas on the road. This results in increased average luminance of the surface, and decreased longitudinal uniformity. Moreover, road surfaces with high average luminance coefficient, Q0, can accommodate larger pole spacing, reducing energy consumption. Using LED luminaires with lower or higher input power than the optimal power, however, result in higher energy consumption.

Simulations of Street Lighting System Using DIALux for Better Energy-Saving Application *By Y. Tan; C.Wooi; H.N.Afrouzi; S. N. Md; O. A. Bakar; W.S. Tan Published in 2022 IEEE International Conference on Power and Energy (PECon)Received from* ***IEEE XPLORE (2022)*** **[4]**

This paper aims to design and simulate different street lighting systems using DIALux for better energy saving application. This design had considered both MS835 and JKR standards and at the same time considered the optimal design of it in University Malaysia Perlis campus. The design starts off with simulating the street lighting using DIALux evo software to calculate the luminous effects, energy demand and eventually costing and energy saving of each different lighting system.

The purpose of comparing these lighting systems was to find an energy saving application to replace existing High Pressure Sodium (HPS) street lighting systems. Compared between 8 types of different lighting systems, it is concluded that Light Emitting Diode LED & LED+PIR is the best lighting system. It has the best performance in terms of low power consumption, low energy demand, an acceptable cost of operation and a short payback period which is 8 years. Therefore, based on current simulations study in University Malaysia Perlis, the proposed street lighting system in LED & LED+PIR street lighting system.

Techno-economic analysis of off-grid photovoltaic LED road lighting systems: A case study for northern, central and southern regions of Turkey *By A. C. Duman, O. Güler Published in Sustainable Cities and Society Received from* ***ELSEVIER (2019)*** **[5]**

This paper presents a techno-economic analysis of off-grid PV LED road lighting systems for northern, central and southern regions of Turkey. Road lighting calculations are conducted using DIALux software for M4 and M5 road lighting classes to obtain optimal LED luminaires, pole sizes, and spacings. Among the obtained LED powers, load profiles are created using real lighting hours of operation of the selected regions. And then, the required PV-battery systems are optimized using HOMER software. Finally, sensitivity analysis is performed for future projections considering possible increases in electricity prices and decreases in component cost of the PV systems.

Average Luminance Calculation in Street Lighting Design,Comparison between BS-EN 13201 and RP-08 Standards *By A. V. Rusu ,C. D.Galatanu ,G. Livint and D. D.Lucache Published in Sustainability 2021 Received from* ***MDPI (2021)*** **[6]**

This paper presents a study on the influence of the observer's position in relation to the calculation surface. This is the initial observation of the research, respectively that the two standards consider the position of the observer differently. For these situations, two types of calculations were performed. For the first set of calculations, the software used was DIALux 4.13 as this software can perform calculations in line with the RP-08 standard. The second set of calculations was performed with a script that offers the possibility to change the observer's position. The conclusion was that EN-13201 has a better approach, but both standards could be improved. The second case study refers to the influence of the longitudinal observer position in an average luminance calculation. If one considers RP-08 as a guideline for performing the calculations, the conclusions are that changing the distance from the observer to the calculation surface has absolutely no effect on the average luminance value.

Efficiency Analysis of Roadway Lighting Replacement in a Selected Polish Municipality By K. Zima and W. Ciepłucha *Published in Applied Sciences 2023 Received from* ***MDPI (2023)*** **[7]**

In this paper, the DIALux application was used to analyze the changes in road lighting depending on the luminaires used and the changes in pole spacing influenced by the height of the light point. Variant and scenario analyses were incorporated into the efficiency analyses, while the calculations themselves were based on detailed cost analyses with reference to Polish catalogs of material inputs and market prices. The authors conducted cost analyses of lighting dismantling and installation, including the subsequent operating costs over 20 years for seven variants of poles with their systems and four variants of luminaires. The results were compared with the existing lighting system in use. An original element of the study is the use of BIM analyses with design variants, combined with analyses of the technical condition of the existing lighting network and an illuminance analysis with estimates of the height and spacing of poles.

The Study of Lighting Quality of LED and HPS Luminaires Based on Various Road Surface Properties By *S.Yoomak and A.Ngaopitakkul Published in CEEGE 2018 Received from* ***E3S Web of Conferences 72, 01005 (2018)*****[8]**

This paper presents an analysis of lighting quality in different road surface conditions using the DIALux software. Dry and wet road surfaces are used to study lighting quality by following classifications of the International Commission on Illumination (CIE). Lighting quality of high pressure sodium (HPS) and light emitting diode (LED) luminaires are compared, based on roadway with a traffic island. Results indicate that the HPS luminaire can provide better average illuminance and average luminance values than the LED luminaire, resulting in positive visual performance. However, the LED luminaire can achieve visual and comfort performance including energy saving due to its light distribution efficiency. For lighting quality on different road surface conditions, the lighter dry road surface materials, the higher the lighting quality. Wet road surfaces cause very bright areas on the road surface alternating with large dark areas. It results in the average luminance of the surface increased while overall uniformity decreased.

Energy efficiency and pay-back calculation on street lighting system By *C. Subramani, S. Surya, J. Gowtham, R. Chari, S. Srinivasan, J. P. Siddharth and H. Shrimali Published in* ***The 11th National Conference on Mathematical Techniques and Applications*** *Received from* ***AIP Conference Proceedings (2019)*** **[9]**

This conference paper was consulted to get a brief idea about the payback period calculation which involves many utilities like number of fixtures replaced, the luminaries replaced, and the orientation of the street lighting setup and so on. It was also consulted to get the idea of the energy savings and the calculations incurred for the various pole spacings and the cost for various pole arrangements which reflects in the annual energy savings. It helped me to make the calculations more precisely and obtain savings pay back graphs for each of the luminaires selected for the dissertation.

1.3. PROBLEM DEFINITION

Owing to the various surfaces of road which are being constructed to improve the reflectance factor (q_o) of the road surface, the selection of the right tarmac for the given road stretch becomes important. Various analyses need to be done for a wide range of road surfaces for the illuminance class-ME4a and the lighting classes-A1, A2 & A3 to determine the performance of streetlight luminaires with various lamps such as HPSV (High-Pressure Sodium Vapour) , MHD (Metal Halide) and Solar LED . The five lighting parameters are evaluated and compared for the best road surface. In this case, the pole height is kept constant. Different pole arrangements with different pole spacings need to be simulated to get the best one for the drivers and the observers positioned. Similarly, for observers four lighting parameters are compared. To get the return investment period/savings payback period, we need to calculate the energy savings of each of these lights in different pole arrangements and the total installation cost.

1.4. OBJECTIVES

- To select various types of streetlights having nearly the same power and compare their lighting performance.
- To analyze which of the road surfaces and the streetlights in a particular arrangement gives the best performance.
- To calculate the total installation cost, annual energy savings and savings payback period of the various lights in different arrangements.
- To compare which of the lamps and the arrangement gives the less payback period value.

1.5. METHODOLOGY

- Estimation of a road stretch of 2km/2000m for the calculations.
- Lighting design with the help of DIALux 4.13 lighting software for simulating all the required objectives.
- Selection of three tarmacs of road surfaces R1, W2 and C2 respectively for comparison and analysis.
- As the design is proposed for a busy city area, the motorized illuminance class is selected to be ME4a according to the DIALux lighting wizard.
- The design is proposed for the roadways belonging to the lighting classes A1, A2 & A3 as suggested by DIALux lighting wizard.
- Corresponding bar graphs are obtained for comparing.
- Position of the four observers to get the best lighting values of the different street-lighting arrangements .
- To find the savings pay back period for each of the lamps in the various arrangements and find the one which gives the least value.
- To obtain graphs for each of the arrangements savings payback period with the three luminaires.

1.6. OUTLINE OF THE DISSERTATION

CHAPTER 1 gives an introduction about the dissertation very briefly. Firstly, it starts giving a basic knowledge of street lighting followed by the literature survey involved in the process. It gives the main idea of the dissertation which is going to be implemented in the upcoming chapters through its objectives and the methodology.

CHAPTER 2 gives all the knowledge we need to know about the street lighting and the terminologies involved in it. It also gives detailed information about all the lighting parameters involved while designing a street. Information has also been provided about the various road surfaces, illuminance classes and lighting classes as recommended by the IESNA and CIE.

CHAPTER 3 gives information about the International and National Road Lighting standards in detail which is kept in view while designing the streets in the DIALux software.

CHAPTER 4 starts with implementing the ideas into reality . It shows the planning, the luminaire details and the working which is done in DIALux 4.13 software to find the lighting parameters of each of the arrangements and the details of the observers' positions.

CHAPTER 5 gives all the graphical analysis and comparison results which are taken from the DIALux 4.13 software. It is prepared by using the MS-Excel and Google Spreadsheets. Final results which are derived after the analysis is also shown here. This chapter also marks the penultimate end of the dissertation.

CHAPTER 6 gives the conclusion of the dissertation and also the future scopes which are involved in it. This also discusses the challenges and the drawbacks involved. This marks the end of the dissertation.

CHAPTER 7 gives the list of the references from where the information was gathered to make this dissertation complete.

CHAPTER-2: VARIOUS CRITERIA AND PARAMETERS OF ROAD LIGHTING

2.1. Introduction [24]

Adaptive lighting has emerged as a new trend in the roadway sector as a result of the advancement of new lighting technologies and efforts to lessen the total energy and environmental effect of lighting. With adaptive lighting, a system's light output is modified in response to shifting traffic circumstances. More particular, the demands of the users of the road are taken into account when adjusting the illumination levels of the roadway. When there is less traffic on the roads, the sidewalks, or both, the lighting intensity can be decreased or lowered. The uniformity of the illumination and an object's contrast are unaffected by lowering the lighting level while keeping the lighting configuration; nevertheless, the contrast thresholds will rise, leading to longer detection times. Additionally, luminaires placed in new lighting designs frequently go above and beyond what is called for in the lighting design. Even if the lights deteriorate and lens dirt builds up over time, the system will eventually meet or surpass the intended level. Energy savings and the elimination of times of over-lighting can both be achieved by adjusting the output of luminaires so that the system maintains the design level for the duration of the lamp's service life. Although it is not specifically adaptive lighting, an adaptive lighting system offers this option for illumination control.

The objectives and methodology have been developed to update Reduced Lighting on Freeways During Periods of Low Traffic Density (Publication No. FHWA-RD-86-018), and to develop application guidelines that address the following issues:

Optimal times and conditions for reducing lighting.
Appropriate lighting levels for various roads and road features.
Appropriate approaches for reducing lighting.
Energy savings and reduction in greenhouse gases that may result from reducing lighting.
Potential legal issues related to reducing lighting, including the development of such issues since the release of the original report.

2.2. Road Lighting Quantities[12]

Power is the most primitive and common parameter for all luminaires. The power indicator not only shows how much electricity the lamp could consume, but it has now become almost the only parameter other than the lamp type. Luminous flux is the basic parameter of a light source that shows how much light energy the light source emits.
There is also another parameter called lamp efficiency, which expresses the rate of use of the lamp from the light source.

Luminance:- The most generally used approach to select quality criteria for lighting roads for motor traffic is based on the luminance concept.This is the minimum value to be maintained throughout the life of the installation. It is dependent on the light distribution of the luminaires,the luminous flux of the lamps,the geometry of the installation and on the reflection properties of the road surface[25].

Luminous Flux:- The unit for the quantity of light flowing from a source in any one second (the luminous power, or luminous flux) is called the lumen. The lumen is evaluated with reference to visual sensation [26].

Luminous Intensity:- The quantity of visible light that is emitted in unit time per unit solid angle[26].

Illuminance:- In photometry, illuminance is the total luminous flux incident on a surface, per unit area. It is a measure of how much the incident light illuminates the surface, wavelength-weighted by the luminosity function to correlate with human brightness perception[27].

Refer to Fig 2.1 for pictorial illustration of the above mentioned terms.

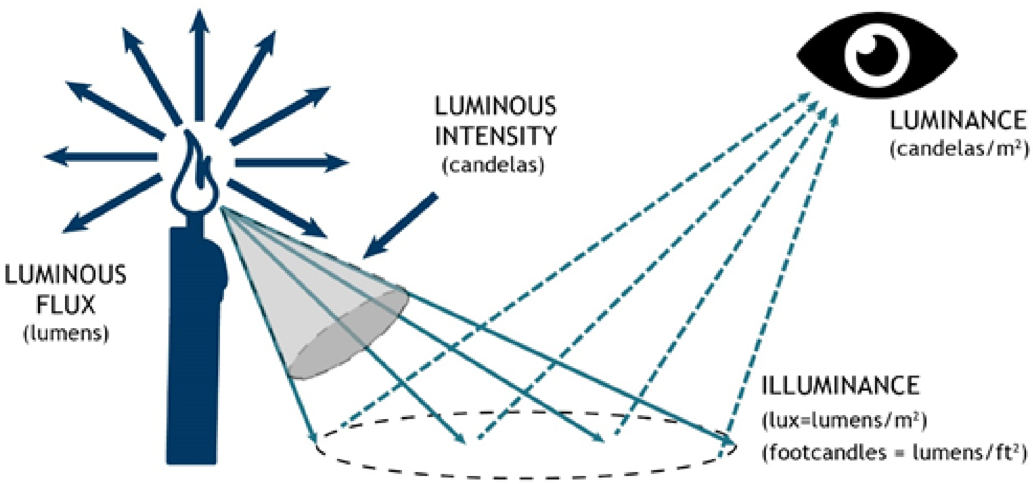


Fig 2.1. Diagram illustrating the meanings of these different terms

2.3. Designing Factors for Road Light

Design factors play a vital role in designing road lighting systems. Different design factors described below are used for road lighting systems:

2.3.1. Road Lighting Classes [10]

According to the CIE recommendation, road lighting installations are designed mainly to suit the needs of motorised traffic, pedestrians, cyclists and resident's road. The M lighting classes are intended for drivers of motorised vehicles on traffic routes, and in some countries, on residential roads, allowing medium to high driving speeds. The appropriate lighting-class has to be selected according to the function of the road, design speed, overall layout, traffic volume, composition and the environmental conditions as shown in Table 2.1.

Table 2.1. Parameter for selection of M lighting classes [10]

Parameter	Options	Weighting Value (V_W)	V_W Selected V_{WS}
Speed	Very High	1	
	High	0.5	
	Moderate	0.5	
Traffic Volume	Very High	1	
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very Low	-1	
Traffic Composition	Mixed with high % of non-motorised	2	
	Mixed	1	
	Motorised Only	0	
Separation of Carriageways	No	1	
	Yes	0	
Intersection	High	1	
	Moderate	0	
Parked Vehicles	Present	0.5	
	Not-Present	0	
Ambient Luminance	High	1	
	Moderate	0	
	Low	-1	
Visual Guidance/ Traffic Control	Poor	0.5	
	Moderate/Good	0	

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

Number of lighting-class M = 6 – V_{ws}

Note: Careful selection of appropriate weighting values in Table 2.1 will yield class numbers between 1 and 6. If the result is not a whole number, the following lower whole number is used.

2.3.2. Lighting Classes [17]

Lighting classes for motorised traffic, for conflict areas and for pedestrians and pedal cyclists are given by the standard EN 13201-2 (CEN 2003a)[11]. The lighting classes are defined by a set of photometric requirements that are regarded as relevant for the road users of the different types of roads. The purpose of standardised lighting classes is to make it easier to develop and use road lighting products. The lighting class standard does not state how the classes should be used. The application of the classes, i.e. what classes to use in what traffic environment and how to select an appropriate class, thus differs between countries.

The lighting class criteria are either based on luminance or on illuminance. The luminance concept is applied on roads for motorised vehicles, where the aim is to provide a bright road surface against which objects can be seen. The luminance is dependent on the amount of light from the light source, the road surface characteristics and the observer's position, and it is thus somewhat complicated to calculate.

The illuminance concept is used when the luminance concept cannot be applied or defined, e.g. in intersections where there are several possible observer positions, or in roundabouts where the road surface cannot serve as a background for objects because of the geometry. The M classes are intended for drivers of motorised vehicles on traffic routes of medium to high driving speed, Table 2.2.

The photometric requirements for the M classes include:

Average road surface luminance ($\overline{L}$): A measure of the brightness of the road surface.
Overall uniformity of road surface luminance (Uo): A measure of the luminance variation.
Longitudinal uniformity of road surface luminance (Ul): A measure of the conspicuity of the repeated pattern of bright and dark patches on the road.
Threshold increment (TI): A measure of disability glare from luminaires.
Edge illuminance ratio (EIR): A measure of the amount of light that falls on an area just outside the edge of a carriageway.

Table 2.2. M lighting classes

Class	Luminance of the road surface				Disability glare	Lighting Of surroundings
	Dry			Wet		
	Minimum Average Luminance	Minimum Overall Uniformity	Minimum Uniformity Index	Minimum Overall Uniformity	Maximum Threshold Increment	Maximum Edge Illuminance Ratio
M1	2.00	0.40	0.70	0.15	10	0.35
M2	1.50	0.40	0.70	0.15	10	0.35
M3	1.00	0.40	0.60	0.15	15	0.30
M4	0.75	0.40	0.60	0.15	15	0.30
M5	0.50	0.35	0.40	0.15	15	0.30
M6	0.30	0.35	0.40	0.15	20	0.30

The C classes are intended for drivers of motorised vehicles, and other road users, on conflict areas such as road intersections, roundabouts, and shopping streets, Table 2.3. The photometric requirements for the C classes include:

- **Average illuminance** ($\overline{E}$): A measure of the amount of light that falls on the road.
- **Overall uniformity of the illuminance** (Uo): A measure of the illuminance variation.

Table 2.3. C Lighting Classes

Class	Horizontal illuminance	
	Minimum Average Illuminance	Minimum Overall Uniformity of the illuminance

C0	**50**	**0.4**
C1	**30**	**0.4**
C2	**20**	**0.4**
C3	**15**	**0.4**
C4	**10**	**0.4**
C5	**7,5**	**0.4**

The P classes are intended for pedestrians and pedal cyclists on footways, cycle tracks and other road areas lying separately or along the carriageway of a traffic route as shown in Table 2.4. The photometric requirements for the C classes include:

Average illuminance ($\bar{E}$): A measure of the amount of light that falls on the road.
Minimum illuminance (E_{min}): A measure of the lowest illuminance on the road area.

	Horizontal illuminance	
Class	**Average Illuminance [minimum]**	**Minimum Illuminance [minimum]**
P1	**15.0**	**3.0**
P2	**10.0**	**2.0**
P3	**7.5**	**1.5**
P4	**5.0**	**1.0**
P5	**3.0**	**0.6**
P6	**2.0**	**0.4**
P7	**Performance not determined**	**Performance not determined**

2.4. Categories of Road Based on Traffic [11]

According to the IS 1944 (Part I and Part II),1970 the level and type of lighting adopted for a road is based mainly on its traffic importance, both vehicular and pedestrian as shown in Table 2.5. The categories of the road are as follows:

Group A - For main roads.

Group A1 - For very important routes with rapid and dense traffic
Group A2 - For other main roads with considerable mixed traffic

Group B - For secondary roads.

Group B1 - For secondary roads with considerable traffic.
Group B2 - For secondary roads with light traffic.

Group C - Lighting for residential and unclassified roads

Group D - Lighting for bridges and flyovers.

Group E - Lighting for town and city centres.

Group F - Lighting for roads with special requirements, such as roads near airfields, Railways and docks.

Table 2.5. Lighting Design parameters IS 1944:1970

Classification of road Lighting installation	Average illumination on Road surface (lux) E_{avg}	Longitudinal Uniformity Ratio (E_{min}/E_{avg}) Illuminance	Transverse Or Overall Uniformity Ratio (E_{min}/E_{max})Illuminance (%)
GROUP A1	30	0.4	33
GROUP A2	15	0.4	33
GROUP B1	8	0.3	20
GROUP B2	4	0.3	20

Table 2.6. Guide for choosing Type of Luminaire for a particular spacing ratio IS 1944: 1970

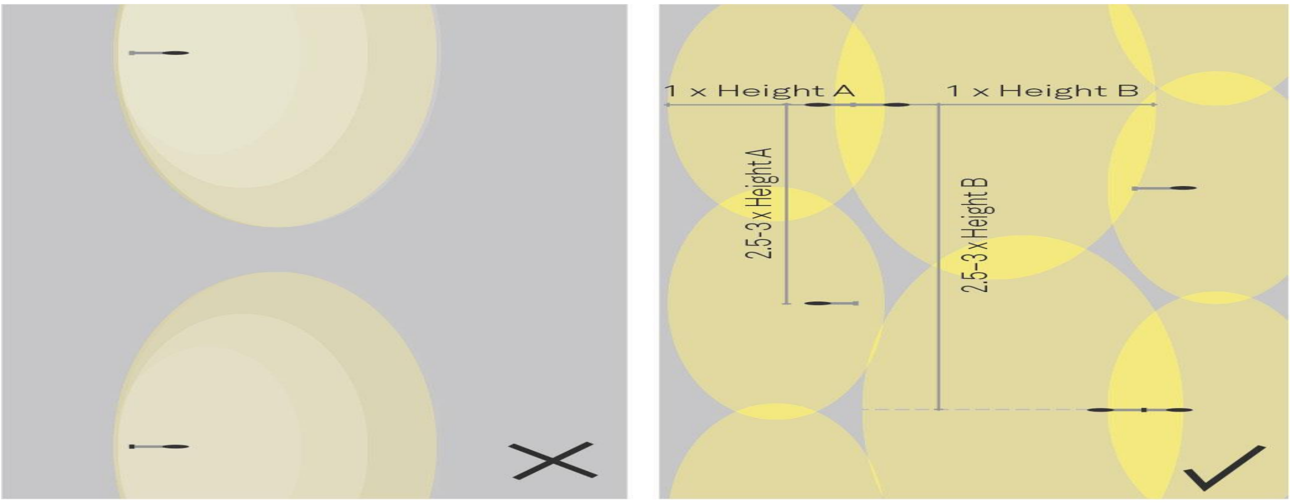
Type of luminaire	Maximum spacing/ height ratio
Cut-off / Full Cut-off	**3**
Semi cut-off	**3.5**
Non-cut-off	**4**

Table 2.6 gives a guide for choosing a particular type of luminaire according to the spacing ratio.

2.5. Lighting Design Guidance [13]

2.5.1. Dimensions and Spacing

Space light fixtures should provide uniform distribution and illumination of roadways and sidewalks. The locations of obstruction such as trees or billboards should be considered. Refer to Fig 2.2.



Measure the width of the street and the height of the proposed light poles to determine the required spacing of lights for even coverage. Light poles that are spaced too far apart result in dark areas that leave street users feeling unsafe.

Fig 2.2. An illustration showing how the heights and spacings of pole in road lighting should be determined

2.5.1.1. Street Light Height [15]

Street lights are installed on high lamp posts. And the roadway light poles are generally in 4 metres(13 feet), 6 metres(20 feet), 8 metres(26-27 feet), 9 metres(30 feet), 10 metres(33 feet), 12 metres(40 feet). Below is the list of the differences. The height of the light pole is generally the application place. Table 2.7 gives a clear view of the mounting height of the luminaire.

10-20 feet, suitable for residential areas, park roads, country roads
20-27 feet, suitable for most urban roads, commuter roads between urban and rural areas
27-33 feet, suitable for urban main roads, expressways and highways, etc.
33-40 feet, suitable for wider roads with high traffic flow, road intersections
> 40ft, high mast light pole for installation in large areas such as airports, shipyards, large industrial areas, sports fields and road intersections.

Standard poles for sidewalks and bike facilities are **4.5–6 m**. [11]

Light poles for roadbeds vary according to the street typology and land use. In most contexts, standard heights for narrow streets in residential, commercial, and historical contexts are between **5–8 m**.

Taller poles between **9m and 12 m** are appropriate for wider streets in commercial or industrial areas. Refer to Fig 2.3 for pictorial illustration of the pole heights.

Table 2.7. Guide for type of luminaire and mounting height of luminaire according to classes of roads IS 1944:1970

Class of road	Mounting Height	Type of luminaire preferred	Type of luminaire Permitted
GROUP A	9-10	cut off	semi cutoff
GROUP B	7.5-10	cut off or semi cutoff	non cut off
GROUP C	less than 7.5	semi cut off	non cut off

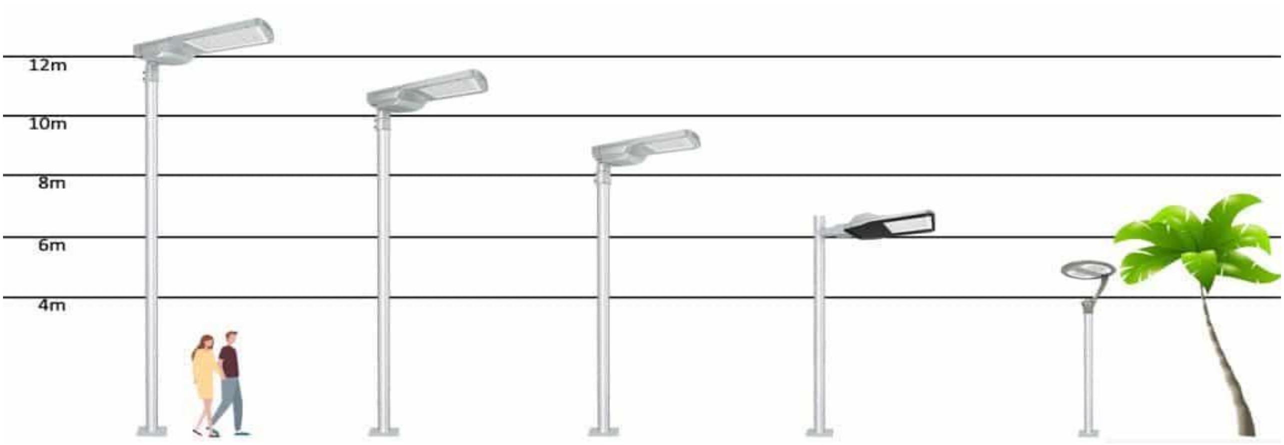


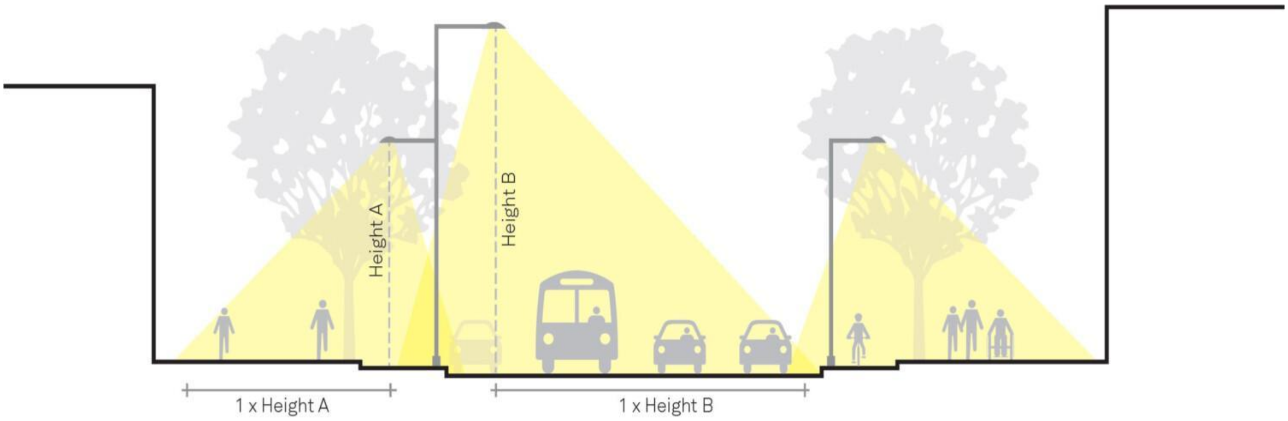
Fig 2.3. Installation height of street light luminaires

2.5.1.2. Pole Spacing

The spacing between two light poles should be roughly 2.5–3 times the height of the pole. Shorter light poles should be installed at closer intervals. The density, speed of travel, and the type of light source along a corridor will also determine the ideal height and spacing. Refer to Fig 2.4 for pictorial illustration.

2.5.1.3. Light Cone

The light cone has roughly the same diameter as the height of the fixture from the ground. The height will therefore determine the maximum suggested distance between two light poles to avoid dark areas. Refer to Fig 2.4 for pictorial illustration.



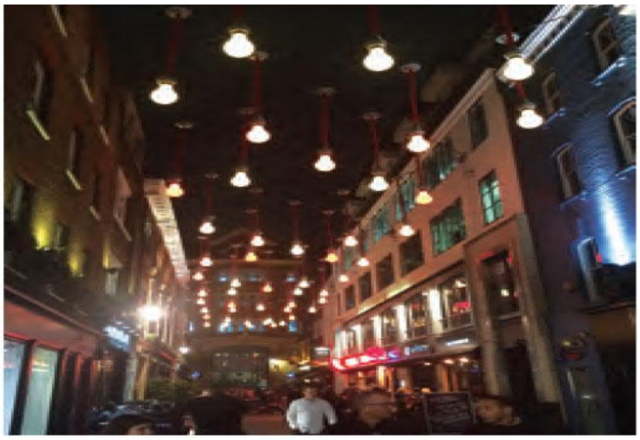
The spacing between light poles is typically 2.5–3 times the height of the fixture. A single row of light poles might be sufficient for a narrow street, while wider streets will require multiple rows.

Fig 2.4. Picture showing throw of light on narrow and wide streets respectively

2.5.2. Varied Light Sources

There is a wide range of light sources that contribute to the overall illumination of the public realm. Well-designed solutions incorporate different types of light sources such as conventional and decorative fixtures, pole-mounted lights, hanging catenary lights, as well as signage and advertising illumination. Borrowed light spilling from storefront or domestic interiors, lights mounted to building exteriors such as hanging lanterns and facade lighting, and lights from cars may add to street illumination at certain times of the day. However, borrowed illumination may not always be consistent, evenly distributed, or designed for human comfort. Refer to Fig 2.5.

Lisbon, Portugal
Street light in historic district.

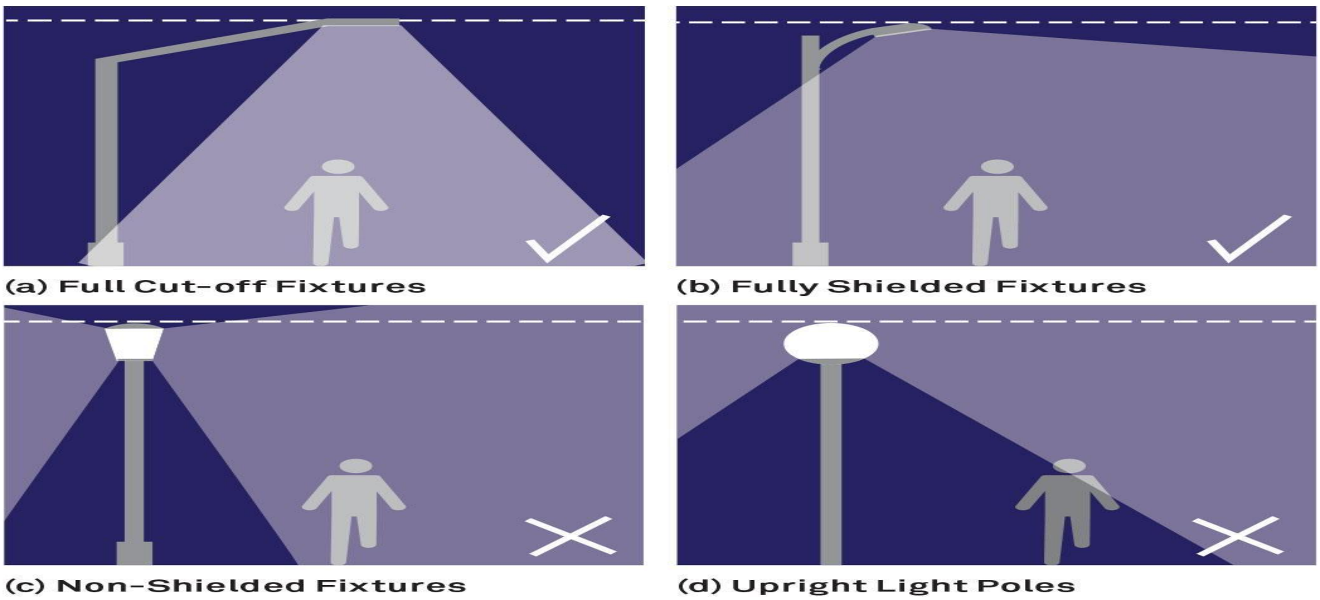


Central London, United Kingdom
Hanging light installation used to illuminate a narrow alley.

Fig 2.5. Cities showing Streetlight selection for wide and narrow streets

2.5.3. Light Pollution

Focus lighting from light poles and fixtures directly onto the street to minimize glare and light pollution that could negatively impact wildlife and human well-being. Shielded and cut-off fixtures with energy-efficient light bulbs are more cost-effective as they use less energy by directing the light toward the ground, reducing light pollution. Refer to Fig 2.6.



Best practices suggest light poles with fixtures parallel to the ground, also called full cut-off fixtures (a). When slightly rotated, fixtures should be fully shielded (b). Avoid fixtures that are not properly shielded (c) and upright light poles (d), which emit light toward the sky.

Fig 2.6. Picture showing benefits of parallel to ground streetlight fixtures

2.5.4. Energy Efficiency

Low-energy solutions such as Light Emitting Diodes (LED)–minimise energy consumption and light pollution. LEDs have a long lifespan of 50,000–70,000 hours when not operated at high temperatures. An emergency power source such as a back-up generator should be considered for lighting along major corridors, especially where electricity supply is unreliable or where storm events may cause power loss. Alternative power sources such as solar panels or battery-operated lighting are appropriate in areas where power is not always easily accessible, such as informal developments. Where a complete street lighting network is not feasible, local authorities should consider interim lighting solutions such as portable lanterns. Buildings within certain districts may be required to display or provide spill or signage lighting at night. Refer to Fig 2.7.

Accra, Ghana
Solar-powered street lights to reduce energy dependency.

Copenhagen, Denmark
LED lights embedded in the pavement.

Fig 2.7. Cities around the world having energy-efficient LED systems

2.5.5. Temperatures, Colors, and Ambience

A consistent approach to colour temperature should be applied throughout the lighting plan, although different colour temperatures can be used to signify different users or types of travel. 3000 Kelvin (K) is often used for pedestrian paths and 5000K for vehicular paths. Refer to Fig 2.8.

Edinburgh, Scotland
Ambient environment created with street lights and storefronts.

Fig 2.8. Depiction of Ambient environment in Scotland, UK

2.6. Pole Arrangement Schemes [15]

2.6.1. Single Sided Arrangement

Single sided arrangement, that is, all lamps are located on one side of the road, and should be used when the width of the road is less than or equal to the installation height. This type of lighting arrangement is usually suitable for narrower roads. Usually the installation height is lower at about 6 metres (20 inches). In addition, as the lens design of street lamps becomes more and more sophisticated, this type of lighting can sometimes be used to illuminate wider roads.When the width (W) of the road is nearly equal to the pole height (H), i.e. W = H then the poles are arranged in one side only.The span between two poles is equal to the road width. Refer to Fig 2.9.

Fig 2.9. Single sided arrangement (arrangement at only one side, upper side or bottom side)

2.6.2. Staggered Arrangement

Staggered arrangement, when the road width is equal to 1 to 1.5 times of the installation height, the lamps are alternately placed on both sides of the road in a "zig-zag" or staggered style. This type of lighting arrangement is usually suitable for medium sized roads. Practice has proved that the lighting effect (uniformity) of staggered street lighting arrangement is often improved without increasing the height of the pole. The span between two poles may not be equal to the road width. Refer to Fig 2.10.

Fig 2.10. Staggered arrangement (two-sided arrangement offset)

2.6.3. Opposite Arrangement

Opposite arrangement, the lamps are placed opposite to each other along the front of the road. When the width of the road is greater than 1.5 times of the installation height, it is more suitable to go with this arrangement. Opposite arrangement is usually suitable for medium to wide roads. This kind of lighting arrangement is very common on main roads, mainly because of convenient construction and excellent lighting effect. The span between two poles may not be equal to the road width. Refer to Fig 2.11.

Fig 2.11. Opposite arrangement(two-sided arrangement)

2.6.4. Twin Central Arrangement

Twin central arrangement, the lamps are installed on the T-shaped mast in the middle of the central island of the road, when the road width is less than or equal to the installation height, the installation height of the lamps should be used. This type of lighting arrangement is usually installed on taller poles and large roads. This type of light distribution method often requires a wide isolation island on the road, which facilitates the installation of light poles and distribution boxes. The span between two poles may not equal the road width. Refer to Fig 2.12.

Fig 2.12. Twin central arrangement(median arrangement)

2.7. Proper Placement of Pole [15]

2.7.1. Pole distance from the roadway (Setback)

This is the distance from the light pole to the road. Because the street lights are generally set on the outside of the street curb, the light poles have a certain horizontal distance from the motor vehicle lane or the non-motor vehicle lane. This horizontal distance is also usually called setback. For most arrangements, setbacks will choose 1 foot to 2 feet. Light poles that are too close are not suitable for installation and are easily affected by accidental traffic accidents, which in turn can cause more accidents. Too far away, and the lighting effect (light level and uniformity) is reduced, and even further distances from the fixture create shadows at low light levels. For the twin central arrangement, the setback is half the width of the isolation island. Refer to Fig 2.13.

2.7.2. Pole Boom(Arm) Length

The use of arms brings the light source closer to the road while keeping the poles positioned away from the edge of the road. Depending on the application, the arm may be a single and/or double arm or a davit arm on top of the pole. There are several different arm lengths and styles of arms used. Single arms, these arms are typically available in 1.5m, 2m and 2.5m lengths. Double arms, these arms face 180° apart and are used to illuminate the opposite lane of a two-way lane. Refer to Fig 2.13.

2.7.3. Overhang

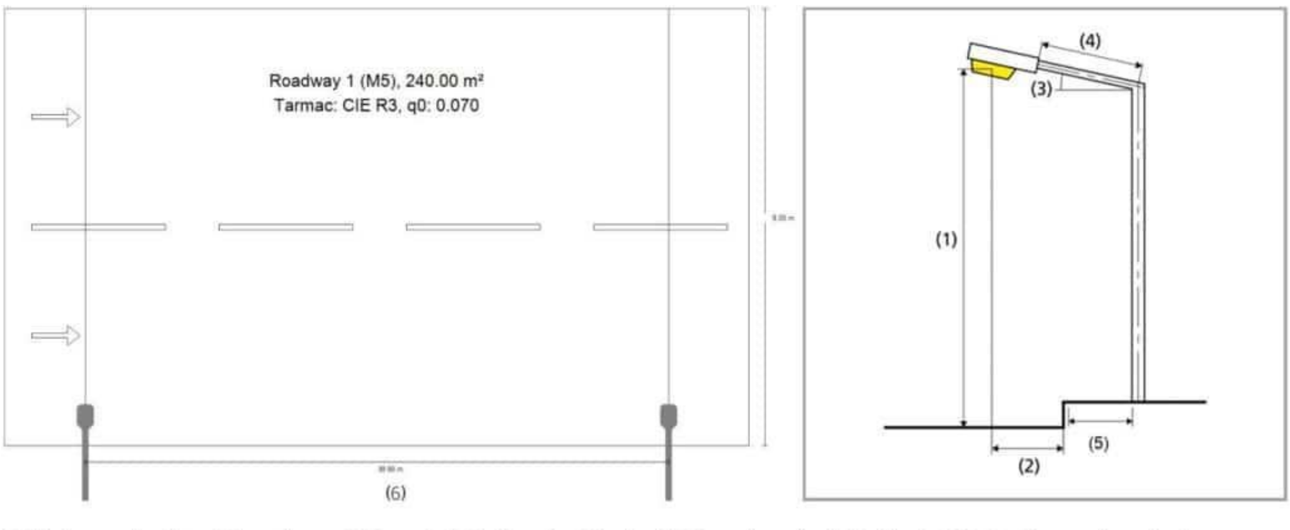
Overhang is the horizontal distance from the centre of the light fixture mounted on the bracket (poles) to the edge of the driveway. In general, the overhang should not exceed a quarter of the installation height to avoid reduced visibility from shoulders, obstacles and sidewalks. In addition, due to the influence of the trees on the road, the overhang will be increased to reduce the influence of the trees on the road. Also set up additional street lights to illuminate the sidewalk. Refer to Fig 2.13.

2.7.4. Boom Tilt Angle (Boom Angle)

Boom tilt angle is the angle between the luminous surface and the horizontal plane (the surface parallel to the ground). Normally the larger the tilt angle, the higher the uniformity in general. In the past, there would be a tilt angle during actual road installation, which was relatively large and had corresponding problems. Uncomfortable glare is increasing as bright light enters the driver's eyes. Therefore, it has been recommended that the tilt angle should be kept below 20 degrees. As more and more project parties require zero uplight, this angle is usually 0. Thanks to the improvement of the lighting distribution, many street lights are often installed on light poles with a 0 tilt angle. Even if the tilt angle is below 20 degrees, by adjusting the fitter, we can achieve 0 degrees to reduce the impact on the natural environment.Refer to Fig 2.13.

2.7.5. Pole to Pole Distance (Spacing)

Spacing is the distance between two consecutive luminaires along the centerline of the road. Usually spacing equal to 3 to 4.5 times is suitable for many road lighting projects. The smaller the pole distance, the better uniformity can usually be obtained, but we will need more light poles, which is not conducive to controlling the cost of the project. The longer the poles distance, the poorer the uniformity, because the illumination and brightness are often lower in places farther away from the lamps, which can easily cause discontinuity in lighting and affect traffic safety. Taking an 8-metre light pole as an example, we generally recommend that the distance between the light poles is about 30 metres (single side lighting). If it is installed on the opposite side or staggered, the distance can be increased to 35 metres or more. Below we have attached a picture showing the setback, boom length, overhang, boom angle, spacing which gives a profound image of these parameters. Refer to Fig 2.13.



(1) Light spot height, (2)overhang, (3)Boom Tilt(inclination) Angle , (4)Boom length, (5)Setback. (6)Pole distance(spacing)

Fig 2.13. A picture showing the placement of poles

2.8. R-Tables for Roadway Lighting [19]

A roadway's reflective characteristics are defined by its physical surface properties. Sufficient data has been collected on the reflectance characteristics of different pavement types to allow them to be described by reflectance tables or "R" tables. Several typical roadway pavements are provided for use, as defined in Table 2.8.

Table 2.8. R-Table for Street lighting

R-Table	Q_o	Description
C1	0.10	CIE C1 - Concrete
C2	0.07	CIE C2 - Asphalt
N1	0.10	CIE Class = 1, Very Diffuse
N2	0.07	CIE Class = 1, Concrete
N3	0.07	CIE Class = 3, Asphalt
N4	0.08	CIE Class = 4, Glossy Asphalt
NZN2	0.09	New Zealand - Glossy Polished Asphaltic Surface
NZN4	0.09	New Zealand - Diffuse Chip Seal Surface
R1	0.10	IES RP-8 - Mostly diffuse reflectance properties characteristic of Portland cement or asphalt surface with a minimum of 15% of the aggregates composed of artificial brightener aggregates.
R2	0.07	IES RP-8 - A combination of diffuse and specular reflectances characteristic of asphalt surfaces with aggregate composed of a minimum of 60% gravel of size greater than 10 mm. Also asphalt surfaces composed of 10% - 15% artificial brightener in aggregate mix.
R3	0.07	IES RP-8 - Slightly specular reflectance typical of asphalt surfaces with dark aggregates, rough texture and some months of use. This surface is common in the United States.
R4	0.08	IES RP-8 - Mostly specular surface typical of very smooth asphalt texture.

UKPA	**0.05**	**UK - Porous Asphalt**
W1	**0.11**	**CIE W1 - Wet Road Surface**
W2	**0.15**	**CIE W2 - Wet Road Surface**
W3	**0.21**	**CIE W3 - Wet Road Surface**
W4	**0.25**	**CIE W4 - Wet Road Surface**
ZOAB	**0.10**	**CIE Class = 2, Dutch Porous Asphalt**

Q_0 is a value that is related to the overall reflectance of the pavement by a factor of π: $Q_0 \times \pi$ = overall reflectance.

2.9. Spread and Throw Angle of Street Light Luminaire [18]

The two main terms related to the street light luminaire are:

1. **Spread Angle:** It is the angle of the luminaire to direct the luminous flux across the road. Refer to Fig 2.14 for pictorial illustration.

2. **Throw angle:** It is the angle of the luminaire to direct the luminous flux along the road. Refer to Fig 2.14 for pictorial illustration.

It is denoted by:

$$\gamma T.\ Again\ \gamma_{max} = \frac{\gamma_1 + \gamma_2}{2}$$

$$When\ \gamma_{max} < 60^{o} - short\ throw\ angle.$$

$$When\ \gamma_{max} > 70^{o} - long\ throw\ angle.$$

$$When\ 60^{0} < \gamma_{max} < 70^{o} - intermidiate\ throw\ angle.$$

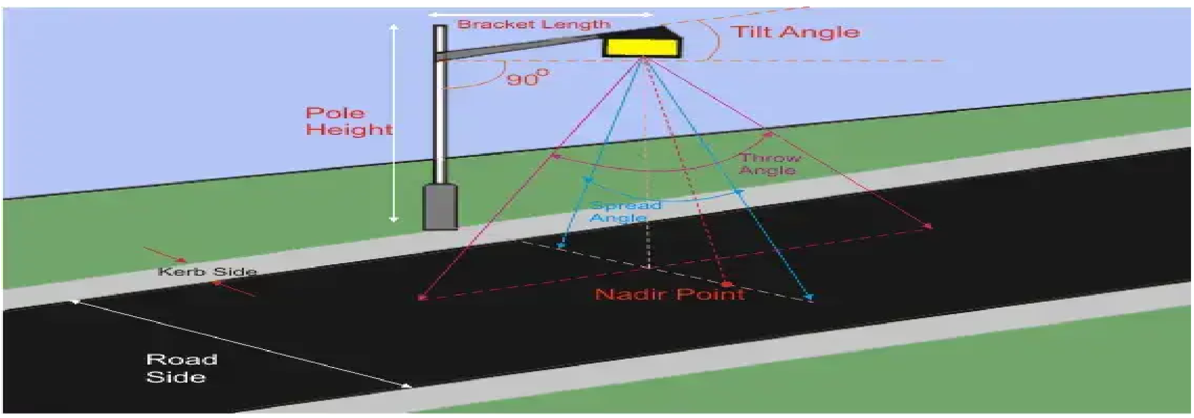


Fig 2.14. Figure showing Spread angle, Throw angle, Tilt angle and Nadir point in Road lighting

2.10. Lamps Used in Street Lighting [18]

Various types of lamps are used in street lighting luminaires. They are

High pressure sodium lamps (SON) (Retrofitting takes place with Efficient LED)
Metal Halide Lamps (Usage has been reduced and will be rare to find in the future)
Low pressure sodium lamps (SOX) (Retrofitting takes place with Efficient LED)
Incandescent Lamp (Discarded & not recommended)
LED (Switching towards Solar LED for efficiency and sustainability)
CFL (Used in Lanes or streets only not widely)
Solar LED (Progressively built to meet increased demands)

2.11. Street Light Design Parameters [18]

Street light design parameters are measured or evaluated or simulated over the span of the road.

- Average maintained luminance level in Lux
- **Average Luminance (L_{avg})-** The average amount of light reflected from the road surface to an observer (measured in cd/m^2).
- **Overall Uniformity (U0)** of Illuminance $\left(\frac{E_{min}}{E_{max}}\right)$ for entire area (span × width) of the road
- **Longitudinal Uniformity** $\left(U_L = \frac{E_{min}}{E_{max}}\right)$ is measured along the length of the road (centre length by default)
- **Transverse Uniformity** $\left(U_t = \frac{E_{min}}{E_{max}}\right)$ is measured across the road along a line passing through the nadir point.
- Disability glare is expressed in **Threshold Increment (TI)**. Threshold Increment is intended to yield the percentage increase in the luminance of the road's surface required to render an object just visible (threshold of visibility) under the proposed lighting system (glare present) as compared to the luminance required to render the object just visible in the absence of glare.
- **Surround Ratio (SR)-** This is a ratio of the average horizontal illuminance on the two longitudinal strips each adjacent to the two edges of the carriageway (the surround illuminance), divided by the average horizontal illuminance on two longitudinal strips each adjacent to the two edges of the carriageway, but lying on the carriageway. The width of all four strips shall be the same, and equal to 5m, or half the width of the carriageway, or the width of the unobstructed strip lying off the carriageway, whichever is the least. For dual carriageways, both carriageways together are treated as a single carriageway unless they are separated by more than 10m.
- **Discomfort Glare** is expressed in glare control marks.

- **Unit Power Density** is measured for unit length.

$$UPD = \frac{\frac{Watt}{Lumen} \times no\ of\ luminaire}{S \times W}$$

Where,

where no. of the luminaire (n) = 1 for single sided pole arrangement
= 2 for double sided pole arrangement
= 2 for staggered sides pole arrangement.

A basic street light controller is not hard to construct. The best Arduino starter kits will already come with the required Arduino and photoresistor for this purpose.

2.12. Main Factors in the Street Lighting Design Scheme [18]

- **Luminance Level Should be Proper**

Luminance always influences the contrast sensitivity of the obstructions with respect to the background. If the street is brighter, then darker surroundings make the car driver adapted, unless the driver will be unable to perceive the objects in the surroundings. As per CIE, 5m away from the road on both sides will be lit by Illuminance level at least 50% of that on the road.

- **Luminance Uniformity must be Achieved**

To provide visual comfort to the viewer's eyes, enough luminous uniformity is needed. Luminous uniformity means the ratio between minimum luminance level to average luminance level, i.e.

$$U_0 = \frac{L_{min}}{L_{max}}$$

It is termed as longitudinal uniformity ratio as it is measured along the line passing through the viewers position in the middle of the traffic facing the traffic flow.

- **Degree of Glare Limitation is always taken into Design Scheme**

Glare means visual discomfort due to high luminance. There are two types of glare created by the street light luminaires, first type is disability glare and second type is discomfort glare. Disability glare is not a strong factor, rather discomfort glare is a common factor due to unplanned street lighting schemes.

- **Lamp Spectra for Visual Sharpness**

It depends on the Proper Luminaries. It is very much essential to make an object as per its size and dimension.

- **Effectiveness of Visual Guidance**

It is also an important factor. It helps a viewer to guess how far another object is from his/her position.

2.13. Installation Requirements [17]

2.13.1. General

The street lighting system layout should generally be as shown in Figure 2.15. Facilities are normally located in the grass utility strip between curb and sidewalk. Wiring is to be underground, in conduit, with an underground junction box at each light installation. Luminaries (light fixtures) are to be 240-Volt, complete with ballast and individual photoelectric control receptacle. Streetlight supply will be 240 volt single phase 4-wire for the layout shown in Figure 2.15. Connected load on one leg must not exceed 24A per leg. Maximum fuse size: 30A. The locations of and spacing between lights will depend on the required average illumination levels and illumination uniformity according to IES(Illumination Engineering Society) accepted levels. A minimum 4 feet horizontal clearance must be provided between any poles or junction boxes and other utilities at grade or underground (fire hydrants, water, sever, gas lines, other electric power lines, etc.). Maintain at least 6 feet clearance between poles or junction boxes and edges of driveways. The entire lighting system must conform to the latest edition of the National Electrical Safety Code.

2.13.2. Pole Installations

1. General

All poles shall be vertical and plumb. Poles shall be located such that the closest part of the pole is not less than 2 feet behind the curb. All poles and lights must be located close enough to the roadway to permit re-lamping and other maintenance by HLD's (High Level Design) vehicles and equipment. Handholes (in fibreglass and aluminium poles) shall not be located on the side of the pole facing the curb. In locations not protected by standard concrete curbs, only anchor base type poles are permitted.

2. Direct Burial Fiberglass Poles For Post-Top Luminaires

This type of installation is permitted only in grass areas protected by concrete curb. It is not acceptable in paved areas, such as where the sidewalk is continuous out to the curb. Wiring from the junction box to the pole may be directly buried. Install a spare Underground feeder (UF) cable from the junction box to the pole.

2.13.3. Luminaire Installations

Luminaires shall be installed in accordance with manufacturer's instructions. Cobra-head type luminaires must be properly levelled, and post top Luminaires must be securely fastened to the light pole in a vertical position. Cobra head luminaires shall be installed at (25-30) feet mounting height. Post top luminaires shall be installed at 14 feet mounting height.

2.13.4. Junction Box Installations

Junction boxes placed shall be of the type specified in Section V- Line F. A junction box must be provided adjacent to each light pole installation, and at each end of all street crossings. ALL junction box lids shall be grounded if metallic in nature. Note that cast iron lids for sidewalk areas must be drilled to accommodate grounding connectors. This note is for older streetlight handhole installations where metallic hand hole lids may have been installed.

2.13.5. Conduit Installations

All wiring runs shall be in Schedule 40 PVC Conduit unless otherwise noted. Normally, the installations will be: 1. Conduits between lights: Two 2 inches conduits, 24 inches minimum cover. 2. Conduit from power source to first junction box: Two 2 inches conduits, 24 inches cover. 3. Street crossings: two 2 inches conduits, 24 inches minimum cover, Schedule 80. 10 Conduit runs shall be as straight as possible between junction boxes. No single run may exceed 300 feet in length or 270° total bends (including the 90° ells up into the junction boxes). Red "Caution" Tape must be furnished in the backfill 12 inches below final grade. At least 12 inches vertical (at a crossing only) or 36 inches horizontal separation must be maintained between lighting conduits and other underground utilities (e.g. water, gas, telephone, power, etc.). In extreme cases, depending on the type of other utility, vertical separation at crossings may be reduced to 6 inches, but only with the approval of HLD Engineering. No foreign facilities such as private electrical wiring, telephone lines, etc. may be placed in the trench with the lighting facilities. Note that HLD must inspect and approve all installations before backfilling. One working day advance notice is required.

2.13.6. Electrical Wiring And Grounding

1. General

The maximum number of lights that can be connected to a single line depends on the light wattage and the spacing between lights. The connected load on either leg of the system must not exceed 30A. In addition, the voltage drop from the power source to the last light at the end of the wiring run must not exceed 5%. One circuit cannot normally run more than about 1800 feet from the power source. If possible, the power source should be located toward the centre of the lighting system rather than at one end.

2. Power Supply

The Developer must consult HLD to determine how electricity will be supplied to the lighting system. In some cases where an HLD underground power distribution system runs along the street, individual lights may be tapped directly into the HLD secondary handholes depending on the design. Elsewhere the Developer must install a completely separate lighting circuit, fed from a single supply point (see Fig 2.15). Such systems shall be installed to include an above ground non-metered pedestal.

3. Fusing

General: Fuses shall be sized for 80% of connected load. Maximum fuse size shall be 30A.

Overhead Power Source: Where the source is overhead secondary lines atop a pole, HLD will install a street lighting relay or fuse box at cost to the developer. Consult HLD if this type of connection is necessary.

Where the supply source is an HLD pad mounted transformer or service handhole, both hot legs of the supply circuit are to be fused with cartridge fuses placed in waterproof fuse holders located within the first lighting junction box determined by HLD Engineering.

Lighting systems fed from Potomac Edison padmount transformers are to have the fuses located within the first lighting junction box. Each lighting fixture shall be fused with a 10A fuse within each lighting handhole.

4. Grounding

A ground rod shall be provided for each streetlight, to be installed in each handhole. See Figure 2.16 for additional grounding details. Ground rods should be installed in junction boxes with the head approximately 8 inches below the closed junction box lid. Rods should be driven before conduits are placed. A bare #6 copper jumpers shall be connected from each ground rod and grounding conductor within the junction box, as shown in Figure 2.16.

The following shall be grounded:

a. All Metal Poles

b. All Junction Box Covers. Note that the round cast iron lids for 18 inches fibre junction boxes must be drilled to accommodate a grounding connector.

c. All Luminaires. Luminaires should be grounded using the ground wire in the UF supply cable.

5. Wiring

a. Systems With A Common Lighting Supply Circuit .

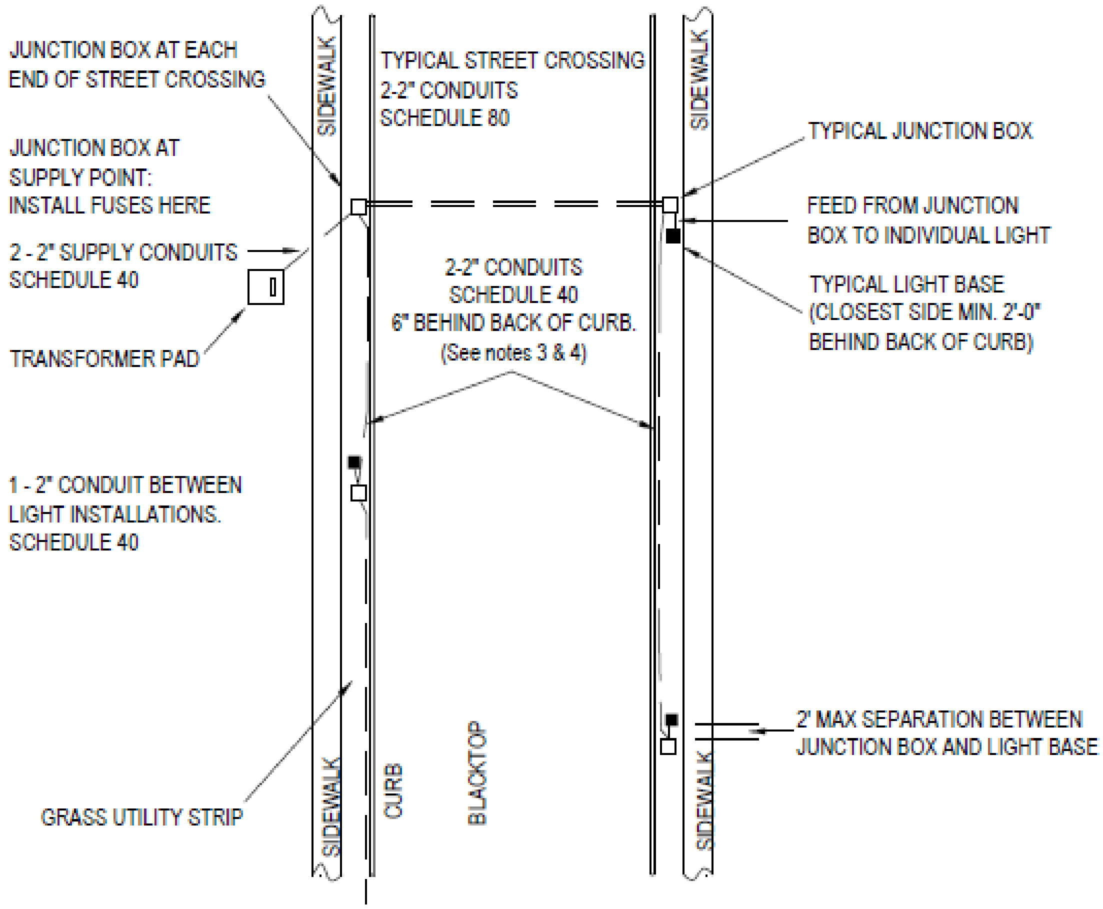
The 240 Volt, 4-Wire feeders between lights are to be either #2 or 1/0 aluminium URD triplex cable with separate ground conductor or 4-#6 THHN CU wire. Wiring from the junction box to each individual light is to be copper #10-2 UF cable (with ground). At each access point (e.g. each junction box), exposed portions of the wiring shall be colour-coded by tape to identify the neutral and each hot leg unless coloured THHN is used. Throughout the entire system, the Neutral shall be coloured WHITE, ground shall be coloured GREEN, one Hot Leg shall be coloured RED, and the remaining Hot Leg can be left without tape, this will be called BLACK on the drawings. Wiring must be colour coded at the connection to the power supply, at the fuses, and at each individual light connection. Lighting loads are to be evenly balanced on the two legs of the 240 volt supply. Alternate lights shall be connected to alternate legs of the triplex feeders.

b. Systems With Lights Individually Connected To HLD Lines.

The supply to each individual light will be 240 volt, 3-wire. Wiring from HLD's padmount, transformer, service handhole, etc. To the light is to be copper #10-2 UF cable (with ground). At each access point (e.g. each junction box), exposed portions of the wiring shall be colour coded to identify the neutral and the single hot leg. Colour the neutral WHITE, and colour the Hot Leg BLACK. To facilitate the wiring installation, HLD will pull-in the run of UF cable from the Developer's street light junction box into HLD's padmount transformer or service handhole and make any connections and/or fuse installations needed inside the transformers or service handhole. The Developer should furnish the fusing and other materials to HLD and should coil up enough UF cable in the streetlight junction box to reach HLD's power supply point.

c. General

All wires shall be extended at least 30 inches into the underground junction boxes; coil up the slack. All connections involving the hot and neutral legs shall be insulated and made watertight with TYCO GTAP-1 or GTAP-2 connectors depending on wire size, see section V – Line H. Grounding connections between bare COPPER grounding wires, to ground rods, and to junction box covers need not be taped.



NOTES:

1. SEE ALSO DETAIL DRAWING OF INDIVIDUAL INSTALLATIONS.
2. ALL CONDUITS SHALL HAVE 24" MIN. COVER.
3. CONDUITS ALONG THE STREET SHALL BE LOCATED 6" BEHIND THE BACK OF THE CURB.
4. LINEAR ROOT DEFLECTORS ARE REQUIRED FOR ANY STREET TREE PLANTINGS WITHIN 5 FEET OF STREETLIGHT CONDUITS.
5. IF POWER SOURCE IS IN POTOMAC EDISON TERRITORY, ABOVE GROUND PEDESTAL IS REQUIRED FOR POWER CONNECTION ADJACENT TO PE TRANSFORMER. SEE APPENDIX A FOR SPECIFICATION.

STREET LIGHTING: TYPICAL LAYOUT AREA	CITY OF HAGERSTOWN, MD. ELECTRIC SYSTEM		
	DATE: 02/27/2018 DWN: JMB		APP:
	SCALE NONE	CONSTRUCTION STANDARDS	H2

Fig 2.15. Typical Layout for Streetlight Pole Installations and the Essential Requirements

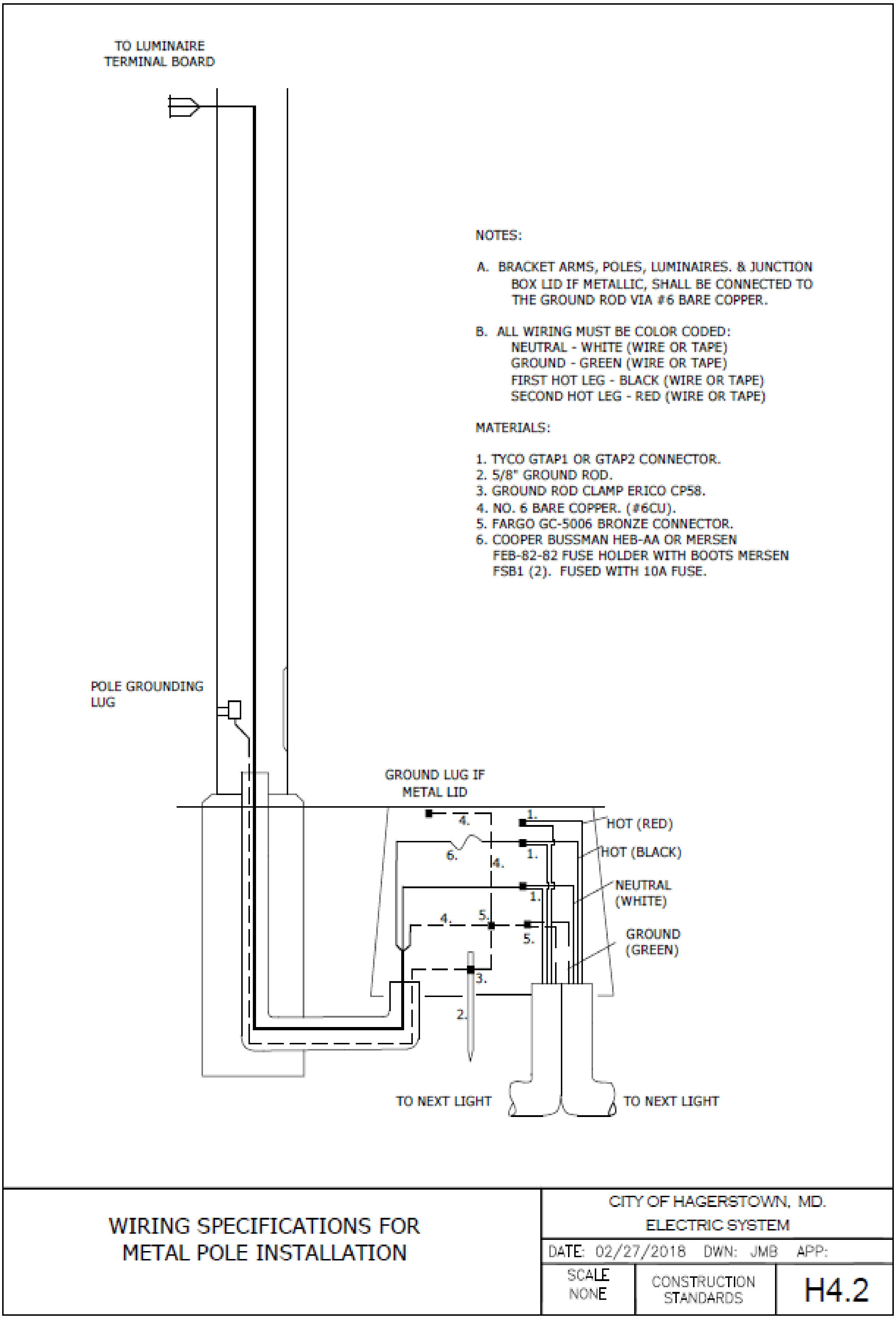


Fig 2.16. Diagram Showing Junction Box, Materials, Wirings, Groundings, Fusings

CHAPTER-3: INTERNATIONAL AND NATIONAL STANDARDS ON ROAD LIGHTING DESIGN

3.1. Introduction

Different countries give standards and recommendations on road lighting to guide road lighting designers. The last detail the standard parameters with the quantitative recommendations for luminance, illuminance, the spacing between the poles, color characteristics and many other features. These standards and recommendations include different documents: CIE 115:2010, EN 13201-1:2014, EN 13201-2:2015, IESNA/ANSI RP-8:2014 and BS 5489-1:2013 etc. which provide guidelines for designing roads, streets and public space lighting. Many institutions, such as the Illuminating Engineering Society of North America, Institution of Lighting Professionals (UK), British Standards Institution (BS), European Committee for Standardisation, International Electrotechnical Commission, American National Standards Institute, International Commission on Illumination (CIE), US Dept of Transportation-Federal Highway Administration are helping in building these national and international standards and recommendations. These documents are written and reviewed by different committees to consider all the perspectives from various stakeholders, including manufacturers, designers, installers, and researchers.

Road lighting is an extensive topic. To focus, the literature review on this study's objectives, lighting surveys included in vehicles, tunnel lighting, collision areas, signal lights, road signs or parking and route areas have not been considered. The CIE recommendations describe two primary purposes of road lighting: 1) to allow all road users, including operators of motor vehicles, motorcycles, pedal cycles, and animal-drawn vehicles, to proceed safely, 2) to allow pedestrians to see hazards, orientate themselves, recognize other pedestrians, and give them a sense of security, A third one is also given, but it does not fall in the scope of the current research work.

The literature indicates that each country employs different road surface properties, depending on manufacturers and materials. Road surfaces are classified as per their specular factor S1 value, which is determined according to the CIE (CIE, 2001). The CIE recommends the following classes for dry road surface conditions: R, N, and C, and for wet road surface conditions, a modified S1 parameter classifies into a W. In Thailand, the most widely used road surface materials are cement or asphalt surfaces (Department of Highways, 2010). Their properties of specular factors S1 and Qo are similar to the R-class of road surfaces in the CIE classification system. The following parameters are optimized to design a roadway lighting system that suits drivers' needs: average illuminance, average luminance, overall uniformity and longitudinal uniformity. It must be noted that surround ratio and threshold increment are also mentioned but are not considered here due to the intricacies involved in their calculation.

Table 3.1 describes these lighting quality parameters for the motorized traffic[11].

Table 3.1. Lighting quality parameters for road lighting for motorized traffic (Source: CIE standard and recommendation)

Aspect	Lighting Quality Parameter	Abbreviation	Formula
Lighting level	Average road surface luminance	L_{avg}	$L_{avg} = Q_o * E_{avg}$
Uniformity	Overall uniformity	U_o	$U_o = L_{min} / L_{avg}$
	Longitudinal Uniformity	UL	$UL = L_{min} / L_{max}$

3.2. CIE Recommendations [11]

Nutshell Description of CIE 180: 2007

The recommendations of the International Commission on Illumination (CIE) are geared to the conditions in the industrialized countries, with their heavy levels of high speed traffic, dominated by the private motor car.

Considering the vehicle types (and hence speeds and stopping distances) frequently found in the less industrialized countries, the following values are suggested. These should be regarded as guidance only: it is generally better to relax the “quality" indicators of uniformity and threshold increment rather than have no lighting at all.

For areas where most of the "traffic" consists of pedestrians and non-motorized vehicles the illuminance value is given, for recognized traffic routes the luminance value is given, but roughly equivalent values of illuminance, for moderately dark road surfaces are given in parenthesis as shown in Table 3.2.

Table 3.2. Recommended light levels for different roads as per CIE: 180:2007

Category	Average level of illuminance	Overall uniformity (Min/Max)	Longitudinal Uniformity (Min/Avg)	Threshold Increment
Residential areas, pedestrians and many non-motorized vehicle	1-2 lux	0.2	Not available	Not Available
Largely residential but some motorized vehicles	4-5 lux	0.2	Not available	Not available
Major access roads, distributors and minor roads	0.5cd/m^2 (~8lux)	0.4	0.5	Not available
Important rural and urban traffic routes	1.0cd/m^2 (~15 lux)	0.4	0.6	20%
High speed roads, dual carriageways	1.5cd/m^2 (~25 lux)	0.4	0.7	15%

3.3. IESNA Recommendations [11]

3.3.1. IESNA Design Methods

ANSI/IESNA RP-8-00: American National Standard Practice for Roadway Lighting Revised in 2000 have three separate design methods:

- Illuminance
- Luminance
- Small Target Visibility (STV)

a. Design Methods: Illuminance

Illuminance method is the classical method used from 1928. The design criteria take into account lighting system alone i.e. lamp, luminaries and photometry and system geometry and one uniformity criterion: average to minimum. It has no constraint on maximum illuminance. Includes veiling luminance criterion, from luminance calculation.

b. Design Methods: Luminance

The Luminance method is an almost recent method from 1983. It takes into account roadway and lighting system interaction like lamp, luminaire and photometry, system geometry roadway surface. It has two uniformity criteria: average to minimum and maximum to minimum. It takes into account the moving observer & glare calculations.

c. Design Methods: STV

Small Target Visibility method (STV) is the brand new in 2000 document unfamiliar and complex metric VL uses luminance, both horizontal and vertical, contrast weighted over entire roadway veiling luminance included. It is mainly an extension of luminance calculations radically different design techniques not suitable for optimization. No values of luminance yet standardized according to this method.

d. Roadway Lighting Criteria:

Following tables show the recommended values of lighting level as per luminance and illuminance design method. The illuminance criteria again depend on the road surface whose classification is given below in Table 3.3. Classification on the roads again divided as per areas of classification. Classification of roads and areas of classification are listed below:

3.3.2. Classification of roads as per IESNA

a. **Freeway –** A divided major roadway with full control of access and with no crossings at grade.

Freeway A- Roads with greater visual complexity and high traffic volumes.
Freeway B- All divided roads with full control of access where lighting is needed.

b. **Expressway** – A divided major roadway for through traffic with partial control of access.

c. **Major** – The part of roadway systems that serves as the principal network for through traffic flow.

d. **Collector** – The roadways serving traffic between major and local roadways.

e. **Local –** Roadways used primarily for direct access to residential, commercial, industrial etc.

3.3.3. Classification of Areas as per IESNA

a. Commercial – That portion of a municipality in a business development where a large number of pedestrians present and heavy demand of parking space during the traffic period.

b. Intermediate – That portion of a municipality that is outside of a downtown area but generally within the zone of influence of a business or industrial development.

c. Residential – A residential development or a mixture of residential and commercial establishments.

Table 3.3, 3.4, 3.5 & 3.6 gives a detailed description of classification of roads according to road surface, L_{avg}, E_{avg} and comparative studies of illuminance values respectively.

Table 3.3. Road surface classifications according to IESNA

Class	Mean luminance Coefficient	Description	Mode of Reflectance
R1	0.10	Portland cement concrete road surface, asphalt with minimum 15% artificial Brightener	Mostly diffused
R2	0.07	Asphalt surface with 60% gravel	Diffuse and specular
R3	0.07	Asphalt surface with dark aggregate	Slightly specular
R4	0.08	Asphalt surface with very smooth Structure	Mostly specular

Table 3.4. Lighting design criteria as per maintained luminance values (L_{avg}) in candelas per square meter

Road Area Classification	Pedestrian Conflict area	Average Luminance (L_{avg}) In cd/m^2	L_{avg}/L_{min}	L_{max}/L_{min}	Veiling luminance to L_{avg}
Freeway Class A		0.6	3.5 to 1	6 to 1	0.3 to 1

Freeway Class B		0.4	3.5 to 1	6 to 1	0.3 to 1
	Commercial	1.0	3 to 1	5 to 1	
Expressway	Intermediate	0.8	3 to 1	5 to 1	0.3 to 1
	Residential	0.6	3.5 to 1	6 to 1	
	Commercial	1.2	3 to 1	5 to 1	
Major	Intermediate	0.9	3 to 1	5 to 1	0.3 to 1
	Residential	0.6	3.5 to 1	6 to 1	
	Commercial	0.8	3 to 1	5 to 1	
Collector	Intermediate	0.6	3.5 to 1	6 to 1	0.4 to 1
	Residential	0.4	4 to 1	8 to 1	
	Commercial	0.6	6 to 1	10 to 1	
Local	Intermediate	0.5	6 to 1	10 to 1	0.4 to 1
	Residential	0.3	6 to 1	10 to 1	

Table 3.5. Lighting design criteria as per maintained illuminance values (E_{avg}) in lux

ROAD AREA CLASSIFICATION	PEDESTRIAN CONFLICT AREA	R1 (lux)	R2 & R3 (lux)	R4 (lux)	E_{avg}/E_{min}
Freeway Class A		6	9	8	3 to 1
Freeway Class B		4	6	5	

	Commercial	10	14	13	
Expressway	Intermediate	8	12	10	3 to 1
	Residential	6	9	8	
	Commercial	12	17	15	
Major	Intermediate	9	13	11	3 to 1
	Residential	6	9	8	
	Commercial	8	12	10	
Collector	Intermediate	6	9	8	4 to 1
	Residential	4	6	5	
	Commercial	6	9	8	
Local	Intermediate	5	7	6	6 to 1
	Residential	3	4	4	

Table 3.6. Comparative Studies Of Illuminance Values (In Lux) Of All Recommendations

Classification of Lighting Installation	BIS	CIE (Maximum)	IESNA (Maximum)	Measured value in Indian road
Imp Traffic Route	30	25	17	45
Other Main Roads	15	15	14	25
Secondary Roads with dense traffic	8	8	12	19
Secondary Roads with Light traffic	4	5	9	9

Residential	-	2	4	23

From the above tables 3.3, 3.4, 3.5 & 3.6, it is clear that the illuminance value measured in Indian roads is near to BIS recommendation. So for designing the road lighting in India the BIS 1944 (Part I and II) is followed.

3.4. Evaluation Method As Per LRC [20]

3.4.1. Luminaire System Application Efficacy (LSAE)

Generally speaking, the evaluation process for LSAE includes four major steps. The first step is to obtain an accurate and representative measurement of the intensity distribution of the luminaire under evaluation. The second step is to determine the task plane dimension by calculating the maximum pole spacing at which the lighting criteria are met for the desired pole layout. The third step is to create a grid on the task plane and calculate the illuminance values at each point. The fourth step is to calculate the LSAE based on the conforming illuminance values and the input power of the luminaire.

3.4.2. CCT, CRI and Chromaticity

For traditional technologies e.g. HID (High Intensity Discharge), fluorescent and incandescent), it is common practice to report the lamp CCT (Co-related Colour Temperature), CRI (Colour Rendering Index) and CIE x,y values as provided by the lamp manufacturer or testing laboratory. For LED luminaires, the IESNA LM-79-08 approved method calls for testing the photometric and colorimetric properties of the complete luminaire using the absolute photometry method (IESNA 2008).

3.4.3. Glare and Uplight

Light radiating at high vertical angles (approximately 75° to 80°) from a street or roadway luminaire can potentially cause glare, although in many situations it is possible to create glare from light at lower angles (e.g., 60°). Glare is a critical issue in area, street and roadway luminaire design, due to the high luminous intensity required for illuminating a large area at night. Designers may need to look at the luminous flux exiting a luminaire at a certain angle (the *glare zone*), the luminaire mounting height, and visually adjacent luminaires to evaluate the potential for glare in a particular situation (NLPIP 2004, 2007). The lighting design criteria in RP-08-00 takes into consideration glare, and this plays an important role in the calculation of pole spacing for a given set of conditions, including the luminaire's intensity distribution, mounting height, type of pavement, etc.

Also, the uplight portion (light that extends to angles greater than 90°) from the luminaire can be considered a waste of light and can contribute to light pollution. More information can be obtained from the IESNA's TM-15-07 Luminaire Classification System for Outdoor Luminaires (IESNA 2007a) and the companion document Addendum A for IESNA TM-15-07: Backlight, Uplight and Glare (BUG) Ratings (IESNA 2007b).

The present document does not directly address glare and light pollution because those issues are contextual; thus, specific information about the application in which the luminaire is used is needed. Additional information and evaluation tools can be found in two methods of predicting light pollution and glare from outdoor lighting installations that the Lighting Research Center has published. The first is a comprehensive method for predicting and measuring the three aspects of light pollution, called the Outdoor Site-Lighting Performance method (Brons et al. 2008). The second is a simple, quantitative model to predict discomfort glare from outdoor lighting installations (Bullough et al. 2008, ASSIST 2011).

3.5. Practicalities and Utility As Per LRC [20]

3.5.1.Optimum Mounting Height and Pole Spacing

The roadway LSAE value is specific to the conditions used in its calculation. Most notably, the LSAE value of a luminaire is linked to the mounting height used to determine the pole spacing. Thus, for a given pole layout and roadway geometry, it is possible to calculate LSAE systematically as a function of mounting height. Generally, the optimum mounting height for a luminaire (the mounting height that yields the maximum LSAE) also yields the maximum pole spacing. With this information available, designers can narrow the selection of luminaires that most likely fit in the application at hand (e.g., if they are required to use a specific mounting height) and fine-tune their design. As an example, Figure 3.1 shows the LSAE values for a sample luminaire at various mounting heights. The data labels above each marker indicate the maximum pole spacing to meet RP-08-00 at that mounting height. This particular luminaire has an optimum mounting height of 25 ft for the road width used in the calculations and provides a spacing of 195 ft between luminaires and an LSAE equal to 32 lm/W.

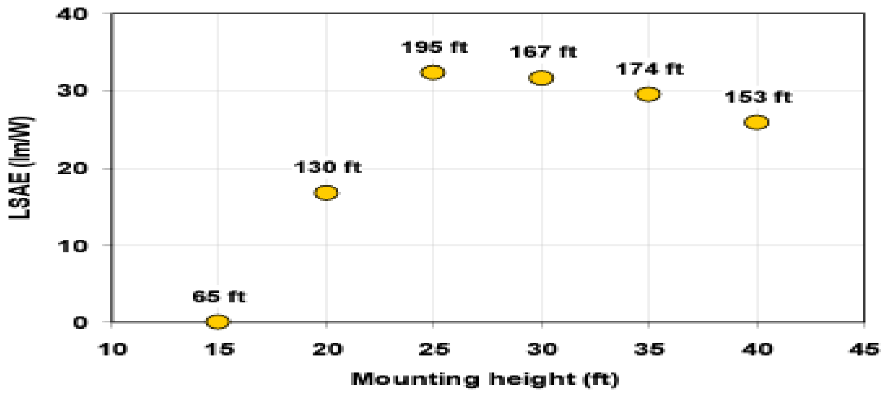


Fig 3.1. LSAE values and pole spacing for various mounting heights for a sample luminaire in a staggered layout

3.5.2. Correlating LSAE to Energy Usage

LSAE is a useful tool to predict energy use for roadway lighting installations. Table 3.7 and Figure 3.2 show a comparison of six commercially available luminaires. The analysis shows the LSAE values for these luminaires in a staggered configuration at their optimum mounting height. This mounting height provides the maximum pole spacing possible to meet RP-08-00 for a collector road with medium pedestrian conflict that is 48-ft wide with four lanes. Using the maximum pole spacing, the number of streetlights in a staggered layout over a one-mile length of roadway was determined, and the power demand per linear mile (kW/mile) was calculated. Table 3.7 summarizes the characteristics of the luminaires and the results. Figure 3.2 shows power demand per mile as a function of LSAE. The plotted LSAE values show a high correlation between higher LSAE and lower power demand values, which means that LSAE values can be used to compare and rank order luminaires in terms of energy efficiency.

Table 3.7. Streetlight characteristics and LSAE results for six commercially available streetlights used to light a one-mile length of collector road to RP-08-00 (IESNA 2000) lighting criteria

Sample	Mounting height (ft)	Pole spacing (ft)	Input power (W)	LSAE (lm/W)	# poles / mile	Power demand (kW/mile)
1	30	135	204	13.9	77	15.8
2	30	120	174	14.9	87	15.1
3	25	90	144	13.4	116	16.8
4	35	215	305	15.1	48	14.7
5	40	190	293	13.6	55	16.0
6	40	165	290	12.2	63	18.3

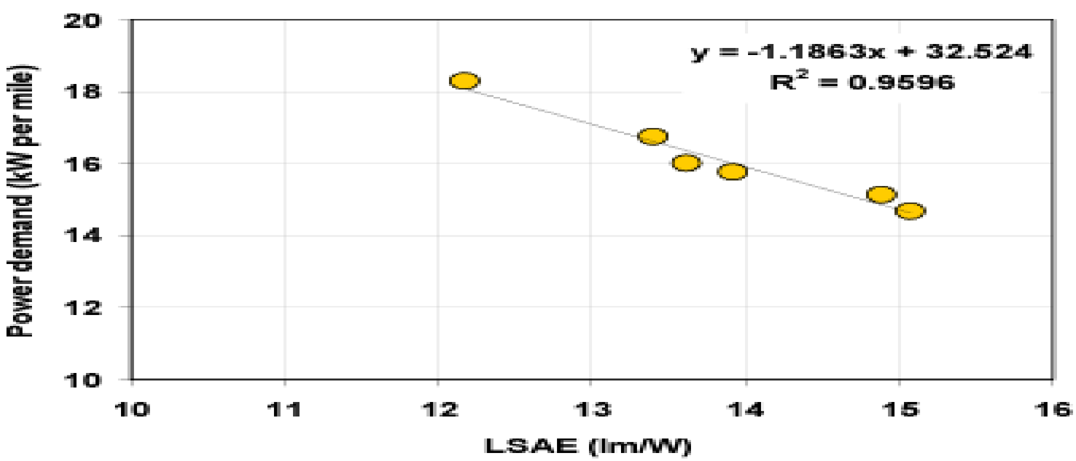


Fig 3.2. Power demand along a one-mile length of collector road that meets RP-08-00 (IESNA 2000) as a function of LSAE.

3.6. International Street Lighting Standards [21]

The Commission Internationale de l'Eclairage (CIE) is one of the main international entities providing standards and guidelines for street and outdoor lighting, particularly roadway lighting. Standard CIE 115-1995 highlights the importance and purpose of street and outdoor lighting in:

Allowing users of vehicles to proceed safely, leading to fewer accidents and fatalities
Facilitate high visibility among pedestrians so they can commute safely
Substantial reduction of criminal activities, leading to a sense of security among residential communities.

Above factors have largely affected the design and installation standards in outdoor lighting since 1976. Examples of international standards and guidelines applicable for street and outdoor lighting and traffic lighting include:

CIE 31-1976—Glare and Uniformity in Road Lightings Installations
CIE 22-1977—Depreciation of Installation and their Maintenance (in Road Lighting)
CIE 47-1979—Road Lighting for Wet Conditions
CIE 48-1980—Light Signals for Road Traffic Control
CIE 66-1984—Road Surfaces and Lighting (Joint Technical Report CIE/PIARC)
CIE 93-1992—Road Lighting as an Accident Countermeasure
CIE 132-1999: Design Methods for Lighting of Roads
CIE 140-2000: Road Lighting Calculations
CIE 136-2000: Guide to the Lighting of Urban Areas
CIE 144-2001: Road Surface and Road Marking Reflection Characteristics
CIE 115-2007: Recommendations for the Lighting of Motorized Traffic (updated)
CIE 180-2007: Technical Report: Road Transport Lighting for Developing Countries
CIE 115-2010: Lighting of Roads for Motor and Pedestrian Traffic
CIE 119-2010: Recommended System for Mesopic Photometry Based on Visual Performance

Other International/Economy-Wide Standards of reference include:

CEN/TR 13201-1: Road Lighting—Part 1: Selection of Lighting Classes
EN 13201-2 Road: Lighting—Part 2: Performance Requirements
ANSI/IESNA RP-8-00: American National Standard Practice for Roadway
ANSI C136.37: Solid-State Light Sources Used in Roadway and Area Lighting
AS/NZS 1158.1/1-1997: Road Lighting—Vehicular Traffic Lighting
AS 1158.2-1971: Standards Association of Australia (SSA) Public Lighting Code—Lighting of Minor Streets
AS CA19-1939: Australian Standard Rules for Street Lighting

ANSI C136.37 is the only international standard focusing exclusively on LED Street and outdoor lighting. The standard specifies a number of requirements for LED luminaires based on existing regional and international LED standards such as operating temperature, correlated color temperature, mounting provisions, dimming, ingress protection, wiring and grounding. The standard aims at providing recommendations and guidance to utilities and manufacturers. The People's Republic of China, Chinese Taipei, Republic of Korea and the United States are the only APEC member economies with economy-wide standards covering specifically LED street and outdoor lighting applications.

3.7. Indian Street Lighting Standards [21]

In order to ensure the citizens' safety and provide guidance to the public lighting authorities the Bureau of Indian Standards (BIS) has established standards (IS 1944) for lighting levels for street lights. The Indian Standard (BIS 1981) has classified the roads based on traffic density of the road (Table 3.8). BIS also provides specifications for Street Lighting Poles (Table 3.9) and recommends mounting height of luminaires and levels of illumination (Table 3.10). Table 3.11 represents the lighting recommendations For junctions.

Table 3.8. Classification of the Roads as per BIS

Group	Description
A1	For very important routes with rapid and dense traffic where the only considerations are the safety and speed of the traffic and the comfort of drivers
A2	For main roads with considerable mixed traffic like main city streets, arterial roads, and thoroughfares
B1	For secondary roads with considerable traffic such as local traffic routes, and shopping streets
B2	For secondary roads with light traffic
C	For residential and unclassified roads not included in the previous groups
D	For bridges and flyovers
E	For towns and city centers
F	For roads with special requirements such as roads near airports, and railways

Source: BIS 1981

Table 3.9. Specifications of street lighting poles as per BIS

Section	Overall length 11 m + 25 mm (base plate)			Overall length 9.5 m +25 mm (base plate)		
	Outside Diameter (mm)	Thickness (mm)	Length (mm) Outside D	Outside Diameter (mm)	Thickness (mm)	Length (mm) Outside D
Bottom section	139.7	4.85	5600	165.1	4.85	5000
Middle section	114.3	4.5	2700	139.7	4.5	2250
Top section	88.9	3.25	2700	114.3	3.65	2250
Planting depth	1800 mm			1800 mm		
Nominal weight of the pole	160 kg			147 kg		
Tolerance on mean weight for bulk supply is 7.5 % Tolerance for single pole weight is 10%						

Source: BIS 1981

Table 3.10. Recommended Levels of Illumination and Mounting Height of Luminaires as per BIS

Type of Road	Road Characteristics	Average Level of Illumination on Road Surface in Lux	Ratio of Minimum/Average Illumination	Type of Luminaire Preferred	Min: Max (%)	Mounting Height of Luminaires
A1	Important traffic routes carrying fast traffic	30	0.4	Cut-off	33	9 to 10 meters
A2	Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways	15	0.4	Cut-off	33	9 to 10 meters
B1	Secondary roads with considerable traffic like local traffic routes, shopping streets	8	0.3	Cut-off or semi-cut-off	20	7.5 to 9 meters
B2	Secondary roads with light traffic	4	0.3	Cut-off or semi-cut-off	20	7.5 to 9 meters

Source: BIS 1981

Table 3.11. Lighting Recommendations For Junctions

Sl No.	Junction Type	E_{avg} (lux)	E_{min}/E_{avg}
1	Key Junctions & Complex Flyover Interchanges	50	0.4
2	Main City Junction Without any interchanges	20	0.4
3	Other Smaller Junctions	15	0.4
4	Pedestrian Crossings	50	—
5	Bus Bays	5	—

CHAPTER 4: PROPOSED STREET LIGHT DESIGNS

4.1. Designed Plans

An urban motorized traffic area is designed which is generally busy and is situated on the outskirts of a developing city. Comparative analysis is performed for the lighting parameters on three different road surfaces, three different pole arrangements under the influence of three different types of street lamps in use. It is to be checked which lamp performs the best in which arrangement and on which road surface. Analysis is performed for the lighting parameters on four observers present in the center of each lane of both the roadways. A specific motorized lighting class has been selected for all the arrangements for comparison and optimisation. Segregation of three lighting classes in three different pole arrangements has been performed under the specific motorized lighting class which was selected at first.

1. Lamps

For this dissertation, the lamps chosen for analyzing the lighting parameters are nearly of the same power as represented in Table 4.1.

Solar Efficient LEDs are used in place of LEDs because the former one provides more efficiency and sustainability compared to the latter.

SON- High Pressure Sodium Vapor Lamps
MHN-TD- Metal Halide Lamps
SOLAR EFF-LED - LED which uses Solar energy with a higher efficiency

Table 4.1. Types Of Lamp Chosen along with their required specifications

LAMP USED	POWER (in W)	LUMINOUS FLUX (in lm)	EFFICACY (in lm/W)
SON	170	14000	82.35294118
MHN-TD	166	12100	72.89156627
SOLAR EFF-LED	170	22079	129.8764706

From Table 5.1, it is found that:-

SON’s power is 170W. It has a luminous flux of 14000lm and efficiency of 82.35lm/W.
MHN-TD’s power is 166W. It has a luminous flux of 12100lm and efficiency of 72.89lm/W.
Solar EFF-LED’s power is 170W. It has a luminous flux of 22079lm and efficiency of 129.87lm/W.

2. Road Length - An estimated road stretch of **2 km** is taken into account for calculation purposes.

3. Road Surfaces

The three road surfaces taken into account while designing the street are:-
R1 : Dry road with a reflectance factor q0 of 0.100
W2 : Wet road with a reflectance factor q0 of 0.150
C2 : Concrete road with a reflectance factor q0 of 0.070

4. Pole Height : The pole height is kept constant **9m** for each of the DIALux designs keeping at bay with the street lighting standards.

5. Pole Arrangements

Zig-Zag : Here, the road width is selected to be **14m**. For alternate/offset arrangements, **width= 1.5* height.** The road surface selected for this arrangement is **R1** .

Opposite : Here, the road width is selected to be **18m.** For double opposing arrangements, **width= 2*height.** The road surface selected for this arrangement is **W2**.

Twin-Central : Here, the road width is selected to be **22m.** For twin-central arrangements, **width** >> **height.** The road surface selected for this arrangement is **C2.**

6. Pole Spacings According To Arrangements [22]

For Zig-Zag Arrangements:- Pole spacing is kept 20m.
For Opposite arrangements:- Pole spacing is kept 24m.
For Twin-Central Arrangements:- Pole spacing is kept 28m.

Refer to Table 4.2 for detailed explanation.

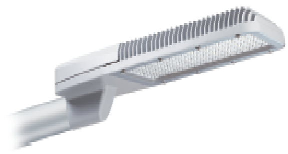
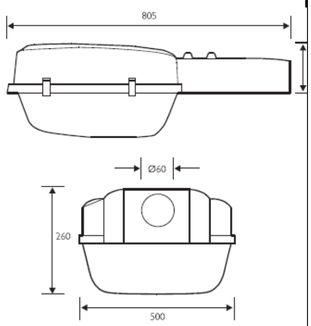
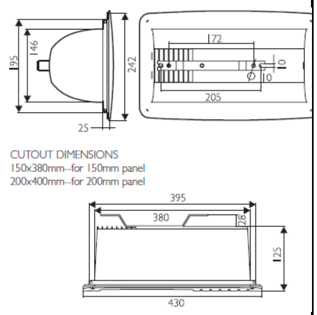
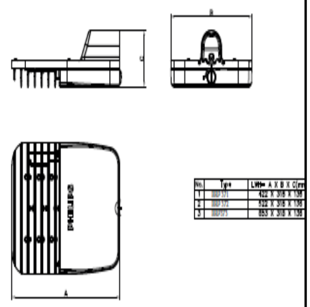
Table 4.2. Pole spacings according to Pole arrangement

TYPE OF ARRANGEMENT	POLE HEIGHT (H) (m)	POLE SPACING (m)	TOTAL ROAD WIDTH (W) (m)
Zig-Zag Arrangement	9	20	14 (W=1.5H)
Opposite Arrangement	9	24	18 (W=2H)
Twin- Central Arrangement	9	28	22 (W>>H)

7. Boom Length :- The boom length varies within a range of **1.5m-2.5m** depending upon the arrangements. It has been designed keeping in view of the boom length standards.

8. Boom Angle:- The boom angle for each design has been kept at **20⁰** constant. This has been done which meets the standard requirements.

9. Detailed description of the Luminaires Used

Information	SON Luminaire	MHN-TD Luminaire	Solar Eff. LED Luminaire
Luminaire Company & Name	Philips SRP 202 closed	Philips MPF 922 Symmetric	Philips BRP 383 Gen 4.0 Solar
Luminaire Picture			
Technical Drawing			
Features	Stainless steel toggles for fixing UV stabilized acrylic bowl to housing. Stainless steel slide lock arrangement for retention of acrylic bowl with housing. Powder coated metallic gear compartment cover. Hinging arrangement for acrylic bowl for ease of maintenance. Retention of gear compartment lid with the housing during maintenance or installation.	Excellent uniform light distribution with bi-directional beam ensured by stippled aluminum, anodised and brightened reflector. Silicon rubber gasket makes the luminaire protected against ingestion of dust and water. Easy maintainable detachable. Gear Tray is provided in the luminaires which carries the ballast, ignitor and condenser. Specially designed mounting arrangement which allows easy and fast installation.	High luminous efficacy of up to 170 lm/Watt. Compatible with multiple battery types (LiFePO4, LMLA GEL). Available in both off grid and hybrid versions. Configurable dimming profile and load wattage. Pressure die-cast aluminum housing for sturdiness and excellent thermal management.
Benefits	Single piece die-cast aluminum (LM6) housing, powder coated in attractive gray color outside. All electrical accessories	Efficient. Low glare. recessed / surface-mounted cast aluminum luminaire.	Brings light to areas without access to the electric grid. Saves energy.

	such as energy efficient copper ballast, electronic ignitor power factor improvement capacitors etc. are pre-wired to a terminal block. High quality electrochemically brightened and anodised faceted aluminum reflector for optimum light distribution with ovoid SON lamps. High quality long lasting felt gasket impregnated with insecticide and water repellent chemicals on the periphery of the housing.		Preserves landscape as no trenching for cabling required. Smart city ready for sustainable cities. Environment friendly. High efficacy reduces cost per light point by reducing battery and panel size. Sturdy construction for long life.
Application	Major city roads Roundabouts Industrial areas Car parks	Under canopy- Low height under canopies up to 6 meter Up To 12m for road Petrol station Motorized roadways	Highways Street Road Parking
Ingress Protection Code	IP 54	IP 65	IP 66
Dimmable	No	No	Yes
Power	170W	166W	170W
Driver Included	No	No	Yes

10. Calculation of the Number of Luminaires Required

For calculation of no. of luminaires required in each street arrangement, we need the pole Spacings of the specific arrangement

For zig-zag arrangement= 20m
For opposite arrangement= 24m
For twin-central arrangement= 28m
Estimated Road stretch= 2000m (2km)

Refer to Table 4.3 for the detailed tabular representation.

No. of luminaires required= Estimated road stretch/ Pole spacing of specific arrangement

MHN-TD has the lowest efficacy of 72.89lm/W. SON has an efficacy of 82.35 lm/W and Solar Eff-LED has the highest efficacy of 129.87 lm/W.

So, for calculation of luminaires required, SON and Solar-Eff LED lamps are required less in number than MHN-TD lamps.

Table 4.3 Table showing the no. of luminaires required for the types of lamps used in the different Arrangements

Type of Lamps	Type Of Arrangement	Pole Spacing (in m)	Road Stretch (in m)	Luminaires Required
MHN-TD	Zig-Zag	20		100
	Opposite	24		83
	Twin-Central	28		71
SON	Zig-Zag	20		88
	Opposite	24		73
	Twin-Central	28		63
Solar Eff-LED	Zig-Zag	20		56
	Opposite	24		47
	Twin-Central	28	2000	40

No. of MHN-TD luminaires required for designing the zig-zag arrangement is 100.
No. of MHN-TD luminaires required for designing the opposite arrangement is 83.
No. of MHN-TD luminaires required for designing the twin-central arrangement is 71.

No. of SON luminaires required for designing the zig-zag arrangement is 88.
No. of SON luminaires required for designing the opposite arrangement is 73.
No. of SON luminaires required for designing the twin-central arrangement is 63.

No. of Solar Eff-LED luminaires required for designing the zig-zag arrangement is 56.
No. of Solar Eff-LED luminaires required for designing the opposite arrangement is 47.
No. of Solar Eff-LED luminaires required for designing the twin-central arrangement is 40.

11. Lighting Parameters Calculated

For Roadways:- In each plan, lighting parameters which has been set as per the ME4a traffic lighting class are:-

L_{avg} (Average Luminance)
U0 (Overall Uniformity)
U1 (Longitudinal Uniformity)
TI (Threshold Increment/Disability Glare)
SR (Lighting of surroundings/ Surround Ratio)

For Observers:- In each plan, lighting parameters which has been set as per the ME4a traffic lighting class are:-

L_{avg} (Average Luminance)
U0 (Overall Uniformity)
U1 (Longitudinal Uniformity)
TI (Threshold Increment/Disability Glare)

4.2. Key Factors Of The Designed Plans

While designing the streetlight plans in DIALux 4.13, the following points have been covered:-

Choosing the Street Standard- CIE 140/ EN 13201

Selecting the Motorized Lighting Class

Primarily, the DIALux lighting wizard has to be visited. According to the European Committee for Standardisation, the following options are selected:-

Typical Speed of main user is - High (> 60km/hr) (chosen)
Slow vehicles (< 40 km/hr) are also permitted.(chosen)
Bicycles and pedestrians are not permitted.(chosen)
Main weather Type- Dry (chosen). Street surfaces are mostly not damp in India. So it's chosen as dry.
Interchanges and Frequency- For simple junctions and interchange density- < 3 pieces per km(chosen). For urban Areas- 1.6 km minimum spacing (chosen).
Traffic flow of Motorised Vehicle- Less than 7000 (chosen)
Does a conflict zone exist- No (chosen)
Complexity of Field of Vision- High. Billboards and advertisements cause disturbance.
Degree of navigational difficulty- High (Chosen)
Brightness of surroundings- Medium (Approaching urban environment)

So, the determined motorized lighting class as per DIALux Lighting Wizard is **ME4a.**

Choosing the Lighting Class

Since, the typical speed of the main user is high i.e. > 60 km/hr as per ME4a. So, no other options are available under this section. We have to move forward to the next section in Lighting Wizard to select the lighting class. It does not have any effect on the limits/standards set by the previous Lighting class.

A1- Only High speed users (> 60km/hr) & other users are not permitted.
This has been chosen for every **zig-zag arrangement** of street lighting as pole spacing for this arrangement is kept to be the least i.e. **20m** (Table 4.2).

A2- High speed users (> 60km/hr) and all other slow vehicles <40km/hr are only permitted.
This has been chosen for every **opposite arrangement** of street lighting and pole spacing for this arrangement is kept to be **24m** (Table 4.2).

A3- All other slow vehicles (<40 km/hr), bicyclists and pedestrians are permitted.
This has been chosen for every **twin-central arrangement** of street lighting and pole spacing for this arrangement is kept to be the most i.e. **28m** (Table 4.2).

4.3. Results Of Each Plan

For each plan, the following DIALux outputs have been taken in this dissertation.

Street & Luminaire Planning details
Photometric results
3D Image of the plan
False Colour Rendering of the Plan
Isolines & E_{avg} value of Valuation field-Roadway 1
Isolines & Photometric results for Observer-1 of Roadway-1
Isolines & Photometric results for Observer-2 of Roadway-1
Isolines & E_{avg} value of Valuation field-Roadway 2
Isolines & Photometric results for Observer-3 of Roadway-2
Isolines & Photometric Results for Observer-4 of Roadway-2

Note:- The red/black outlined boxes at the corner of the streets in the figures represent the luminaire arrangements with its adjacent luminaire positioning coordinates.
The red/black arrows at the left hand side of the streets in the figures represent the observer's position on the lane.

4.3.1. Results of Proposed Plan I

Lamp used- SON 170W
Arrangement- Opposite
Lighting Class- A1
Road width- 9*2= 18m

Road Surface- W2 (Wet road)
Reflectance value(qo- 0.150)

Fig 4.1 represents the street & luminaire planning details of the plan.
Fig 4.3 represents the 3D image of the plan.
Fig 4.4 illustrates the false colour rendering of the plan.

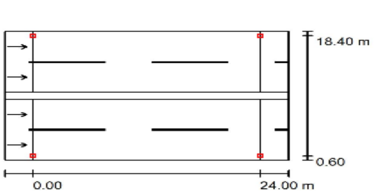
The L_{avg}, U0, UI, TI & SR values for road surfaces are found to be 1.20 cd/m^2, 1.31, 0.74, 5 and 0.93 respectively. It is illustrated in Fig 4.2.
The E_{avg} value is found to be 13 lux. Refer to Fig 4.5 & 4.8
Isoline values for roadways range from 7-25 lux. Fig 4.5 and 4.8 represents the values
All the observers fulfill the lighting criteria of ME4a lighting class except U0. Fig 4.6, Fig 4.7, Fig 4.9 and Fig 4.10 represent the values obtained for the observers.

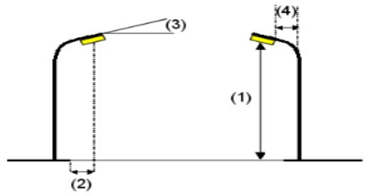
Street Profile

Roadway 2	(Width: 9.000 m, Number of lanes: 2, tarmac: W2, q0: 0.150)
Median 1	(Width: 1.000 m, Height: 0.500 m)
Roadway 1	(Width: 9.000 m, Number of lanes: 2, tarmac: W2, q0: 0.150)

Light loss factor: 0.67

Luminaire Arrangements





Luminaire:	PHILIPS SRP 202 / 150W CLOSED,
Luminous flux (Luminaire):	10020 lm
Luminous flux (Lamps):	14000 lm
Luminaire Wattage:	170.0 W
Arrangement:	Double row, opposing
Pole Distance:	24.000 m
Mounting Height (1):	9.000 m
Height:	8.884 m
Overhang (2):	0.642 m
Boom Angle (3):	20.0 °
Boom Length (4):	2.500 m

Maximum luminous intensities

at 70°:	190 cd/klm
at 80°:	205 cd/klm
at 90°:	228 cd/klm

Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.
Arrangement complies with glare index class D.0.

Fig 4.1. Street & Luminaire Planning Details of Plan I

Light loss factor: 0.67

Scale 1:215

Calculation Field List

1 Valuation Field Roadway 1
Length: 24.000 m, Width: 9.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: W2, q0: 0.150
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	1.20	0.28	0.74	5	0.93
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✓	✓	✓

2 Valuation Field Roadway 2
Length: 24.000 m, Width: 9.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 2.
tarmac: W2, q0: 0.150
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	1.10	0.31	0.69	5	0.93
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✓	✓	✓

Activate Windows
Go to Settings to activate Windows

Fig 4.2. Photometric Results of Plan-I

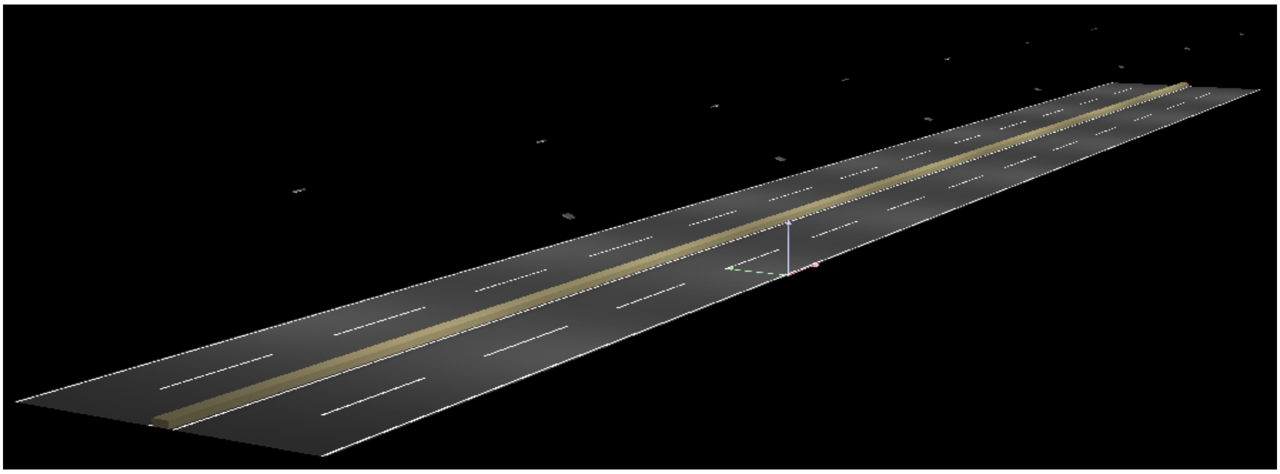


Fig 4.3. 3D Image of Plan-I

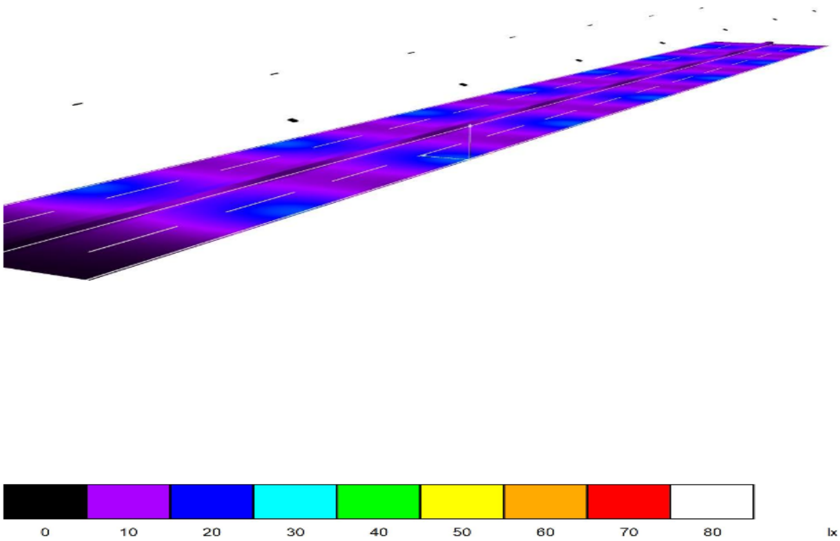
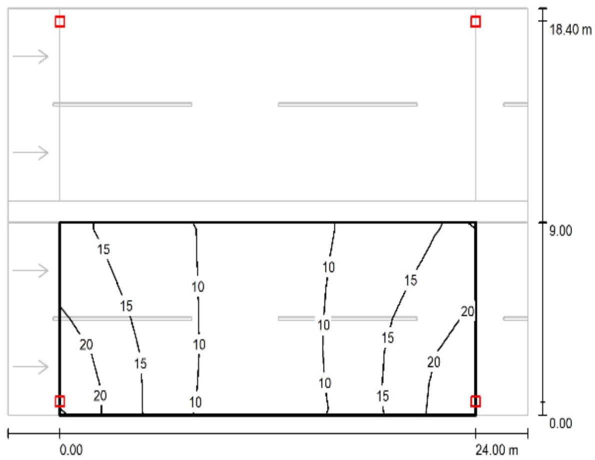


Fig 4.4. False Colour Rendering of Plan-I

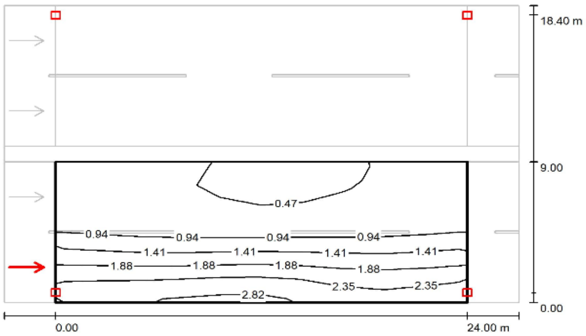


Values in Lux, Scale 1 : 215

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
13	7.57	23	0.575	0.331

Fig 4.5. Isolines and E_{avg} value of Valuation Field- Roadway 1

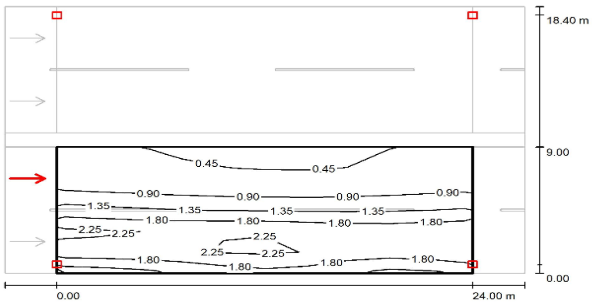


Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 2.250 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.20	0.32	0.90	5
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✓	✓

Fig 4.6. Isolines & Photometric results for Observor-1 of Roadway-1

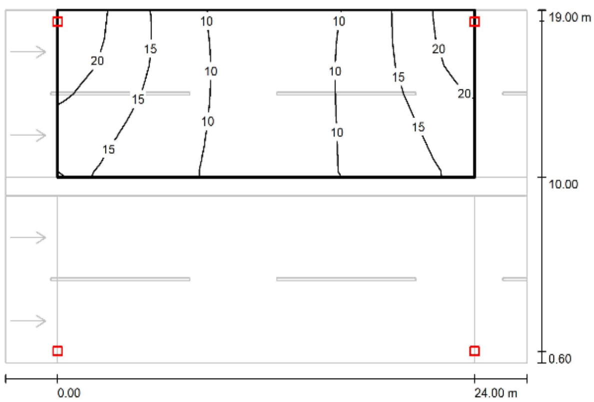


Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 6.750 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.34	0.28	0.74	4
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✓	✓

Fig 4.7. Isolines & Photometric results for Observor-2 of Roadway-1

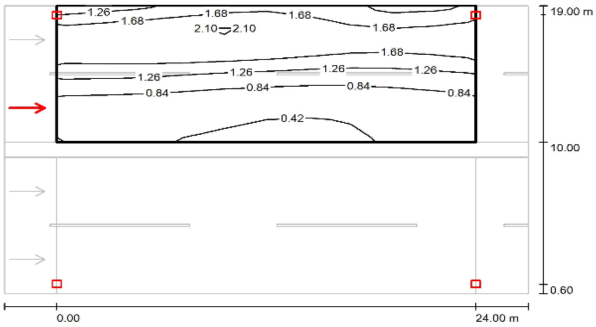


Values in Lux, Scale 1 : 215

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
13	7.57	23	0.575	0.331

Fig 4.8. Isolines and E_{avg} value of Valuation Field- Roadway 2

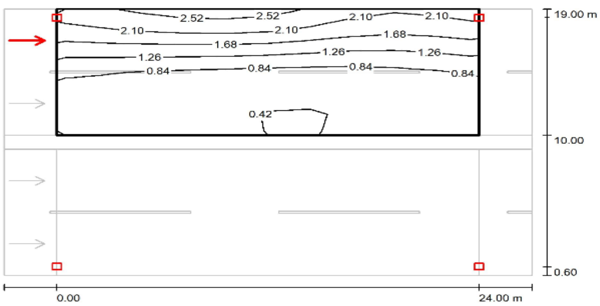


Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 12.250 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.21	0.31	0.69	5
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✓	✓

Fig 4.9. Isolines & Photometric results for Observor-3 of Roadway-2



Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 16.750 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.10	0.36	0.82	5
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✓	✓

Fig 4.10. Isolines & Photometric results for Observor-4 of Roadway-2

4.3.2. Results of Proposed Plan II

Lamp used- SON 170W
Arrangement- Zig-Zag
Lighting Class- A2
Road width- 7*2= 14m
Road Surface- R1 (Dry road)
Reflectance value(qo- 0.100)

Fig 4.11 represents the street & luminaire planning details of the plan.
Fig 4.13 represents the 3D image of the plan.
Fig 4.14 illustrates the false colour rendering of the plan.

The L_{avg}, U0, UI, TI & SR values for road surfaces are found to be 1.64, 0.76, 0.68, 5 and 0.91 respectively. Fig 4.12 illustrates the values.

The E_{avg} value is found to be 19 lux. Refer to Fig 4.15 and 4.18.

Isoline values for roadways range from 13-26 lux. Fig 4.15 and 4.18 represent the values.

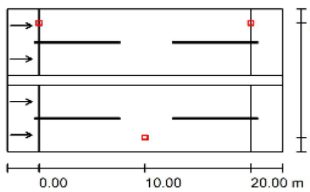
All the observers fulfill the lighting criteria of ME4a lighting class. Fig 4.16, 4.17, 4.19 & 4.20 represent all the values obtained for observers.

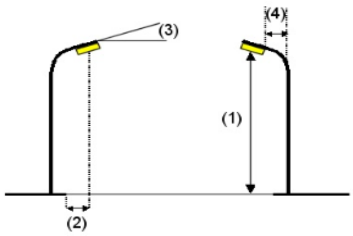
Street Profile

Roadway 2	(Width: 7.000 m, Number of lanes: 2, tarmac: R1, q0: 0.100)
Median	(Width: 1.000 m, Height: 0.500 m)
Roadway 1	(Width: 7.000 m, Number of lanes: 2, tarmac: R1, q0: 0.100)

Light loss factor: 0.67

Luminaire Arrangements





Luminaire:	PHILIPS SRP 202 / 150W CLOSED,
Luminous flux (Luminaire):	10020 lm
Luminous flux (Lamps):	14000 lm
Luminaire Wattage:	170.0 W
Arrangement:	Double row, with offset
Pole Distance:	20.000 m
Mounting Height (1):	9.000 m
Height:	8.884 m
Overhang (2):	1.500 m
Boom Angle (3):	20.0 °
Boom Length (4):	2.500 m

Maximum luminous intensities

at 70°:	190 cd/klm
at 80°:	205 cd/klm
at 90°:	228 cd/klm

Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.

Arrangement complies with glare index class D.0.

Fig 4.11. Street & Luminaire Planning Details of Plan II

Light loss factor: 0.67

Scale 1:186

Calculation Field List

1 Valuation Field Roadway 1
Length: 20.000 m, Width: 7.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: R1, q0: 0.100
Selected Lighting Class: ME4a

(All lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	UI	TI [%]	SR
Calculated values:	1.64	0.75	0.68	5	0.91
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✓	✓	✓	✓

2 Valuation Field Roadway 2
Length: 20.000 m, Width: 7.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 2.
tarmac: R1, q0: 0.100
Selected Lighting Class: ME4a

(All lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	UI	TI [%]	SR
Calculated values:	1.63	0.76	0.68	5	0.91
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✓	✓	✓	✓

Activate Windows

Fig 4.12. Photometric Results of Plan-II

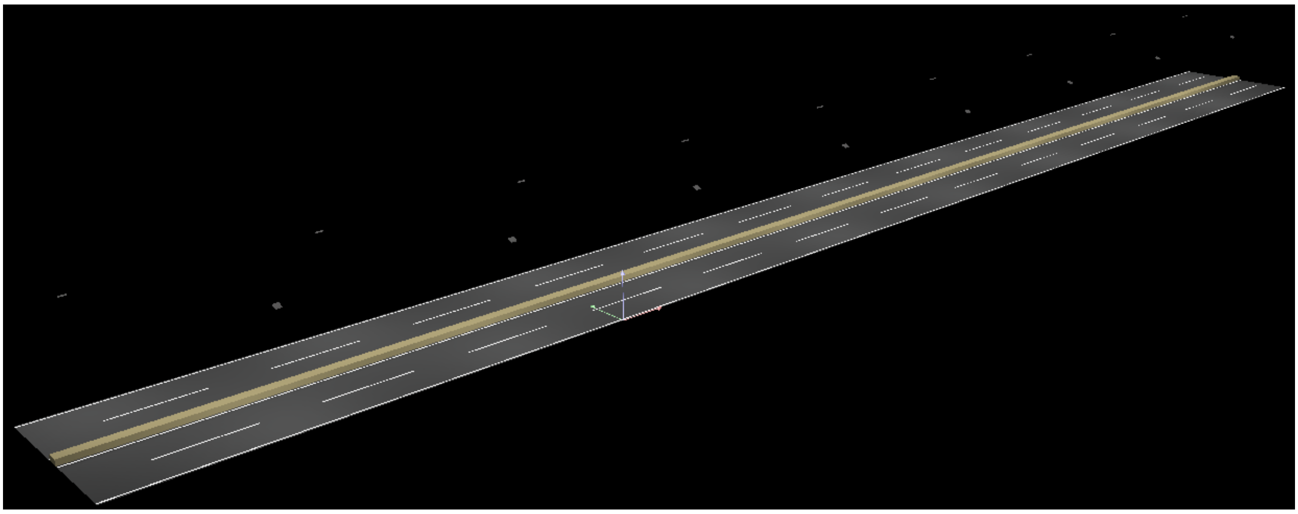


Fig 4.13. 3D Image of Plan-II

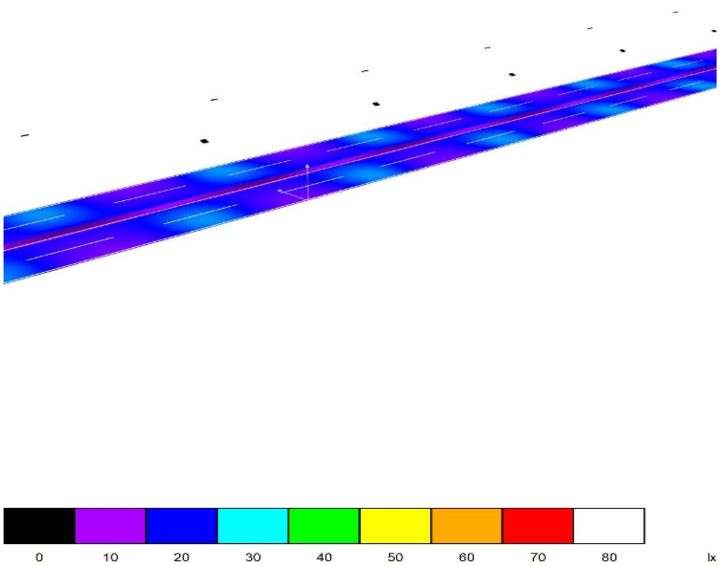


Fig 4.14. False Colour Rendering of Plan-II

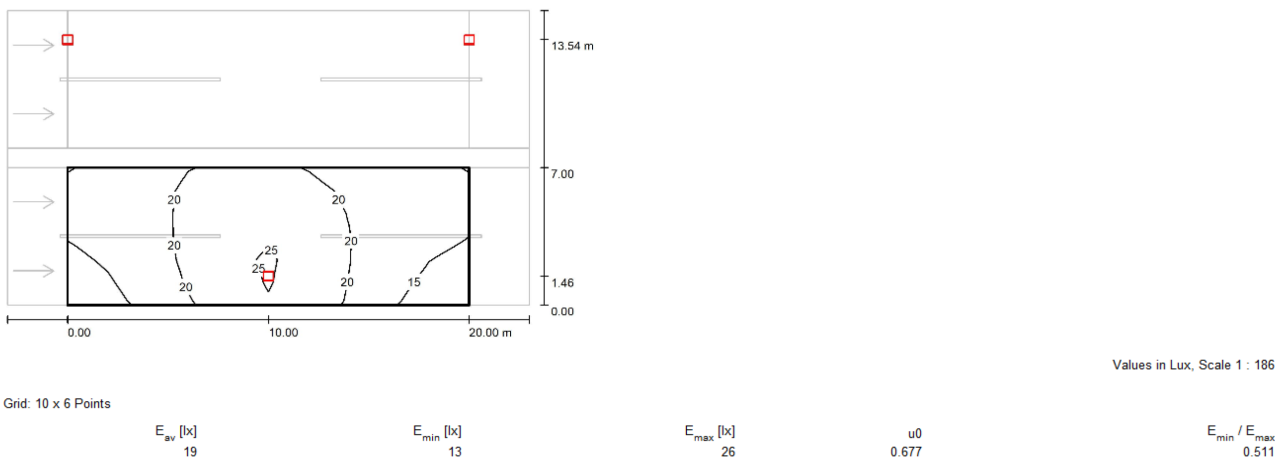
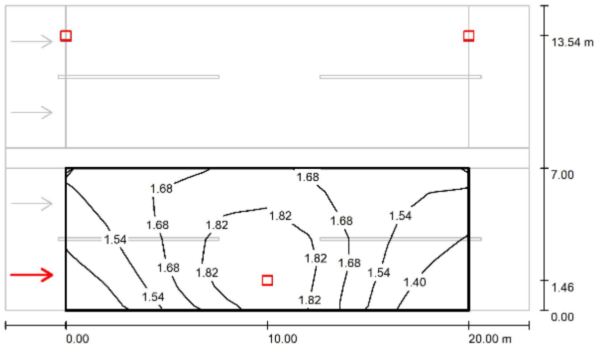


Fig 4.15. Isolines and E_{avg} value of Valuation Field- Roadway 1

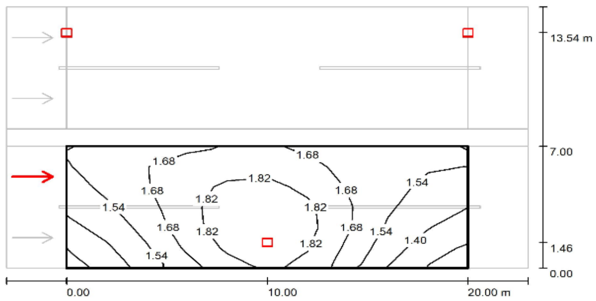


Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 1.750 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.64	0.77	0.68	5
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig 4.16 Isolines & Photometric results for Observor-1 of Roadway-1

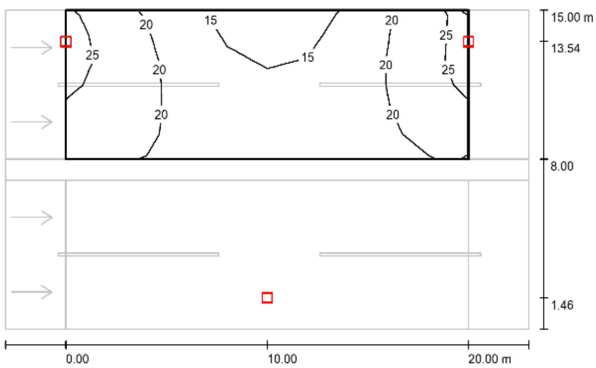


Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 5.250 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.64	0.75	0.83	5
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig 4.17 Isolines & Photometric results for Observor-2 of Roadway-1

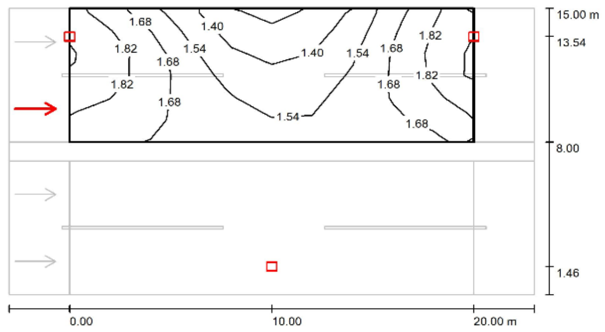


Values in Lux, Scale 1 : 186

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
19	13	26	0.677	0.511

Fig 4.18 Isolines and E_{avg} value of Valuation Field- Roadway 2

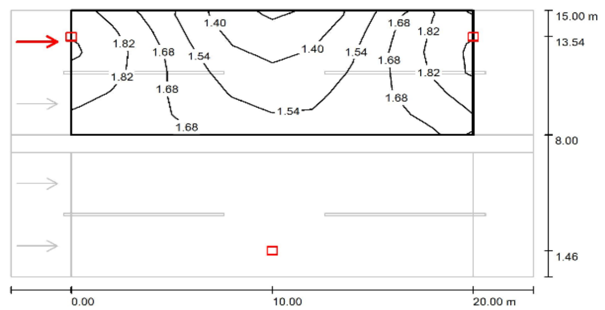


Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 9.750 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	UI	TI [%]
Calculated values:	1.63	0.76	0.83	5
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig 4.19 Isolines & Photometric results for Observor-3 of Roadway-2



Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 13.250 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	UI	TI [%]
Calculated values:	1.63	0.77	0.68	4
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig 4.20 Isolines & Photometric results for Observor-4 of Roadway-2

4.3.3. Results of Proposed Plan III

Lamp used- SON 170W
Arrangement- Twin-Central
Lighting Class- A3
Road width- 11*2= 22m
Road Surface- C2 (Concrete road)
Reflectance value(qo- 0.070)

Fig 4.21 & 4.22 both represent the street & luminaire planning details of the plan.
Fig 4.24 represents the 3D image of the plan.
Fig 4.25 illustrates the false colour rendering of the plan.

The L_{avg}, U0, UI, TI & SR values for road surfaces are found to be 0.68 cd/m^2 (fails the criteria), 0.33(fails the criteria), 0.46(fails the criteria), 8 and 0.84 respectively. Fig 4.23 illustrates these values.
The E_{avg} value is found to be 13 lux. Refer to Fig 4.26 & 4.29.
Isoline values for roadways range from 4-36 lux. Refer to Fig 4.26 & 4.29.
All the observers fulfill only the limits of SR in the ME4a lighting class. Fig 4.27, 4.28, 4.30 & 4.31 represent the values obtained for observers.

Street Profile

Roadway 2	(Width: 11.000 m, Number of lanes: 2, tarmac: C2, q0: 0.070)
Median 1	(Width: 1.000 m, Height: 0.500 m)
Roadway 1	(Width: 11.000 m, Number of lanes: 2, tarmac: C2, q0: 0.070)

Light loss factor: 0.67

Luminaire Arrangements

Luminaire:	PHILIPS SRP 202 / 150W CLOSED,		
Luminous flux (Luminaire):	10020 lm	Maximum luminous intensities	
Luminous flux (Lamps):	14000 lm	at 70°:	190 cd/klm
Luminaire Wattage:	170.0 W	at 80°:	205 cd/klm
Arrangement:	on Median	at 90°:	228 cd/klm
Pole Distance:	28.000 m	Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.	
Mounting Height (1):	9.000 m	Arrangement complies with glare index class D.0.	
Height:	8.884 m		
Overhang (2):	2.042 m		
Boom Angle (3):	20.0 °		
Boom Length (4):	2.500 m		

Fig 4.21 Street & Luminaire Planning details of Plan-III

Luminaire:	PHILIPS SRP 202 / 150W CLOSED,		
Luminous flux (Luminaire):	10020 lm	Maximum luminous intensities	
Luminous flux (Lamps):	14000 lm	at 70°:	190 cd/klm
Luminaire Wattage:	170.0 W	at 80°:	205 cd/klm
Arrangement:	on Median	at 90°:	228 cd/klm
Pole Distance:	28.000 m	Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.	
Mounting Height (1):	9.000 m	Arrangement complies with glare index class D.0.	
Height:	8.884 m		
Overhang (2):	-0.358 m		
Boom Angle (3):	20.0 °		
Boom Length (4):	2.584 m		

Fig 4.22 Street & Luminaire Planning details of Plan-III (Continued)

Light loss factor: 0.67

Scale 1:244

Calculation Field List

1 Valuation Field Roadway 1
Length: 28.000 m, Width: 11.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: C2, q0: 0.070
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	0.68	0.33	0.46	7	0.83
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✗	✗	✗	✓	✓

2 Valuation Field Roadway 2
Length: 28.000 m, Width: 11.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 2.
tarmac: C2, q0: 0.070
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	0.69	0.30	0.41	8	0.84
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✗	✗	✗	✓	✓

Fig 4.23 Photometric Results of Plan-III

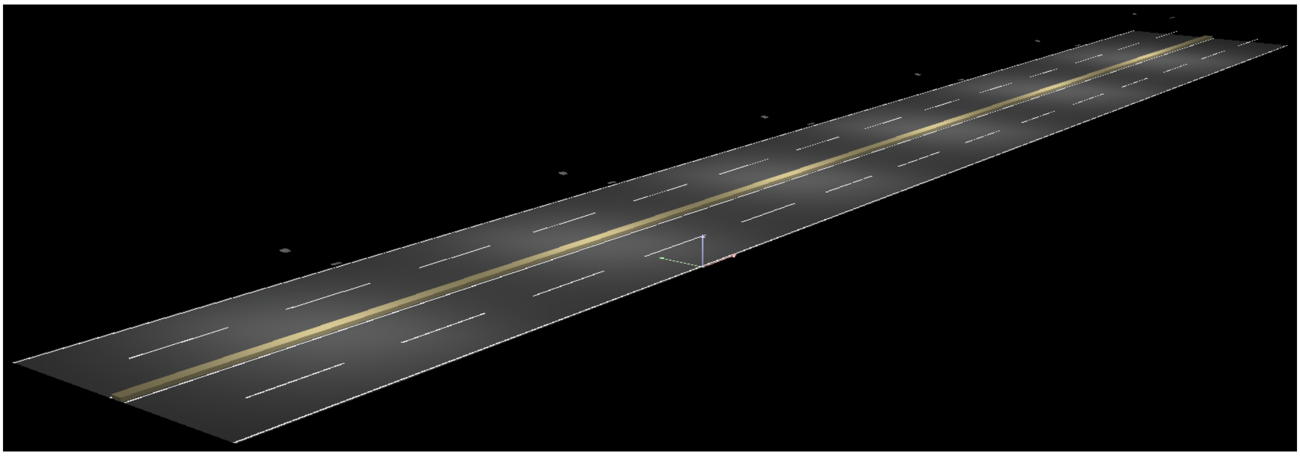


Fig 4.24 3D Image of Plan-III

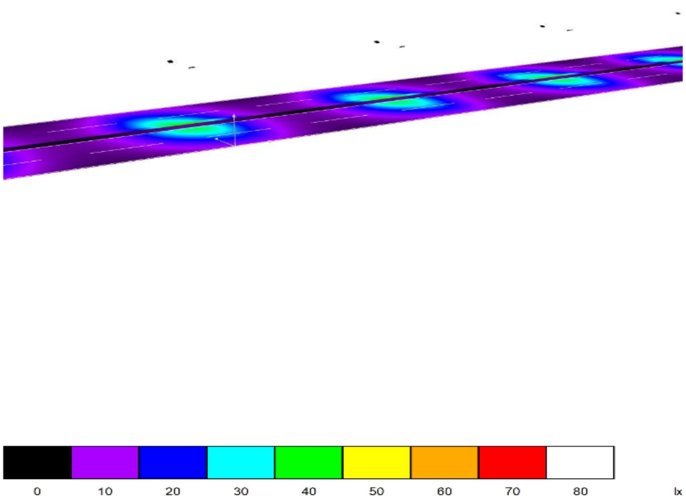
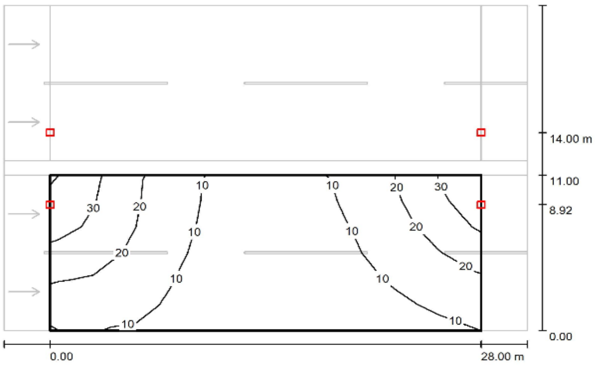


Fig 4.25 False Color Rendering of Plan-III

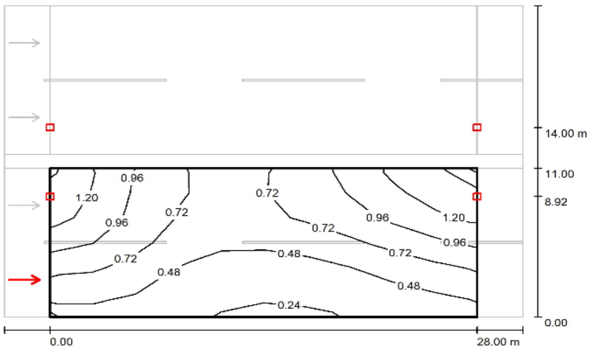


Values in Lux, Scale 1 : 244

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
13	4.05	36	0.301	0.113

Fig 4.26 Isolines & E_{avg} Value of Valuation Field- Roadway 1

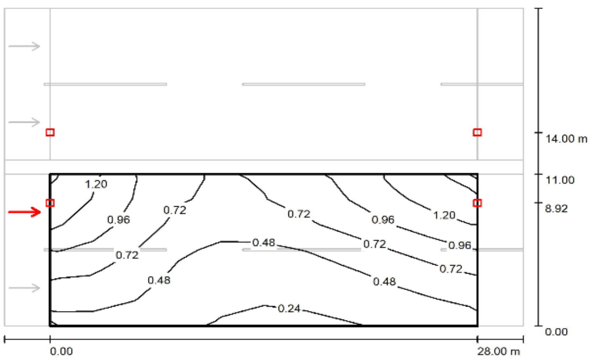


Values in Candela/m², Scale 1 : 244

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 2.750 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.71	0.33	0.46	5
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✗	✗	✗	✓

Fig 4.27 Isolines & Photometric Results for Observer-1 of Roadway-1

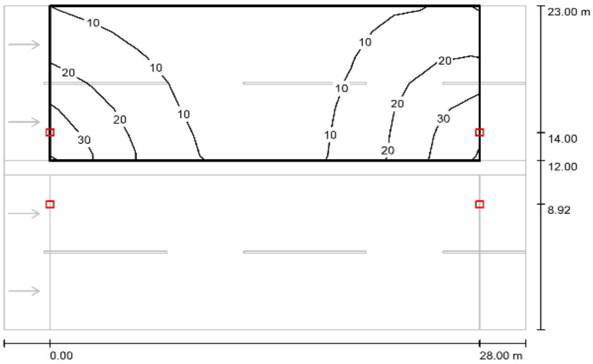


Values in Candela/m², Scale 1 : 244

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 8.250 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.68	0.33	0.51	7
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✗	✗	✗	✓

Fig 4.28 Isolines & Photometric Results for Observer-2 of Roadway-1

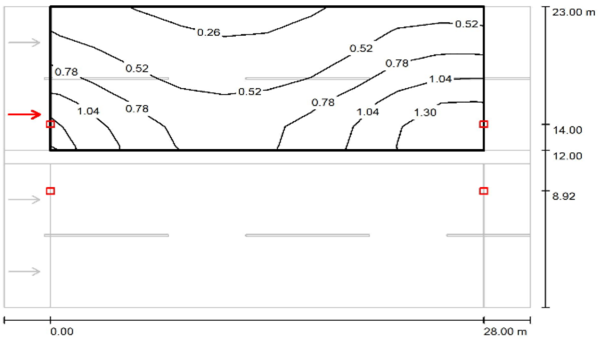


Values in Lux, Scale 1 : 244

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
13	3.99	36	0.298	0.111

Fig 4.29 Isolines & E_{avg} Value of Valuation Field- Roadway 2

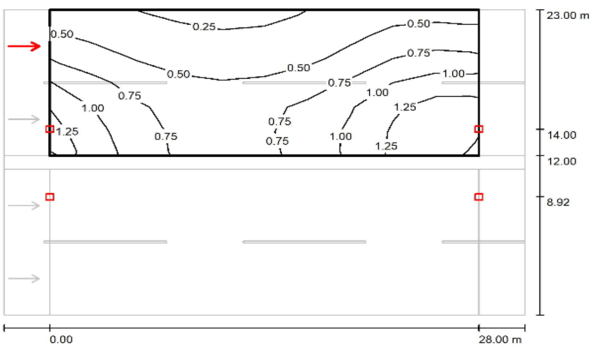


Values in Candela/m², Scale 1 : 244

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 14.750 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.69	0.30	0.47	8
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✗	✗	✗	✓

Fig 4.30 Isolines & Photometric Results for Observer-3 of Roadway-2



Values in Candela/m², Scale 1 : 244

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 20.250 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.72	0.31	0.41	5
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✗	✗	✗	✓

Fig 4.31 Isolines & Photometric Results for Observer-4 of Roadway-2

4.3.4. Results of Proposed Plan IV

Lamp used- MHN-TD 166W
Arrangement- Opposite
Lighting Class- A1
Road width- 9*2= 18m
Road Surface- W2 (Wet road)
Reflectance value(qo- 0.150)

Fig 4.32 represents the street & luminaire planning details of the plan.
Fig 4.34 represents the 3D image of the plan.
Fig 4.35 illustrates the false colour rendering of the plan.

The L_{avg}, U0, UI, TI & SR values for road surfaces are found to be 0.93 cd/m^2, 0.32(fails the criteria), 0.59(fails the criteria), 3 and 0.89 respectively. Fig 4.33 illustrates this value.
The E_{avg} value is found to be 14 lux. Refer to Fig 4.36 & 4.39.
Isoline values for roadways range from 7-28 lux. Refer to Fig 4.36 & 4.39.
All the observers fail to fulfill the limits of U0 in the ME4a lighting class.
Specifically, Observer 2 & 3 fails to fulfill the limits of UI along with U0. Fig 4.37, 4.38, 4.40 & 4.41 represents the values obtained for observers.

Street Profile

Roadway 2	(Width: 9.000 m, Number of lanes: 2, tarmac: W2, q0: 0.150)
Median 1	(Width: 1.000 m, Height: 0.000 m)
Roadway 1	(Width: 9.000 m, Number of lanes: 2, tarmac: W2, q0: 0.150)

Light loss factor: 0.67

Luminaire Arrangements

Luminaire:	PHILIPS MPF 922 [SYMMETRIC] CLOSED		
Luminous flux (Luminaire):	8641 lm	Maximum luminous intensities	
Luminous flux (Lamps):	12100 lm	at 70°:	246 cd/klm
Luminaire Wattage:	166.0 W	at 80°:	137 cd/klm
Arrangement:	Double row, opposing	at 90°:	31 cd/klm
Pole Distance:	24.000 m	Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.	
Mounting Height (1):	9.000 m	Arrangement complies with luminous intensity class G1.	
Height:	8.887 m	Arrangement complies with glare index class D.2.	
Overhang (2):	0.600 m		
Boom Angle (3):	20.0 °		
Boom Length (4):	2.500 m		

Fig 4.32 Street & Luminaire Planning Details of Plan-IV

Light loss factor: 0.67 Scale 1:215

Calculation Field List

1 Valuation Field Roadway 1
Length: 24.000 m, Width: 9.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: W2, q0: 0.150
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	0.93	0.32	0.59	3	0.89
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✗	✓	✓

2 Valuation Field Roadway 2
Length: 24.000 m, Width: 9.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 2.
tarmac: W2, q0: 0.150
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	0.93	0.32	0.59	3	0.89
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✗	✓	✓

Activate Windows
Go to Settings to activate Windows.

Fig 4.33 Photometric Results of Plan-IV

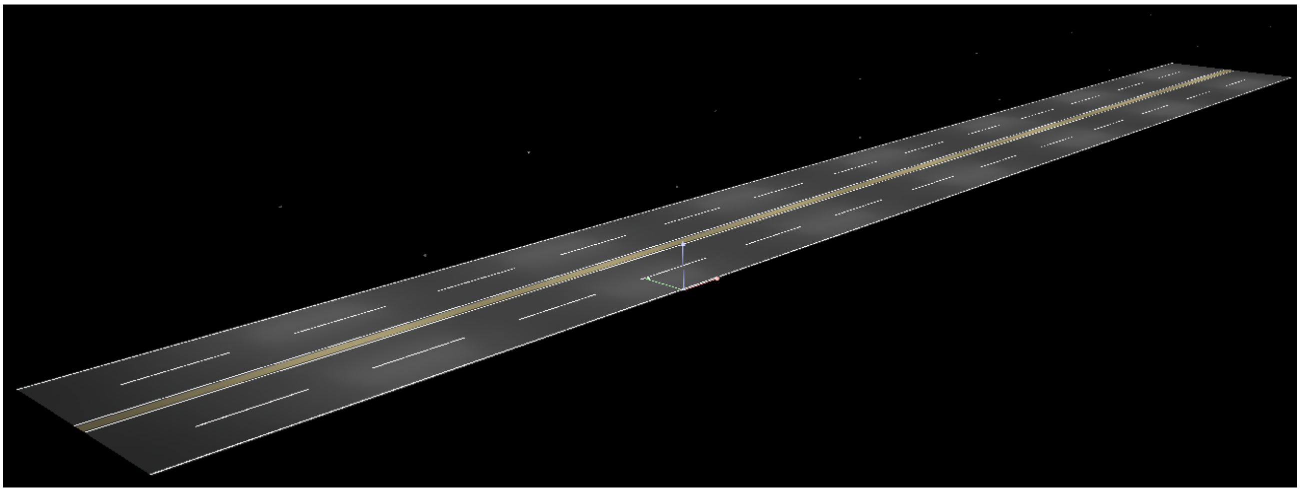


Fig 4.34 3D Image of Plan-IV

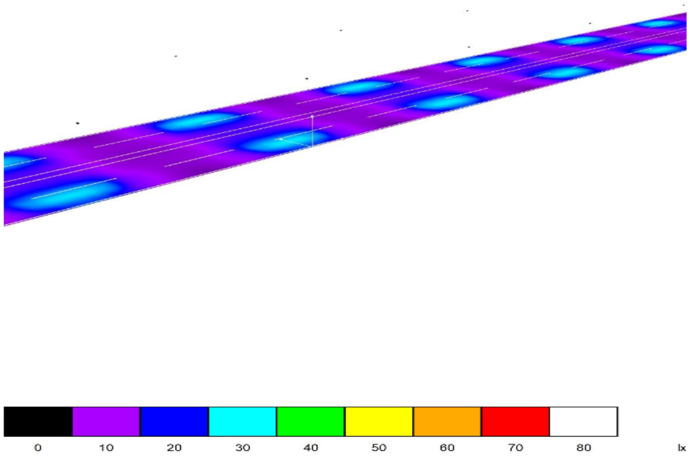
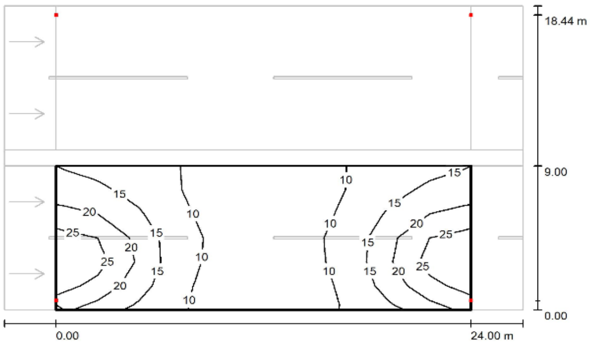


Fig 4.35 False Color Rendering of Plan-IV

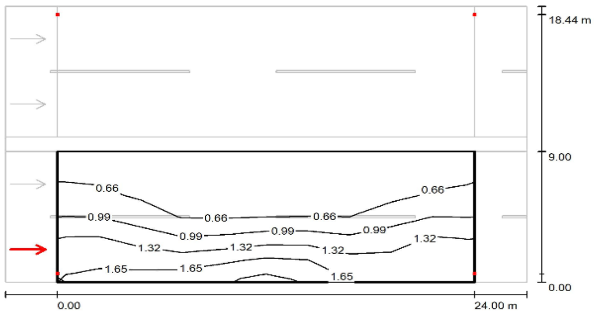


Values in Lux, Scale 1 : 215

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
14	7.26	28	0.502	0.258

Fig 4.36 Isolines & E_{avg} Value of Valuation Field- Roadway 1

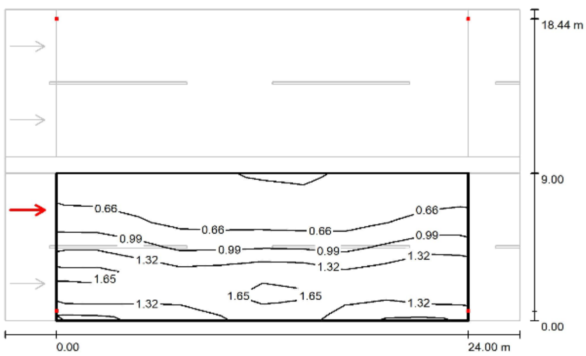


Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 2.250 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.93	0.36	0.75	3
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✓	✓

Fig 4.37 Isolines & Photometric Results for Observer-1 of Roadway-1

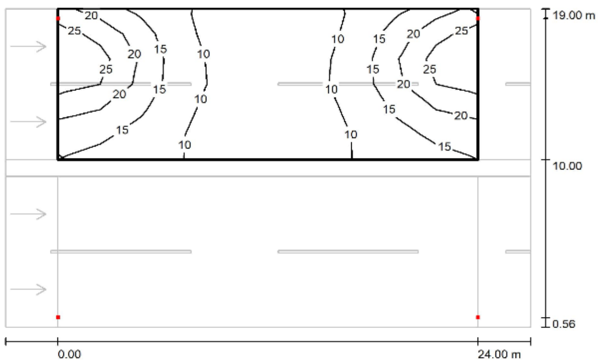


Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 6.750 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.02	0.32	0.59	3
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.38 Isolines & Photometric Results for Observer-2 of Roadway-1

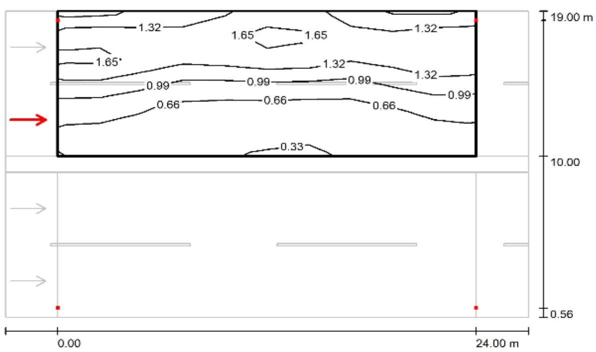


Values in Lux, Scale 1 : 215

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
14	7.26	28	0.502	0.258

Fig 4.39 Isolines & E_{avg} Value of Valuation Field- Roadway 2

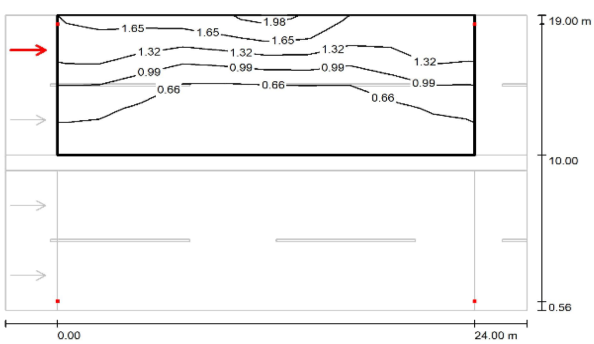


Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 12.250 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.02	0.32	0.59	3
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.40 Isolines & Photometric Results for Observer-3 of Roadway-2



Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 16.750 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.93	0.36	0.75	3
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✓	✓

Fig 4.41 Isolines & Photometric Results for Observer-4 of Roadway-2

4.3.5. Results Of Plan-V

Lamp used- MHN-TD 166W
Arrangement- Zig-Zag
Lighting Class- A2
Road width- 7*2= 14m
Road Surface- R1 (Dry road)
Reflectance value(qo- 0.100)

Fig 4.42 represents the street & luminaire planning details of the plan.
Fig 4.44 represents the 3D image of the plan.
Fig 4.45 illustrates the false colour rendering of the plan.

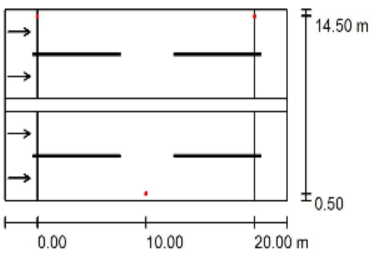
The L_{avg}, U0, UI, TI & SR values for road surfaces are found to be 1.61 cd/m^2, 0.73, 0.63, 2 and 0.92 respectively. Fig 4.43 illustrates these values.
The E_{avg} value is found to be 20 lux. Refer to Fig 4.46 & 4.49.
Isoline values for roadways range from 13-30 lux. Refer to Fig 4.46 & 4.49.
All the observers fulfill all the lighting criteria of the ME4a lighting class. Fig 4.47, 4.48, 4.50 & 4.51 represents the values obtained for the observers.

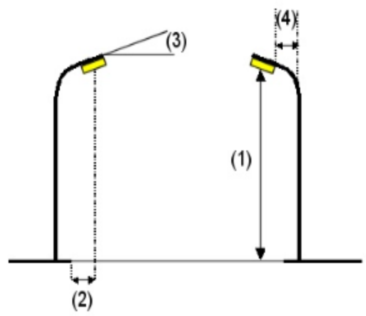
Street Profile

Roadway 2	(Width: 7.000 m, Number of lanes: 2, tarmac: R1, q0: 0.100)
Median 1	(Width: 1.000 m, Height: 0.500 m)
Roadway 1	(Width: 7.000 m, Number of lanes: 2, tarmac: R1, q0: 0.100)

Light loss factor: 0.67

Luminaire Arrangements





Luminaire:	PHILIPS MPF 922 [SYMMETRIC] CLOSED
Luminous flux (Luminaire):	8641 lm
Luminous flux (Lamps):	12100 lm
Luminaire Wattage:	166.0 W
Arrangement:	Double row, with offset
Pole Distance:	20.000 m
Mounting Height (1):	9.000 m
Height:	8.887 m
Overhang (2):	0.541 m
Boom Angle (3):	20.0 °
Boom Length (4):	2.500 m

Maximum luminous intensities	
at 70°:	246 cd/klm
at 80°:	137 cd/klm
at 90°:	31 cd/klm

Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.
Arrangement complies with luminous intensity class G1.
Arrangement complies with glare index class D.2.

Fig 4.42 Street & Luminaire Planning Details of Plan-V

Light loss factor: 0.67 Scale 1:186

Calculation Field List

1 Valuation Field Roadway 1
Length: 20.000 m, Width: 7.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: R1, q0: 0.100
Selected Lighting Class: ME4a

(All lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	1.61	0.75	0.63	2	0.92
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✓	✓	✓	✓

2 Valuation Field Roadway 2
Length: 20.000 m, Width: 7.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 2.
tarmac: R1, q0: 0.100
Selected Lighting Class: ME4a

(All lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	1.61	0.75	0.63	2	0.92
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✓	✓	✓	✓

Activate Windows

Fig 4.43 Photometric results of Plan-V

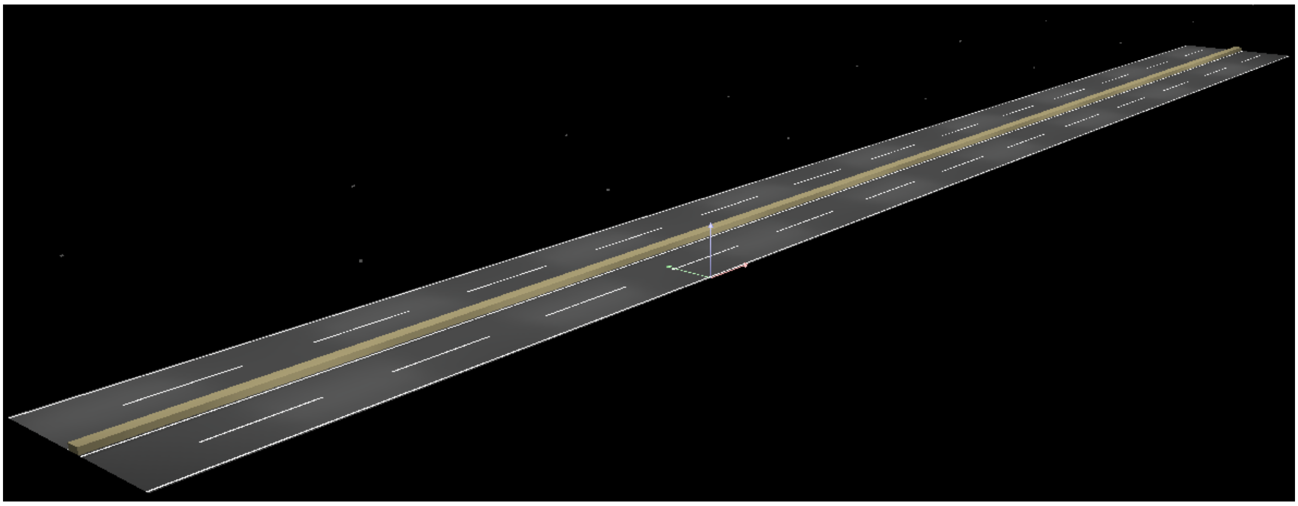


Fig 4.44 3D Image Of Plan-V

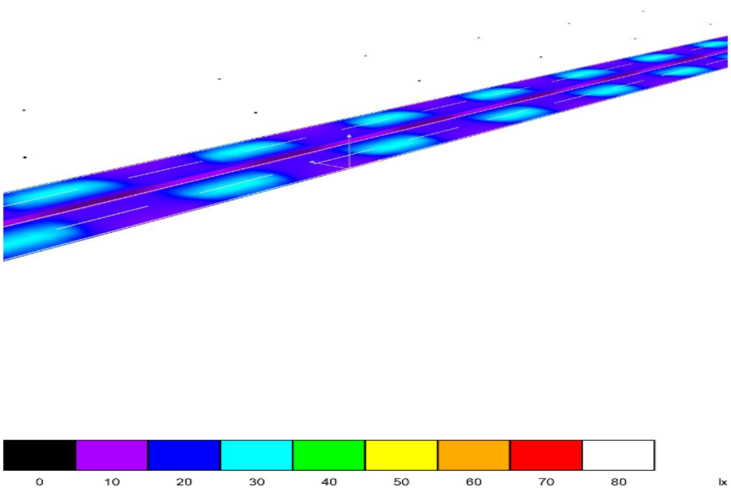
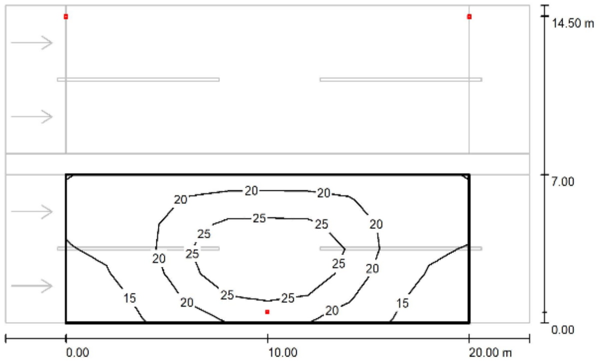


Fig 4.45 False Colour Rendering of Plan-V

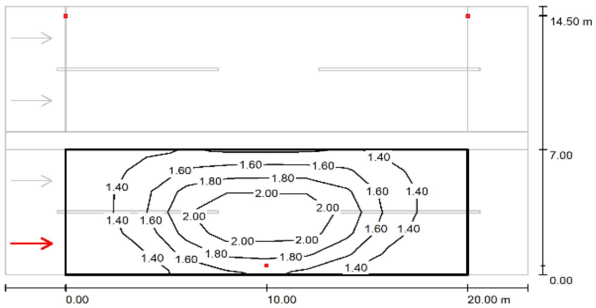


Values in Lux, Scale 1 : 186

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
20	13	30	0.660	0.436

Fig 4.46 Isolines & E_{avg} Value of Valuation field Roadway-1

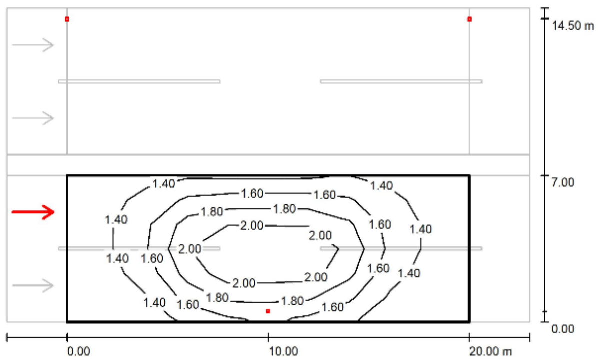


Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 1.750 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.61	0.75	0.63	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig 4.47 Isolines & Photometric Results For Observor-1 of Roadway-1

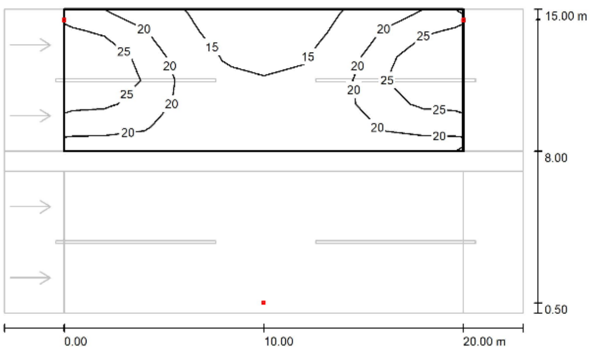


Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 5.250 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.61	0.75	0.73	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig 4.48 Isolines & Photometric Results For Observor-2 of Roadway-1

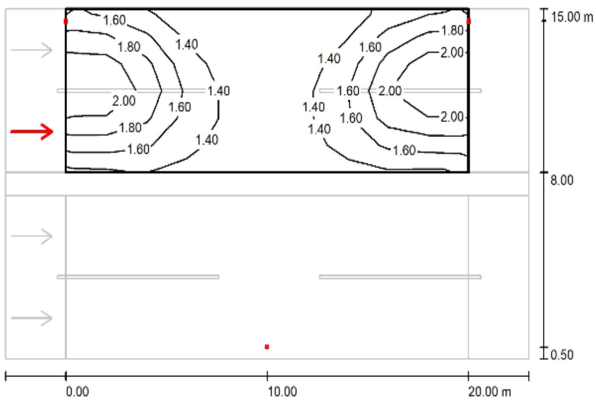


Values in Lux, Scale 1 : 186

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
20	13	30	0.660	0.436

Fig 4.49 Isolines & E_{avg} Value of Valuation field Roadway-2

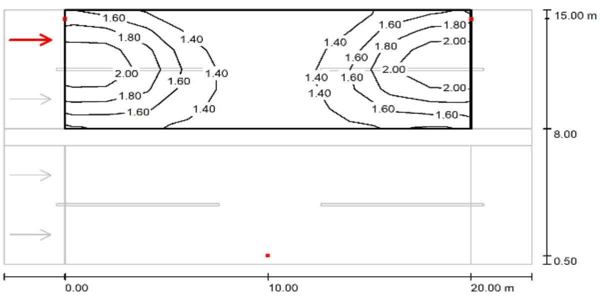


Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 9.750 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	UI	TI [%]
Calculated values:	1.61	0.75	0.73	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig 4.50 Isolines & Photometric Results For Observor-3 of Roadway-2



Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 13.250 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	UI	TI [%]
Calculated values:	1.61	0.75	0.63	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig 4.51 Isolines & Photometric Results For Observor-4 of Roadway-2

4.3.6. Results of Proposed Plan VI

Lamp used- MHN-TD 166W
Arrangement- Twin-Central
Lighting Class- A3
Road width- 11*2= 22m
Road Surface- C2 (Concrete road)
Reflectance value(qo- 0.070)

Fig 4.52 & 4.53 both represent the street & luminaire planning details of the plan.
Fig 4.55 represents the 3D image of the plan.
Fig 4.56 illustrates the false colour rendering of the plan.

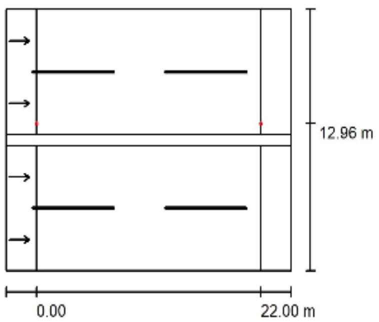
The L_{avg}, U0, UI, TI & SR values for road surfaces are found to be 0.77 cd/m^2, 0.30(Fails the criteria), 0.44(fails the criteria), 4 and 0.91 respectively. Fig 4.54 illustrates these values.
The E_{avg} value is found to be 16 lux. Refer to Fig 4.57 & 4.60.
Isoline values for roadways range from 5-43 lux. Refer to Fig 4.57 & 4.60.
Observer 1 and 4 fail to meet the criteria of U0, Observer 2 fails to meet the criteria of UI, Observer 3 fails to meet the criteria of L_{avg}, U0 and UI of the lighting class ME4a. Fig 4.58,4.59, 4.61 & 4.62 represent the values for the observers.

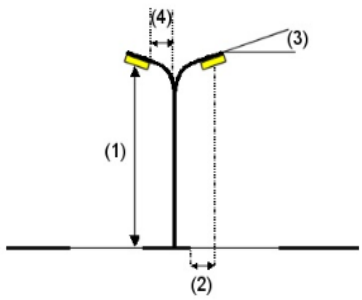
Street Profile

Roadway 2	(Width: 11.000 m, Number of lanes: 2, tarmac: C2, q0: 0.070)
Median 1	(Width: 1.000 m, Height: 0.500 m)
Roadway 1	(Width: 11.000 m, Number of lanes: 2, tarmac: C2, q0: 0.070)

Light loss factor: 0.67

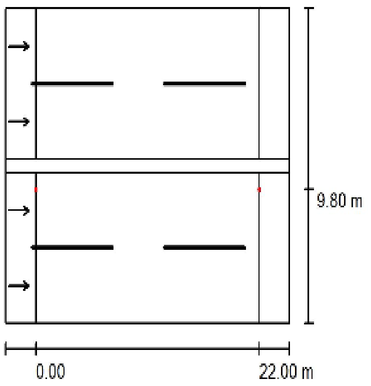
Luminaire Arrangements

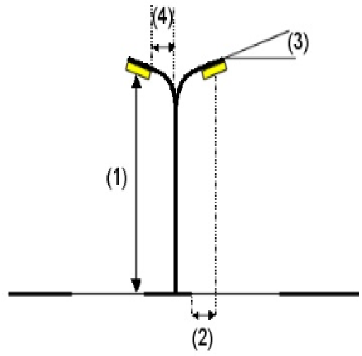




Luminaire:	PHILIPS MPF 922 [SYMMETRIC] CLOSED		
Luminous flux (Luminaire):	8641 lm	Maximum luminous intensities	
Luminous flux (Lamps):	12100 lm	at 70°:	246 cd/klm
Luminaire Wattage:	166.0 W	at 80°:	137 cd/klm
Arrangement:	on Median	at 90°:	31 cd/klm
Pole Distance:	22.000 m	Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.	
Mounting Height (1):	9.000 m	Arrangement complies with luminous intensity class G1.	
Height:	8.887 m	Arrangement complies with glare index class D.2.	
Overhang (2):	1.000 m		
Boom Angle (3):	20.0 °		
Boom Length (4):	1.459 m		

Fig 4.52 Street & Luminaire Planning Details of plan VI





Luminaire:	PHILIPS MPF 922 [SYMMETRIC] CLOSED
Luminous flux (Luminaire):	8641 lm
Luminous flux (Lamps):	12100 lm
Luminaire Wattage:	166.0 W
Arrangement:	on Median
Pole Distance:	22.000 m
Mounting Height (1):	9.000 m
Height:	8.887 m
Overhang (2):	-6.059 m
Boom Angle (3):	20.0 °
Boom Length (4):	1.700 m

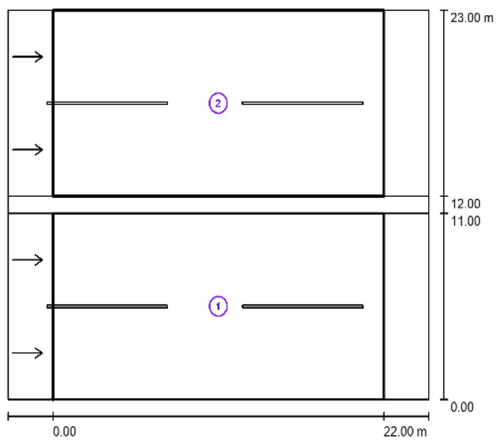
Maximum luminous intensities	
at 70°:	246 cd/klm
at 80°:	137 cd/klm
at 90°:	31 cd/klm

Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.

Arrangement complies with luminous intensity class G1.

Arrangement complies with glare index class D.2.

Fig 4.53 Street & Luminaire Planning Details of plan VI (continued)



Light loss factor: 0.67

Scale 1:250

Calculation Field List

1 Valuation Field Roadway 1
Length: 22.000 m, Width: 11.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: C2, q0: 0.070
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	0.77	0.30	0.44	4	0.91
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✗	✓	✓

2 Valuation Field Roadway 2
Length: 22.000 m, Width: 11.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 2.
tarmac: C2, q0: 0.070
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	0.74	0.30	0.45	4	0.94
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✗	✗	✗	✓	✓

Activate Windows
Go to Settings to activate Windows.

Fig 4.54 Photometric Results of Plan VI

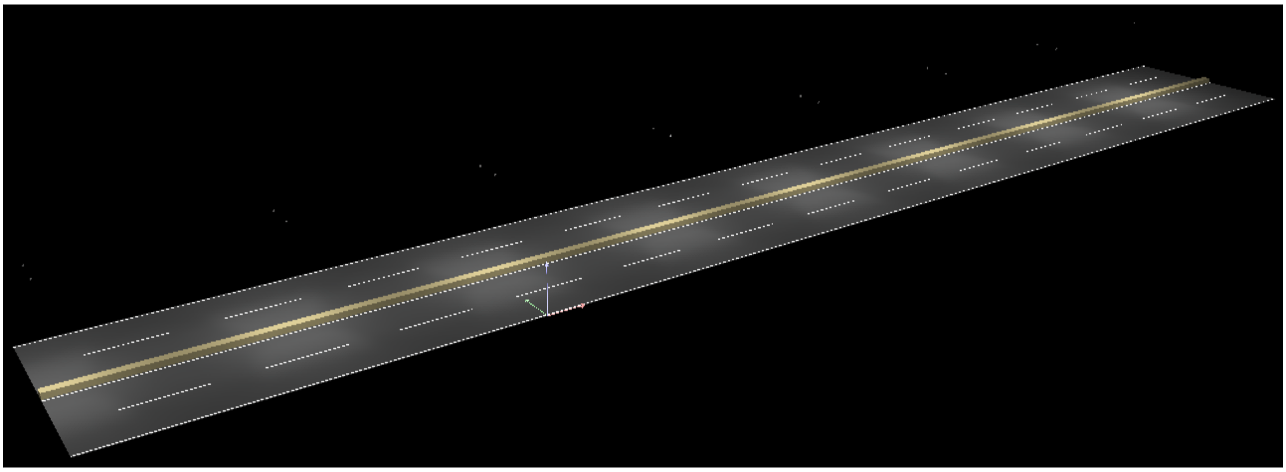


Fig 4.55 3D Image of Plan VI

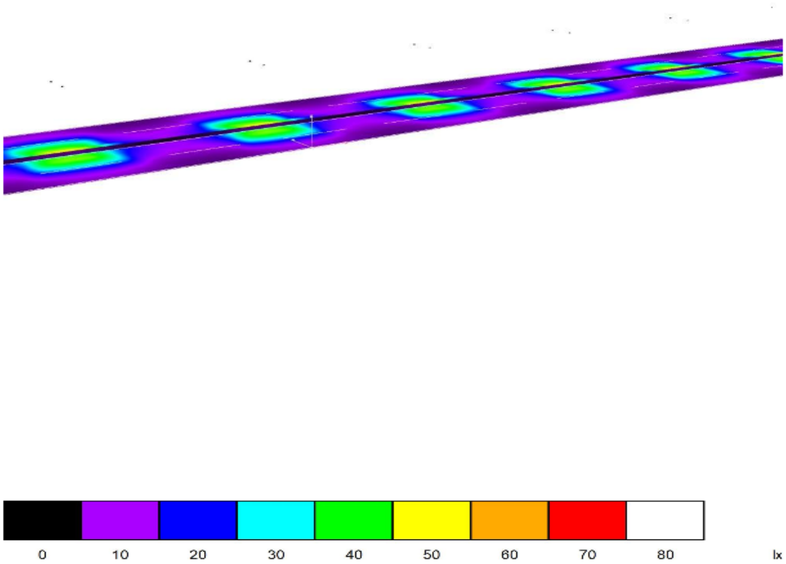
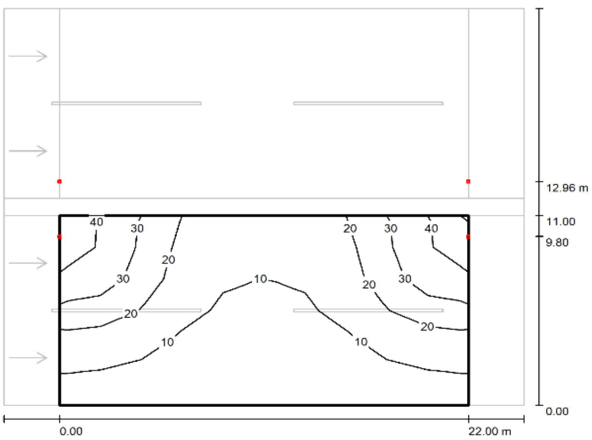


Fig 4.56 False Colour Rendering Of Plan VI

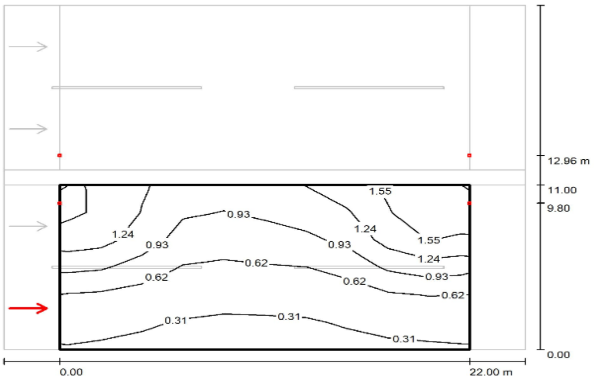


Values in Lux, Scale 1 : 201

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
16	4.96	43	0.304	0.116

Fig 4.57 Isolines & E_{avg} Value of Valuation Field Roadway-1

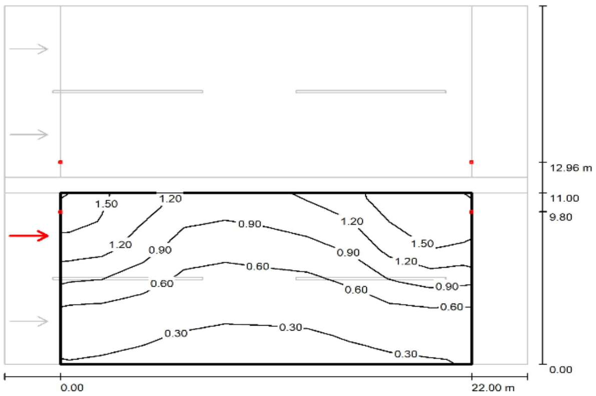


Values in Candela/m², Scale 1 : 201

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 2.750 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.80	0.30	0.69	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✓	✓

Fig 4.58 Isolines & Photometric Results for Observor-1 of roadway-1

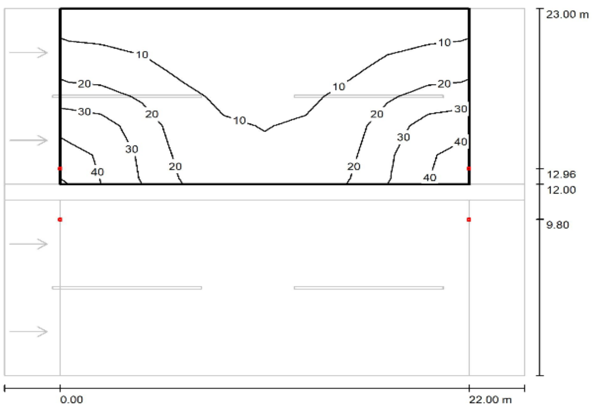


Values in Candela/m², Scale 1 : 201

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 8.250 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.77	0.30	0.44	4
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.59 Isolines & Photometric Results for Observor-2 of roadway-1

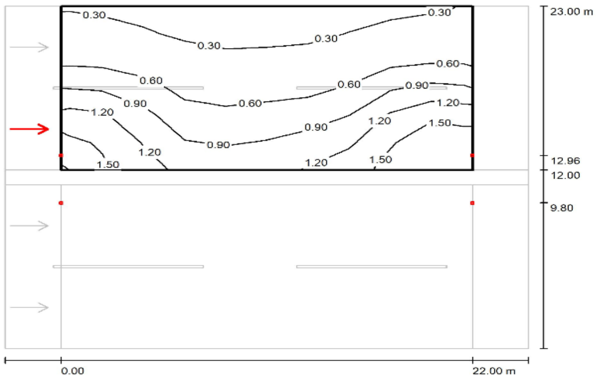


Values in Lux, Scale 1 : 201

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
16	4.86	43	0.306	0.114

Fig 4.60 Isolines & E_{avg} Value of Valuation Field Roadway-2

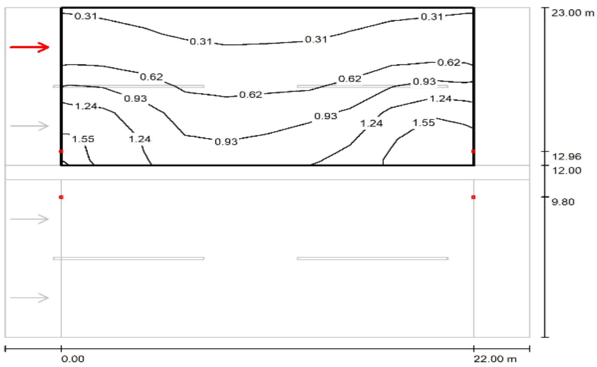


Values in Candela/m², Scale 1 : 201

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 14.750 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.74	0.30	0.45	4
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✗	✗	✗	✓

Fig 4.61 Isolines & Photometric Results for Observor-3 of Roadway-2



Values in Candela/m², Scale 1 : 201

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 20.250 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.78	0.30	0.71	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✓	✓

Fig 4.62 Isolines & Photometric Results for Observor-4 of Roadway-2

4.3.7. Results of Proposed Plan VII

Lamp used- SOLAR EFF-LED 170W
Arrangement- Opposite
Lighting Class- A1
Road width- 9*2= 18m
Road Surface- W2 (Wet road)
Reflectance value(qo- 0.150)

Fig 4.63 represents the street & luminaire planning details of the plan.
Fig 4.65 represents the 3D image of the plan.

Fig 4.66 illustrates the false colour rendering of the plan.

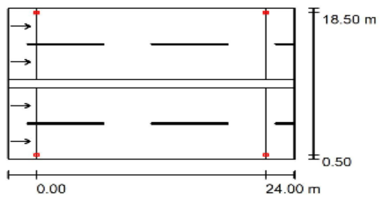
The L_{avg}, U0, UI, TI & SR values for road surfaces are found to be 1.27 cd/m^2, 0.38(fails the criteria), 0.42(fails the criteria), 2 and 0.99 respectively. Fig 4.64 illustrates this.
The E_{avg} value is found to be 26 lux. Refer to Fig 4.67 & 4.70.
Isoline values for roadways range from 9-51 lux.
All the 4 observers fulfill all the lighting criteria of the ME4a lighting class except for U0 and UI. Fig 4.68, 4.69, 4.71 & 4.72 represents the values obtained by the observers.

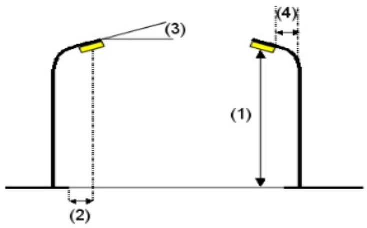
Street Profile

Roadway 2	(Width: 9.000 m, Number of lanes: 2, tarmac: W2, q0: 0.150)
Median 1	(Width: 1.000 m, Height: 0.500 m)
Roadway 1	(Width: 9.000 m, Number of lanes: 2, tarmac: W2, q0: 0.150)

Light loss factor: 0.67

Luminaire Arrangements





Luminaire:	PHILIPS BRP383 LED220NW 170W 220-240V DWV PSR		
Luminous flux (Luminaire):	22079 lm	Maximum luminous intensities	
Luminous flux (Lamps):	22079 lm	at 70°:	415 cd/klm
Luminaire Wattage:	170.0 W	at 80°:	504 cd/klm
Arrangement:	Double row, opposing	at 90°:	533 cd/klm
Pole Distance:	24.000 m	Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.	
Mounting Height (1):	9.000 m	Arrangement complies with glare index class D.0.	
Height:	9.000 m		
Overhang (2):	0.500 m		
Boom Angle (3):	20.0 °		
Boom Length (4):	2.500 m		

Fig 4.63 Street & Luminaire Planning Details of plan VII

Light loss factor: 0.67 Scale 1:215

Calculation Field List

1 Valuation Field Roadway 1
Length: 24.000 m, Width: 9.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: W2, q0: 0.150
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	UI	TI [%]	SR
Calculated values:	1.27	0.38	0.42	2	0.99
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✗	✓	✓

2 Valuation Field Roadway 2
Length: 24.000 m, Width: 9.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 2.
tarmac: W2, q0: 0.150
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	UI	TI [%]	SR
Calculated values:	1.65	0.36	0.30	1	0.99
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✗	✓	✓

Activate Windows
Go to Settings to activate Windows.

Fig 4.64 Photometric Results of Plan-VII

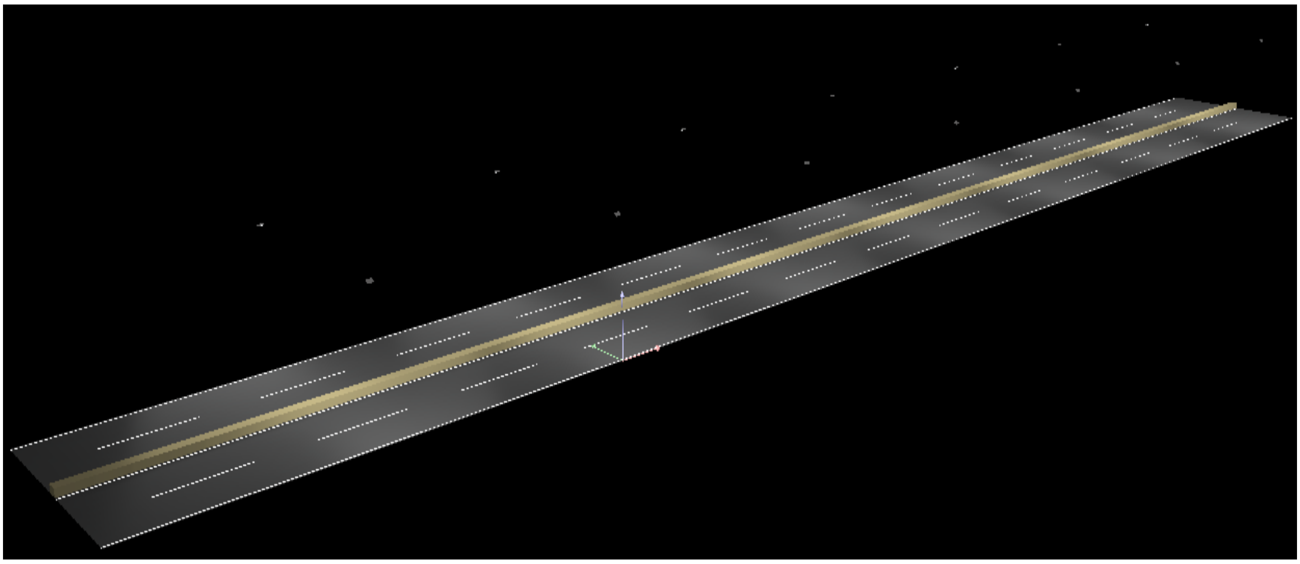


Fig 4.65 3D Image of Plan VII

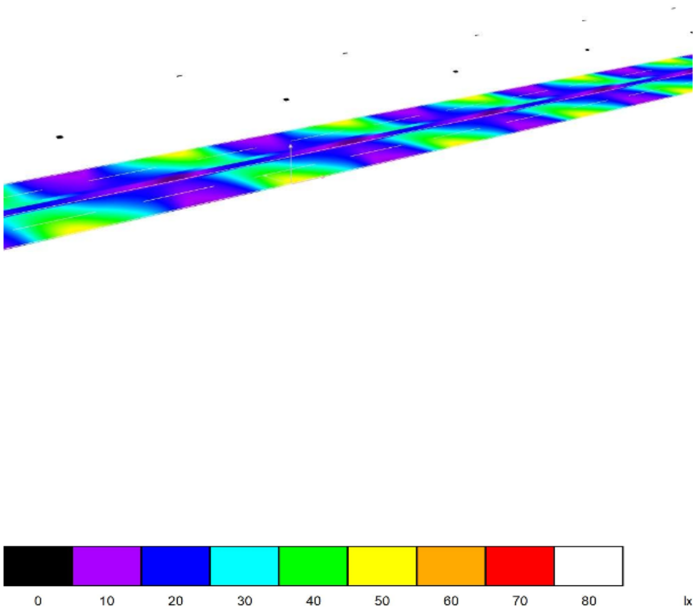
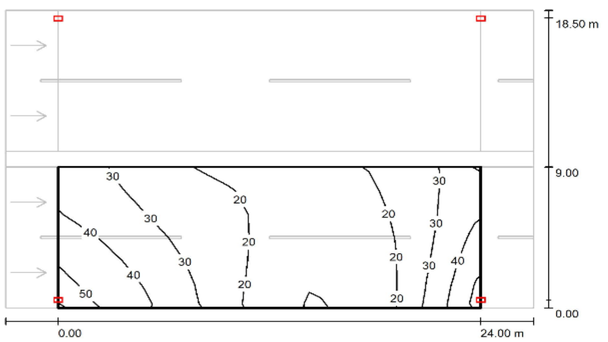


Fig 4.66 False Colour Rendering of plan VII

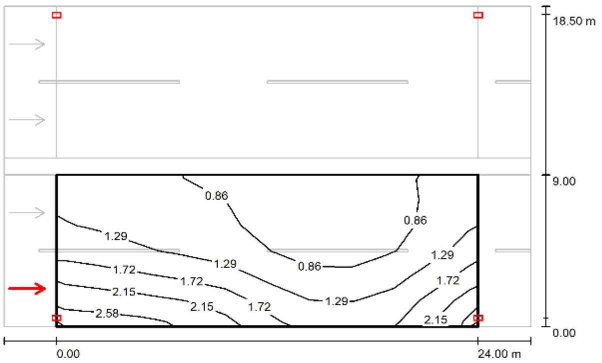


Values in Lux, Scale 1 : 215

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
26	9.08	51	0.348	0.178

Fig 4.67 Isolines & E_{avg} of Valuation Field Roadway-1

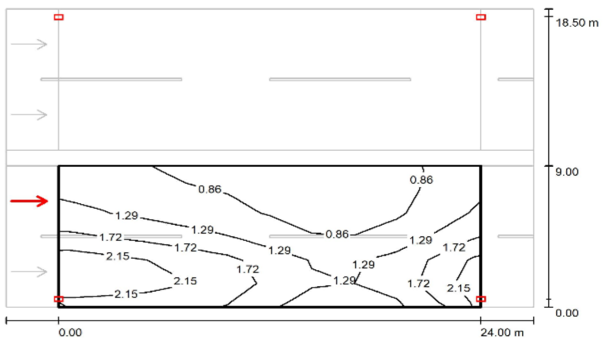


Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 2.250 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.27	0.38	0.52	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.68 Isolines & Photometric Results For Observor-1 of Roadway-1

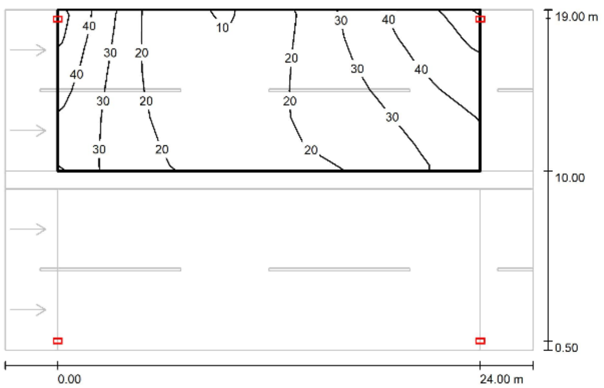


Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 6.750 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.35	0.38	0.42	1
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.69 Isolines & Photometric Results For Observor-2 of Roadway-1

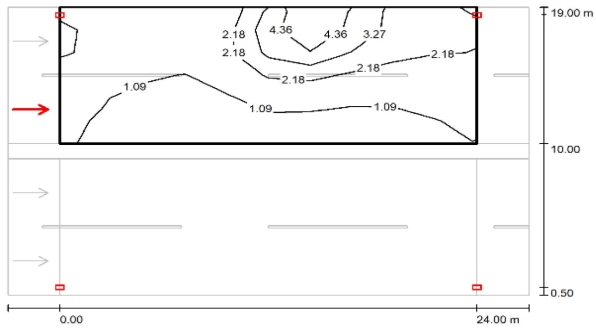


Values in Lux, Scale 1 : 215

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
26	9.08	51	0.348	0.178

Fig 4.70 Isolines & E_{avg} of Valuation Field Roadway-2

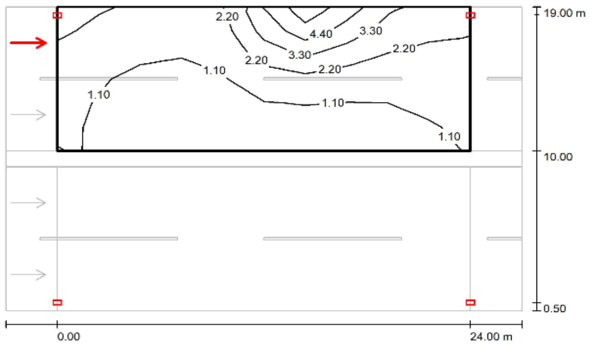


Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 12.250 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.81	0.36	0.55	1
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.71 Isolines & Photometric Results For Observor-3 of Roadway-2



Values in Candela/m², Scale 1 : 215

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 16.750 m, 1.500 m)
tarmac: W2, q0: 0.150

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.65	0.36	0.30	1
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.72 Isolines & Photometric Results For Observor-4 of Roadway-2

4.3.8. Results of Proposed Plan VIII

Lamp used- SOLAR-EFF LED 170W
Arrangement- Zig-Zag
Lighting Class- A2
Road width- 7*2= 14m
Road Surface- R1 (Dry road)
Reflectance value(qo- 0.100)

Fig 4.73 represents the street & luminaire planning details of the plan.
Fig 4.75 represents the 3D image of the plan.
Fig 4.76 illustrates the false colour rendering of the plan.

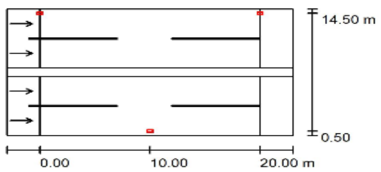
The L_{avg}, U0, UI, TI & SR values for road surfaces are found to be 2.87 cd/m^2, 0.58, 0.48(fails the criteria), 1 and 0.99 respectively. Fig 4.74 illustrates these values.
The E_{avg} value is found to be 36 lux. Refer to Fig 4.77 & 4.80.
Isoline values for roadways range from 18-55 lux. Refer to Fig 4.77 & 4.80.
All the 4 observers fulfill all the lighting criteria of the ME4a lighting class except for UI and UI. Fig 4.78, 4.79, 4.81 & 4.82 represents the values obtained by the observers.

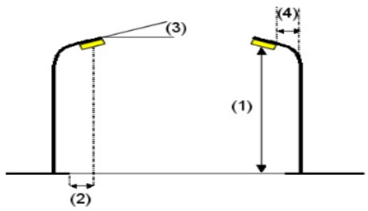
Street Profile

Roadway 2	(Width: 7.000 m, Number of lanes: 2, tarmac: R1, q0: 0.100)
Median 1	(Width: 1.000 m, Height: 0.500 m)
Roadway 1	(Width: 7.000 m, Number of lanes: 2, tarmac: R1, q0: 0.100)

Light loss factor: 0.67

Luminaire Arrangements





Luminaire:	PHILIPS BRP383 LED220NW 170W 220-240V DWV P7 HP		
Luminous flux (Luminaire):	22079 lm	Maximum luminous intensities	
Luminous flux (Lamps):	22079 lm	at 70°:	415 cd/klm
Luminaire Wattage:	170.0 W	at 80°:	504 cd/klm
Arrangement:	Double row, with offset	at 90°:	533 cd/klm
Pole Distance:	20.000 m	Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.	
Mounting Height (1):	9.000 m	Arrangement complies with glare index class D.0.	
Height:	9.000 m		
Overhang (2):	0.500 m		
Boom Angle (3):	20.0 °		
Boom Length (4):	2.500 m		

Fig 4.73 Street & Luminaire Planning Details of plan VIII

Light loss factor: 0.67 Scale 1:186

Calculation Field List

1 Valuation Field Roadway 1
Length: 20.000 m, Width: 7.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: R1, q0: 0.100
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	UI	TI [%]	SR
Calculated values:	2.80	0.58	0.47	1	0.99
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✓	✗	✓	✓

2 Valuation Field Roadway 2
Length: 20.000 m, Width: 7.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 2.
tarmac: R1, q0: 0.100
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	UI	TI [%]	SR
Calculated values:	2.87	0.58	0.48	1	0.99
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✓	✗	✓	✓

Activate Windows
Go to Settings to activate Windows.

Fig 4.74 Photometric Results of Plan VIII

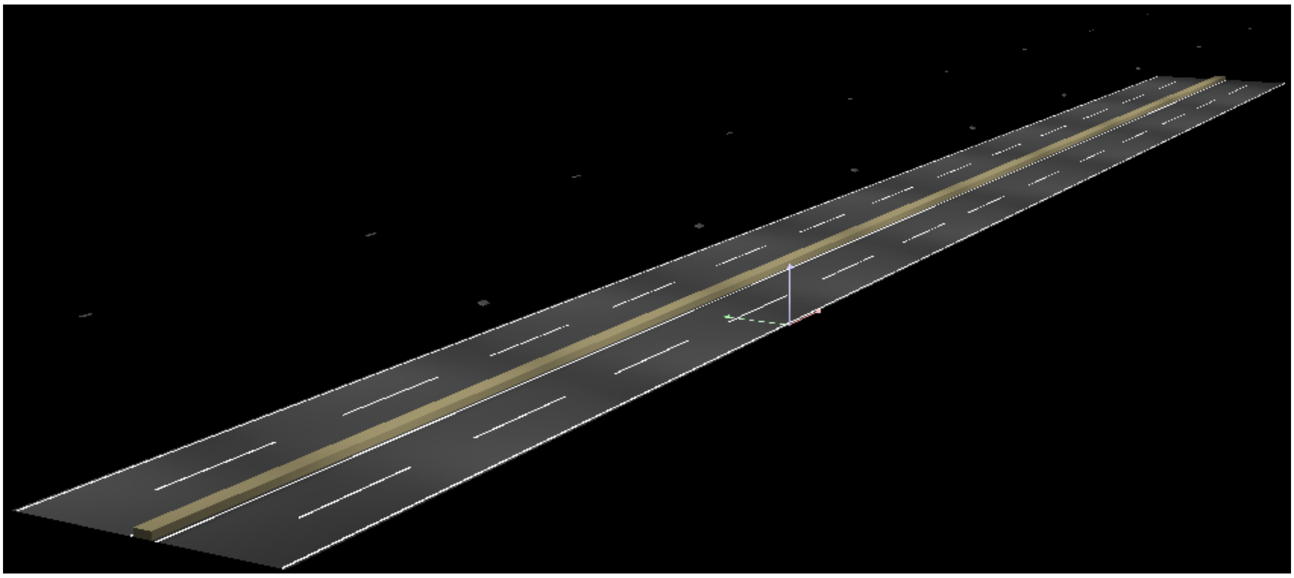


Fig 4.75 3D Image Of Plan VIII

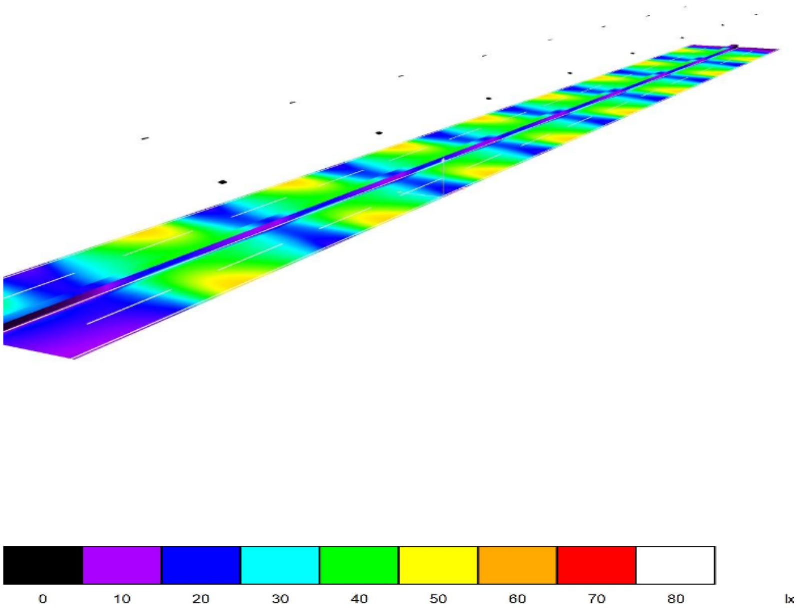
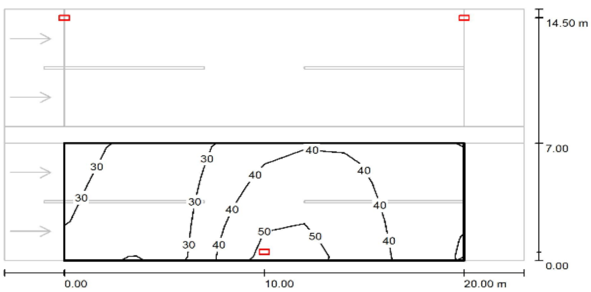


Fig 4.76 False Colour Rendering of Plan VIII

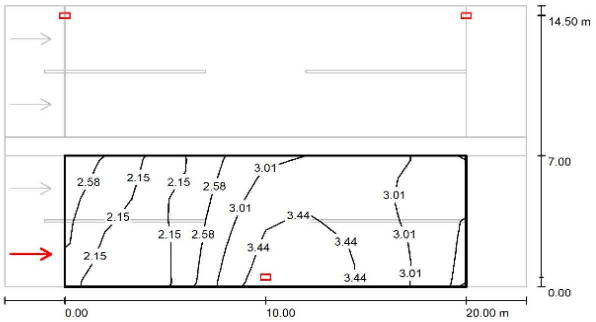


Values in Lux, Scale 1 : 186

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
36	18	55	0.506	0.331

Fig 4.77 Isolines & E_{avg} Value Of Valuation Field- Roadway 1

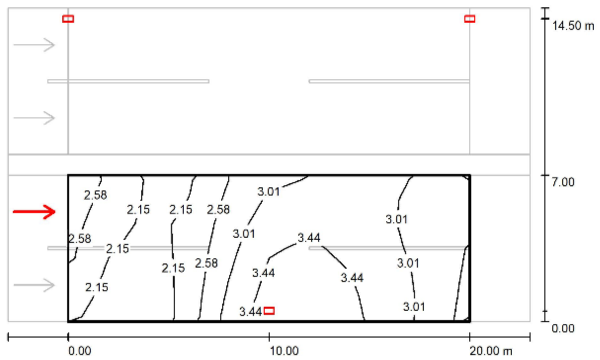


Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 1.750 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	2.81	0.58	0.47	1
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✗	✓

Fig 4.78 Isolines & Photometric Results For Observor-1 of Roadway-1

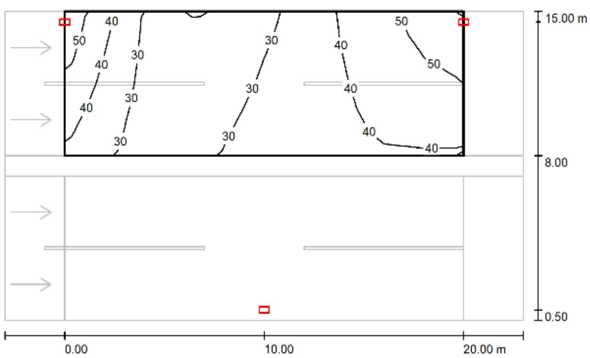


Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 5.250 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	2.80	0.58	0.59	1
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✗	✓

Fig 4.79 Isolines & Photometric Results For Observor-2 of Roadway-1

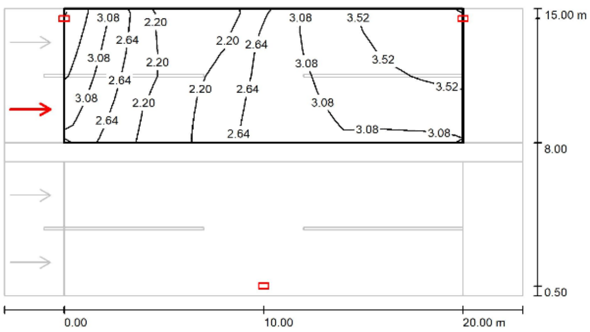


Values in Lux, Scale 1 : 186

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
36	18	55	0.506	0.331

Fig 4.80 Isolines & E_{avg} Value Of Valuation Field- Roadway 2

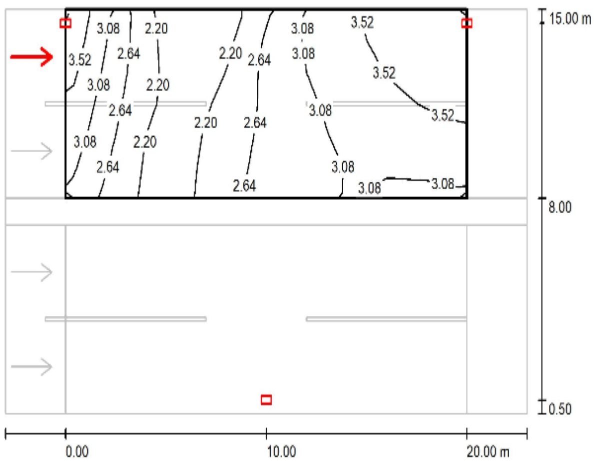


Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 9.750 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	2.88	0.58	0.58	1
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✗	✓

Fig 4.81 Isolines & Photometric Results For Observor-3 of Roadway-2



Values in Candela/m², Scale 1 : 186

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 13.250 m, 1.500 m)
tarmac: R1, q0: 0.100

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	2.87	0.59	0.48	1
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✗	✓

Fig 4.82 Isolines & Photometric Results For Observor-4 of Roadway-2

4.3.9. Results of Proposed Plan IX

Lamp used- SOLAR-EFF-LED 170W
Arrangement- Twin-Central
Lighting Class- A3

Road width- 11*2= 22m
Road Surface- C2 (Concrete road)
Reflectance value(qo- 0.070)

Fig 4.83 & 4.84 both represent the street & luminaire planning details of the plan.
Fig 4.86 represents the 3D image of the plan.
Fig 4.87 illustrates the false colour rendering of the plan.

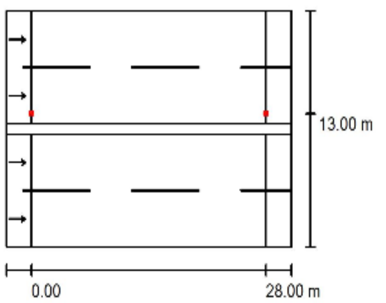
The L_{avg}, U0, UI, TI & SR values for road surfaces are found to be 1.30 cd/m^2, 0.14(fails the criteria), 0.14(fails the criteria), 1 and 0.83 respectively. Fig 4.85 illustrates these values.
The E_{avg} value is found to be 29 lux. Refer to Fig 4.88 & 4.91.
Isoline values for roadways range from 4-87 lux. Refer to Fig 4.88 & 4.91.
All the 4 observers fulfill all the lighting criteria of the ME4a lighting class except for U0 and UI. Fig 4.89, 4.90, 4.92 & 4.93 represents the values obtained by the observers.

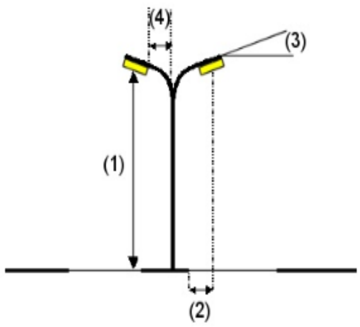
Street Profile

Roadway 2	(Width: 11.000 m, Number of lanes: 2, tarmac: C2, q0: 0.070)
Median 1	(Width: 1.000 m, Height: 0.500 m)
Roadway 1	(Width: 11.000 m, Number of lanes: 2, tarmac: C2, q0: 0.070)

Light loss factor: 0.67

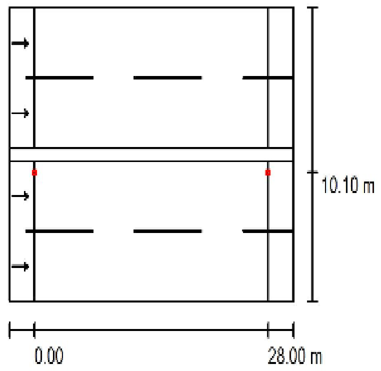
Luminaire Arrangements

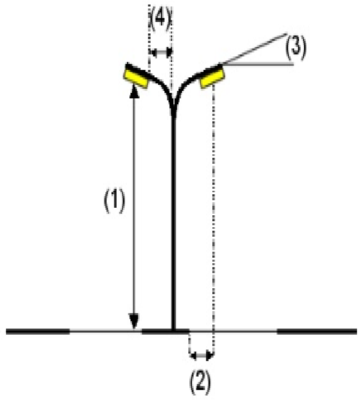




Luminaire:	PHILIPS BRP383 LED220NW 170W 220-240V DWV P7 HP		
Luminous flux (Luminaire):	22079 lm	Maximum luminous intensities	
Luminous flux (Lamps):	22079 lm	at 70°:	415 cd/klm
Luminaire Wattage:	170.0 W	at 80°:	504 cd/klm
Arrangement:	on Median	at 90°:	533 cd/klm
Pole Distance:	28.000 m	Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.	
Mounting Height (1):	9.000 m	Arrangement complies with glare index class D.0.	
Height:	9.000 m		
Overhang (2):	1.000 m		
Boom Angle (3):	20.0 °		
Boom Length (4):	1.500 m		

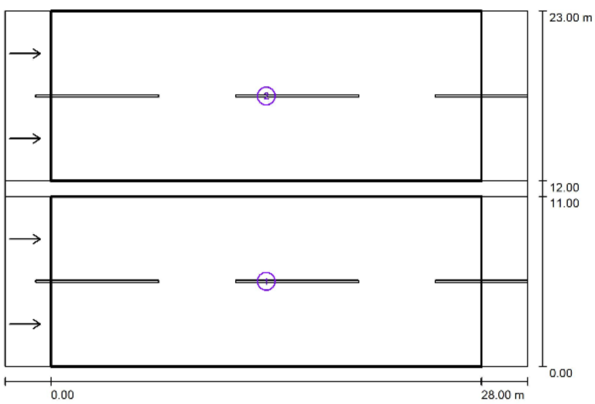
Fig 4.83 Street & Luminaire Planning Details of Plan IX





Luminaire:	PHILIPS BRP383 LED220NW 170W 220-240V DWV P7 HP		
Luminous flux (Luminaire):	22079 lm	Maximum luminous intensities	
Luminous flux (Lamps):	22079 lm	at 70°:	415 cd/klm
Luminaire Wattage:	170.0 W	at 80°:	504 cd/klm
Arrangement:	on Median	at 90°:	533 cd/klm
Pole Distance:	28.000 m	Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.	
Mounting Height (1):	9.000 m	Arrangement complies with glare index class D.0.	
Height:	9.000 m		
Overhang (2):	-1.500 m		
Boom Angle (3):	20.0 °		
Boom Length (4):	1.400 m		

Fig 4.84 Street & Luminaire Planning Details of Plan IX (Continued)



Light loss factor: 0.67

Scale 1:244

Calculation Field List

1 Valuation Field Roadway 1
Length: 28.000 m, Width: 11.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 1.
tarmac: C2, q0: 0.070
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	1.30	0.14	0.14	1	0.83
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✗	✓	✓

2 Valuation Field Roadway 2
Length: 28.000 m, Width: 11.000 m
Grid: 10 x 6 Points
Accompanying Street Elements: Roadway 2.
tarmac: C2, q0: 0.070
Selected Lighting Class: ME4a

(Not all lighting performance requirements are met.)

	L_{av} [cd/m²]	U0	Ul	TI [%]	SR
Calculated values:	1.24	0.15	0.14	2	0.83
Required values according to class:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15	≥ 0.50
Fulfilled/Not fulfilled:	✓	✗	✗	✓	✓

Activate Windows
Go to Settings to activate Windows.

Fig 4.85 Photometric Results of Plan IX

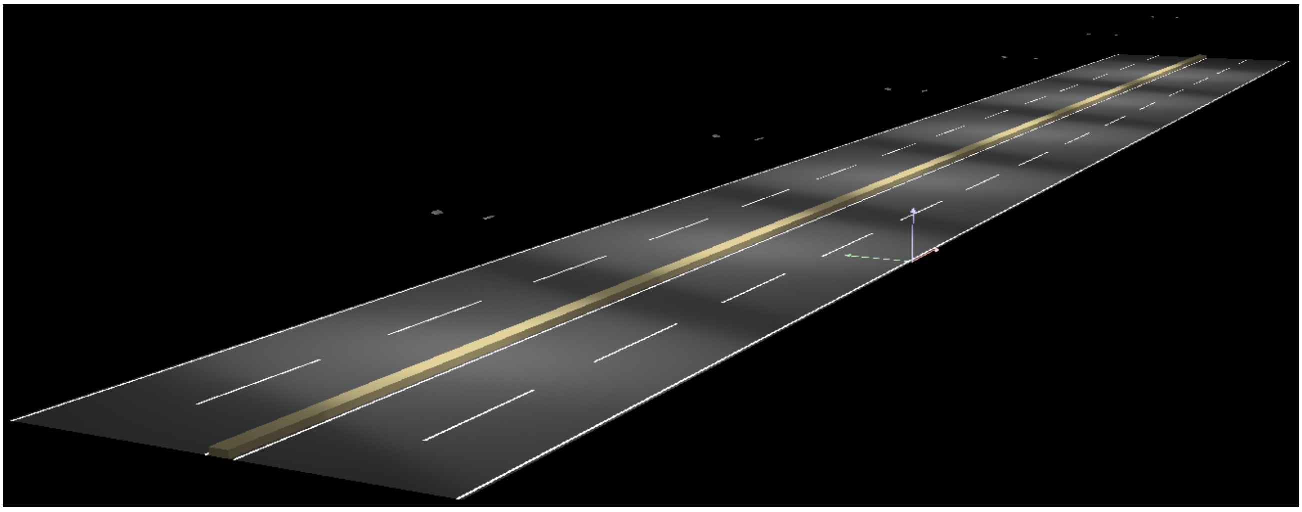


Fig 4.86 3D Image of Plan IX

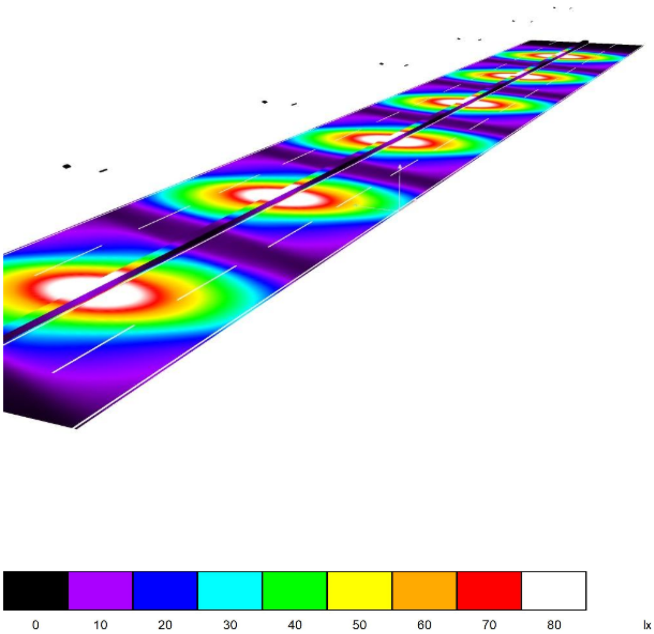
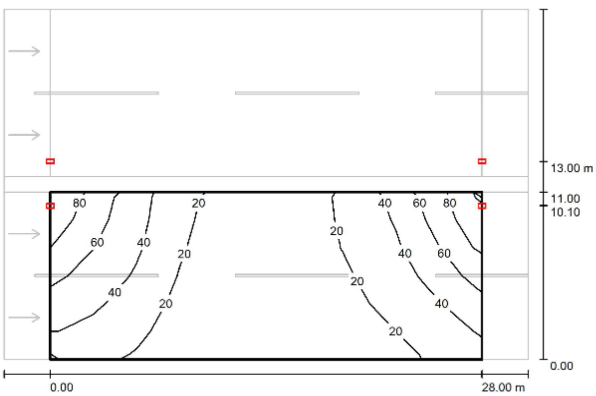


Fig 4.87 False Colour Rendering Of Plan IX

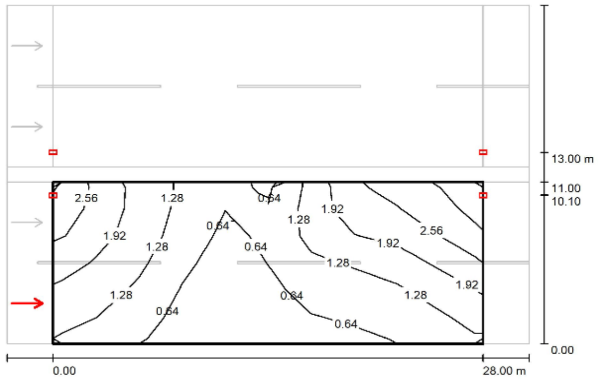


Values in Lux, Scale 1 : 244

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
29	3.66	87	0.126	0.042

Fig 4.88 Isolines & E_{avg} Value Of Valuation field-Roadway 1

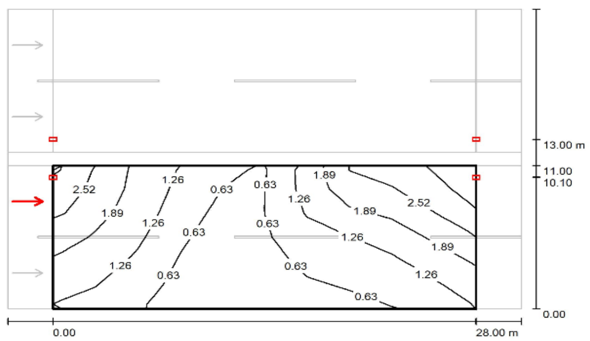


Values in Candela/m², Scale 1 : 244

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 2.750 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.34	0.14	0.16	1
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.89 Isolines & Photometric Results For Observer-1 of Roadway-1

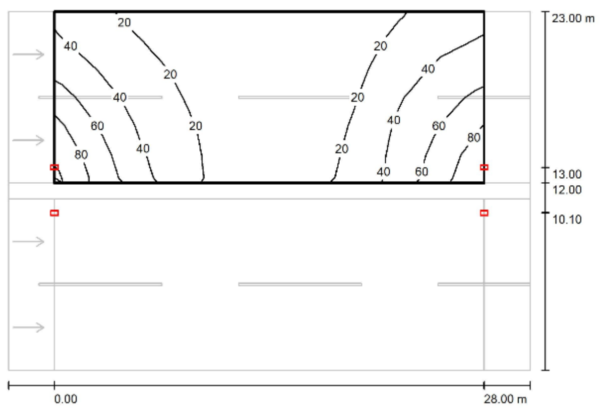


Values in Candela/m², Scale 1 : 244

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 8.250 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.30	0.14	0.14	1
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.90 Isolines & Photometric Results For Observer-2 of Roadway-1

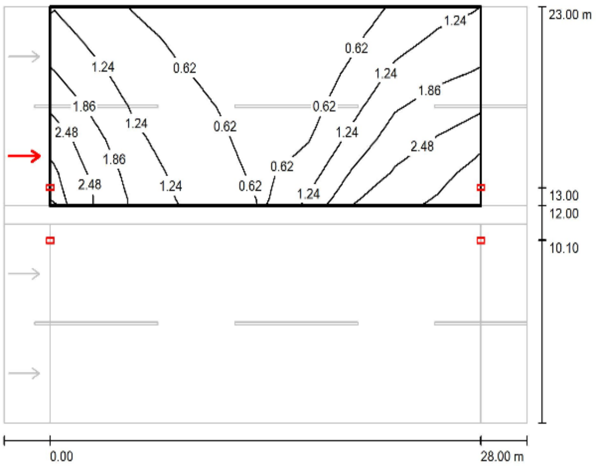


Values in Lux, Scale 1 : 244

Grid: 10 x 6 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
29	3.67	88	0.126	0.042

Fig 4.91 Isolines & E_{avg} Value Of Valuation field- Roadway 2

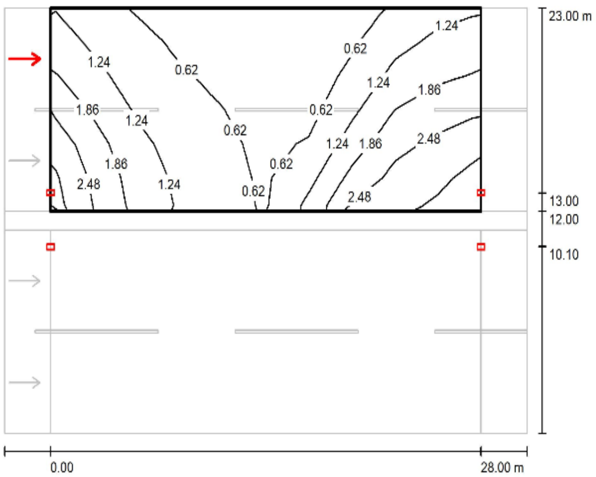


Values in Candela/m², Scale 1 : 244

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 14.750 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.24	0.15	0.16	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.92 Isolines & Photometric Results For Observer-3 of Roadway-2



Values in Candela/m², Scale 1 : 244

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 20.250 m, 1.500 m)
tarmac: C2, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	1.28	0.16	0.14	1
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✗	✗	✓

Fig 4.93 Isolines & Photometric Results For Observer-4 of Roadway-2

4.4. Luminance Diagram Of The Luminaires

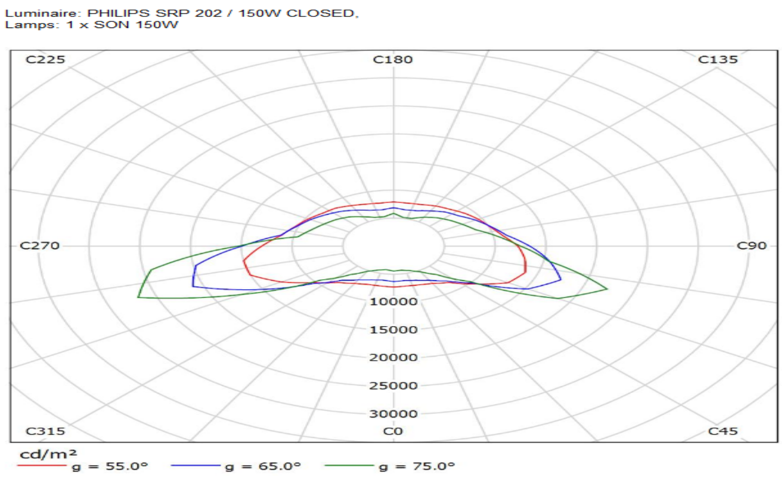


Fig 4.94 Luminance Diagram Of SON Lamp For Plan-I, II & III

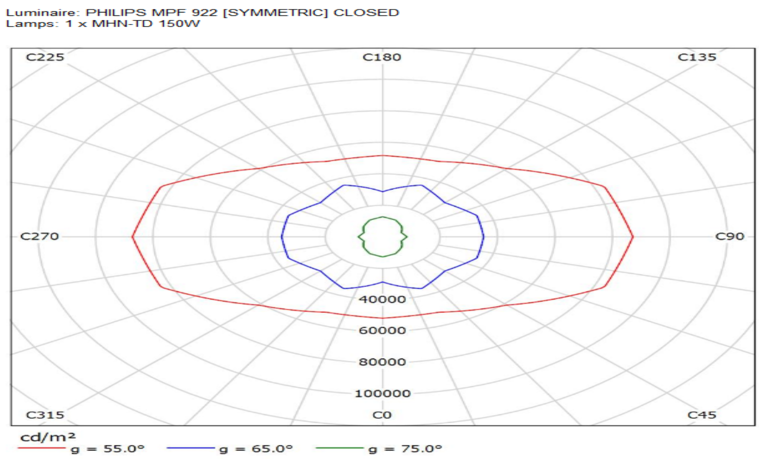


Fig 4.95 Luminance Diagram Of MHN-TD Lamp For Plan-IV, V & VI

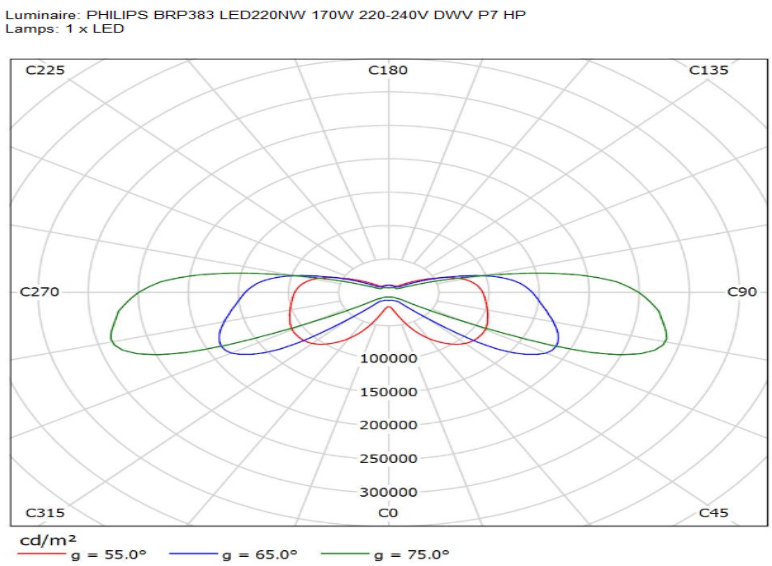


Fig 4.96 Luminance Diagram Of Solar-Eff LED Lamp For Plan- VII,VIII & IX

4.5. Tabular Summary Of the Designed Plans

A spreadsheet has been created which summarizes all the designed 9 plans in the different arrangements taken. Different lighting parameters of ME4a illuminance class and their respective performance under different street lamps has been represented in Table 4.4. For the four observers taken into consideration, their response to the lighting parameters in different arrangements has been represented in Table 4.5.

Table 4.4 Tabular Representation of the Designed DIALux Plans with their Photometric Results

Class Standard	Street Arrangement	Road Width	Sub-Lighting Class	Pole Spacing	Pole Height	Standard for ME4a Illuminance class	Lamps		
							SON	MHN-TD	SOLAR EFF-LED
						E_{avg} (lux)	19	20	36
						L_{avg} cd/m^2 (>=0.75)	1.64	1.61	2.8
						U0 (>=0.40)	0.76	0.75	0.58
						UI (>=0.60)	0.68	0.63	0.48
						TI (<=15)	5	2	1
R1 (Dry Road)	Zig-Zag	14m	A2	20m		SR (>=0.5)	0.91	0.92	0.99
						E_{avg} (lux)	14	14	26
						L_{avg} cd/m^2 (>=0.75)	1.41	0.93	1.65
						U0 (>=0.40)	0.33	0.32	0.38
						UI (>=0.60)	0.77	0.59	0.42
						TI (<=15)	5	3	2
W2 (Wet Road)	Opposite	18m	A1	24m		SR (>=0.50)	0.94	0.89	0.99
						E_{avg} (lux)	13	16	29
						L_{avg} cd/m^2 (>=0.75)	0.69	0.77	1.3
						U0 (>=0.40)	0.33	0.3	0.15
						UI (>=0.60)	0.46	0.45	0.14
						TI (<=15)	8	4	2
C2 (Concrete Road)	Twin-Central	22m	A3	28m	9m	SR (>=0.50)	0.84	0.94	0.83

Table 4.5 Tabular Summary of the Observers' Response to the Lighting Parameters For the Designed Street Arrangements

Class Standard	Street Arrangement	Standard for ME4a Illuminance class	Observers											
			Observer-1			Observer-2			Observer-3			Observer-4		
			SON	MHN-TD	SOLAR EFF-LED	SON	MHN-TD	SOLAR EFF-LED	SON	MHN-TD	SOLAR EFF-LED	SON	MHN-TD	SOLAR EFF-LED
R1 (Dry Road)	Zig-Zag	L_{avg} cd/m^2 (>=0.75)	1.64	1.61	2.81	1.63	1.61	2.8	1.63	1.61	2.88	1.63	1.61	2.87
		U0 (>=0.40)	0.77	0.75	0.58	0.75	0.75	0.58	0.76	0.75	0.58	0.77	0.75	0.59
		UI (>=0.60)	0.68	0.63	0.59	0.83	0.73	0.59	0.83	0.73	0.59	0.68	0.63	0.48
		TI (<=15)	5	2	1	5	4	1	5	2	1	4	2	1
W2 (Wet Road)	Opposite	L_{avg} cd/m^2 (>=0.75)	1.41	0.93	1.27	1.57	1.02	1.35	1.25	1.02	1.81	1.16	0.93	1.65
		U0 (>=0.40)	0.33	0.36	0.38	0.32	0.32	0.38	0.33	0.32	0.36	0.38	0.36	0.36
		UI (>=0.60)	0.88	0.75	0.36	0.77	0.59	0.52	0.67	0.59	0.55	0.83	0.75	0.3
		TI (<=15)	5	3	2	4	3	1	5	3	1	5	3	1
C2 (Concrete Road)	Twin-Central	L_{avg} cd/m^2 (>=0.75)	0.71	0.8	1.34	0.68	0.77	1.3	0.69	0.74	1.24	0.72	0.78	1.28
		U0 (>=0.40)	0.33	0.3	0.14	0.33	0.3	0.14	0.3	0.3	0.14	0.31	0.3	0.16
		UI (>=0.60)	0.46	0.44	0.16	0.51	0.44	0.14	0.47	0.45	0.16	0.41	0.71	0.14
		TI (<=15)	5	4	1	7	4	1	8	4	2	5	2	1

CHAPTER- 5: RESULTS ANALYSIS AND COMPARISON

After obtaining the results from the DIALux 4.13 Lighting Design Software, analysis and comparison has been done for the various lighting parameters using Tabular presentation and Graphical representation. Also, the following analyses has been made before coming to a conclusion:-

Tabular and Graphical Analysis of the lighting Parameters for Zig-Zag arrangement & R1 tarmac
Tabular and Graphical Analysis of the lighting Parameters for Opposite arrangement & W2 tarmac
Tabular and Graphical Analysis of the lighting Parameters for Twin-Central arrangement & C2 tarmac
Tabular Representation Of the Observers' positions in each arrangement
Tabular and Graphical Analysis of the lighting parameters for the Observers in presence of the different lamps
Tabular and Graphical representation of E_{avg} of three lamps in different arrangements
Calculation of the total installation cost of each of the three lamps in the designed arrangements
Calculation of the annual energy savings of each lamp in the designed arrangements
Calculation and Graphical representation of the Pay-back period of each lamp in the designed arrangements

5.1. Tabular and Graphical Analysis of the Lighting Parameters for Zig-Zag Arrangement having R1 tarmac

Table 5.1 represents the tabular illustration of Lighting parameters for each type of lamp in the zig-zag Arrangement.

Table 5.1 Lighting parameters for each type of lamp in the Zig-Zag Arrangement

ZIG-ZAG ARRANGEMENT ROAD SURFACE- R1										
TRAFFIC LIGHTING CLASS- ME4a SUB-LIGHTING CLASS-A2										
	L_{avg} cd/m^2 (>=0.75)		U0 (>=0.40)		UI (>=0.60)		TI [%] (<=15)		SR (>=0.50)	
TYPE OF LAMP	Roadway-1	Roadway-2	Roadway-1	Roadway-2	Roadway-1	Roadway-2	Roadway-1	Roadway-2	Roadway-1	Roadway-2
SON	1.64	1.63	0.75	0.76	0.68	0.68	5	5	0.91	0.91

MHN-TD	**1.61**	**1.61**	**0.75**	**0.75**	**0.63**	**0.63**	**2**	**2**	**0.92**	**0.92**
SOLAR EFF- LED	**2.8**	**2.87**	**0.58**	**0.58**	**0.47**	**0.48**	**1**	**1**	**0.99**	**0.99**

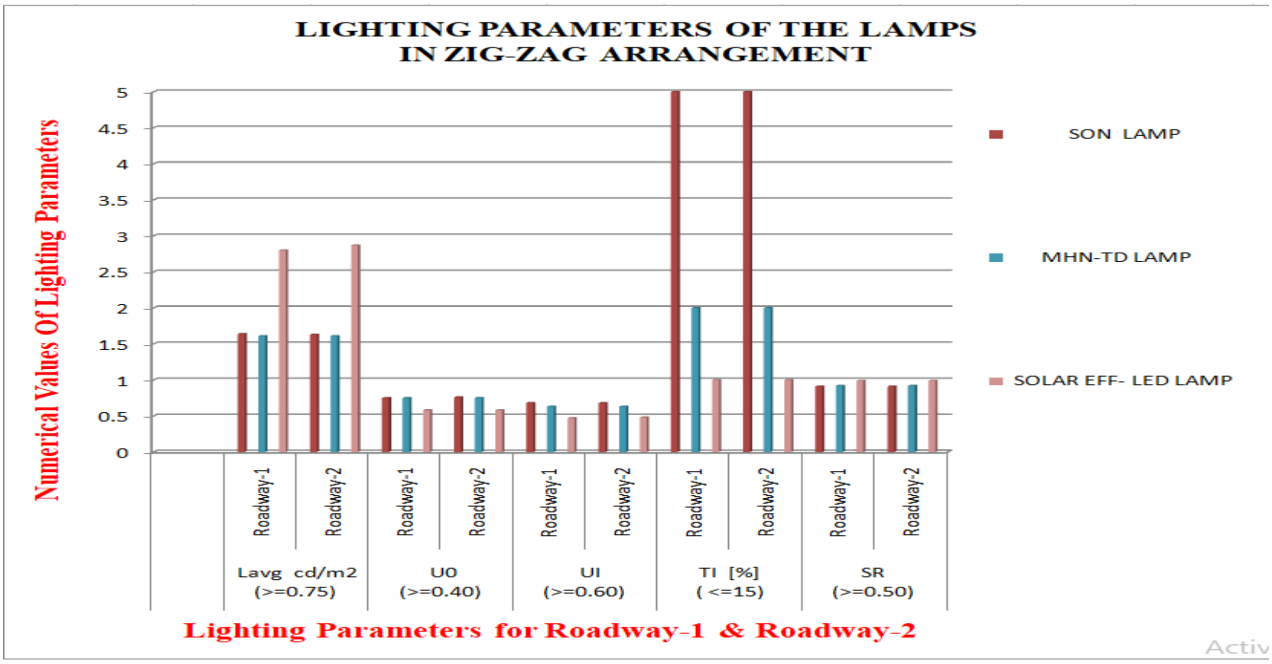


Fig 5.1 Column Bar showing Performance of the Lighting parameters For each Lamp in Zig-Zag Arrangement

From Fig 5.1, the following results are obtained:-

For L_{avg},

Solar efficient LED gives the best value of 2.88.

For U0,

Both SON & MHN-TD lamps give the best value of 0.76 or 0.75.

For UI,

SON lamp gives the best value of 0.68.

Solar efficient LED fails to fulfill the criteria of the class ME4a.

For TI,

SON lamp gives the best value of 5.

For SR,

Solar Efficient LED gives the best value of 0.99.

5.2. Tabular and Graphical Analysis of the Lighting Parameters for Opposite Arrangement having W2 tarmac

Table 5.2 represents the tabular illustration of Lighting parameters for each type of lamp in the Opposite Arrangement.

Table 5.2 Lighting parameters for each type of Lamp in the Opposite arrangement

OPPOSITE ARRANGEMENT ROAD SURFACE- W2										
TRAFFIC LIGHTING CLASS-ME4a SUB-LIGHTING CLASS- A1										
TYPE OF LAMP	L_{avg} cd/m^2 (>=0.75)		U0 (>=0.40)		UI (>=0.60)		TI [%] (<=15)		SR (>=0.50)	
	Roadway-1	Roadway-2	Roadway-1	Roadway-2	Roadway-1	Roadway-2	Roadway-1	Roadway-2	Roadway-1	Roadway-2
SON	1.41	1.16	0.32	0.33	0.77	0.67	5	5	0.92	0.94
MHN-TD	0.93	0.93	0.32	0.32	0.59	0.59	3	3	0.89	0.89
SOLAR EFF-LED	1.27	1.65	0.38	0.36	0.42	0.3	2	1	0.99	0.99

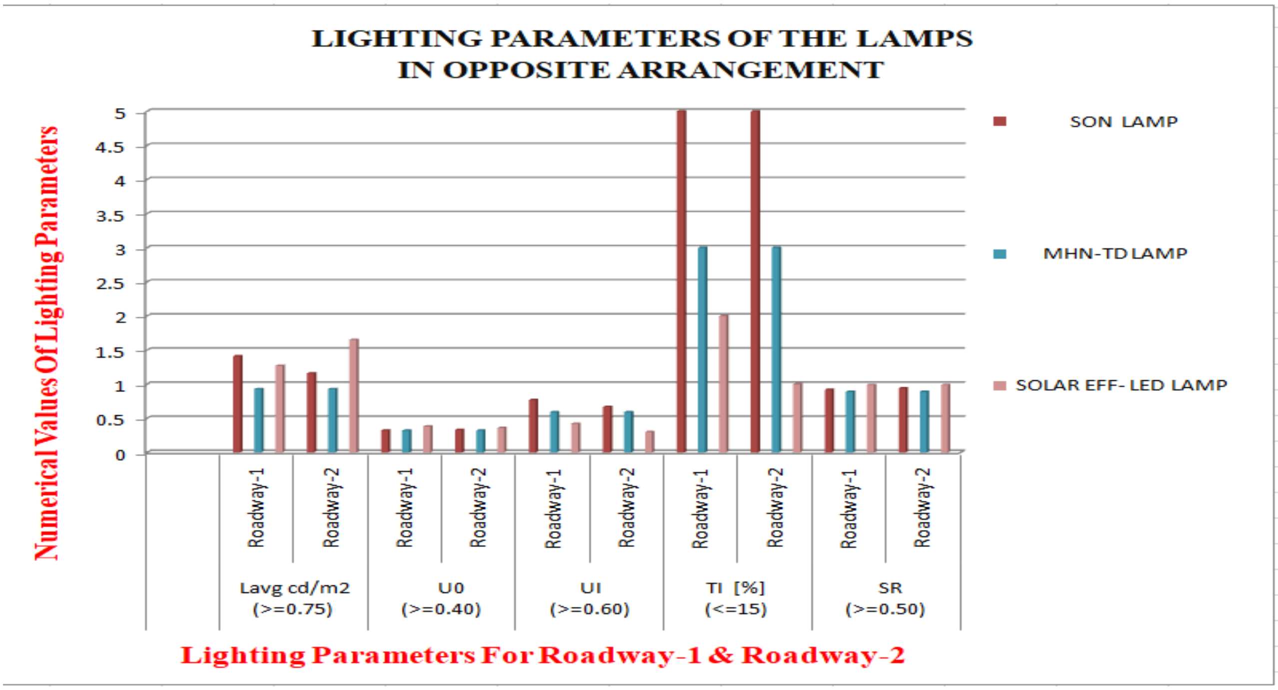


Fig 5.2 Column Bar showing Performance of the Lighting parameters For each Lamp in Opposite Arrangement

From Fig 5.2, the following results are obtained:-

For L_{avg},

Solar efficient LED gives the best value of 1.65. Refer to Fig 5.2.

For U0,

All the lamps fail to meet the criteria of the class ME4a.

For UI,

SON lamp gives the best value of 0.77.

Solar Efficient LED and MHN-TD both fail to fulfill the criteria of the class ME4a.

For TI,

SON lamp gives the best value of 5.

For SR,

Solar Efficient LED gives the best value of 0.99.

5.3. Tabular and Graphical Analysis of the Lighting Parameters for Twin-Central Arrangement having C2 tarmac

Table 5.3 represents the tabular illustration of Lighting parameters for each type of lamp in the Twin-Central Arrangement.

Table 5.3 Lighting parameters for each type of Lamp in the Twin-Central Arrangement

TWIN-CENTRAL ARRANGEMENT ROAD SURFACE-C2										
LIGHTING CLASS:-ME4a SUB-LIGHTING CLASS-A3										
	L_{avg} cd/m^2 (>=0.75)		U0 (>=0.40)		UI (>=0.60)		TI [%] (<=15)		SR (>=0.50)	
TYPE OF LAMP	Roadway-1	Roadway-2	Roadway-1	Roadway-2	Roadway-1	Roadway-2	Roadway-1	Roadway-2	Roadway-1	Roadway-2
SON	0.68	0.69	0.33	0.3	0.46	0.41	7	8	0.83	0.84
MHN-TD	0.77	0.74	0.3	0.3	0.44	0.45	4	4	0.91	0.94

SOLAR EFF- LED	**1.3**	**1.24**	**0.14**	**0.15**	**0.14**	**0.14**	**1**	**2**	**0.83**	**0.83**

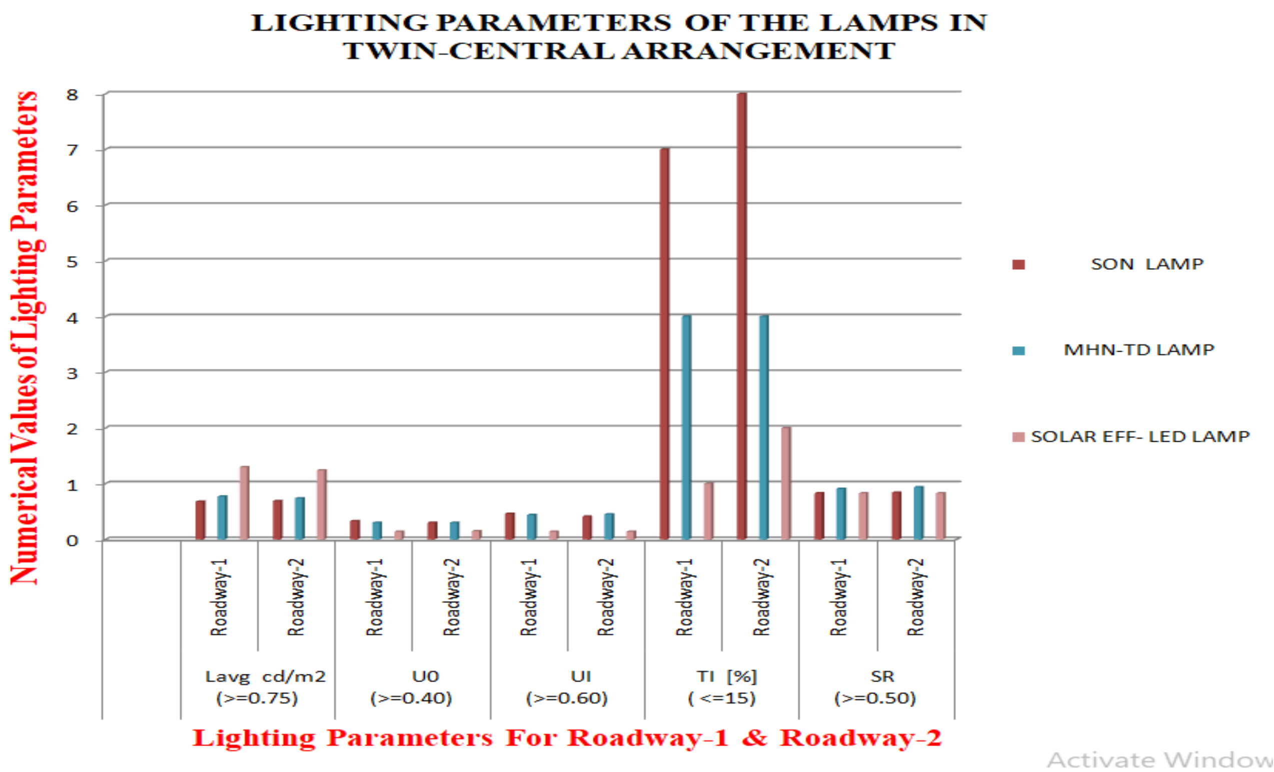


Fig 5.3 Column Bar showing Performance of the Lighting parameters for each Lamp in Twin-Central Arrangement

From Fig 5.3, the following results are obtained:-

For L_{avg},

Solar efficient LED gives the best value of 1.3.

SON fails to meet the criteria of lighting class ME4a.

For U0,

All the lamps fail to meet the criteria of the class ME4a.

For UI,

All the lamps fail to fulfill the criteria of the class ME4a.

For TI,

SON lamp gives the best value of 8.

For SR,

Solar Eff. LED gives the best value of 0.99.

FINAL CONCLUSION DERIVED FOR STREET LIGHT ARRANGEMENTS AND ROAD TARMAC

L_{avg}(Preferred)- Solar Efficient LED in Zig-Zag arrangement having dry road tarmac (R1).

U0 (Preferred)- SON & MHN-TD in Zig-Zag arrangement having dry road tarmac (R1).

UI (Preferred)- SON in Twin-central arrangement having concrete road tarmac (C2).

TI (Preferred)- SON in Opposite arrangement having wet road tarmac (W2).

SR (Preferred)- Solar Efficient LED in all arrangements for dry, wet and concrete roads R1, W2 and C2 respectively.

5.4. Tabular and Graphical Representation Of the Observers' positions in each Arrangement

Table 5.4 illustrates the tabular representation of the position of the four observers who are present in each lane of the designed street arrangements.

Table 5.4 Position Of Four Observers present in each lane of the designed Street arrangements

OBSERVER	TYPE OF ARRANGEMENT	X-AXIS (metres)	Y-AXIS (metres)	Z-AXIS (metres)
OBSERVER-1	OPPOSITE	-60	1.75	1.5
	ZIG-ZAG	-60	1.75	1.5
	TWIN-CENTRAL	-60	2.75	1.5
OBSERVER-2	OPPOSITE	-60	5.25	1.5
	ZIG-ZAG	-60	5.25	1.5
	TWIN-CENTRAL	-60	8.25	1.5
OBSERVER-3	OPPOSITE	-60	10.25	1.5
	ZIG-ZAG	-60	9.75	1.5
	TWIN-CENTRAL	-60	14.75	1.5
OBSERVER-4	OPPOSITE	-60	14.75	1.5
	ZIG-ZAG	-60	13.25	1.5
	TWIN-CENTRAL	-60	20.25	1.5

5.5. Tabular Analysis Of The Lighting Parameters For The Four Observers Present In Every Arrangement

Table 5.5 illustrates the tabular representation for the lighting parameters for the observers present in different types of street arrangements.

Table 5.5 Lighting parameters for the observers present in different type of street arrangements

TYPE OF LAMPS	TYPE OF ARRANGEMENT	L_{avg} cd/m^2 (>= 0.75)				U0 (>=0.40)				UI (>=0.60)				TI [%] (<=15)			
		OBSERVER-1	OBSERVER-2	OBSERVER-3	OBSERVER-4	OBSERVER-1	OBSERVER-2	OBSERVER-3	OBSERVER-4	OBSERVER-1	OBSERVER-2	OBSERVER-3	OBSERVER-4	OBSERVER-1	OBSERVER-2	OBSERVER-3	OBSERVER-4
SON	OPPOSITE	1.41	1.57	1.25	1.16	0.33	0.32	0.33	0.38	0.88	0.77	0.67	0.83	5	4	5	5
	ZIG-ZAG	1.64	1.63	1.63	1.63	0.77	0.75	0.76	0.77	0.68	0.83	0.83	0.68	5	5	5	4
	TWIN-CENTRAL	0.71	0.68	0.69	0.72	0.33	0.33	0.3	0.31	0.46	0.51	0.47	0.41	5	7	8	5
MHN-TD	OPPOSITE	0.93	1.02	1.02	0.93	0.36	0.32	0.32	0.36	0.75	0.59	0.59	0.75	3	3	3	3
	ZIG-ZAG	1.61	1.61	1.61	1.61	0.75	0.75	0.75	0.75	0.63	0.73	0.73	0.63	2	2	2	2
	TWIN-CENTRAL	0.8	0.77	0.74	0.78	0.3	0.3	0.3	0.3	0.69	0.44	0.45	0.71	2	4	4	2
SOLAR EFF-LED	OPPOSITE	1.27	1.35	1.81	1.65	0.38	0.38	0.36	0.36	0.36	0.52	0.55	0.3	2	1	1	1
	ZIG-ZAG	2.81	2.8	2.88	2.87	0.58	0.58	0.58	0.59	0.59	0.59	0.59	0.48	1	1	1	1
	TWIN-CENTRAL	1.34	1.3	1.24	1.28	0.14	0.14	0.14	0.16	0.16	0.14	0.16	0.14	1	1	2	1

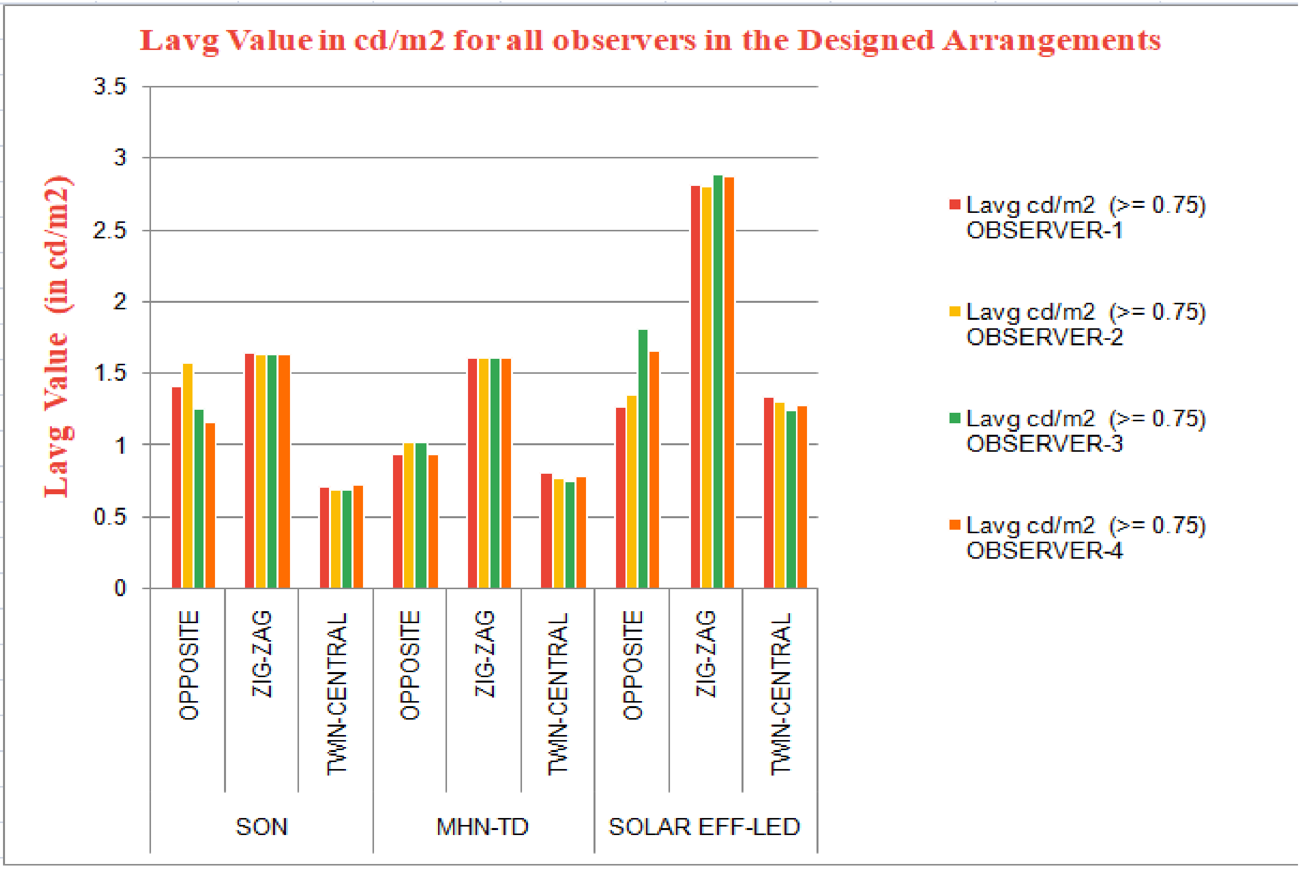


Fig 5.4 Column Chart representing performance of L_{avg} for all the observers in each designed Arrangement

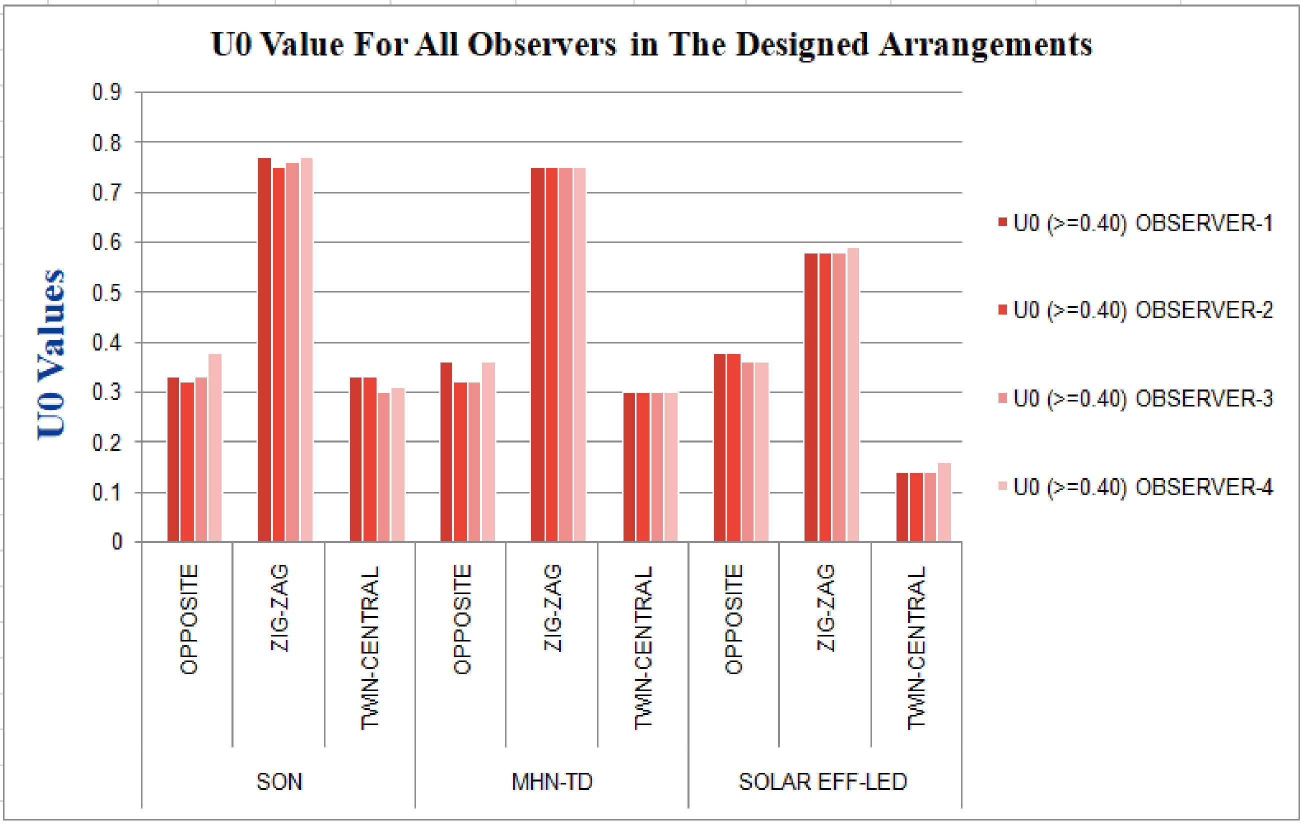


Fig 5.5 Column Chart representing performance of U0 for all the observers in each designed Arrangement

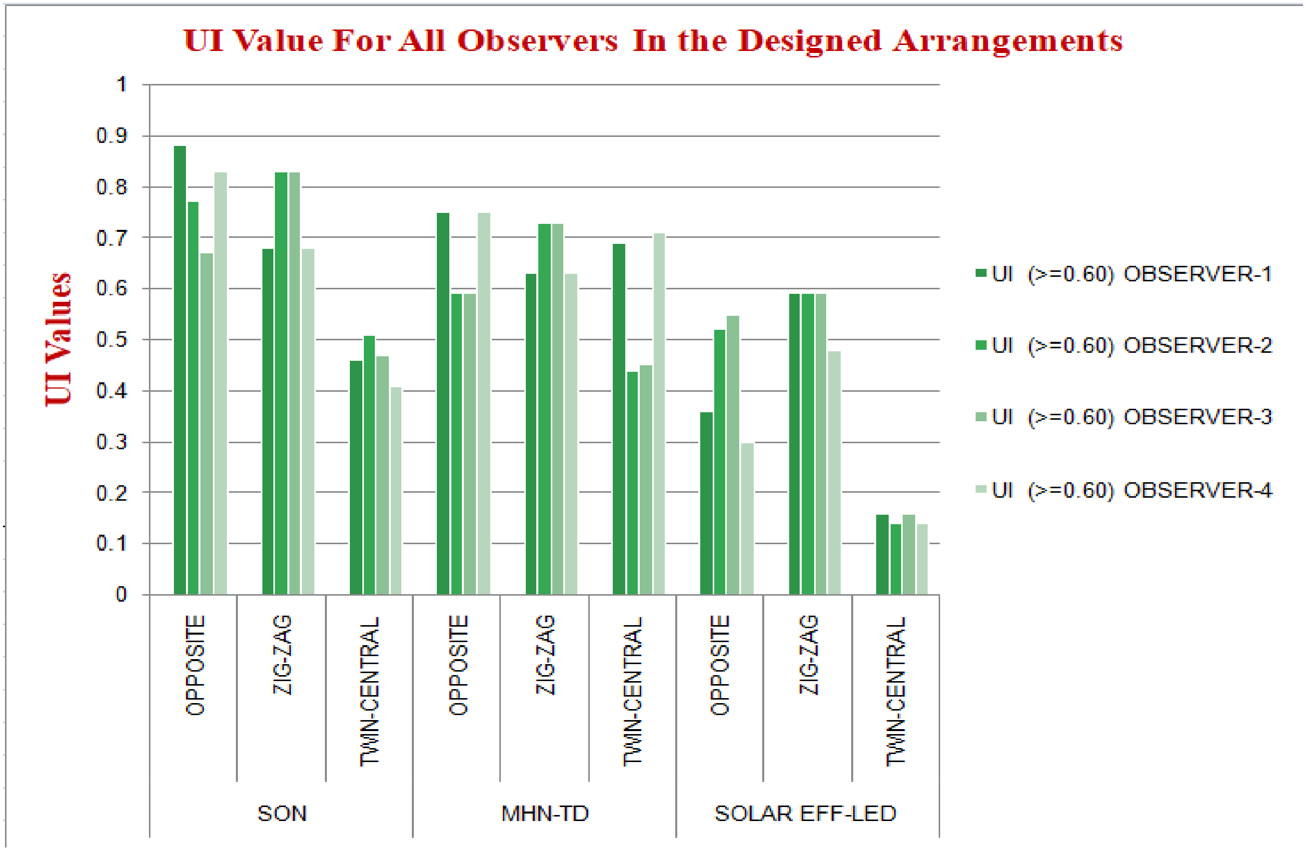


Fig 5.6 Column Chart representing performance of UI for all the observers in each designed Arrangement

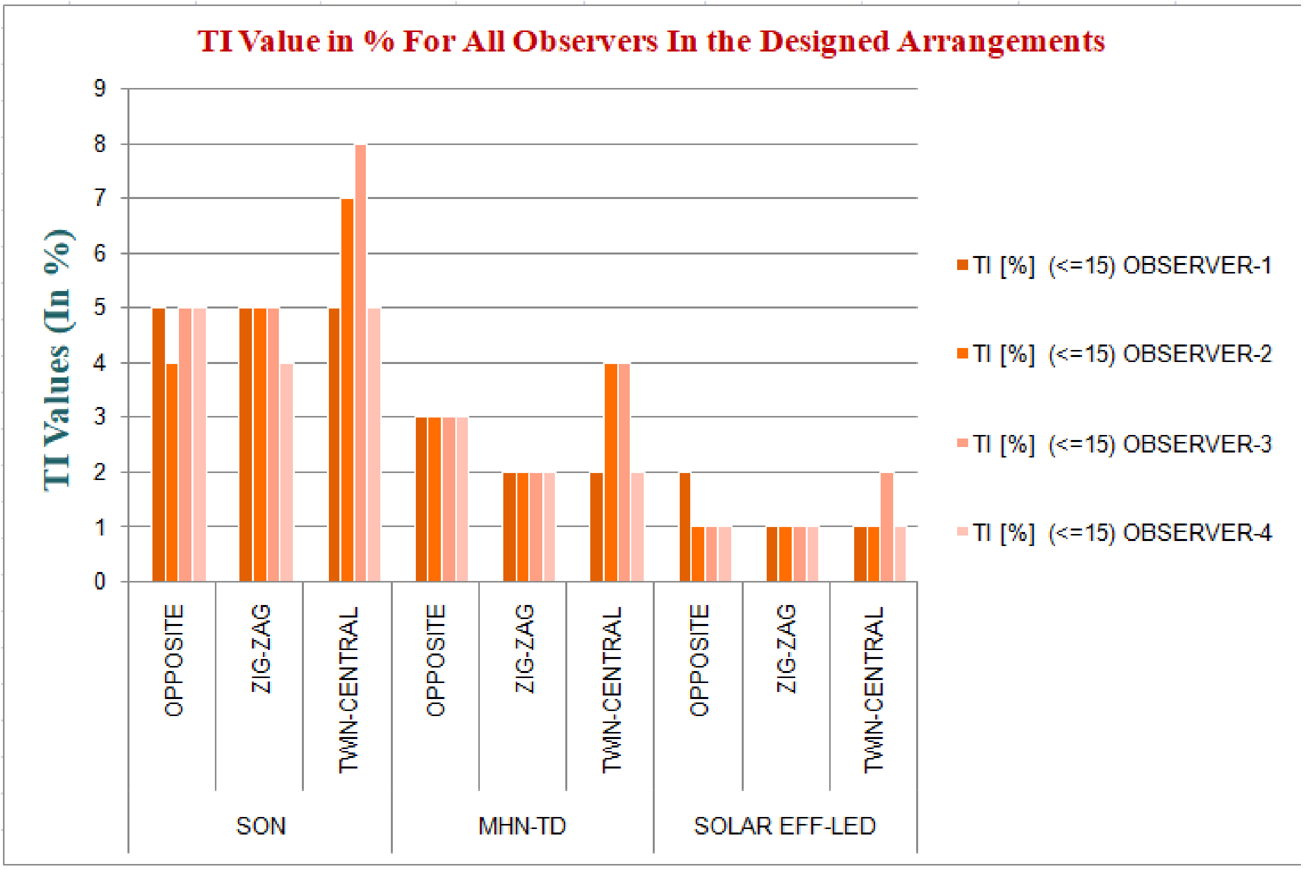


Fig 5.7 Column Chart representing performance of UI for all the observers in each designed Arrangement

For L_{avg} (Refer to Fig 5.4):

Observer-1 Solar Eff. LED in zig-zag arrangement gives a value of 2.81.
Observer-2 Solar Eff. LED in zig-zag arrangement gives a value of 2.80.
Observer-3 Solar Eff. LED in zig-zag arrangement gives a value of 2.88.
Observer-4 Solar Eff. LED in zig-zag arrangement gives a value of 2.87.

For U0 (Refer to Fig 5.5):

Observer-1 SON in zig-zag arrangement gives a value of 0.77.
Observer-2 MHN-TD & SON in zig-zag arrangement gives a value of 0.75.
Observer-3 SON in zig-zag arrangement gives a value of 0.76.
Observer-4 Solar Eff. LED in zig-zag arrangement gives a value of 0.77.

In most of the cases, all the observers fail to meet the basic criteria of U0.

For UI (Refer to Fig 5.6):

Observer-1 SON in the opposite arrangement gives the best value of 0.88.
Observer-2 SON in the zig-zag arrangement gives the best value of 0.77.
Observer-3 SON in the zig-zag arrangement gives the best value of 0.83.
Observer-4 SON in the opposite arrangement gives the best value of 0.83.

In half of the cases, all the observers fail to meet the basic criteria of UI.

For TI (Refer to Fig 5.7):

Observer-1 SON in every arrangements
Observer-2 SON in twin-central arrangement
Observer-3 SON in twin-central arrangement
Observer-4 SON in opposite and twin-central arrangement

Final Conclusion Derived For Observers

For L_{avg}- All the observers of Solar eff-LED in zig-zag arrangement gives a value more than 2.80.

For U0- Observer 1 & Observer 4 of SON in zig-zag arrangement gives a value of 0.77.

For UI- Observer 1 of SON in the opposite arrangement gives a value of 0.83.

For TI- High for all observers of SON in twin-central arrangement.

5.6. Analysis of E_{avg} of the Lamps in Designed Arrangements

Table 5.6 demonstrates the tabular representation of the calculated E_{avg} of the designed arrangements for each of the lamps.

Table 5.6 Tabular Representation of the Calculated E_{avg} of the designed arrangements for each of the lamps

TYPE OF ARRANGEMENT	TYPE OF LAMP	CALCULATED AVG. ILLUMINANCE (lux)
OPPOSITE	SON	14
	MHN-TD	14
	SOLAR EFF-LED	26
ZIG-ZAG	SON	19
	MHN-TD	20
	SOLAR EFF-LED	36
TWIN-CENTRAL	SON	13
	MHN-TD	16
	SOLAR EFF-LED	29

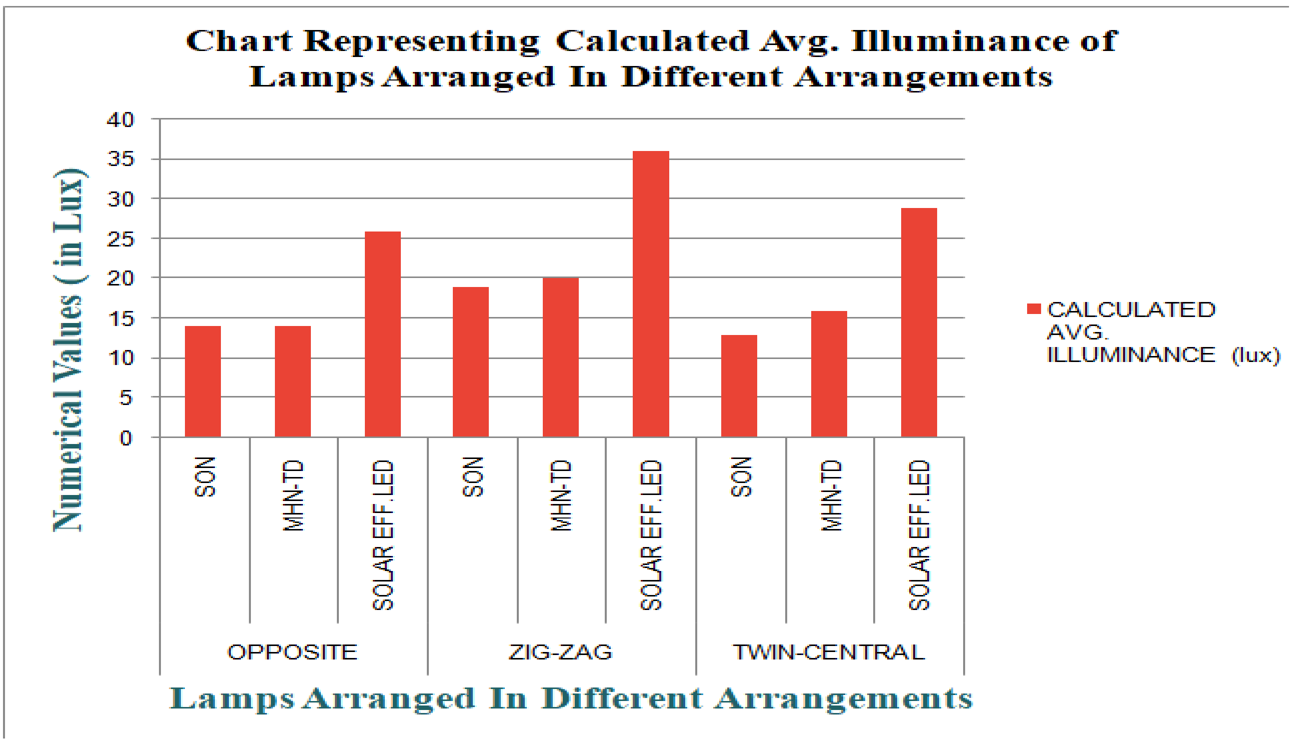


Fig 5.8 Column Chart Showing the E_{avg} value (in lux) of the various lamps arranged in different Arrangements.

From Fig 5.8, the following results are concluded:-

E_{avg} is found to be the maximum in the proposed plan of Solar Eff-LED in zig-zag arrangement which gives 36 lux.

For SON, maximum E_{avg} is found to be 19 lux in zig-zag arrangement.

For MHN-TD, maximum E_{avg} is found to be 20 lux in zig-zag arrangement.

All the lamps give their maximum E_{avg} when placed in zig-zag arrangement.

E_{avg} is found to be the minimum in the proposed plan of SON in twin-central arrangement which gives 13 lux.

For MHN-TD, minimum E_{avg} is found to 14 lux when placed in opposite arrangement.

For Solar Eff-LED, minimum E_{avg} is found to 26 lux when placed in opposite arrangement.

On Indian and other densely populated roads, where the traffic rush is always increasing, Solar Eff-LED should be used in the zig-zag arrangement to satiate the need for the demanding illuminance levels.

5.7. Calculation of the Total Installation Cost of each of the Three Lamps in the Three Designed Arrangements

From the Philips price catalog of 2012,

The price of the specific SON lamp is Rs 8000[28].
The price of the specific MH lamp is Rs 5670[28].
The price of the specific Solar Eff-LED lamp is Rs 25000.

From 2012-2023, the average inflation rate in India is 6.02%.

Hence, the present price= (6.02/100)* Previous price + Previous price (Refer to Table 5.7)
It is not applicable for Solar Eff-LED lamps as they were not present at that time in abundance.

Sky lifting charge for a single street luminaire = Rs 1000 (Refer to Table 5.7)

So, Total installation cost of a specific arrangement is

(Present value * no. of luminaires required) + (Sky lifting charge* no. of luminaires required) (Refer to Table 5.7)

Table 5.7 Total Installation Cost of Every Type of Lamp in Every Designed Arrangement

Type of Streetlight	Price (As per Catalog) In 2012 (in Rs)	INFLATION Rate (%)	Present Value (in Rs)	No. Of Luminaires Required for a Selected Road Stretch			Sky Lifting Charges (in Rs)	Total Installation Cost (in Rs)		
				Zig-Zag	Opposite	Twin-Central		Zig-Zag	Opposite	Twin-Central
MHN-TD	5670	6.02	6011.33	100	83	71	1000	701133	581940	497804
SON	8000	6.02	8481.6	88	73	63		834381	692157	597341
Solar Eff-LED	—	—	25000	56	47	40		1456000	1222000	1040000

Since the price of Solar Eff- LED is very high, the total installation cost for this lamp in every arrangement gets expensive.

The lowest price is for the MHN-TD in every arrangement as Metal Halide lamps are getting cheaper due to its restricted use with the advancement in the field of lighting industry.

5.8. Calculation of the Annual Energy Consumption of each Lamp in the designed Arrangements

Street light operating hours generally range from 6 p.m - 5 a.m daily. So, a street light luminaire consumes electricity 11 hours daily and consumes energy within that duration only.

To calculate the total energy consumption of the lamps used for each designed arrangement,

Total Energy Consumption (W-hr)= Power * No. of luminaires required * No. of hours
The annual energy consumption of the lamps per year in every arrangement can be found by this method.

By referring to Table 5.8, the following results for each lamp can be calculated.

Energy Consumption/year= (Total Energy Consumption/1000)*365

Electricity tariff = Rs 10/ k-w-hr

Annual operating hrs. Of each lamp in the plan= 365*11 hrs=4015 hrs

Electricity Consumption/ year= Energy Consumption/year*Electricity tariff

Note: Yrs- Abbreviation for Years

Table 5.8 Representation of the total load, annual energy consumption and annual electricity consumption of every lamp in the designed arrangements

Type of Lamp	Power (in W)	No. Of Luminaires Required			No. Of Hours (in hr)	Total Energy Consumption (in W-hr)			Energy Consumption/year (W-hr/1000)*365			Electricity Tariff per k-W-hr (in Rs)	Electricity Consumption/year (in Rs/yr)		
		Zig-Zag	Opposite	Twin-Central		Zig-Zag	Opposite	Twin-Central	Zig-Zag	Opposite	Twin-Central		Zig-Zag	Opposite	Twin-Central
MHN-TD	166	100	83	71		182600	151558	129646	66649	55318.67	47320.79		666490	553186.7	473207.9
SON	170	88	73	63		164560	136510	117810	60064.4	49826.15	43000.65		600644	498261.5	430006.5
Solar Eff-LED	170	64	53	45	11	119680	99110	84150	43683.2	36175.15	30714.75	10	436832	361751.5	307147.5

From Table 5.8, the following results have been derived:

The maximum annual electricity consumption for the MHN-TD lamps is when it is arranged in a zig-zag pattern i.e. Rs 666490/year.

The minimum annual electricity consumption for the MHN-TD lamps is when it is arranged in a twin-central pattern i.e. Rs 473207.90/year.

The maximum annual energy consumption for the SON lamps is when it is arranged in an opposite pattern i.e. Rs 600644/year.

The minimum annual energy consumption for the SON lamps is when it is arranged in a twin-central pattern i.e. Rs 43006.50/year.

The maximum annual energy consumption for the Solar Eff-LED lamps is when it is arranged in a zig-zag pattern i.e. Rs 436832/year.

The minimum annual energy consumption for the Solar Eff-LED lamps is when it is arranged in a twin-central pattern i.e. Rs 307147.50/year.

5.9. Calculation and Analysis of the Pay-back Period of the Lamps in the Designed Arrangements

To calculate the savings payback period / return investment period, the following calculation should be followed. Refer to Table 5.9.

From Table 5.8, the base value is taken for the MHN-TD lamps on which the annual electricity cost savings is calculated for SON & Solar Eff-LED lamps in every designed arrangement.

Annual electricity cost savings for SON(in specified arrangement)= Annual electricity consumption of MHN-TD (in specified arrangement) - Annual electricity consumption of SON (in specified arrangement).

Annual electricity cost savings for Solar Eff-LED(in specified arrangement)= Annual electricity consumption of MHN-TD (in specified arrangement) - Annual electricity consumption of Solar Eff-LED (in specified arrangement).

Savings Payback Period= Installation Cost of an arrangement/ Annual Electricity Cost Savings

Table 5.9 Tabular Representation of Savings Payback Period of the Lamps in the designed Arrangements

Type Of Lamp	Installation Cost (in Rs)			Electricity Cost Savings (in Rs/Yr)			Savings Pay-Back Period (in Yrs)		
	Zig-Zag	Opposite	Twin-Central	Zig-Zag	Opposite	Twin-Central	Zig-Zag	Opposite	Twin-Central
SON	834381	692157	597341	65846	54925	43197	12.7	12.6	13.8
Solar EFF-LED	1456000	1222000	1040000	284262	232388	200184	5.1	5.3	5.2

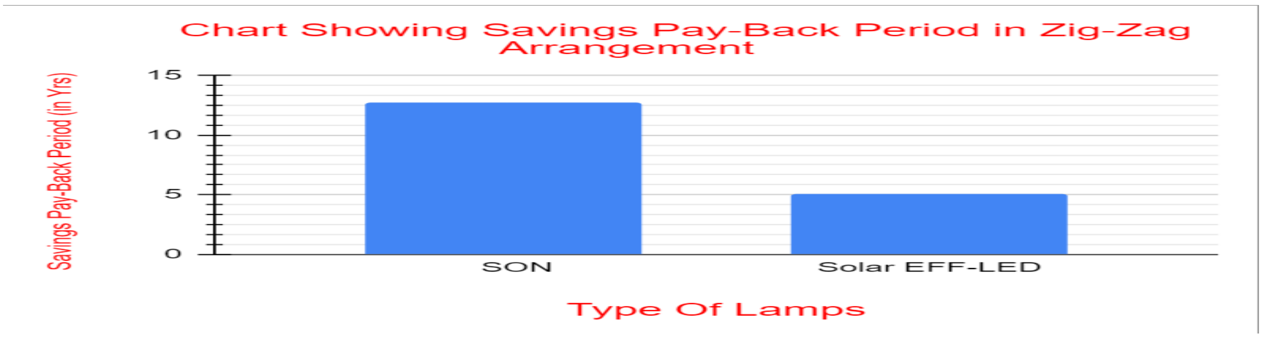


Fig 5.9 Column Chart showing savings payback period of the lamps in Zig-Zag Arrangement

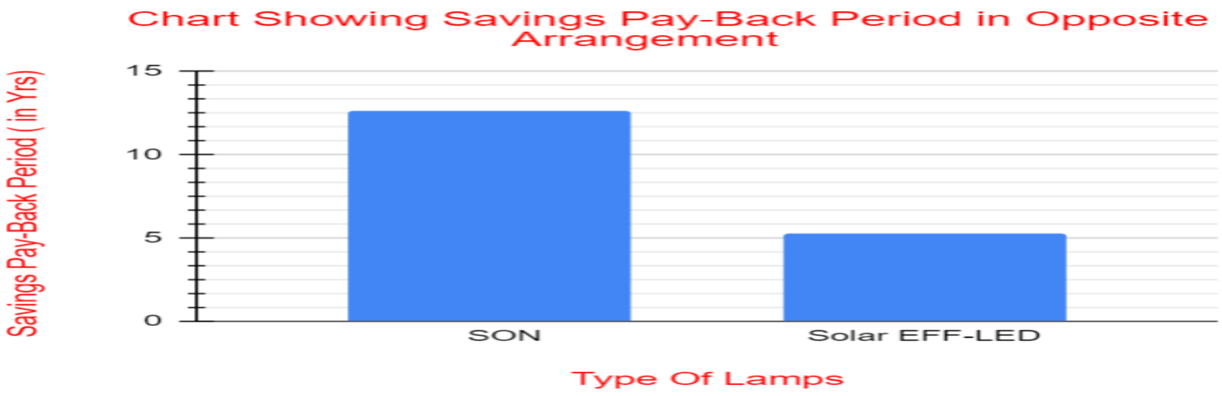


Fig 5.10 Column Chart showing savings payback period of the Lamps in Opposite arrangement

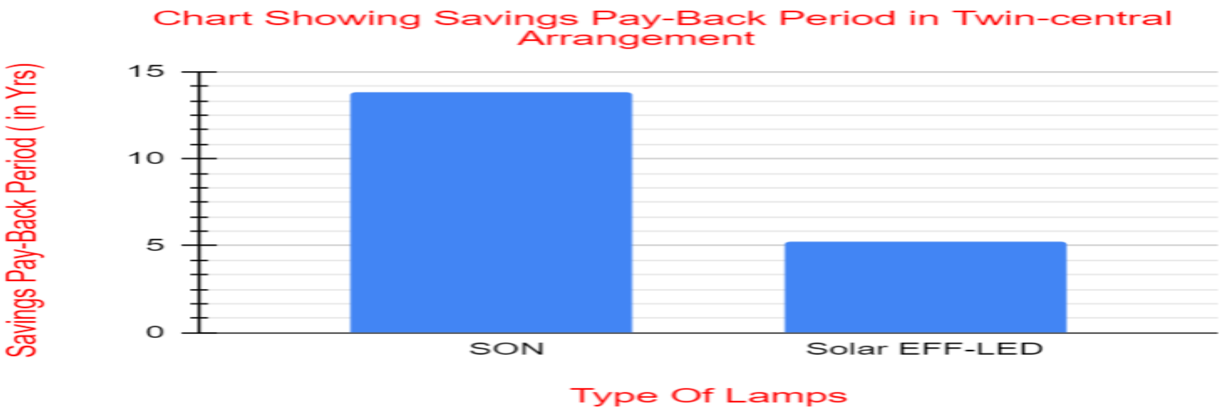


Fig 5.11 Column Chart showing savings payback period of the Lamps in Twin-Central arrangement

From Fig 5.9, 5.10 & 5.11, it can be concluded that:-

For every designed arrangement, the most cost-efficient lamp is Solar Eff-LED which gives an average savings pay-back period of 5.2 years.

The average life expectancy of LED lamps is 50000 hours[29].

Life expectancy of LED(in yrs.)= Average life expectancy of LED/Annual operating hrs. of LED

= 50000/4015= 12.45 years.

Hence, the following result is viable.

The second preferred lamp is SON as it falls much behind the previous lamp with an average savings pay-back period of about 13.03 years.

The average life expectancy of SON lamps is 24000 hours [30].

Life expectancy of SON(in yrs.)= Average life expectancy of SON/Annual operating hrs. Of SON

= 24000/4015=5.97 years.

Hence, the following result is not viable.

CHAPTER-6: CONCLUSION & FUTURE SCOPE

6.1. Conclusion

This dissertation finally gave a brief idea of the functioning of the lighting parameters of the three different lamps which are commonly used in three different street arrangements.The traffic illuminance class selected throughout all the plans is ME4a (By European Standards). This is selected because normally the speed of the users on Indian roads generally remains above 60km/hr. The lighting classes which come under this class are A1, A2 and A3 respectively. Every opposite, zig-zag and twin-central arrangement has A1, A2 and A3 classes respectively for every lamp.

Each of these lighting classes have been taken for different arrangements. Each of these arrangements has a specific road surface with a reflectance factor qo which gives different lighting parameters for the arrangements. Beginning with the street arrangements, the L_{avg} value is preferred for Solar Eff- LED arranged in Zig-Zag pattern having dry road tarmac (R1). U0 value is preferred for both SON & MHN-TD lamps in Zig-Zag arrangement having dry road tarmac (R1). UI value is preferred for SON lamps in Twin-Central arrangement having concrete road tarmac (C2). TI value is preferred for SON lamps in Opposite arrangement having wet road tarmac (W2). SR value is preferred for Solar Efficient LED lamps in all the arrangements for dry, wet and concrete roads R1, W2 and C2 respectively.

Placement of four observers is done in every plan by default. Lighting parameters for the four observers were found out to see which observer gets the best lighting level among all of them. By default, all the observers are always situated at the center of every respective lane. For L_{avg}, all the observers of Solar Eff-LED in a zig-zag arrangement give a value more than 2.80. For U0, Observer 1 & Observer 4 of SON in zig-zag arrangement gives a value of 0.77. For UI, Observer 1 of SON in the opposite arrangement gives a value of 0.83. For TI, value is high for all observers of SON in twin-central arrangement. The average illuminance (E_{avg}) was found to be maximum i.e. 36 lux for Solar- Eff LED in the zig-zag pattern and minimum i.e. 13 lux for SON lamps in the twin-central arrangement. Solar Eff-LED arranged in a zig-zag pattern is found to be the best for Indian roads as it is always in need of enhancement in lighting levels due to the rapid urbanization of the least developed cities in India.

MHN-TD lamps have a lower efficiency (72.89 lm/W) as compared to SON (82.35 lm/W) and Solar Eff-LED (129.87 lm/W) lamps. SON gives an average savings payback period of 13.03 years which is not viable. Solar Eff-LED gives the best savings payback period with an average of 5.2 years which is viable.

6.2. Future Scope

Since the illumination industry is booming, efficiency of street lights will play a key factor in the long run. More street light luminaires will turn up touching an efficacy of 200-250 lm/W in the long run. Moreover, the advancement in LED lighting has already restricted the use of HPSV, LPSV (Low Pressure Sodium Vapour), MH, CFL(Compact Fluorescent Lamps) and other HID (High Intensity Discharge) lamps since the last decade. Nowadays, retrofitting in most of the municipalities is done with the LED's which were installed a few years back with the high efficient ones because of their performance. However, it lags behind in some of the specific lighting parameters as concluded above and upgradation is expected to be executed in the coming years.

Apart from that, the roads should be constructed in such a way so that their reflective property increases and adds more visual comfort for the pedestrians, drivers and other users. Glare restriction also remains an important task. Switching towards Solar LEDs and other sustainable ways are always ongoing to increase the efficiency as well as consume less power.

LED's are being manufactured which gives a less savings pay-back period i.e. less than 5 years so that the installation cost can be recovered within that period and maximum profit can be achieved thereafter. With recent improvements and sustainable methods, the life expectancy of LEDs can be further increased to 21 years.

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