Studies on Energy Efficient Road Lighting Design

A thesis submitted towards partial fulfilment

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Submitted by

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Certificate

This is to certify that the thesis entitled **Studies on Energy Efficient Road Lighting Design**

submitted by **Rupoi Tudu**, (Exam. Roll No.**M4ILN24023B** Registration No.**144124 OF 2018-2019**) Academic session 2023-2024 of this university in partial fulfilment of requirements for the award of degree of Master of Engineering in Illumination Engineering, Department of Electrical Engineering, in Jadavpur university, Kolkata, West Bengal, this document is a Bonafede record of the work carried out by him under my guidance and supervision.

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The thesis is hereby approved as a credible study of an engineering subject carried out and represented in a satisfactory manner to warrant its acceptance as a prerequisite to the degree for which it has been submitted.

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I hereby declare that the thesis entitled **Studies on Energy Efficient Road Lighting Design** , submitted for the award of degree of Master of Engineering in Illumination Engineering of Jadavpur University is based on the original work done by me under the guidance of Jadavpur University. I also declare that I have followed all the principles of academic honesty, have not misrepresented, or fabricated or falsified any facts/data in my submission and the work presented in this thesis has not been included in any other thesis submitted previously for the award of any other degree.

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Abstract

Artificial lighting consumes a considerable amount of energy. Using energy efficient luminaires, effective controls and careful design can result in reduced consumption of energy. Reducing the unnecessary electric lighting decreases heat gain, thus saving air-conditioning energy and improving thermal comfort. Proper electric lighting design improves visual performance and visual comfort by maintaining adequate and appropriate illuminance while controlling reflection and glare.

Now a days most conventional luminaires are being replaced by LED luminaires owing to their high efficacy. These luminaires when incorporated with occupancy and daylight sensors can generate large amount of energy savings.

In this thesis work an attempt has been made to give a solution towards energy efficient lighting for a new construction type Road light space by analysing the energy consumption with conventional as well as LED light sources separately. Comparisons are made in terms of Lighting Power Density keeping other design constraints same which shows energy saving up to 60% is possible just by using LED luminaires instead of conventional fixtures. Calculation of Return on Investment is also shown indicating that the additional investment in LED luminaires is totally worthy. All Simulations are run using lighting design software DIA Lux 4.13. Without using DIALUX software, simulation lighting design cannot done correctly.

The lighting designs and simulations to follow in the subsequent chapters are done in of the author of this thesis.

CONTENTS

CHAPTER 1

Introduction

1.**Introduction**

The advancement of road lighting technologies plays a significant role in enhancing roadway visibility, safety, and energy efficiency. Traditionally, High-Pressure Sodium Vapor (HPSV) lamps have been widely adopted for road lighting due to their high lumen output and reliability. However, in recent years, Light Emitting Diode (LED) technology has gained substantial popularity as a viable alternative due to its energy efficiency, longer lifespan, and flexibility in photometric distribution [1].

The photometric distribution of a light source is a critical factor that influences the quality and effectiveness of road lighting. It refers to the way light is distributed across the road surface and surrounding areas, impacting aspects such as illuminance uniformity, glare, and light pollution. Proper photometric distribution helps to ensure that road surfaces are evenly illuminated, allowing drivers and pedestrians to navigate safely. This is especially crucial on high-traffic routes, where inadequate lighting can lead to accidents and compromised visibility.

This investigation aims to analyze and compare the photometric distribution of LED and HPSV lighting for various road types, including residential, arterial, and collector roads. By examining parameters such as light intensity, uniformity, and spillover, this study will highlight the strengths and limitations of each technology in providing effective illumination. The insights gained from this comparison will contribute to more informed choices in road lighting design and may support the broader shift towards sustainable and high-performance lighting systems in urban and rural settings.

The design of street lighting has many objectives and considerations: night-time safety of the community members and the road users, the reduction of crime and fear of crime, minimizing its effect on the environment whilst enhancing the night-time ambience, provide public lighting that is cost effective, taking into account energy conservation and sustainability.

Studies show that a well-designed street lighting shall reduce crime rates by twenty percent in the public places [2] due to the fact that improved street lighting will lead to increase social surveillance and decrease criminal opportunities. Work has been reported by many authors concerning the effect of improved street lighting on crime levels. However, their findings focus only on the role of street lighting in the reduction of crime rates through improving visibility and by increasing the number of people on the street in the public area while the energy saving and illumination level is not reviewed. This paper highlights the energy efficient street lighting system design.

1.1 Literature Review

Yoomak *et al.* [1]

Lighting quality is a crucial factor in ensuring optimal visual performance and comfort for road users, directly influencing driver alertness. It is determined by several factors such as luminaire characteristics, mounting height, pole spacing, and road surface properties, which influence the reflectivity and visibility of the roadway. Studies have compared different lighting technologies, particularly High-Pressure Sodium (HPS) and Light Emitting Diode (LED) luminaires, under varying road surface conditions like dry and wet surfaces. Research utilizing DIA Lux software has demonstrated that HPS luminaires typically offer better average illuminance and luminance, enhancing visual performance, but LED luminaires outperform in terms of overall and longitudinal uniformity, as well as energy efficiency, due to superior light distribution. Wet road surfaces generally improve lighting quality by increasing average luminance but reduce uniformity. Additionally, road surfaces with higher luminance coefficients allow for larger pole spacing, contributing to energy savings. For LED systems, the pole arrangement and luminaire mounting height play significant roles in optimizing performance and energy consumption. Single-sided arrangements work well for narrow roads, while opposite and staggered arrangements are more efficient for wider roads. The study also underscores that energy efficiency does not always correlate with lower input power; the 150W LED luminaire, for example, offers superior energy efficiency compared to conventional HPS luminaires. Overall, this body of work highlights the importance of tailored lighting designs for specific road conditions to enhance both safety and energy efficiency.

Shailesh *et al.* [2]

This paper explores the performance of LED luminaires in road lighting applications, specifically comparing their economic viability to high-pressure sodium vapor (HPSV) lighting. As road lighting is a critical component of urban infrastructure, the study emphasizes the need for government agencies to prioritize its development due to its substantial impact on economic and social stability. While the initial capital cost of LED lighting is higher than that of HPSV, the long-term savings from reduced power consumption and maintenance justify the investment, offering significant returns over the product's lifespan. Additionally, the implementation of LED street lighting contributes to lower harmful emissions and mitigates light pollution due to its highly directional nature. The paper also suggests that integrating LED systems with solar photovoltaic (PV) modules could enhance energy independence, despite the upfront costs, by further promoting energy savings and sustainability. Overall, the findings indicate a promising trend toward the eventual replacement of HPSV lighting by LEDs in road applications, highlighting the importance of adopting innovative lighting solutions for future urban development.

Jettanasen *et al.* [3]

This paper examines the transition from high-pressure sodium (HPS) lamps to light-emitting diode (LED) technology in roadway lighting, emphasizing the benefits of improved energy efficiency

and lighting quality. Historically, HPS lamps have dominated Thailand's street lighting since the 1980s, but their high energy consumption has prompted a shift towards LEDs, which offer approximately 40% energy savings and better power quality. The analysis employs simulation software (DIA Lux) to assess lighting quality, revealing that while LED luminaires maintain minimum illuminance levels and improve uniformity, further enhancements in lighting quality are necessary. Additionally, experimental setups evaluate energy savings and power performance, indicating LEDs outperform HPS in both scenarios, including those with solar power integration. Financial assessments, including discounted payback periods and internal rates of return, demonstrate that despite higher initial costs, the investment in LED luminaires can be recouped within three and a half years, highlighting their economic feasibility over a ten-year project life. Although the transition to LEDs presents challenges, particularly concerning initial costs, the findings suggest significant potential for improving Thailand's roadway lighting standards. Future research will focus on optimizing mounting heights and pole spacing to enhance illumination and uniformity further, while also exploring the integration of solar power to maximize energy efficiency and utility benefits.

Annika K. Jägerbrand [4]

This study investigates the performance of LED road lighting across various road types, focusing on compliance with safety regulations and potential energy efficiency improvements. While LED lighting for vehicular traffic generally meets the required standards for luminance and uniformity, pedestrian and bicycle paths often fall short, typically aligning with the lowest lighting class. The analysis highlights significant energy savings achievable by adapting lighting levels to minimum existing standards or lower classes, with potential reductions ranging from 6% to 61% for vehicular roads, especially when utilizing dimming schedules that can save up to 49%. The findings indicate that while a dimming schedule effectively reduces energy use without compromising safety, there is limited room for energy efficiency improvements on pedestrian and bicycle paths. Furthermore, the study notes that the power demand for LED road lighting is notably lower than that of traditional lighting sources, though pedestrian and bicycle road lighting remain less efficient. It suggests that enhancing luminance uniformity could further decrease energy consumption across all road types. The study also emphasizes the importance of considering road surface reflection properties and external light sources, which can impact measurement outcomes. Overall, the results advocate for integrating dimming strategies and adjusting lighting levels to optimize energy savings in roadway lighting systems, while also providing insights for future research on large-scale energy optimization strategies for urban environments.

Tetri *et al.* [5]

This article explores the energy efficiency of outdoor lighting, emphasizing the advantages of new light sources, particularly light-emitting diodes (LEDs), and smart lighting systems. It highlights the importance of optimizing road lighting to enhance visibility and safety by maximizing contrast between the background and objects, including the interaction between road lighting and vehicle headlights. The study compares the environmental impacts of high-pressure sodium (HPS) and LED luminaires, finding them similar at present but predicting LEDs will become more

environmentally friendly over their life cycle due to advancements in luminous efficacy and optical performance. The potential energy savings from replacing HPS lamps with LED luminaires are significant, estimated at 31% with current technology and up to 83% with future improvements, particularly when combined with smart lighting controls that can reduce burning hours and extend luminaire lifespan. Furthermore, the article discusses the need for innovative measurement techniques, such as 3D modelling and mesopic photometry, to improve lighting design and effectiveness. It emphasizes that while enhancing energy efficiency, road lighting must prioritize visual performance and user safety, ensuring a comfortable and secure environment for all road users. Overall, the integration of advanced LED technology and smart lighting solutions presents substantial opportunities for energy conservation and improved urban lighting design.

Ayaz *et al*. [6]

This study examines the implementation of various simulation methods for road illumination systems, emphasizing the necessity for controllable, reliable, and energy-efficient lighting. Three simulation approaches are compared: a general-purpose program, a proprietary industry-standard software, and a multiple regression-based model. Simulations of twelve geometric configurations reveal significant discrepancies, with simulated luminance values being 31.80–33.23% lower than those measured in the field, attributed to factors like partial interreflection and spill light from adjacent sources. The study highlights the inadequacy of current simulation tools in accurately predicting road lighting quality parameters, noting that they often underestimate average luminance by over 30% due to unaccounted stray light and idealized pavement conditions. Future research is encouraged to enhance simulation accuracy by incorporating peripheral light sources, variations in road surface reflectance, and advanced technologies such as AI and machine learning. The anticipated shift towards LED-based lighting systems is noted, with simulations serving as a valuable method for ensuring compliance with lighting standards. Overall, the findings underscore the need for improved simulation methodologies to better reflect real-world conditions and enhance the design of road illumination systems, ultimately contributing to reduced light pollution and energy consumption.

Mohd Zin *et al.* [7]

This study evaluates the feasibility of adopting energy-efficient street lighting technologies, specifically light-emitting diodes (LEDs) and induction lighting, as alternatives to traditional High Pressure Sodium Vapor (HPSV) street lighting in Malaysia. The analysis conducted by TNB reveals that LED street lights offer substantial energy savings of 40-60%, significantly outpacing the 20% savings provided by induction lights. The research involved on-site installations and photometric performance measurements of various LED and induction technologies from multiple manufacturers. Results indicated that LED luminaires not only demonstrate superior energy efficiency but also feature enhanced electrical characteristics, colour temperature, and colour rendering index (CRI) compared to HPSV systems. Furthermore, all tested LED technologies met the Malaysian road class lighting requirements, while induction technologies fell short. This highlights the advantages of LED technology, particularly its favourable luminance distribution, making it suitable for direct replacement of existing HPSV luminaires. The findings suggest a

strong case for TNB to transition to LED street lighting, reinforcing the potential for greener, more efficient urban lighting solutions.

Jamaludin *et al.* [8]

This study explores the potential of retrofitting high-pressure sodium vapor (HPSV) street lighting with light-emitting diode (LED) lamps as a cost-effective strategy for energy reduction in road lighting applications. While LED lamps exhibit superior efficacy and significantly lower wattage consumption, their structural differences compared to HPSV lamps can adversely impact light distribution. The research utilized Light Intensity Distribution (LID) curve measurements and Backlight, Up light, and Glare (BUG) rating evaluations to analyse the photometric performance of both lamp types when installed in identical HPSV luminaires. Findings revealed that while HPSV lamps outperformed LEDs in luminous flux and light intensity, the retrofitted LED lamps demonstrated a much higher efficacy rating. However, the retrofitting resulted in a notable decrease in light output ratio (LOR), from 83% to 49%, primarily due to the larger size of the LED lamps, which obstructed optimal light distribution. Despite the reduction in overall illumination levels, the study suggests that adopting LED technology through retrofitting can still yield energy savings and provide an opportunity for authorities to maintain acceptable lighting levels at lower costs. The results advocate for further exploration of luminaire housing designs to enhance compatibility with LED technology, ultimately benefiting both public safety and environmental sustainability.

D. Czyżewski [9]

This paper explores the luminance distribution on the surface of COB LEDs from various observation angles, focusing on how the distribution varies across different LEDs and their respective areas. The study reveals that the luminance is not uniformly distributed, with significant variations depending on the axial direction and specific LED design. For instance, LED1 and LED2 show luminance fluctuations ranging from 25% to 100% of maximum luminance within the light-emitting chip area, while LED3 exhibits a wider range of 10-100%. Notably, the maximum luminance does not always occur at the center of the LED surface, and the luminance gradient is most pronounced in LED3, where it can be nearly four times higher than the average. The research also highlights that up to a 75-degree observation angle, the maximum luminance remains relatively high (70% for LED1 and LED2, and 53% for LED3). The study emphasizes the importance of micro-chip distribution in COB LEDs, with LEDs 1 and 3 showing orderly patterns, while LED2 lacks a clear distribution. This variability is crucial for lighting fixture designers, as they must account for uneven luminance when designing optical systems. Future research will build on these findings to enhance the understanding of luminance modeling in LEDs and address the thermal stability concerns of individual LEDs in practical applications.

Ramli *et al.* [10]

The use of LED technology, while not new, has seen increased attention in street lighting as a potential replacement for High-Pressure Sodium Vapor (HPSV) lights, especially given rising energy costs and tariffs. LEDs are recognized for their energy-saving potential, but their adoption in street lighting remains limited, partly due to the complex specifications required for safe and effective lighting, such as those outlined in Malaysia's MS-825 standards. Initial trials in Malaysia, including a pilot project on a federal road with a 6-lane dual carriageway, have focused on testing LED lighting performance in real-world scenarios, particularly in terms of road structure and

onsite illuminance measurements. Comparative studies between LED and HPSV lighting systems reveal that while LEDs can meet MS-825 specifications, achieving optimal lighting levels might require adjustments to wattage, pole height, and spacing. Additionally, financial analysts suggest that LED street lighting systems have an attractive return on investment (ROI), potentially yielding payback within five years, which aligns with typical warranty periods. This indicates that replacing HPSV lights with LEDs could be a cost-effective solution, especially as LED technology continues to advance, allowing for higher luminous efficacy at lower power consumption and reduced maintenance costs over time.

Gordic *et al.* [11]
With street lighting costs posing a substantial financial burden for municipalities, energy efficiency measures are crucial. Recent research has explored various strategies to enhance energy efficiency in public lighting systems, including replacing traditional luminaires, installing LED corn bulbs, and incorporating dimming control systems. LED luminaires have proven to be energy-efficient, offering high luminous efficacy and compatibility with smart lighting systems; however, their high upfront costs can be prohibitive for many local governments. LED corn bulbs present a cost-effective alternative, particularly for retrofitting low-power high-intensity discharge lamps (e.g., HPM 125W, HPS 70W), and are economically advantageous in most scenarios, especially in regions with low electricity prices. However, the condition of existing luminaires is a key consideration, as LED corn bulbs are only suitable if the existing fixtures are well-maintained; otherwise, new, efficient luminaires are recommended. This research also highlights the potential for multi-criteria decision-making (MCDM) analysis in optimizing energy-efficient solutions for street lighting, accounting for economic, environmental, and social factors. The proposed methodology enables municipalities to conduct location-specific feasibility studies, and future research will focus on validating LED corn bulbs' photometric performance in street lighting and incorporating MCDM for sustainable decision-making.

Shailesh *et al.* [12]
With road lighting being essential to urban infrastructure and social stability, studies are increasingly focused on the potential of LED luminaires to replace traditional High-Pressure Sodium Vapor (HPSV) lighting in city streets. Although the initial cost of LED systems is higher, the long-term economic advantages, energy savings, and environmental benefits justify the investment. Compared to HPSV lights, LEDs are more efficient, providing significant savings in power consumption, reducing maintenance needs, and offering a quicker return on investment. Additionally, LED lighting’s directional nature minimizes light pollution by focusing illumination exactly where needed, thereby enhancing energy conservation. The aesthetic and functional benefits of LEDs, particularly their white light, improve visibility and contribute to perceptions of safety and security on the roads. Furthermore, integrating LED systems with solar photovoltaic (PV) modules is suggested to reduce dependency on the electrical grid, though this increases initial costs. Research indicates that switching to LED lighting not only cuts costs but also supports environmental goals by reducing emissions. These findings underscore the importance for municipalities to prioritize LED upgrades in their road lighting infrastructure to achieve economic, environmental, and social benefits.

1.2 Problem statement

The effectiveness of road lighting is heavily influenced by the photometric distribution of the lighting technology used. LEDs and High-Pressure Sodium Vapour (HPSV) lamps are commonly employed, each with distinct characteristics. LEDs offer energy efficiency, focused light, and longer lifespan, while HPSV lamps, though traditionally preferred for brightness and durability, have lower colour rendering and more diffuse light patterns, impacting visibility and energy use. The problem lies in comparing the photometric distribution of these technologies to determine which offers the best balance of safety, efficiency, and sustainability for road lighting.

1.3 Objectives

The objective of this thesis work is:

- To determine an optimum lighting solution for construction a new type of road lighting
- To save electrical energy in the road without compromising on the lighting design parameters and also without neglecting the effect on workers' health or mood
- Failure to properly established lighting design parameters may result in high capital costs and may lead to long lasting lighting design parameters.

1.4 Methodology

- Determination of photopic luminance from Luminous Intensity of Road lighting.
- Measurement of photopic road light luminance and vertical road light illuminance under cool white LED lamp and adaptation conditions.
- Determination of S/P ratios, CCT & SPD of the lamps.
- Calculation of LED and HPSV luminance
- Simulation of adaptation luminance using Evo Dia lux software.
- Comparison of the obtained results by graphical and analytical comparative studies.

1.5. Thesis Outline

In **chapter 1**, an introduction to the thesis work has been given. It also includes, problem definition, objective, methodology and organisation of the thesis.

In **chapter 2,** Introduction of Computer Aided Lighting Design to the thesis work has been given, it also includes Introduction, Historical of Lighting Design, Lighting Design Software, DIA Lux: A Comprehensive tool of Lighting Design, DIA Lux 4.13: An Overview, DIA Lux Evo: An Overview and Comparison Between DIA Lux 4.13 & DIA Lux Evo.

In **chapter 3**, Concept about Lighting designed and standard

In **chapter 4,** Used instrument details and research on Existing Road lighting .

In **chapter 5**, Result, Discussion and analysis to the thesis work has been given, it also includes producing Lighting Design for Road light Using DIA Lux. Specifications of Producing Lighting, Comparison between Existing & Producing avg. illuminations, Comparison between existing & producing overall Uniformity, Comparison between Existing & Producing Lighting Power

Density (LPD), Comparison between Existing & Producing Lighting Energy Consumption per year, Comparison between Existing & Producing Lighting Energy Cost per year.

In **chapter 6**, Conclusion of the thesis work is drawn and future scope of this work is highlighted.

At last, all the references have been given

CHAPTER 2

Street Lighting

2. Street Lighting

2.1 overview

Street lighting is critical in ensuring safe travel during nighttime, promoting security, enhancing visibility, and improving overall urban aesthetics. Understanding the theory behind street lighting, including design principles, luminance, glare management, and the types of lamps used, is essential for illumination engineers to effectively implement lighting solutions that meet safety and efficiency standards.

Street lighting is defined as the illumination provided along roadways to ensure the safe movement of vehicles and pedestrians at night. The primary objective of street lighting is to enhance visibility and comfort while reducing accidents and crime incidents. Proper street lighting design involves balancing the needs of visibility, aesthetics, and energy efficiency. It is also crucial in creating a safe environment, thereby encouraging community engagement.

The primary principles for designing street lighting schemes include the diffusion principle and the specular reflection principle. The diffusion principle uses reflectors to direct light downward, spreading it uniformly over the road surface to prevent glare and enhance visibility. Conversely, the specular reflection principle involves curved reflectors that project light at a large angle of incidence; this method is generally suited for straight road sections but may produce glare.

The main objectives of a street lighting design scheme include achieving a perfect visual sensation for safety, providing an illuminated environment for the rapid movement of vehicles, and ensuring clear visibility of objects for comfortable navigation by road users. These objectives guide the selection of lighting arrangements and equipment to meet specific conditions along various types of roads.

Several factors must be considered in street lighting design. These include the average maintained luminance level, uniformity of illumination, and glare limitation. Adequate luminance is essential for enabling road users to see and react to may obstacles safely, while uniformity helps prevent drastic changes in visibility that can be disorienting. Additionally, glare management is critical to avoid visual discomfort, which can impede the effectiveness of street lighting.

Different types of lamps are utilized in street lighting, including high-pressure sodium lamps, metal halide lamps, and low-pressure sodium lamps. Each type has unique properties regarding efficiency, colour rendering, and application suitability. Selecting the appropriate lamp type contributes to the overall effectiveness of the lighting scheme, addressing both energy efficiency and environmental impact.

Average illuminance in street lighting can be calculated using the lumen method, taking into consideration factors such as the maintenance factor and the coefficient of utilization (COU). The formula for average illuminance includes parameters for the total lumens emitted by the luminaires and the area being illuminated to ensure optimal lighting conditions on the road.

Glare is identified as a significant concern in street lighting design, categorized into disability glare and discomfort glare. Disability glare can momentarily impede a driver’s ability to see, while

discomfort glare affects visibility over an extended period. Effective glare management strategies include appropriate luminaire placement, lighting intensity adjustment, and using fixtures that control light distribution to minimize glare.

By mastering the principles and practices of street lighting design, illumination engineers contribute significantly to urban safety, energy efficiency, and the overall quality of life for road users.

2.2. Definition of Street Lighting

Street lighting refers to the provision of illumination along public roads and streets, typically achieved through lights mounted on poles or columns to enhance visibility during nighttime. Such lighting serves multiple purposes, including ensuring the safety of pedestrians and vehicles, deterring crime, and improving the overall aesthetic appeal of urban areas. Street lighting is essential for facilitating comfortable and secure movement in public spaces after dark, creating a sense of safety and connectivity within communities. In essence, street lighting is a critical infrastructure element that contributes substantially to public safety and urban environment quality.

2.3 Type of Lamp

Here is a detailed explanation of **Metal Halide (MH), Light Emitting Diode (LED), and High-Pressure Sodium Vapor (HPSV)** lamps, focusing on their characteristics, advantages, and common applications in street lighting and other areas.

3.3.1. Metal Halide (MH) Lamps

Overview: Metal halide lamps are a type of high-intensity discharge (HID) lamp. They generate light by passing an electric arc through a mixture of gases, including vaporized mercury and metal halides (compounds of metals with halogen elements). These lamps are known for their bright, white light.

Lumen Output: Metal halide lamps produce a high amount of lumens per watt (ranging from 75 to 100 lumens per watt). This makes them efficient compared to older incandescent or fluorescent bulbs, but they are less efficient than LEDs.

- Colour Rendering Index (CRI): MH lamps have a high CRI (60-90), meaning they provide better colour accuracy and quality of light compared to HPSV lamps, which tend to produce yellow or orange light.
- Lifespan: Metal halide lamps have a moderate lifespan of about 10,000 to 20,000 hours. However, they tend to lose their brightness (lumens) significantly over time, with some dropping up to 50% before reaching the end of their life.
- Warm-up Time: These lamps take time to reach full brightness (several minutes), which can be a disadvantage in applications where immediate lighting is required.
- Common Applications: Metal halide lamps are often used in street lighting, stadiums, parking lots, and other large outdoor areas where bright white light is required.

Advantages:

- Good light quality (high CRI) with natural-looking colours.
- High lumen output, suitable for large outdoor spaces.

Disadvantages:

- Significant loss of brightness over time.
- Long warm-up period.
- Higher energy consumption compared to LEDs.

Fig no-3.3.1: Metal Halide (MH) Lamps

3.3.2. Light Emitting Diode (LED) Lamps

Overview: LEDs are solid-state lighting devices that convert electrical energy directly into light. They have become increasingly popular due to their high energy efficiency, long life, and versatility.

- Lumen Output: LEDs produce 80-150 lumens per watt or more, making them the most energy-efficient lighting technology available. The lumen output can vary depending on the design and application, but they are typically more efficient than both MH and HPSV lamps.
- Colour Rendering Index (CRI): LEDs have a high CRI (typically 70-90), providing excellent colour rendering and a variety of colour temperature options (cool white, warm white, daylight). This makes them suitable for applications where accurate colour perception is important, such as urban streets and residential areas.
- Lifespan: LEDs can last 50,000 to 100,000 hours, making them the longest-lasting lighting option. Unlike MH or HPSV, LEDs do not suffer a drastic reduction in brightness over time, maintaining a consistent output for most of their life.

- Instant On/Off: LEDs provide full brightness instantly, with no warm-up time needed, which is highly advantageous for street lighting and other public spaces that need immediate illumination.
- Dimming Capability: LEDs are easily dimmable and compatible with smart lighting systems, allowing for adaptive lighting controls to save energy during off-peak hours.
- Common Applications: LEDs are now widely used in street lighting, parking lots, outdoor areas, and indoor commercial and residential settings due to their superior efficiency and long lifespan.

Advantages:

- Extremely energy-efficient (high lumens per watt).
- Long lifespan with minimal lumen depreciation.
- No warm-up time; instant-on functionality.
- Lower maintenance costs over time.
- Dimmable and compatible with smart lighting controls.

Disadvantages:

- Higher initial cost compared to traditional lighting technologies.
- Light pollution concerns (can be mitigated with proper shielding and colour temperature control).

Fig no-3.3.2: Light Emitting Diode (LED) Lamps

3.3.3. High Pressure Sodium Vapor (HPSV) Lamps

Overview: High pressure sodium vapor (HPSV) lamps are also a type of HID lamp. They are known for their characteristic orange or yellow light. HPSV lamps are widely used in street lighting because of their energy efficiency, despite their poor colour rendering.

- Lumen Output: HPSV lamps have an efficient lumen output, ranging from 80 to 150 lumens per watt. This makes them comparable to LEDs in terms of raw efficiency, although LEDs often outperform them in practical applications.
- Colour Rendering Index (CRI): HPSV lamps have a low CRI (around 20-30), meaning they provide poor colour rendering. Objects lit by HPSV light appear yellowish or monochromatic, making it harder to distinguish colours at night. This can be problematic for areas requiring clear visibility.
- Lifespan: HPSV lamps generally have a long lifespan, ranging from 24,000 to 30,000 hours. However, like MH lamps, they lose brightness over time, typically reducing their lumen output by 10-20% over their lifetime.
- Warm-up Time: Similar to MH lamps, HPSV lamps require several minutes to reach full brightness after being turned on, making them less practical for situations where instant light is needed.
- Common Applications: HPSV lamps are widely used in street lighting, highway lighting, parking lots, and industrial lighting. They are favoured in areas where colour accuracy is less important but efficiency and low operating costs are priorities.

Advantages:

- High energy efficiency, especially compared to older technologies.
- Long lifespan with relatively low maintenance costs.
- Suitable for large outdoor spaces with minimal colour requirements.

Disadvantages:

- Poor colour rendering (yellow/orange light).
- Long warm-up period before reaching full brightness.
- Lumen depreciation over time.

Fig no-3.3.3: High Pressure Sodium Vapor (HPSV) Lamps

Summary Table:

Feature	Metai Halide (MH)	LED	High Pressure Sodium (HPSV)
Lumen out (per watt)	75-100 lumens/watt	80-150 Lumens/watt	80-150 Lumens/watt
Colour Rendering (CRI)	60-90 (good)	70-90 (Excellent)	20-30 (Poor)
Lifespan	10,000-20,000 hours	50,000-100, 000 hours	24,000-30,000 hours
Warm-up time	Several minutes	Instant	Several minutes
Efficiency	Moderate	Hight	Hight
Initial Cost	Moderate	Hight	Moderate
Light Colour	White	Varied (White, Warm, cool)	Yellow/Orange

- LED lamps are increasingly becoming the preferred choice for street lighting due to their emergy efficiency, long lifespan, excellent colour rendering, and smart control capabilities.
- Meta Halide lamps provide high quality white light but are being phased out due to shorter lifespan and higher maintenance costs.
- High pressure sodium vapor lamps are still used in some areas where energy efficiency is needed but colour rendering is less important.

2.4 Street type

2.4.1. Residential Streets

Residential street lighting typically focuses on providing sufficient illumination to ensure safety, visibility, and aesthetic appeal in neighbourhood environments. Here are some common elements often found in residential street lighting:

1. Design: Street lamps are often designed to blend with the surrounding architecture. They are shorter in height than highway lights, typically around 10-20 feet. Traditional styles include post-top luminaires with decorative features like lantern-shaped or globe fixtures.
2. Light Sources: LED lights have become the standard due to their energy efficiency and long lifespan. The light is often warm or neutral to provide pleasant ambiance, typically ranging between 3000K and 4000K.
3. Placement: Poles are generally spaced evenly along streets, often staggered on opposite sides. The goal is to avoid dark spots while not creating excessive brightness that might disturb residents.
4. Energy Efficiency: Solar-powered options are also becoming popular in some neighbourhoods for sustainability.

Fig no: 3.4.1. Residential Streets

2.4.2. Arterial Roads

Arterial roads are major thoroughfares designed to handle high traffic volumes, connecting different areas of a city or town. Lighting for these roads is crucial to ensure safety and efficient traffic flow, especially at night. Key characteristics of arterial road lighting include:

Height and Placement: Streetlights on arterial roads are taller, typically ranging from 30 to 50 feet, and are spaced farther apart compared to residential lighting. They are often mounted on poles positioned along the road medians or sides to provide consistent illumination.

Light Intensity: The light is usually brighter and more uniform to improve visibility for drivers. LEDs are commonly used for their high efficiency and low maintenance.

Design: Functional and minimalist, focusing on maximum light coverage with minimal glare or light pollution.

Safety Considerations: Lighting is positioned to minimize shadows, especially at intersections, pedestrian crossings, and bus stops.

Collector Roads**:** Intermediate roads that connect residential streets to arterial roads, needing moderate lighting levels.

2.4.3. Pedestrian Areas

For pedestrian areas, lighting is essential for safety, security, and ambiance. Key characteristics of lighting in these areas include:

1. Low Height: Pedestrian lighting poles are typically shorter (around 10-15 feet) to provide closer and more focused illumination, ensuring sidewalks and paths are well-lit.

2. Soft, Warm Lighting: The lights are often designed to create a welcoming and comfortable atmosphere, with a softer glow (usually around 3000K) to avoid harshness while maintaining visibility.
3. Decorative Fixtures: Pedestrian areas often feature more decorative lighting fixtures, such as lanterns or vintage-style lamps, to enhance the environment's aesthetic appeal.
4. Energy Efficiency and Sustainability: Solar-powered and energy-efficient LED lights are frequently used in these areas.

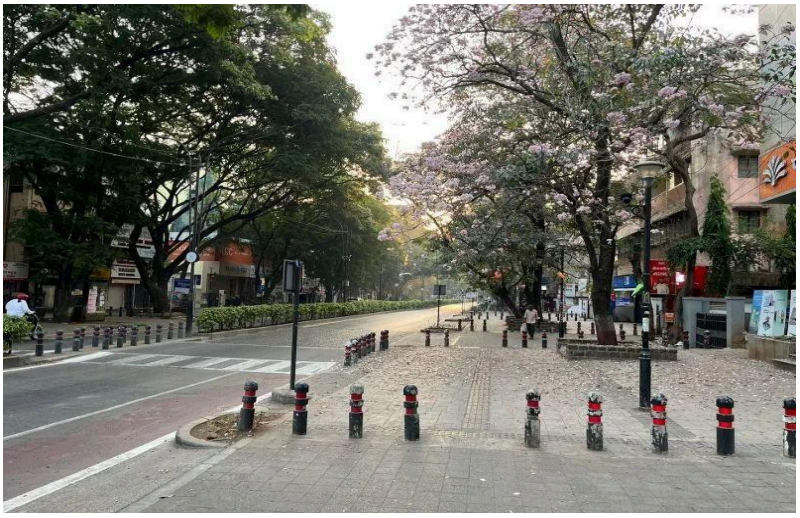


Fig no-3.4.3: pedestrian areas for safety, & security

3.4.4. Collector Roads: These roads serve to gather traffic from local streets and funnel it onto arterial roads. Collector roads balance accessibility with moderate traffic flow, making them important for moving vehicles from residential areas to main roads.

Key Characteristics of Collector Roads

- Purpose: Collector roads gather traffic from local streets (such as residential areas) and direct it to arterial roads, making them a key link in the network for managing neighborhood and city traffic flow.
- Traffic Volume: They handle moderate traffic volumes compared to arterial roads, accommodating vehicles from residential areas, commercial zones, and small businesses.
- Speed Limits: Collector roads have moderate speed limits, generally between those of local streets and arterial roads. Speed is often controlled through signage, road width, and sometimes traffic-calming measures.
- Design: These roads typically have two lanes but may include additional lanes or turn lanes at intersections. Some collector roads include bicycle lanes, pedestrian sidewalks, or crosswalks to enhance safety.

Examples of Collector Roads

- Streets connecting residential neighborhoods to major roads in a city or town.
- Roads around school zones, parks, or public amenities that connect to main roads.

Lighting for Collector Roads

Lighting on collector roads is designed to provide visibility for drivers, pedestrians, and cyclists, enhancing safety. Standards usually dictate a balance between sufficient brightness and minimizing light pollution, often with LED streetlights spaced for optimal coverage.

Fig no. 3.3.4. Collector Roads

3.4.5 Expressways/Highways High-speed, high-capacity roads that connect major regions and cities. They are typically limited-access, with controlled entry and exit points, and are designed for long-distance travel.

Key Characteristics of Expressways/Highways

- Purpose: Expressways facilitate the rapid movement of people and goods over long distances. They connect cities, regions, and major economic areas, reducing travel time and congestion on smaller roads.
- Traffic Volume and Speed: These roads are built to handle high traffic volumes, typically with speeds of 55-70 mph (90-120 km/h) or more, depending on location and regulations. Speed limits are higher on expressways to support long-distance travel efficiency.
- Controlled Access: Expressways are limited-access roads, meaning entry and exit are restricted to designated points, usually through interchanges with ramps. This setup eliminates traffic signals and minimizes intersections, enhancing safety and allowing for uninterrupted traffic flow.

Expressways and highways are major road types designed for high-speed, long-distance travel. They prioritize efficiency, safety, and uninterrupted traffic flow and are essential for connecting cities, regions, and even countries.

Lighting for Expressways and Highways

Lighting on expressways and highways is crucial for night travel, enhancing visibility and safety. Typically, lighting is:

- Uniform: Ensuring consistent lighting across lanes to prevent glare or shadowing.
- Bright but Efficient: Using high-output LED or high-pressure sodium lights to illuminate long stretches while reducing power consumption.
- Spaced for Optimal Coverage: Often placed at greater intervals than in urban roads, targeting interchanges, ramps, and complex areas.

3.4.6 Service or Access Roads These roads run parallel to major roads, providing access to adjacent properties without disrupting main road traffic. They are commonly found near commercial or industrial areas.

Examples of Service/Access Roads

- Roads running parallel to highways that provide access to roadside hotels, restaurants, and gas stations.
- Access roads in commercial areas, which serve shopping plazas, restaurants, and parking areas without forcing vehicles to exit directly onto a major road.
- Residential access roads that connect homes located along a busy main road but maintain a lower-speed environment.

3.4.7 Lighting on Service/Access Roads

Lighting for service roads is generally less intense than on highways or arterial roads but is designed to ensure safety for pedestrians, cyclists, and vehicles accessing nearby properties. Key considerations include:

- Uniform Lighting: Provides consistent visibility for drivers accessing properties, businesses, or other areas adjacent to the main road.
- Pedestrian Safety: Lighting often emphasizes crosswalks, sidewalks, and pedestrian-heavy zones.
- Glare Reduction: To avoid affecting drivers on the adjacent highway or arterial road, service road lighting is designed to minimize glare.

Fig no: 3.4.7 Lighting on Service

Chapter 3:

Lighting design

3.1 Conventional Lighting Design

Uniformity and Luminance: Lighting levels are designed to ensure consistent brightness across the roadway, reducing dark spots and providing uniform light distribution. Standards like the IES (Illuminating Engineering Society) and CIE (International Commission on Illumination) provide guidelines on the minimum luminance required for different road types.

Conventional Lighting design is the comprehensive process of planning, implementing, and optimizing light systems in a space to ensure adequate illumination, safety, energy efficiency, and visual appeal. Here is a detailed look at the different elements of lighting design, especially as it applies to street lighting and public spaces.

3.1.1. Lighting Design Principles

Functionality: The primary goal of lighting is to ensure proper visibility for intended activities, whether driving, walking, or enhancing security.

Aesthetics: Lighting affects the mood and appearance of a space, highlighting architectural features or landscapes. In urban environments, the aesthetics of street lighting can define a city's nighttime identity.

Energy Efficiency: Modern lighting designs aim to minimize energy consumption through advanced technologies like LED fixtures, solar power, and smart lighting controls.

Safety and Security: Well-lit areas reduce accidents, crime, and enhance the perception of safety in both public and private spaces.

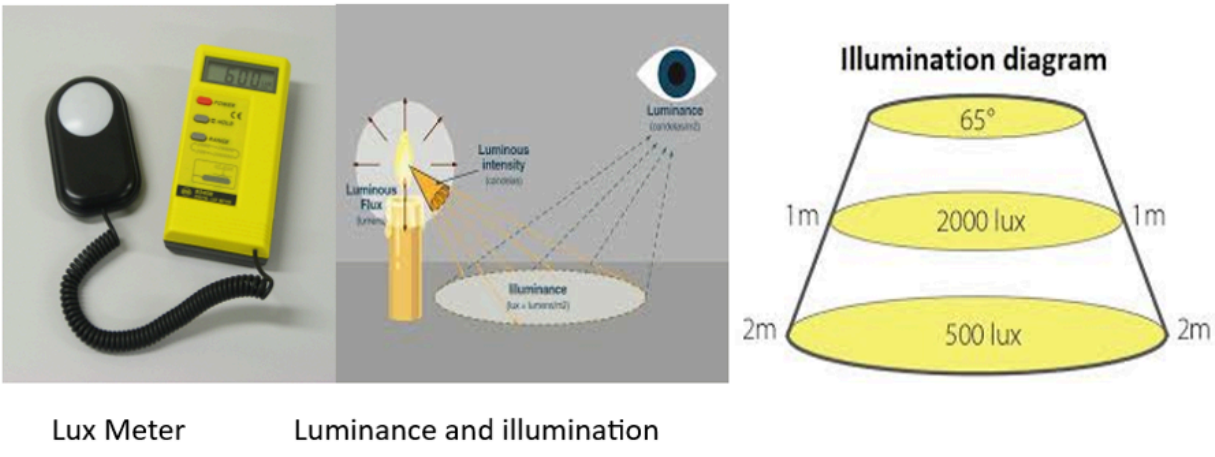
3.1.2. **Illuminance and Luminance Levels**

Illuminance (Lux)**:** The amount of light that hits a surface (lumens per square meter). Street lighting must meet certain lux levels based on road classification and activity.

Residential Streets: ~3-10 lux

Arterial Roads: ~20-30 lux

Pedestrian Areas: ~5-15 lux



Lux Meter Luminance and illumination

Fig no-3.1.2: Lux Meter & Luminance and illumination

Luminance (cd/m²)**:** The brightness of the light seen by an observer, which impacts how well people can see objects or surfaces. Proper luminance levels help improve visibility for drivers and pedestrians.

3.1.3. **Types of Lighting Technologies**

LED (Light Emitting Diodes)**:** LEDs dominate street lighting because of their energy efficiency, long lifespan, low maintenance, and good colour rendering. They provide:

Energy savings (up to 60% compared to traditional lighting)

Long operational life (50,000 hours or more)

Lower light pollution due to focused beams

Fig no-3.1.3: LED (Light Emitting Diodes)

High-Pressure Sodium (HPS): Older Street lighting technology, known for its characteristic yellow glow. Though efficient, it lacks good colour rendering (making it harder to distinguish colours at night).

Induction Lighting: Used in some applications but less common now due to LED advancements. These are long-lasting but have been largely replaced by LEDs.

Fig no-3.1.3: High-Pressure Sodium (HPS)

3.1.4. **Lighting Design Parameters**

Uniformity Ratio**:** A measure of how evenly light is distributed. It's the ratio between the average and minimum illumination levels.

High uniformity**:** Results in consistent lighting across the surface, reducing dark spots.

Low uniformity**:** Creates uneven lighting, which can lead to areas of poor visibility.

Glare Control**:** Glare is unwanted light that can cause discomfort or reduce visibility. Glare can be minimized using luminaires designed with proper shielding and directional lighting.

3.1.5. **Road and Area Classification**

Residential Roads**:** These roads are typically less trafficked and require softer, warmer lighting with shorter poles (6-8 meters). The focus is on comfort, aesthetics, and safety for residents and pedestrians.

Arterial Roads**:** These are high-traffic roads that need higher illumination levels (20-30 lux). Poles are taller (9-12 meters) with cooler lighting to improve visibility for fast-moving vehicles.

Collector Roads**:** These roads fall between residential and arterial roads, requiring moderate lighting levels and spacing.

Pedestrian Areas**:** Lighting here is crucial for both visibility and creating a safe environment. Typically, lighting is diffused with softer, more uniform illumination to ensure comfort without harsh glare.

3.1.6. **Types of Light Distribution**

Type I Distribution**:** Best for narrow paths like sidewalks, providing lateral distribution of light.

Type II Distribution**:** Suitable for wider paths and walkways.

Type III Distribution**:** Used for parking lots or areas where a wide light spread is needed.

Type IV Distribution**:** Focused on one direction, used for perimeter lighting along large buildings or fences.

Type V Distribution**:** Provides circular light distribution, ideal for open areas like plazas or intersections

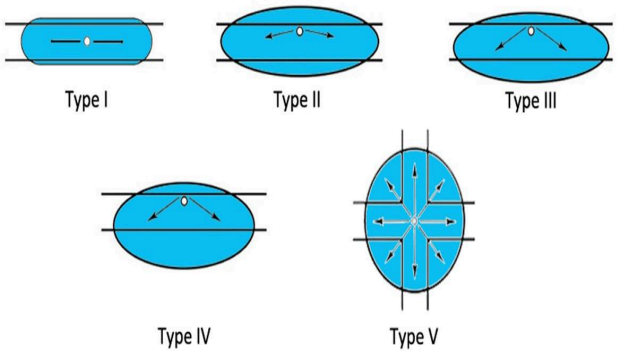


Fig no-3.1.6: Types of Light Distribution

3.1.7. **Mounting Height and Pole Design**

Pole Height: Varies based on the area and type of road. Taller poles (9-12 meters) are used for highways and arterial roads, while shorter poles (6-8 meters) are better suited for residential streets and pedestrian zones.

Pole Spacing: The distance between poles must be calculated to ensure proper light coverage without dark spots or excessive overlap. For example:

Highways: Poles are spaced farther apart (40-50 meters)

Residential streets: Poles are closer together (20-30 meters)

Fig no-3.1.7: Mounting Height and Pole

3.1.8. **Lighting Controls and Smart Systems**

Dimming Controls: Dimming lights during off-peak hours can save energy without compromising safety.

Motion Sensors: Lights can brighten or dim based on motion detection, reducing energy consumption during periods of low activity.

Smart Lighting: Internet of Things (IoT) technologies enable remote control of street lights, allowing for real-time adjustments, monitoring, and energy optimization.

Adaptive Lighting: The system adjusts brightness based on ambient conditions (time of day, weather, or traffic levels).

3.1.9. **Environmental Considerations**

Light Pollution: Poorly designed lighting can contribute to skyglow, affecting wildlife and disrupting natural cycles. Proper luminaire design and focused lighting reduce unnecessary light spillage.

Energy Efficiency: Using energy-efficient lighting, such as LEDs and smart controls, is a key component of sustainable design. Solar powered street lights are also being adopted to harness renewable energy.

Material Use: Designing with durable, recyclable materials for poles and fixtures promotes sustainability.

3.1.10. **Aesthetic Integration**

Architectural Lighting: In urban areas, lighting is often used to highlight buildings, landmarks, and public spaces. Architectural lighting balances functionality with visual appeal, creating a vibrant night-time environment.

Landscaping and Accent Lighting: Beyond streets, lighting can enhance parks, pedestrian walkways, and other urban areas by accentuating landscaping or water features, creating an inviting ambiance at night.

Chapter 4:

Case study of Design

4.1 INPUT DATA

a street lighting simulation setup, likely in a software for road lighting design. It shows a road segment with a series of lights on either side

1. Road Dimensions
    - Road Width: 20 meters (e.g., 3 lanes, each 4 meters wide)
    - Road Segment Length**:** 100 meters
2. Lighting Pole Information
    - Pole Height: 9 meters
    - Pole Spacing: 25 meters between poles
    - Pole Arrangement**:** Opposite (poles on both sides of the road, directly across from each other)
3**.** Lamp Specifications
    - Lamp Type: LED
    - Luminous Flux: 12,000 lumens per lamp
    - Lamp Colour Temperature: 4000K (neutral white)
    - Lamp Tilt Angle**:** 5 degrees (tilted slightly towards the road)
4. Road Surface Reflectance
    - Surface Material: Asphalt
    - Reflectance Factor: 0.15 (15% reflectance typical for asphalt)
5. Environmental Conditions
    - Ambient Light Level: 0 lux (assumes no surrounding light sources)
    - Weather Conditions**:** Clear
6. Observation Points
    - Measurement Grid: Points every 2 meters along the length and width of the road
    - Observer Height: 1.5 meters (approximate eye level for a seated driver)
7. Standards and Requirements
    - Illumination Level Standard: 20 lux minimum average (for urban arterial roads)
    - Uniformity Ratio (Emin/**Eavg):** 0.4 minimum

- DRAWING OF THE ROAD AREA GIVING PLAN AND POLE ELEVATION

The plan of the HPSV, MH, LED, street lighting design as shown in Fig no. 4.1, 4.2, 4.3, provides the width, and height of the area. It also gives information about the type of pole height and whether there are any constraints in locating the luminaire.

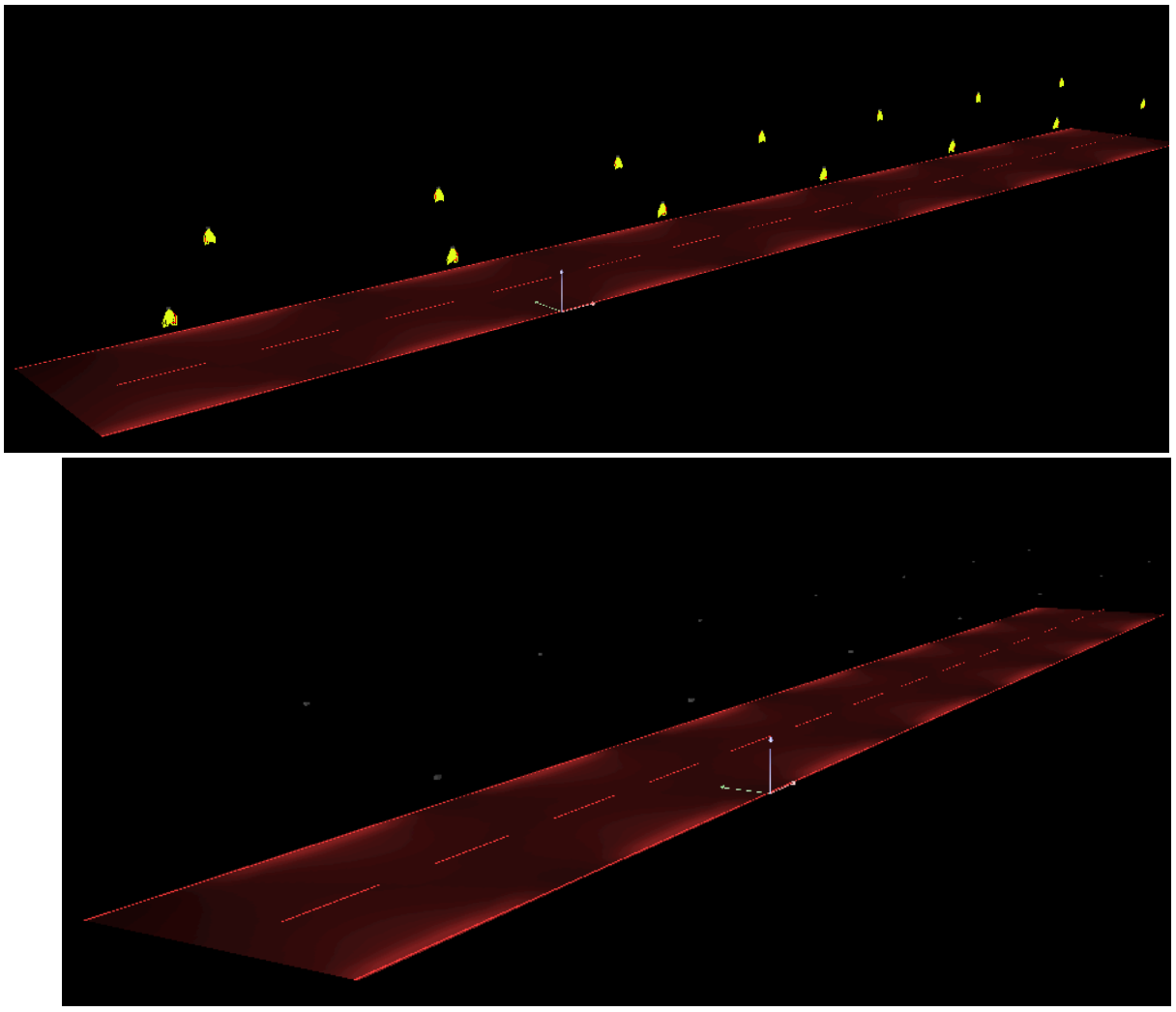
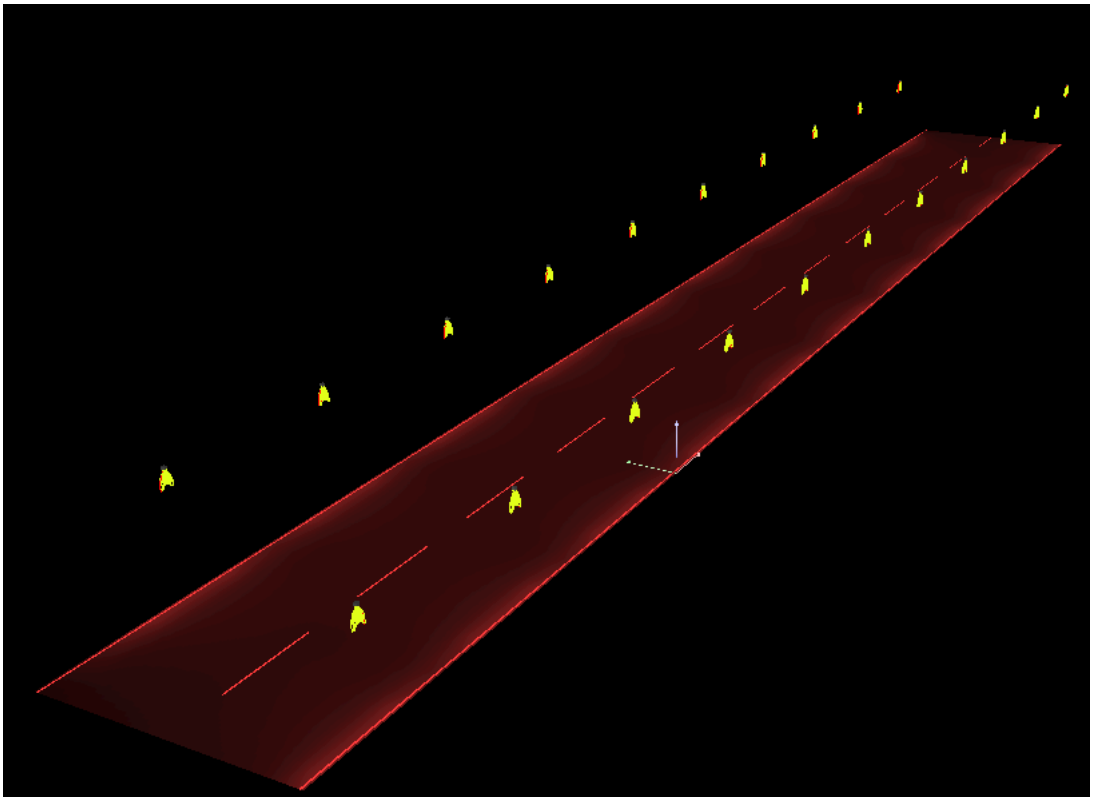


Fig no-4.1Plan of the HPSV lamp 3D light distribution and Floor plan display design



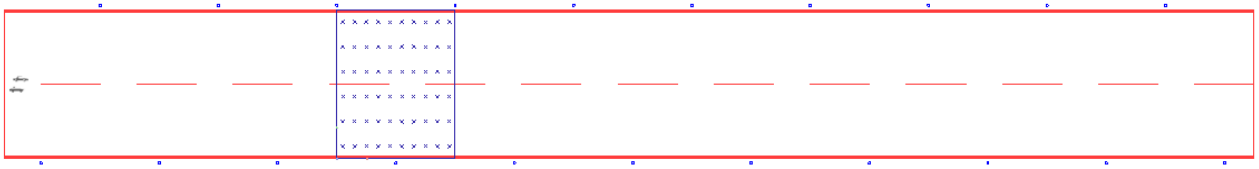
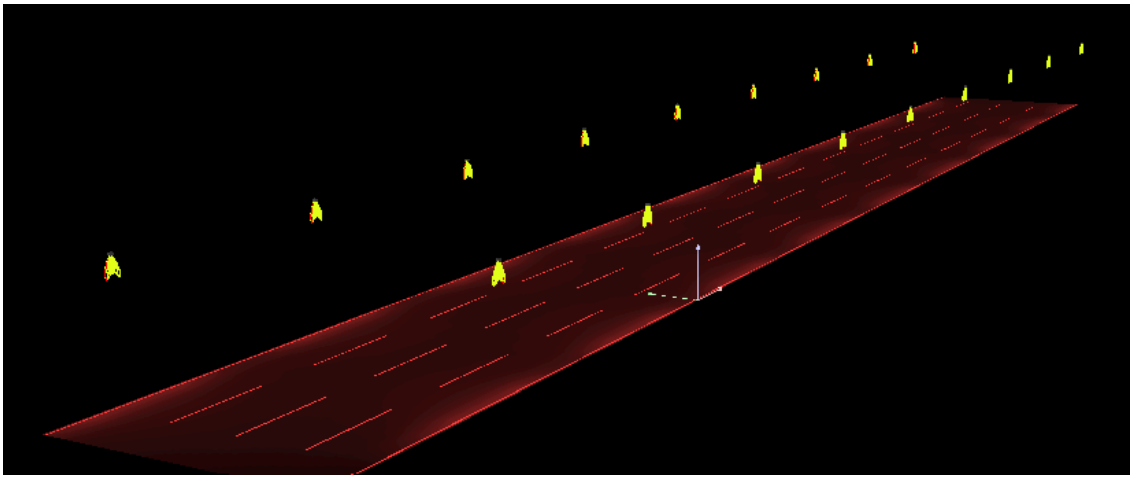


Fig no-4.2 plan of the Metal Halide lamp (MH) 3D light distribution and floor plan design



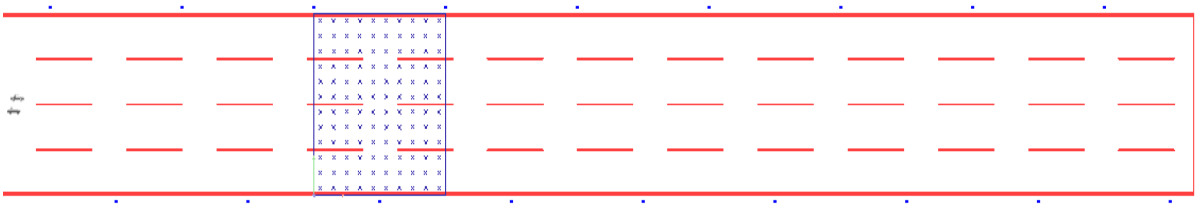


Fig no-4.3 plan of the Light Emitting diode (LED) lamp 3D light distribution and floor plan design

• REFLECTION PROPERTIES OF THE SURROUNDINGS

This data helps in deciding the reflectance of the Road width and pole height. According to National Lighting Code 2010, the reflectance values for major interior surfaces are considered as follows.

Road width: 20 m

Pole height: 9 m

• TASK TO BE PERFORMED

This helps in deciding the illumination level and glare limitation value for the particular type of application from the standards.

• HEIGHTS and weight OF TABLES AND WORK spaces

This helps in positioning luminaires and also determining the workplan height. Generally, it is taken as Road Weight 20 meter and Pole Height 9 meter road spaces.

• INTERACTION OF DAYLIGHT

It helps in determining the dimming pattern for the luminaires

4.2 DESIGN CONSIDERATIONS

All the considerations for the **HPSV** design are given in **Table no**: 4.2.1 Some of these considerations are as per standards, some of them are input from Average luminance and some of them are assumptions.

Street 1 / Valuation Field Roadway 1 / Observer 1 / **Table (L)**

18.333	1.68	1.36	0.80	0.57	0.61	1.00	2.52	2.05	2.13	1.98
15.000	0.67	0.62	0.56	0.55	0.58	0.70	0.64	0.63	0.65	0.66
11.667	0.42	0.42	0.43	0.42	0.45	0.51	0.45	0.41	0.42	0.41
8.333	0.38	0.39	0.40	0.40	0.41	0.42	0.41	0.39	0.39	0.40
5.000	0.47	0.54	0.53	0.57	0.61	0.59	0.53	0.42	0.41	0.43
1.667	0.63	0.86	1.41	1.94	1.85	1.76	1.44	0.96	0.91	0.55
m	**1.300**	**3.900**	**6.500**	**9.100**	**11.700**	**14.300**	**16.900**	**19.500**	**22.100**	**24.700**

Attention: The coordinates refer to the image above. Values in Candela/m².

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 5.000 m, 1.500 m)
tarmac: R3, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.78	0.49	0.67	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Table-4.2.1. HPSV Design Considerations

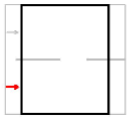
Here is a summarized overview of typical values for **High Pressure Sodium Vapor (HPSV) 250W** street lighting:

- **Average Luminance**:
    1. **30 to 70 cd/m²**
    2. This represents the typical brightness level seen from the street surface under the light.
- **Overall Uniformity (Uo)**:
    1. **0.4 to 0.6**
    2. Indicates the evenness of light distribution over the area. Lower values indicate more variation in brightness.
- **Longitudinal Uniformity (Ul)**:
    1. **0.6 to 0.8**
    2. Measures the consistency of lighting along the road's length. Higher values indicate better uniformity.
- **Threshold Increment (TI)**:
    1. **1.5% to 2.5%**
    2. Reflects the ability to perceive small changes in light, contributing to visibility for drivers and pedestrians.

Parameters	Value
Road dimension	As per Dialux 4.13 drawing
Road width	20.000 meter
Pole height	9.000 meter
Luminaire mounting height	9.190 meter
Light loss factor	0.67
Correction faction	1.000
Average luminance Lav [cd/m^2]	0.78
Overall university	0.49

- All the considerations for the **MH** design are given in **Table no**: 4.2.2 Some of these

Street 1 / Valuation Field Roadway 1 / Observer 1 / **Table (L)**



18.333	1.27	1.27	1.30	1.26	1.41	1.40	1.46	1.50	1.41	1.31
15.000	0.63	0.66	0.70	0.62	0.60	0.61	0.60	0.61	0.60	0.60
11.667	0.47	0.46	0.47	0.45	0.42	0.42	0.43	0.44	0.44	0.45
8.333	0.39	0.41	0.42	0.42	0.43	0.44	0.44	0.44	0.41	0.39
5.000	0.50	0.49	0.53	0.52	0.52	0.52	0.55	0.58	0.52	0.51
1.667	1.32	1.41	1.47	1.38	1.30	1.27	1.26	1.27	1.20	1.31
m	**0.800**	**2.400**	**4.000**	**5.600**	**7.200**	**8.800**	**10.400**	**12.000**	**13.600**	**15.200**

Attention: The coordinates refer to the image above. Values in Candela/m².

Grid: 10 x 6 Points
Observer Position: (-60.000 m, 5.000 m, 1.500 m)
tarmac: R3, q0: 0.070

	L_{av} [cd/m²]	U0	UI	TI [%]
Calculated values:	0.78	0.50	0.85	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

considerations are as per standards, some of them are input from Average luminance and some of them are assumptions.

Table-4.2.2 Metal Halide Design Considerations

Here are some example performance metrics for **Metal Halide** lamps in street lighting applications. These values can vary based on factors such as pole height, lamp power, spacing, and road surface reflectance,

Example Metal Halide Lighting Performance Data

1. Average Luminance (Lav)

- Typical Value: 1.0 - 1.5 cd/m² (candela per square meter)
- This is suitable for main roads, collector roads, or urban arterial roads with moderate traffic. For residential roads, the target is generally lower, around 0.5 cd/m².

2. Overall Uniformity (Uo)

- Formula: $Uo = \frac{L_{\min}}{L_{\text{avg}}}$
- Typical Value: 0.3 - 0.4

- The overall uniformity represents how evenly the light is distributed across the road surface. For Metal Halide lamps, uniformity tends to be lower than with LEDs, but values of around 0.4 are often considered acceptable for urban streets.

3. Longitudinal $Ul = \frac{L_{min}}{L_{max}}$ Uniformity (Ul)

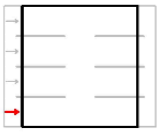
- Formula:
- Typical Value: 0.5 - 0.6
- Longitudinal uniformity assesses how evenly the light is distributed along the road in the direction of travel. Higher longitudinal uniformity helps drivers see consistently ahead. For Metal Halide lamps, values around 0.5 to 0.6 are common but can vary based on the pole arrangement and lamp spacing.

4. Threshold Increment (TI)

- Typical Value**:** 10 - 15% (lower values are better)
- The threshold increment measures the level of glare, which can reduce visibility. Metal Halide lamps, especially with older fixtures, can produce more glare than LEDs, resulting in higher TI values. A TI under 15% is generally acceptable for road safety, but values closer to 10% are preferable.

Parameters	Value
Road dimension	As per Dialux 4.13 drawing
Road width	20.000 meter
Pole height	9.000 meter
Luminaire mounting height	9.190 meter
Light loss factor	0.67
Correction faction	1.000
Average luminance Lav [cd/m^2]	0.78
Overall university	0.50

- All the considerations for the **LED** design are given in **Table no**: 4.2.3 Some of these considerations are as per standards, some of them are input from Average luminance and some of them are assumptions.



19.167	2.29	2.42	1.83	1.28	1.19	1.65	2.48	2.98	3.27	2.52
17.500	0.77	0.79	0.76	0.77	0.80	0.80	0.79	0.86	0.88	0.80
15.833	0.60	0.61	0.64	0.68	0.61	0.58	0.60	0.60	0.59	0.59
14.167	0.48	0.50	0.50	0.53	0.49	0.47	0.48	0.46	0.48	0.47
12.500	0.40	0.43	0.42	0.44	0.41	0.40	0.40	0.39	0.40	0.39
10.833	0.36	0.38	0.38	0.39	0.36	0.35	0.36	0.37	0.36	0.34
9.167	0.34	0.35	0.35	0.35	0.34	0.34	0.36	0.37	0.36	0.34
7.500	0.34	0.36	0.36	0.36	0.36	0.36	0.38	0.38	0.38	0.35
5.833	0.39	0.38	0.39	0.40	0.40	0.40	0.41	0.39	0.41	0.40
4.167	0.47	0.48	0.47	0.48	0.49	0.48	0.48	0.47	0.51	0.47
2.500	0.64	0.70	0.76	0.78	0.73	0.72	0.71	0.64	0.61	0.62
0.833	1.61	2.38	2.87	3.19	2.50	2.34	2.45	1.86	1.33	1.20
m	**0.950**	**2.850**	**4.750**	**6.650**	**8.550**	**10.450**	**12.350**	**14.250**	**16.150**	**18.050**

Attention: The coordinates refer to the image above. Values in Candela/m².

Grid: 10 x 12 Points
Observer Position: (-60.000 m, 2.500 m, 1.500 m)
tarmac: R3, q0: 0.070

	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.78	0.43	0.79	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Table no: -4.2.3 LED Design Considerations

When evaluating LED street lighting systems,

1. Average Luminance

- **Typical Value**:
    1. Residential streets: 5–10 cd/m²
    2. Arterial roads: 10–20 cd/m²
    3. Collector roads: 10–20 cd/m²
    4. Pedestrian areas: 10–30 cd/m²

2. Overall Uniformity (Uo)

1. **Formula:**
   Uo= $\frac{L_{\text{min}}}{L_{\text{avg}}}$ **Lmin** is the minimum luminance and **Lavg** is the average luminance.
2. **Typical Value:**
    1. For roads: 0.3–0.5 (ideal values for urban streets are around 0.4)
    2. For pedestrian areas: 0.5–0.7

3. Longitudinal Uniformity (Ul)

1. **Formula:** $\text{Ul} = \frac{L_{\text{min, longitudinal}}}{L_{\text{avg, longitudinal}}}$

2. **Typical Value**:

Generally, a longitudinal uniformity of 0.4–0.6 is expected for arterial roads and highways.

4. Threshold Increment (TI)

1. Formula:

TI= $\frac{\Delta L}{L_{\text{ref}}}$ where **ΔL** is the change in luminance and **Lref** is the reference luminance.

2.Typical Value:

For road lighting, a TI of 0.02–0.05 is considered acceptable for good visibility without excessive glare.

Parameters	Value
Road dimension	As per Dialux 4.13 drawing
Road width	20.000 meter
Pole height	9.000 meter
Luminaire mounting height	9.184 meter
Light loss factor	0.67
Correction faction	1.000
Average luminance Lav [cd/m^2]	0.78
Overall university	0.43

4.3 TYPES OF LAMPS AND LUMINAIRES USED

The details of the lamps and luminaires used for the design have been given in Tables 4.2 and 4.3.

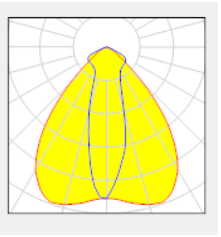
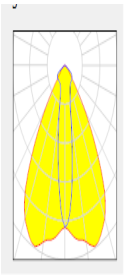
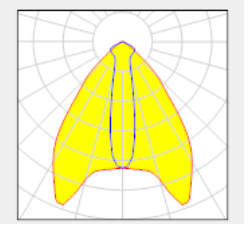
Conventional Sources Used		
	Manufacture- PHILIPS Luminaire- PHILIPS MWF330/400W Lamp- son T 400W Luminous Flux 47500lm Power- 445.0W Correction factor-1.000	
	Manufacture- PHILIPS Luminaire- PHILIPS 330/400W Lamp- HPI T 400W Luminous Flux 30500lm Power- 433.0 W Correction faction-1.000	
	Manufacture- PHILIPS Luminaire- PHILIPS MWF 330/400W Lamp- HPI T 250W Luminous Flux 17000lm Power- 270.0 W Correction faction- 1	

Table 4.2: Technical Details of Conventional Fixtures Used

4.4 DESIGN DETAILS

The design of the road with conventional and LED light fixtures was done. The design summary of more light areas, representing one or more such street areas, have been shared. It includes all the necessary input data like overall dimension of the street, light loss factor and reflectance factor, height of work plane over which the illumination level is calculated and output data like average level of illumination, overall uniformity, LPD value. It also shows an isoline diagram i.e. the points of similar illuminances joined by a contour. Details of the luminaires used for simulation is also obtained from the summary report. The luminaire coordinate lists for some areas have also been shared so as to show the position and mounting height of the luminaires. Report of illuminances on the workstations and for most occupied positions have also been given for some detailed on the road working areas.

Summary of Design Details

Feature	LED	HPSV
Colour Temperature (CCT)	3000K–6000K (adjustable)	~2000K (amber-yellow)
Colour Rendering (CRI)	80–90+ (good colour rendering)	< 25 (poor colour rendering)
Energy Efficiency	50–70% more efficient than HPSV	Less efficient, higher consumption
Luminous Efficacy	100–150 lumens per watt	70–120 lumens per watt
Lifespan	50,000–100,000 hours	20,000–24,000 hours
Maintenance	Low (due to long lifespan)	Higher (due to shorter lifespan)
Light Distribution	Directional (customizable optics)	Omnidirectional (less control)
Light Pollution	Low (controlled beam)	High (more spill light)

Chapter 5:

Result Analysis

5. Case study of a new Lighting Design in using DIA Lux 4.13

5.1. Road with Producing HPSV Lighting Design:

Road Dimension:

- Pole height: 9 m
- Road width: 20 m
- Luminaire mounting height: 9.190 m
- Distance between two poles: 16.000 m
- Boom angle: 00.0^0
- Overhang: -0.559 m
- Distance pole to roadway: 0.559 m
- Total Grid: 10x6= 60

Luminaire Used in Producing Lighting designed:

- HPSV Lights of 250 watts

DIA Lux Designed Producing Road light:

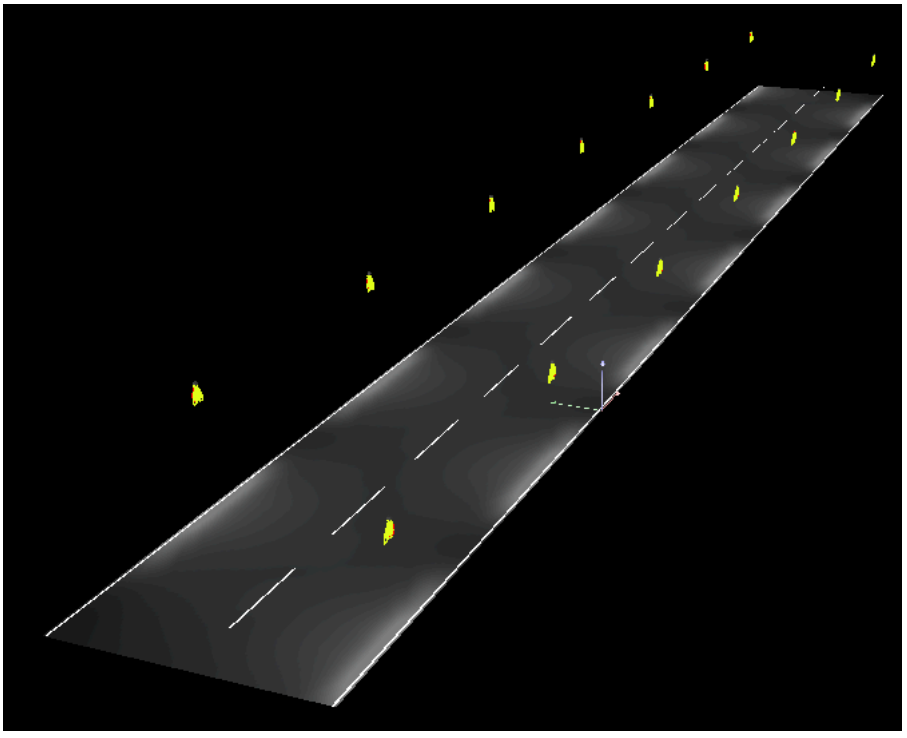
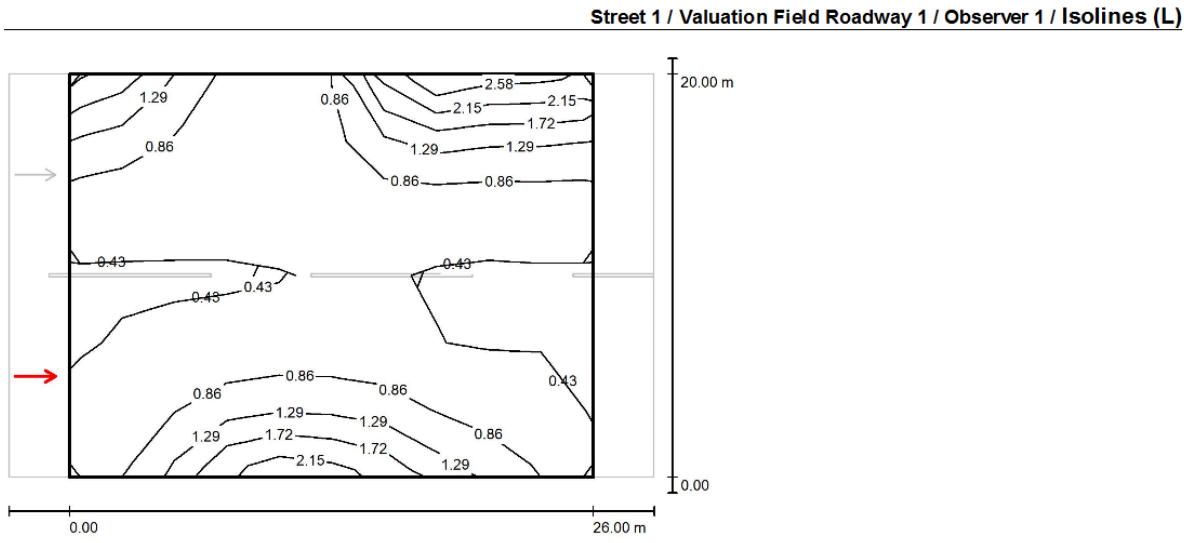


Fig no:5.1 HPSV 3D light distribution Dialux Road lighting design

- **DESIGN SUMMARY WITH CONVENTIONAL FIXTURE**
  In Fig. 4.2, the positions of the conventional fixtures for Partitioned Workstation are shown. In addition to the luminaire positions, the figure also shows Isolux lines that An HPSV (High-Pressure Sodium Vapor) Simulation Road Observer Isolines Diagram visually represents the distribution of light across a road as observed from a driver's perspective. HPSV lamps are widely used in road lighting due to their high efficiency and distinctive yellow-orange colour, although they provide limited colour rendering. This isolines diagram helps designers assess how well the light from these fixtures covers the road surface, ensuring uniformity and visibility for drivers and pedestrians.



	L_{av} [cd/m²]	U0	Ul	TI [%]
Calculated values:	0.78	0.49	0.67	2
Required values according to class ME4a:	≥ 0.75	≥ 0.40	≥ 0.60	≤ 15
Fulfilled/Not fulfilled:	✓	✓	✓	✓

Fig no:5.2 simulation Observer position isolines diagram

The values obtained throughout the room are as follows:

- Average Illuminance Value: 0.78
- Overall Uniformity: 0.49
- Longitudinal uniformity:0.67

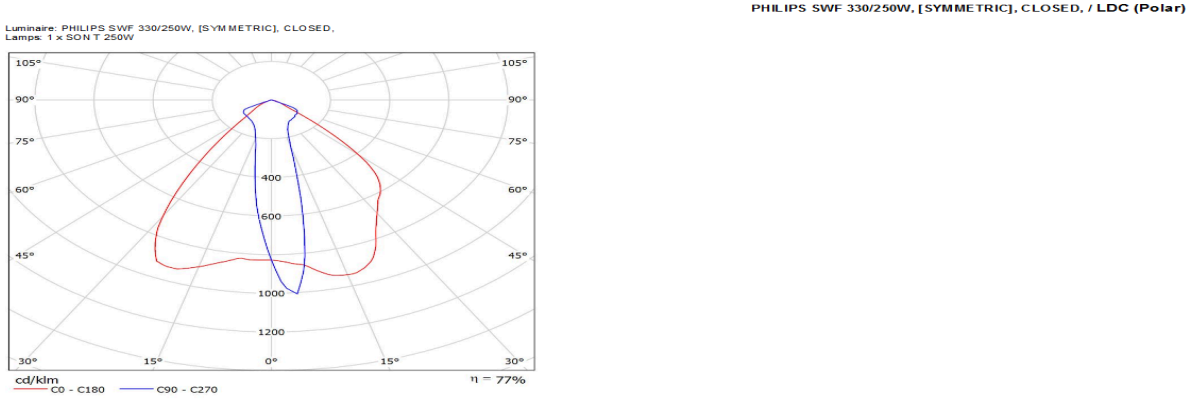


Fig no:5.3 Simulation LDC (Polar) Diagram

Fig no:5.3 A Polar Diagram is a graphical representation commonly used in Lighting Design Calculations (LDC) to show the distribution of light emitted from a luminaire (light fixture). It is especially useful for understanding the directional characteristics of a light source, such as a streetlight or a floodlight. Unlike a typical rectangular grid or iso-lux diagram, a polar diagram shows light intensity relative to different angles in a circular format.

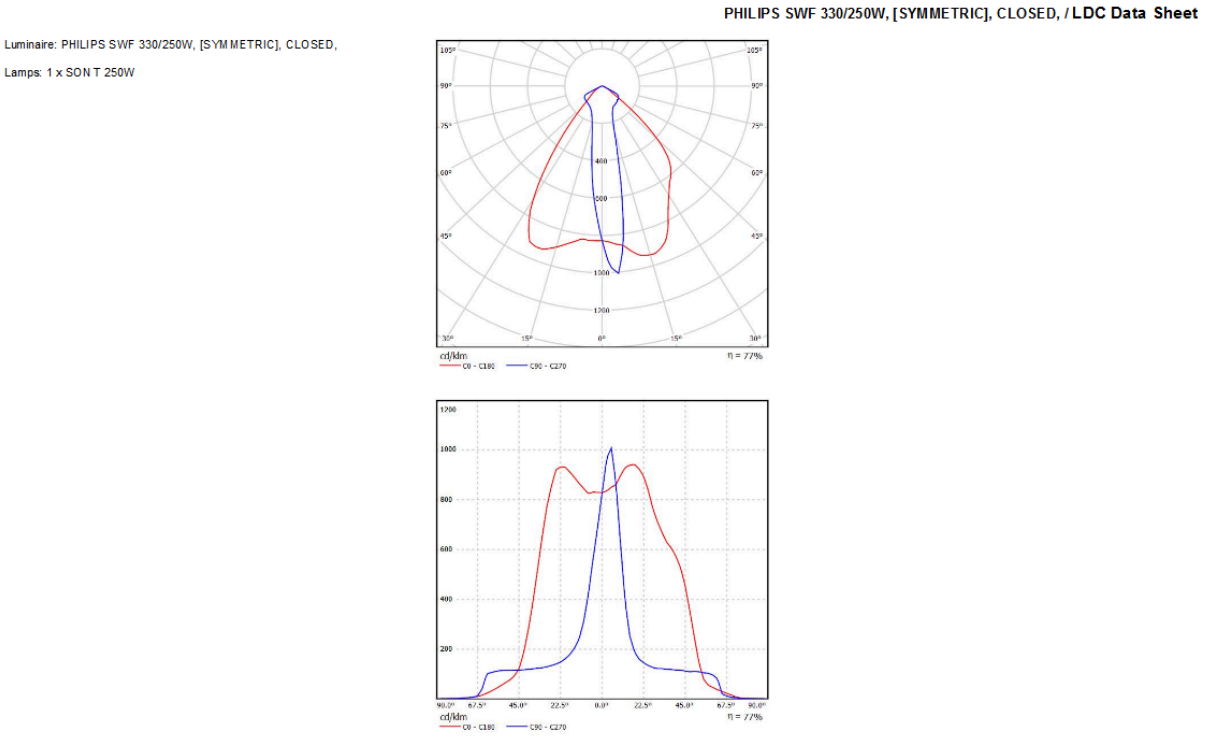


Fig no: 5.4 Simulation symmetric LDC data sheet diagram

Fig no: 5.4 A symmetrical LDC (Lighting Design Calculation) data sheet diagram is typically used to represent the output of a lighting design simulation, showing how light is distributed across a space. This is often used for street lighting, sports arenas, or other large area lighting designs.

5.2. Road with Producing Metal halide (MH) Lighting Design:

Road Dimension:

- Pole height: 9 m
- Road width: 20 m
- Luminaire mounting height: 9.190 m
- Distance between two poles: 16.000 m
- Boom angle: 0.0^0
- Overhang: -0.559 m
- Distance pole to roadway: 0.559 m
- Total Grid: 10x6=60

Luminaire Used in Producing Lighting designed:

- Metal Halide Lights of 250 watts

DIA Lux Designed Producing Road light:

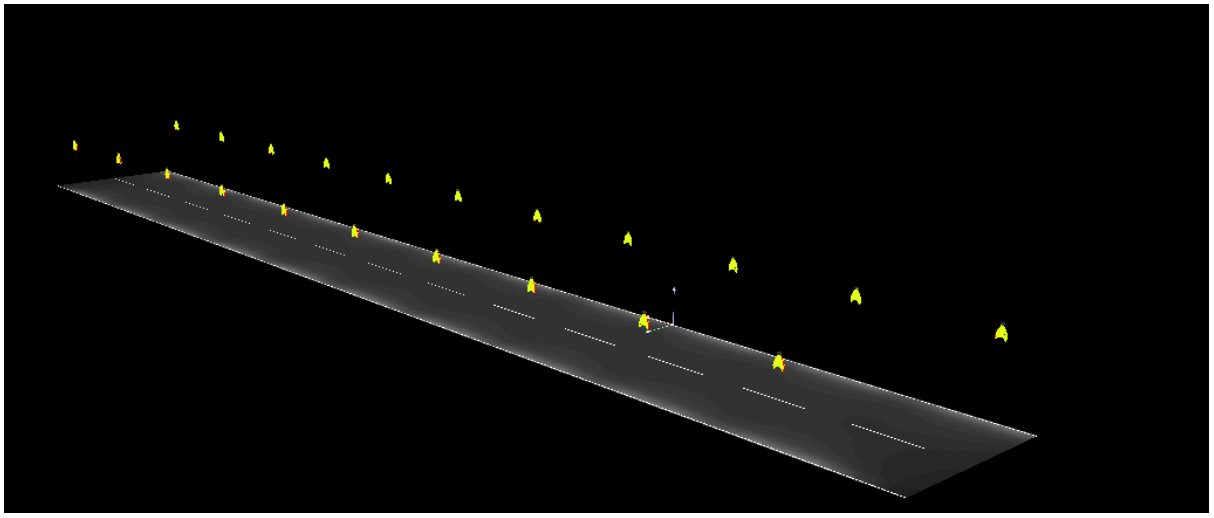


Fig no: 5.4 MH 3D light distribution Metal Halide Dialux Road lighting design

- **DESIGN SUMMARY WITH CONVENTIONAL FIXTURE**

  In Fig. 5.7, the positions of the conventional fixtures for road light isoline diagram are shown. In addition to the luminaire positions, the figure also shows Isolux lines that A Metal Halide Simulation Road Observer Isolines Diagram is used in roadway lighting design to visualize how light from metal halide fixtures illuminates a road surface, as seen from a driver's or pedestrian's viewpoint. Isolines, also called iso-lux lines, represent areas of equal light intensity (measured in lux) across the road surface. This type of diagram helps ensure uniform lighting distribution, enhances visibility, and minimizes glare for road users.

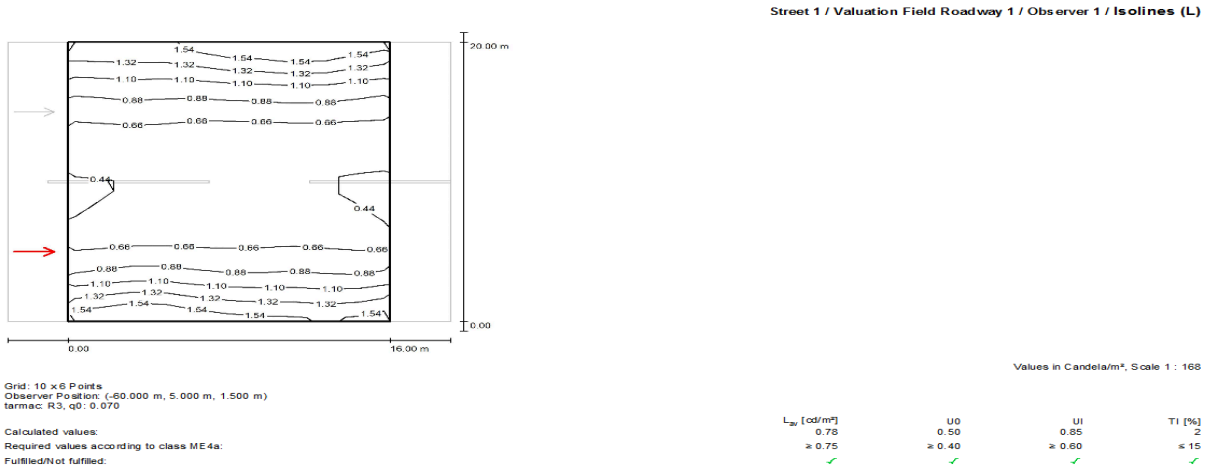


Fig no: 5.7 simulation Road Observer isolines diagram

The values obtained throughout the road are as follows:

- Average Illuminance Value: 0.78
- Overall Uniformity: 0.50
- Longitudinal uniformity:0.85

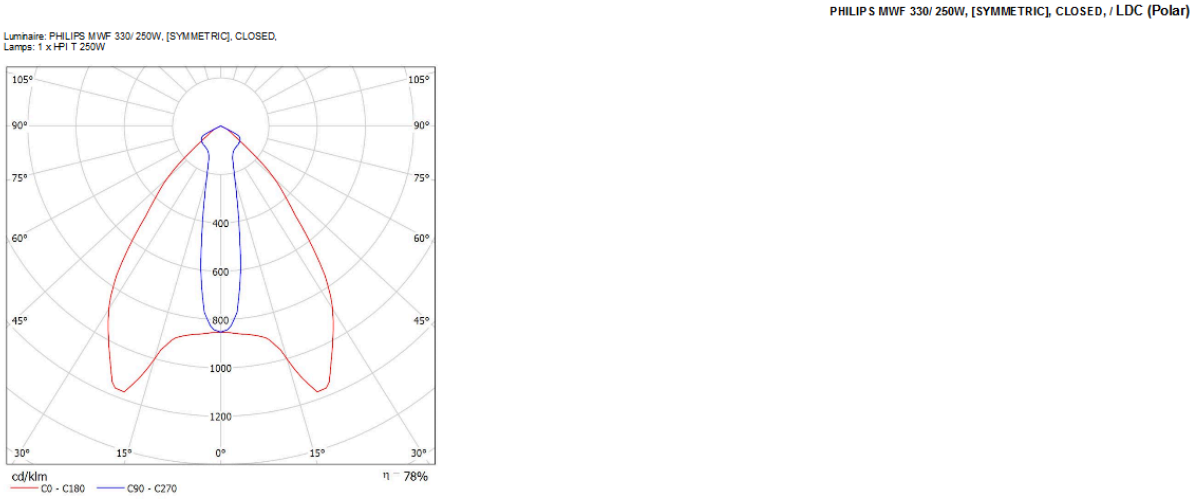


Fig no: 5.5 Symmetric LDC poler Diagram

In Fig no: 5.5 A Polar Diagram for a Metal Halide Lamp Simulation in Lighting Design Calculation (LDC) is a graphical representation of the light distribution from a lighting fixture, typically in a 360-degree view. The polar diagram displays how the light from the lamp is spread in various directions, showing the intensity of light at different angles.

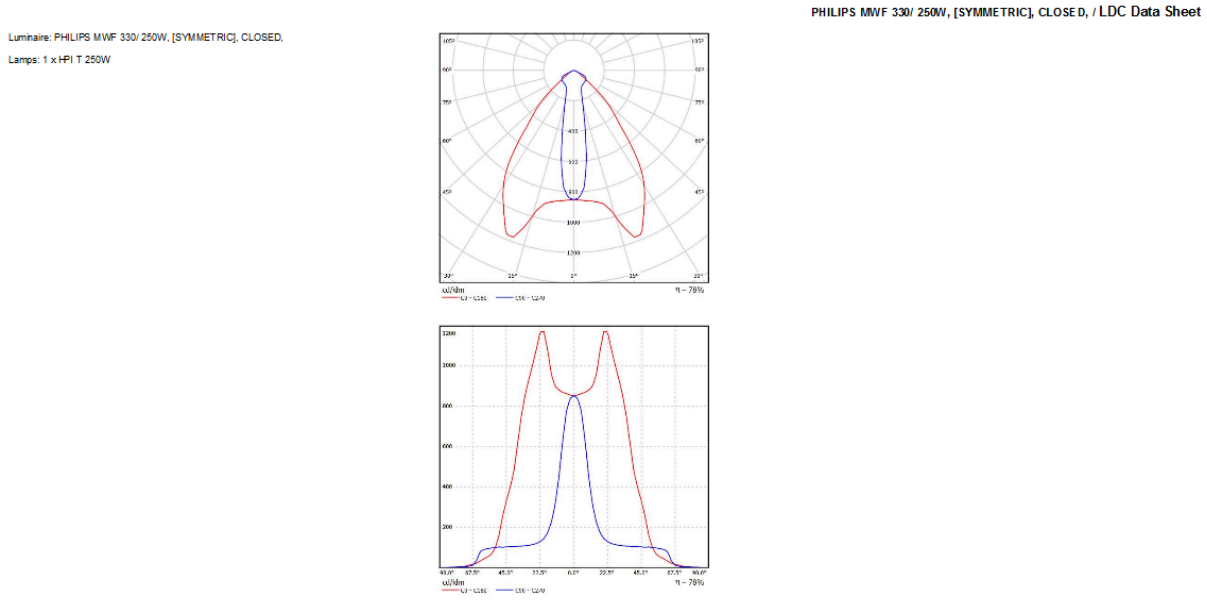


Fig no: 5.6 Simulation 4 lanes road planning diagram

In Fig no: 5.6 A Metal Halide Simulation for a 4-Lane Road Planning Diagram is a detailed visual representation of how street lighting is designed to illuminate a roadway. This type of diagram

helps urban planners and lighting designers ensure that the road is sufficiently lit while maintaining uniformity, minimizing glare, and optimizing energy use.

5.3. Road with Producing LED Lighting Design:

Road Dimension:

- Pole height: 9 m
- Road width: 20 m
- Luminaire mounting height: 9.184 m
- Distance between two poles: 19.000 m
- Boom angle: 1.0^0
- Overhang: -0.650 m
- Distance pole to roadway: 0.653 m
- Total Grid: 10x12=120

Luminaire Used in Producing Lighting designed:

- Light emitting diode (LED) Lights of 250 watts

DIA Lux Designed Producing Road light:

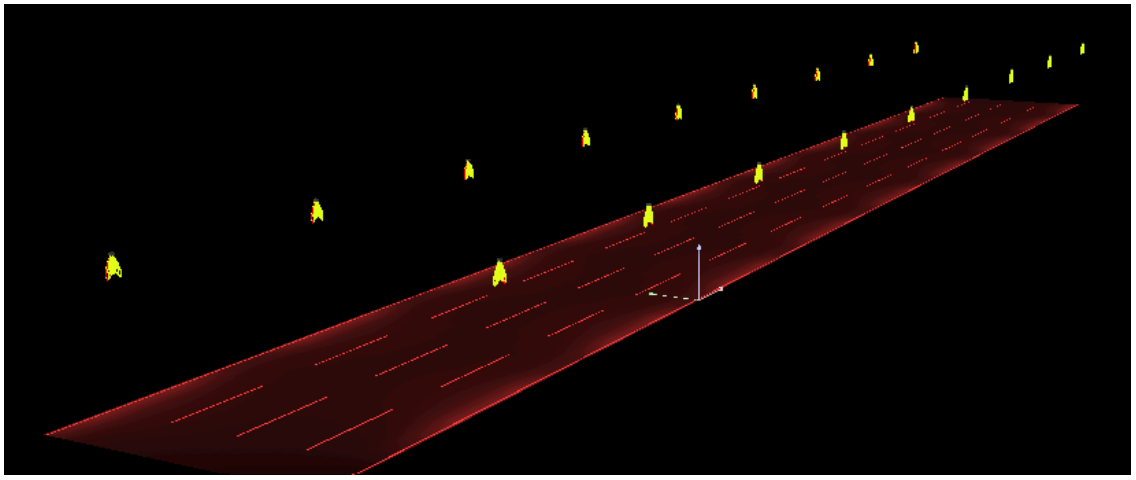


Fig no: 5.8 LED 3D light distribution Dialux road lighting design

- **DESIGN SUMMARY WITH CONVENTIONAL FIXTURE**

In Fig. 5.9 the positions of the conventional fixtures for road are shown. In addition to the luminaire positions, the figure also shows Isolines that An LED Simulation Road Observer Isolines Diagram for road lighting is a visual representation that shows illuminance levels (measured in lux) on a roadway surface, from the perspective of an observer (e.g., a driver). This type of diagram uses isolines contour lines that connect points of equal light intensity on the road surface to help lighting designers visualize and ensure that the illumination meets safety standards for visibility and uniformity.

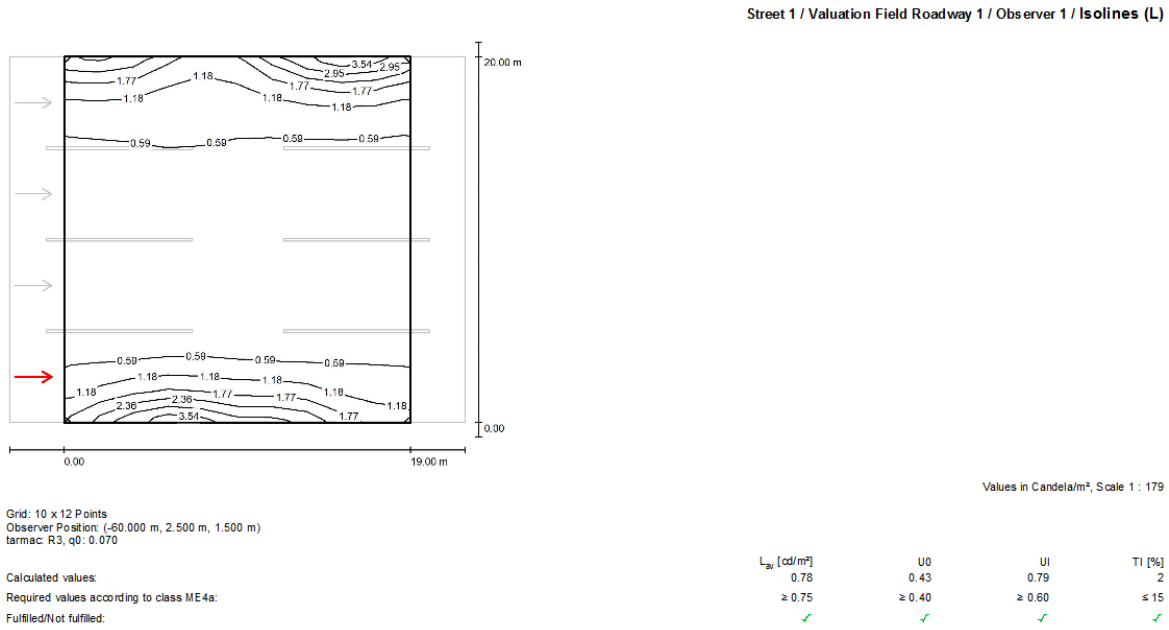


Fig no:5.9 Simulation Road observer Isolines diagram

The values obtained throughout the road are as follows:

- Average Illuminance Value: 0.78
- Overall Uniformity: 0.43
- Longitudinal uniformity:0.79

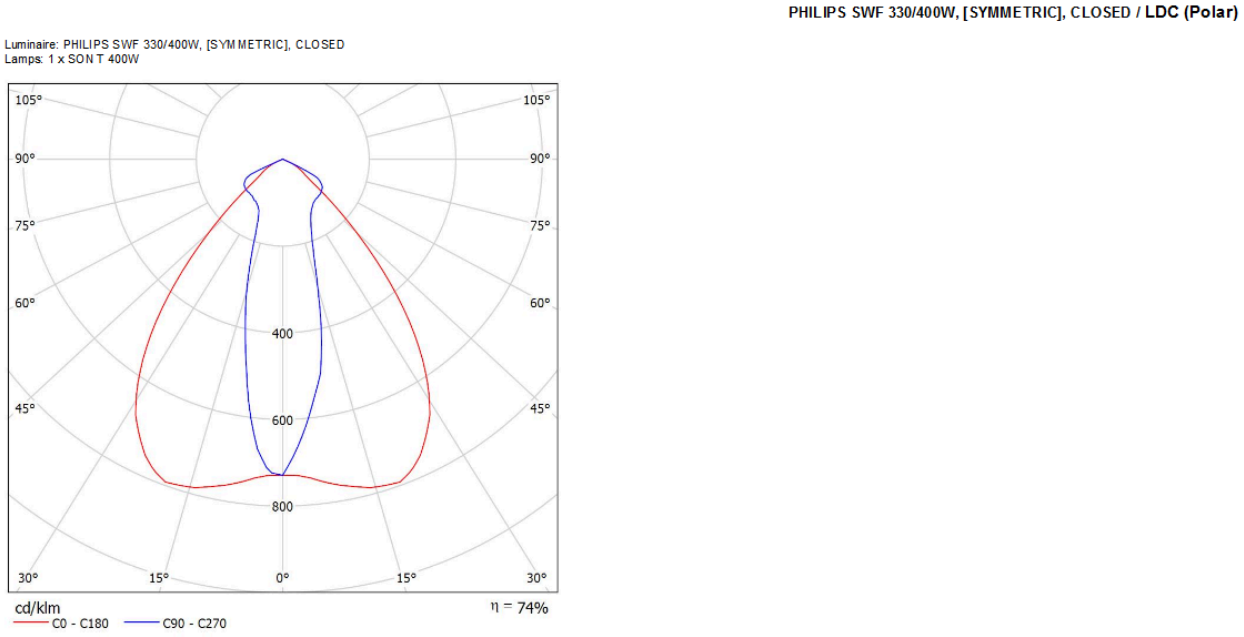


Fig no: 5.10 Symmetric LDC Polar Diagram

in Fig no: 5.10 A Symmetric LDC Polar Diagram for an LED lighting fixture shows how light is distributed from the fixture in various directions, typically for applications like street lighting, area lighting, or even indoor lighting. LEDs are commonly used for these purposes due to their energy efficiency and directional light output. In a polar LDC diagram, the light distribution is visualized in 360 degrees around the fixture, allowing designers to understand how well an LED light will cover a specific area.

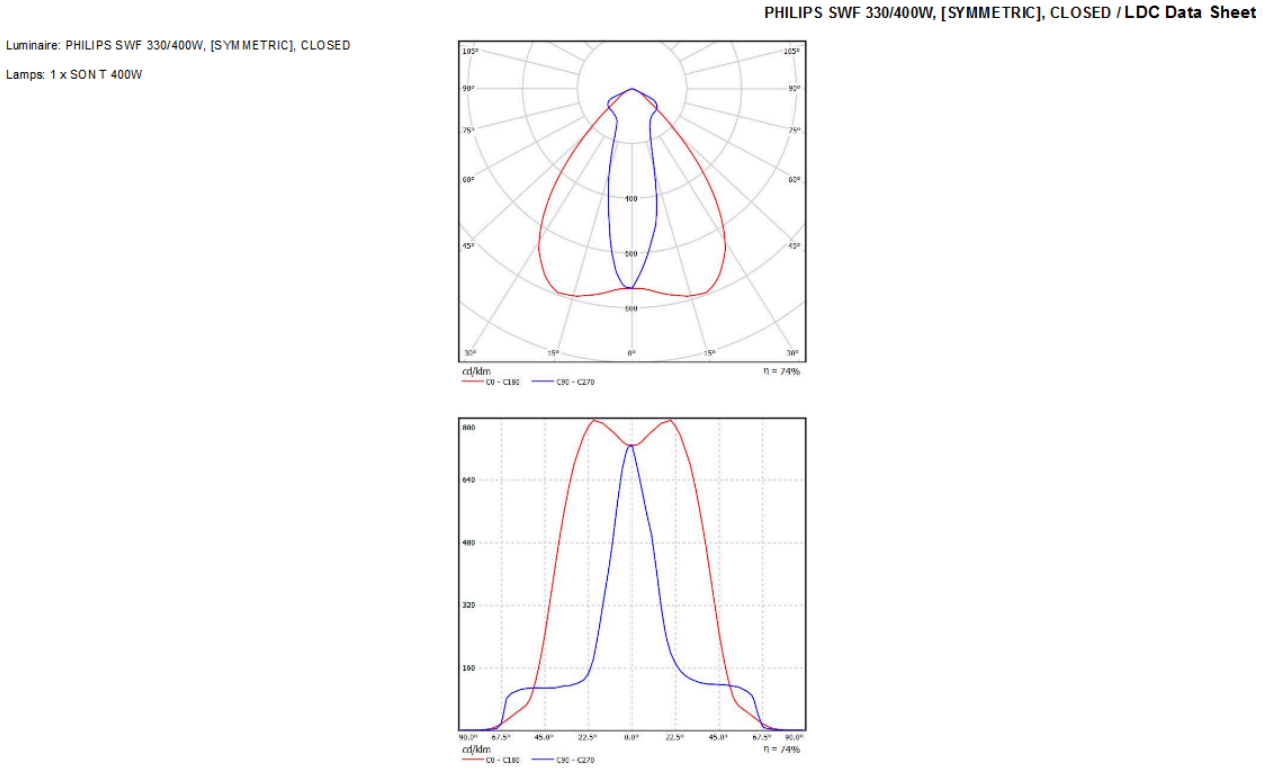


Fig no:5.11 Simulation symmetric LDC date sheet diagram

An LED Simulation in Fig no:5.11 Symmetric LDC (Light Distribution Curve) Datasheet Diagram provides a detailed view of how an LED fixture distributes light symmetrically across an area. This diagram is often included in datasheets for lighting products to help designers and engineers understand the light output characteristics for applications such as street lighting, parking lots, or general area illumination.

5.4. DISTANCE AVERAGE LUMINANCE CHART, AXIS TITLE, AND TABLE

POLE DISTANCE	HIGH-PRESSURE SODIUM VAPOR (HSPV)	METAL HELIDE (MH)	LIGHT-EMITTING DIODE (LED)
22	0.48	0.57	0.42
24	0.49	0.56	0.42
26	0.49	0.56	0.41
28	0.47	0.57	0.42
30	0.45	0.58	0.48
32	0.41	0.56	0.34
34	0.38	0.51	0.31
36	0.36	0.5	0.27
38	0.32	0.47	0.22
40	0.32	0.41	0.24

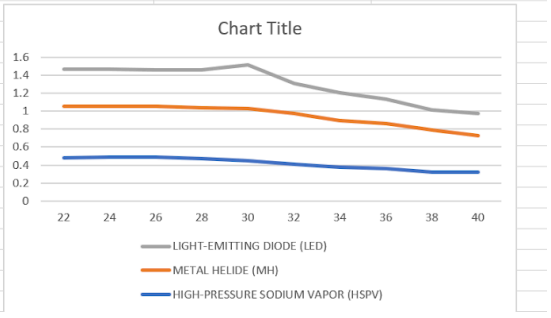


Fig no 5.12 Pole distance average luminance

To Fig no: 5.12 analyse the average luminance based on pole distances, I'll include the High-Pressure Sodium Vapor (HPSV) data as well, and calculate the average luminance for each lighting type at each pole distance.

The data for each type at given pole distances is:

- **Pole Distances (ft or m)**: 22, 24, 26, 28, 30, 32, 34, 36, 38, 40
- **High-Pressure Sodium Vapor (HPSV)**: 0.48, 0.49, 0.49, 0.47, 0.45, 0.41, 0.38, 0.36, 0.32, 0.32
- **Metal-Halide Lamp (MH)**: 0.57, 0.56, 0.56, 0.57, 0.58, 0.56, 0.51, 0.50, 0.47, 0.41
- **Light-Emitting Diode (LED)**: 0.42, 0.42, 0.41, 0.42, 0.48, 0.34, 0.31, 0.27, 0.24, 0.24

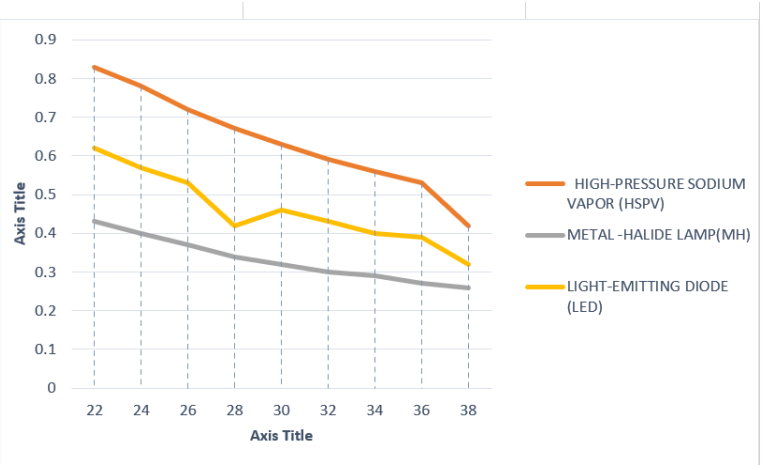
I will calculate the average luminance for each lighting type across these pole distances.

The average luminance values for each lighting type across the given pole distances are as follows:

- **High-Pressure Sodium Vapor (HPSV)**: 0.417
- **Metal-Halide Lamp (MH)**: 0.529
- **Light-Emitting Diode (LED)**: 0.355

This shows that, on average, the Metal-Halide Lamp has the highest luminance across the pole distances, followed by High-Pressure Sodium Vapor, with LED having the lowest average luminance among the three.

METAL -HALIDE LAMP(MH)	LIGHT-EMITTING DIODE (LED)
0.48	0.68
0.43	0.62
0.4	0.57
0.37	0.53
0.34	0.42
0.32	0.46
0.3	0.43
0.29	0.4
0.27	0.39
0.26	0.32



Fif no: 5.13 Average luminance

Based on the data presented in the fig no: 5.13 here is an analysis of the average luminance for each type of street lighting:

The average luminance values for each lighting type are as follows:

- **Metal-Halide Lamp (MH)**: 0.346
- **Light-Emitting Diode (LED)**: 0.482

This indicates that, on average, the LED lighting has a higher luminance than the Metal-Halide Lamp across the data points provided.

HIGH-PRESSURE SODIUM VAPOR (HSPV)	METAL HELIDE (MH)	LIGHT EMITTING DIODE (LED)
0.75	0.84	0.63
0.7	0.79	0.55
0.67	0.77	0.47
0.62	0.72	0.4
0.54	0.68	0.4
0.47	0.6	0.3
0.41	0.53	0.24
0.38	0.49	0.23
0.36	0.45	0.19
0.34	0.41	0.19

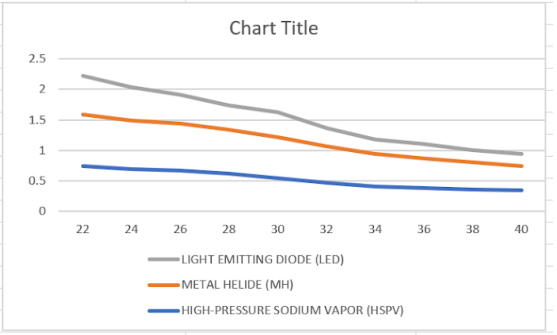


Fig no: 5.14 Longituditional uniformity

To analyse longitudinal uniformity in this context, we focus on how consistently each lighting type provides illumination across varying pole distances. Longitudinal uniformity is a key factor in road lighting, as it ensures that lighting levels are relatively consistent across the length of the road, reducing dark spots and improving visibility.

In general, longitudinal uniformity can be calculated using the following formula:

$$\text{Longitudinal Uniformity (LU)} = \frac{\text{Minimum Illuminance}}{\text{Average Illuminance}}$$

Using this formula, we'll calculate the longitudinal uniformity for each lighting type (HPSV, MH, and LED) across the given pole distances.

Here's the data for each lighting type:

- **High-Pressure Sodium Vapor (HPSV)**: 0.48, 0.49, 0.49, 0.47, 0.45, 0.41, 0.38, 0.36, 0.32, 0.32
- **Metal-Halide Lamp (MH)**: 0.57, 0.56, 0.56, 0.57, 0.58, 0.56, 0.51, 0.50, 0.47, 0.41
- **Light-Emitting Diode (LED)**: 0.42, 0.42, 0.41, 0.42, 0.48, 0.34, 0.31, 0.27, 0.24, 0.24

I will calculate the longitudinal uniformity for each type.

It appears the data from earlier calculations isn't accessible. I'll re-define the values and perform the longitudinal uniformity calculations again.

POLE DISTANCE	HIGH-PRESSURE SODIUM VAPOR (HSPV)	METAL HELIDE (MH)	LIGHT-EMITTING DIODE (LED)
22	2	2	2
24	2	2	2
26	2	2	2
28	2	2	2
30	2	2	2
32	2	2	2
34	2	3	2
36	2	3	2
38	2	2	2
40	2	3	2

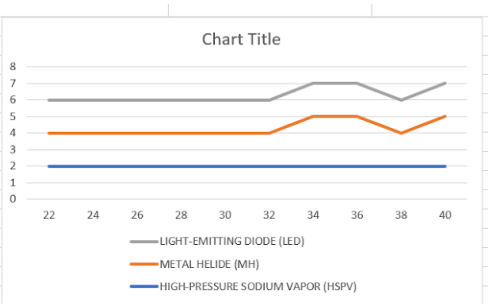


Fig no: 5.15 Threshold increment

The **Threshold Increment (TI)** is a measure of the glare caused by road lighting and is critical for evaluating visibility conditions for drivers, especially in adverse lighting environments. TI is usually expressed as a percentage and represents the additional brightness needed for an object to be visible in the presence of glare. A higher TI means more glare, reducing visibility and causing discomfort to drivers.

To analyse the Threshold Increment for this figno:5.15 we would ideally need specific information on glare levels or contrast values at each pole distance. Without that specific data,

he typical formula for calculating TI is:

$$TI = \frac{\text{Veiling Luminance (Lv)}}{\text{Average Road Luminance (Lavg)}} \times 100$$

where:

- Veiling Luminance (Lv**)** represents the glare component, usually measured based on the lighting design and geometry.
- Average Road Luminance (Lavg) is the average luminance of the road surface, which we calculated previously for each light type.

- **Table no:** 1 HPSV Luminaire Pole details value

LAMP	POLE DISTANCE	MAINTAINED AVERAGE ILLUMINANCE (Eav) lux	AVERAGE LUMINANCE (Lav) Cd/m^2	OVERALL UNIFORMITY (Uo)	LUMINAIRE DETAILS
HPSV	14	20	1.46	0.47	Lamp: SON T 250W, Luminous flux: 27000lm, Power: 279.0W, Correction factor:1.000
	16	18	1.27	0.48	Lamp: SON T 250W, Luminous flux: 27000lm, Power: 279.0W, Correction factor:1.000
	18	16	1.13	0.49	Lamp: SON T 250W, Luminous flux: 27000lm, Power: 279.0W, Correction factor:1.000
	20	14	1.03	0.48	Lamp: SON T 250W, Luminous flux: 27000lm, Power: 279.0W, Correction factor:1.000
	22	13	0.92	0.48	Lamp: SON T 250W, Luminous flux: 27000lm, Power: 279.0W, Correction factor:1.000
					Lamp: SON T 250W, Luminous flux: 27000lm,

	24	12	0.83	0.49	Power: 279.0W, Correction factor:1.000
	26	11	0.78	0.49	Lamp: SON T 250W, Luminous flux: 27000lm, Power: 279.0W, Correction factor:1.000
	28	10	0.72	0.47	Lamp: SON T 250W, Luminous flux: 27000lm, Power: 279.0W, Correction factor:1.000
	30	9.58	0.67	0.45	Lamp: SON T 250W, Luminous flux: 27000lm, Power: 279.0W, Correction factor:1.000

- **Table no**: 2 Metal Halide (MH) Luminaire Pole details

LAMP	POLE DISTANCE	MAINTAINED AVERAGE ILLUMINANCE (Eav)	AVERAGE LUMINANCE (Lav)	OVERALL UNIFORMITY (Uo)	LUMINAIRE DETAILS
METAL HALIDE (MH) LAMP	22	6.74	0.48	0.57	Lamp: HPI T 250W, Luminous flux: 17000lm, Power: 270.0WCarrection factor: 1.000
	24	6.16	0.43	0.56	Lamp: HPI T 250W, Luminous flux: 17000lm, Power: 270.0WCarrection factor: 1.000
					Lamp: HPI T 250W, Luminous

	26	5.64	0.40	0.56	flux: 17000lm, Power: 270.0WCarrection factor: 1.000
	28	5.24	0.37	0.57	Lamp: HPI T 250W, Luminous flux: 17000lm, Power: 270.0WCarrection factor: 1.000
	30	4.90	0.34	0.58	Lamp: HPI T 250W, Luminous flux: 17000lm, Power: 270.0WCarrection factor: 1.000
	32	4.59	0.32	0.56	Lamp: HPI T 250W, Luminous flux: 17000lm, Power: 270.0WCarrection factor: 1.000
	24	4.31	0.30	0.51	Lamp: HPI T 250W, Luminous flux: 17000lm, Power: 270.0WCarrection factor: 1.000
	36	4.08	0.29	0.50	Lamp: HPI T 250W, Luminous flux: 17000lm, Power: 270.0WCarrection factor: 1.000
	38	3.87	0.27	0.47	Lamp: HPI T 250W, Luminous flux: 17000lm, Power: 270.0WCarrection factor: 1.000
	40	3.67	0.27	0.41	Lamp: HPI T 250W, Luminous flux: 17000lm, Power: 270.0WCarrection factor: 1.000

- Table no: 3 Light Emitting diode (LED) Luminaire Pole details

LAMP	POLE DISTANCE	MAINTAINED AVERAGE ILLUMINANCE (Eav)	AVERAGE LUMINANCE (Lav)	OVERALL UNIFORMITY (Uo)	LUMINAIRE DETAILS
LIGHT EMITTING DIODE(LED)	25	7.27	0.51	0.46	Lamp: HPI T 250W, Luminous flux:17000lm, Power: 270.0W, Correction factor:1.000
	30	5.99	0.42	0.48	Lamp: HPI T 250W, Luminous flux:17000lm, Power: 270.0W, Correction factor:1.000
	35	5.15	0.36	0.34	Lamp: HPI T 250W, Luminous flux:17000lm, Power: 270.0W, Correction factor:1.000
	40	4.53	0.32	0.24	Lamp: HPI T 250W, Luminous flux:17000lm, Power: 270.0W, Correction factor:1.000

Chapter 6:

Conclusion

6.1 CONCLUSION

the investigation into LED and HPSV lighting photometric distribution for roadways shows that LED lighting generally provides greater advantages in terms of energy savings, light uniformity, and visibility. LEDs offer a more consistent and controlled light distribution, minimizing issues like glare and light spill, which enhances safety for drivers and pedestrians. Additionally, LEDs have better colour rendering, improving visual clarity and making them particularly effective in busy or complex environments.

While HPSV lighting can be useful in certain conditions, such as areas with frequent fog due to its warmer colour, it lacks the efficiency, durability, and precise distribution offered by LEDs. As a result, switching to LED lighting is often recommended to optimize energy use, reduce maintenance needs, and create a more environmentally friendly road lighting system.

6.2 CHALLENGES FACED

Most of the inputs for lighting simulations are dimensional data that are generally obtained from the Dialux drawings. Some Important data like the colour of road width and pole height or materials for how much lamp watt, how long lifespan lamp year and high-quality low-quality etc are decided only after lighting design is done. Thus, some assumptions in values are required to carry out the lighting simulation which may result in variation from the actual measured values. Approximate input data used such as road dimensions, reflectance, light loss factor, furniture and architectural elements significantly affect the lighting calculations. If the actual site condition does not match the input data, differences occur between measured values and simulated values.

In many areas, the luminaire positions are already fixed owing to some constraints like smoke. It is sometimes quite challenging for a lighting designer to achieve the standard values of illuminances and uniformity in those spaces using the given luminaire layout.

6.3 FUTURE SCOPE OF WORK

As it is seen from the glare comparison of the simulation result obtained for LED and conventional light sources, the HPSV lamps obtained from LED light source is higher that obtained from LED. In some cases, it is even higher than the recommended value. Work can be done to improve the intensity distribution of the LED luminaires so that the glare can be reduced. This can be done by using more suitable optics.

In this case only direct intensity distribution type of luminaires have been used. Further study with indirect and direct as well as only indirect distribution type of luminaires can be done. Those distributions can even help to reduce glare values.

Other newer methods for glare evaluation can be used to check the glare and then a comparison study can be done between these methods of glare simulate and the Dialux method.

Field evaluation of energy saving using the sensors can also be done so as to properly verify the cost savings.

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