STUDIES ON ENERGY EFFICIENT LIGHTING DESIGN FOR INDOOR AND OUTDOOR APPLICATION AREAS

A thesis Submitted towards partial fulfilment of the requirements for the degree of

Master of Technology

in

Illumination Technology & Design

Submitted by

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

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Internship Duration : Start Date : 8th May, 2023 – End Date : 15th December, 2023

During this period, Suman demonstrated exceptional skills and commitment in fulfilling the responsibilities associated with the position. The key responsibilities included:

- Assisting in the design of lighting systems for various projects.
- Creating detailed lighting plots, sections, and elevations using CAD/DIALUX software.
- Collaborating with the design team to develop innovative lighting concepts and presentations.
- Conducting comprehensive research on lighting products, trends, and technology.
- Providing support during onsite lighting setup and testing.

Suman exhibited a strong understanding of lighting design principles, and their proficiency in CAD/DIALUX software significantly contributed to the success of our projects. Moreover, their effective communication and teamwork skills greatly enhanced the overall collaborative efforts within the team.

We extend our best wishes to Suman for his future endeavours and trust that the skills and experience gained during this internship will be valuable assets in their professional journey.

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ACKNOWLEDGEMENT CERTIFICATE

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The title of his thesis was **"Optimizing the Design of Car parking Area: Enhancing Efficiency, Safety and Sustainability"** which was carried out under the guidance of **Mr. Gulab Jha - General Manager**, Product & Marketing (Lighting & Luminaire department). During the tenure, he has been sincere, hardworking and diligent in carrying out the assignment entrusted to him.

We wish him all success in his future endeavour.

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Abstract

Artificial lighting serves as an essential component of our daily routines. By integrating energy-efficient luminaires alongside thoughtfully crafted luminaire layouts, strategic controls, and meticulous installation practices, the way is paved for decreased energy consumption not only in the immediate future but also over the long haul.

Installing the modern days advance Light Emitting Diode (LED) luminaires can be helpful to create good compounding value for the particular place. Specially where spaces like living room, gallery room etc. needs to be highlighted through spectacular detailing of lighting and distribution.

Reducing the unnecessary electric lighting decreases heat gain, thus saving air-conditioning energy and improving thermal comfort. Effective electric lighting design enhances both visual performance and comfort by ensuring optimal and suitable levels of illuminance while managing reflections and glare to create a more pleasant and productive visual environment.

In contemporary outdoor design, optimized design also plays a pivotal role in reducing overall costs for the client. Instead of merely proposing a single solution for the project, it is crucial to thoroughly evaluate and analyse costs, observing the potential reductions achievable through design optimization in every aspect.

Through this practical work, detailed analysis with comparisons are made in terms of Average illuminance level, Uniformity, Lighting Power Density and costing - keeping other design factor also into the consideration also.

All Simulations are run using lighting design software DIALux EVO. Also, with the help of AutoCAD software – necessary marking of lighting points is done so installation can be smooth.

The lighting designs and simulations to follow in the subsequent chapters are done in Mahal lamp shades (Lighting consultancy), Kolkata based branch during the internship period & the other part of the thesis (outdoor design) are done in the Goldmedal Electricals Private Limited, Mumbai (Head office).

Keywords: *Optimization, Photometric parameters, DIALux EVO, Lighting calculation, Cost calculation.*

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Chapter: 1
INTRODUCTION

1.1 INTRODUCTION:

Lighting design stands as a cornerstone in the realms of architectural and urban planning, driving innovation and championing sustainability. Its significance extends far beyond mere illumination, as it includes our surroundings, human behaviour, and safeguards our overall well-being. Looking ahead, prioritizing optimized lighting design becomes imperative for meticulously planning the illumination of various sites and spaces. [1]

In this pursuit, both indoor and outdoor lighting demand equal scrutiny and innovative solutions. Consequently, it becomes imperative to navigate the complexities of modern lighting design with a keen eye toward minimizing light pollution and maximizing efficiency.

Maximizing daylight utilization is also essential for energy conservation. While daylight is the preferred light source, managing glare and preventing overheating are crucial considerations. Striking a balance between illuminance levels and thermal conditions is key to achieving an effective design solution [2]

By embracing cutting-edge lighting technologies and cultivating a culture of responsible design practices, it can be achieved to mitigate of natural darkness while charting a path toward a sustainable future. Through collaborative efforts and a shared commitment to environmental collaboration, it can be ensured that future generations inherit a world where the luminous beauty of our surroundings harmonizes seamlessly with ecological integrity.

1.2 LITERATURE REVIEW:

- **An educational approach to a Lighting Design Simulation using DIALux evo Software [3]**
  A.F.C. Vizeu da Silva, A. Oliveira Godinho, A Faustino Agreira , M. M. Travassos Valdez
  The objective of the paper is to reassess lighting design in urban areas, considering rising global energy consumption and environmental impact. Key aims include achieving balance between energy efficiency and sustainability, with a focus on Light emitting diode (LED) technology like Correlated colour temperature and colour rendering index.
  Managing rising energy demand requires strategic urban lighting design, especially with Light emitting diode (LED) technology's prevalence. Tools like DIALux evo will simulate environmental gains like CO2 reduction. Architectural lighting is vital for both aesthetics and functionality, impacting productivity. Specific illuminance levels cater to various spaces; such as offices require 350 lux, classrooms need 250 lux. Tailored lighting solutions accommodate diverse activities, from technical work to presentations and reading.

- **Efficient Lighting Design for Multiuse Architecture Studio Classroom using DIALux Evo 9 [4]**
  Muhammad Lazuardy Nurrohmanl, Putri Feros , Wahyuningl Rizki Fitria Madinal and Novianthi Pratiwil
  This paper emphasizes the importance of architectural lighting for both aesthetics and functionality. It explores the impact on productivity, offers lighting level recommendations for offices and classrooms, and advocates for tailored solutions. The

paper highlights the benefits of natural light and suggests neutral white (4000K) fixtures to improve overall illumination.

Architectural lighting shapes both the look and function of spaces. It delves into how proper lighting can boost productivity, citing optimal illuminance levels for offices and classrooms. It acknowledges the diverse activities in each space, highlighting the benefits of natural light in offices for a positive atmosphere and improved performance

- **Optimizing the luminous environment using DIALux software at "Constantin and Elena" Elderly House [5]**

  Estelle Guerrya, Cătălin Daniel Gălătanu , Laurent Canalea, Georges Zissisa

  Redefining the lighting design for elderly living spaces by incorporating tailored solutions, optimize environments and enhancing well-being is very important. This includes exploring a novel design process, testing it empirically, and integrating advanced software tools like DIALux Evo and MATLAB functions for precision and efficiency. Overall, the goal is to challenge traditional paradigms and create more supportive living spaces for the elderly.

- **Energy Analysis of efficient lighting system design for lecturing room using DIALux evo 3[6]**

  Mohd Athir Kamaruddinl a, Yanuar Z. Ariefl b , Mohd Hafizi Ahmadi

  The objective is to advocate for energy-efficient lighting design by comparing Compact fluorescent lamp (CFL) and Light emitting diode (LED) systems. It also highlights methods for calculating lighting and the benefits of simulation software in streamlining design and reducing errors, aiming to improve living standards amidst rising electricity costs.

  Increasing electricity demand and depleting resources raise tariffs, affecting living standards. This project promotes efficient lighting design to reduce costs. The study compares compact fluorescent lamp (CFL) and light emitting diode (LED) lighting in a UTM SPACE KL Building lecture room, revealing that light emitting diode (LED) yields 30-50% annual energy cost savings compared to compact fluorescent lamp (CFL), with simulations offering more accurate insights than manual calculations.

  Various methods, including DIALux Evo simulation, AutoCAD, and manual calculation, assess lighting. Building data is gathered, focusing on lighting type selection for quality. The study examines a lecture room in Kuala Lumpur, with DIALux Evo providing illuminance isoline results for compact fluorescent lamp (CFL) and light emitting diode (LED) lighting, aiding designers and minimizing errors, saving time.

- **Calculation of energy saving potential for lighting with DIALux evo[7]**

  Martin Hemmerling, Marco Seegers, Daniel Witzel

  The objective is to promote energy savings in building design by advocating for the integration of new age light emitting diode (LED) lighting. Integrating modern light emitting diode (LED) lighting, intelligent control technology, and combined electric and daylight solutions in building design is crucial for energy efficiency. However, despite potential savings, many opportunities remain untapped due to factors like

limited awareness, overlooked daylight contributions, and complex energy analysis methods. Historically, advanced tools for assessing integrated lighting strategies were accessible only to experts, hindering widespread adoption. Yet, recent advancements, such as the new version of DIALux Evo, are democratizing access to these capabilities. This empowers more practitioners to unlock energy-saving potential in their designs, despite previous obstacles.

1.3 PROBLEM DEFINITION:

Inadequate lighting in work environments can result in eye strain, fatigue, headaches, stress, and increased accident risks. Conversely, excessive lighting can lead to issues such as glare, headaches, and stress, posing safety and health concerns. Both scenarios can contribute to errors, diminished work quality, and reduced productivity. Research indicates that implementing effective & optimized lighting solutions in the workplace or general places or sites yields tangible benefits, including enhanced productivity and reduced error rates.

Therefore, it is essential to develop a comprehensive lighting design tailored to architectural studio, office spaces, and also in outdoor spaces - considering various important factors. Additionally, selecting appropriate standards and optimizing their placement is crucial for achieving energy savings without inflating installation costs.

1.4 OBJECTIVES:

Indoor lighting design in architectural studios aims to enhance lighting quality, while outdoor lighting design is equally crucial for achieving optimized designs that minimize costs. The main objective is to utilize the available space for various activities during optimized lighting design. The main aim to achieve this goal by employing light emitting diode (LED) light sources, and providing best lighting solution from companies end.

- Evaluating the places to observe the electrical points and lighting loads that is allowed for the sites.
- Designing the places with modern light emitting diode (LED) luminaires with the latest lighting software.
- To ensure the placement of light emitting diode (LED) luminaires remains same as the lighting design, so client can get optimized and desirable results.
- Calculation of the optimum cost-effective solution that is good for short term as well as long term vision.

1.5 METHODOLOGY:

- Employing specialized software to assess planning files effectively.
- Conducting site visits or engaging in remote discussions with clients to identify crucial parameters essential for lighting design.

- Developing comprehensive lighting designs for the entire site utilizing appropriate IES files and conducting calculations according to industry standards.
- Utilizing AutoCAD to mark lighting points accurately.
- Ensuring precise placement of luminaires in accordance with the design specifications.
- Verifying the installation process and providing detailed reports to the company for review.

1.6 THESIS OUTLINE:

This thesis is divided into five chapters.

- The first chapter deals with introduction to the work, motivation to take up this project, literature review, Problem definition and details about the project.
- Chapter 2: The background theory and terminologies of fundamental of lighting design is discussed. And also, detailed theory of Indoor & Outdoor Lighting Design is highlighted.
- Chapter 3: Design analysis and summary of lighting design for indoor (architectural studio cum office) which is discussed properly with suitable picture and explanation.
- Chapter 4: Design analysis and comparative study of outdoor lighting design ("Lighting of Outdoor parking area") is highlighted.
- Chapter 5: Conclusion of the thesis work is discussed and future scope of this work is highlighted.

  Finally, all the references have been provided.

Chapter: 2

Fundamentals of Lighting Design

Light is electromagnetic radiation visible to the human eye, part of a spectrum that includes radio waves, microwaves, infrared, ultraviolet, X-rays, and gamma rays. It behaves both as particles (photons) and waves, exhibiting characteristics like wavelength and frequency. Different wavelengths correspond to different colors. Light is vital for vision, photosynthesis, communication (via fiber optics), and technologies like lasers and solar panels, driving discoveries in physics and optics [8]

Now, "Lighting design" is the strategic use of light to enhance the aesthetics and functionality of a space. Working with architects and engineers, designers select fixtures, determine placement, and design control systems to achieve desired effects like ambiance and visibility. By considering factors like purpose, architecture, and human comfort, they create visually appealing environments for various settings, including homes, offices, and outdoor areas [9][10].

2.1 Background theory of Lighting Design:

Lighting design theory encompasses various principles and concepts aimed at creating effective, aesthetically pleasing, and functional lighting solutions for various environments, such as residential spaces, commercial buildings, theaters, and outdoor landscapes. Here are some fundamental elements of lighting design theory [9][10].

i. Functionality: Lighting design should primarily serve the purpose of the space. This involves considering tasks that need to be performed in the space and providing adequate illumination for safety, visibility, and productivity.

ii. Aesthetic: Lighting can greatly influence the mood, ambiance, and visual appeal of a space. Designers use lighting to create focal points, highlight architectural features, and evoke specific emotions.

iii. Balance and Contrast: Achieving balance in lighting involves distributing light evenly throughout the space to avoid glare or shadows. Contrast, on the other hand, involves creating visual interest by varying light levels and intensities.

iv. Color Temperature: The color temperature of light affects the perceived warmth or coolness of a space. Designers consider the color temperature of light sources to complement the overall design scheme and create the desired atmosphere [10].

v. Layering: Effective lighting design often involves layering different types of lighting, such as ambient, task, and accent lighting. This approach provides flexibility and allows for different lighting scenes based on the specific needs of the space.

vi. Energy Efficiency: With growing concerns about energy consumption and sustainability, lighting designers strive to incorporate energy-efficient lighting solutions, such as light emitting diode (LED) technology, daylight harvesting, and motion sensors, to minimize environmental impact and reduce operating costs.

vii. Human-Centric Design: Understanding the physiological and psychological effects of light on human beings is essential in lighting design. Designers consider factors such as circadian rhythms, glare, and color rendering to create lighting environments that promote well-being and enhance comfort.

viii. Architectural Integration: Lighting should seamlessly integrate with the architecture and interior design of a space. Designers collaborate closely with architects and interior designers to ensure that lighting fixtures and techniques complement the overall design vision.

ix. Flexibility and Control: Incorporating lighting control systems allows users to adjust light levels, colors, and scenes according to changing needs and preferences. This flexibility enhances user experience and maximizes the functionality of the lighting design.

x. Safety and Compliance: Lighting design must adhere to safety regulations and standards to ensure the well-being of occupants. Designers consider factors such as proper illumination levels, emergency lighting systems, and accessibility requirements

2.2 Foundation of Lighting Design:

When crafting a lighting scheme for indoor or outdoor settings, it's essential to contemplate the following design principles [11]:

• Evaluating whether the lighting is intended for a secure or potentially hazardous environment.

• Determining the appropriate level of illumination necessary for the activities conducted within the space.

• Identifying the optimal working plane elevation to attain the recommended illuminance level.

• Selecting the suitable types of lamps and luminaires based on their lumen output.

• Considering the available mounting height for installation.

• Striving for uniformity in the distribution of light.

• Addressing the specific color rendering requirements for the designated tasks.

• Calculating the total electrical energy consumption of the lighting system.

• Implementing measures to mitigate light pollution.

The lighting design software interface is also shown fig: 2.1 & 2.2

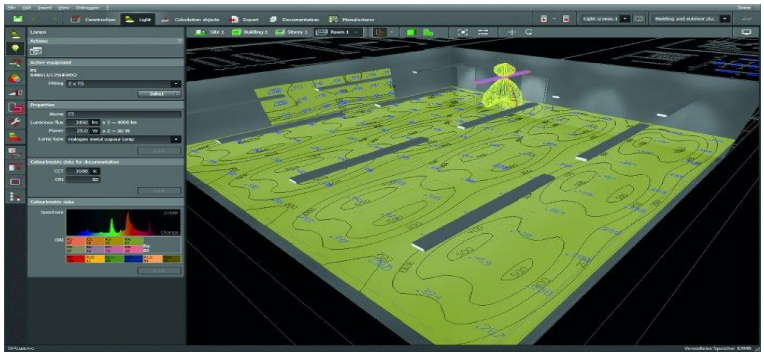


Fig: 2.1: DIALux EVO software interface

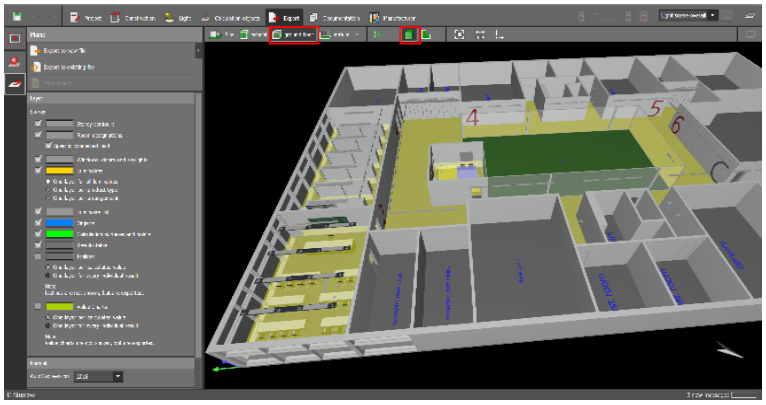


Fig: 2.2: DIALux EVO building view interface

2.3 Lighting Design Parameters:

Few important parameters of lighting design [11][12] is:

I. **Correlated Color Temperature (CCT) and Color Rendering Index (CRI)**:

Color temperature, as shown in fig 2.3, and color rendering are important characteristics of lamps and for lighting design, that significantly influence the quality and appearance of lighting in a space.

Color temperature refers to the perceived warmth or coolness of the light emitted by a lamp, measured in Kelvin (K). Lower color temperatures (e.g., 2700K to 3000K) produce warmer, more yellowish light similar to incandescent lamps, often used in residential and hospitality settings for a cozy ambiance. Higher color temperatures (e.g., 4000K to 6500K) emit cooler, bluish-white light resembling daylight, commonly used in commercial and industrial environments for better visibility and alertness.

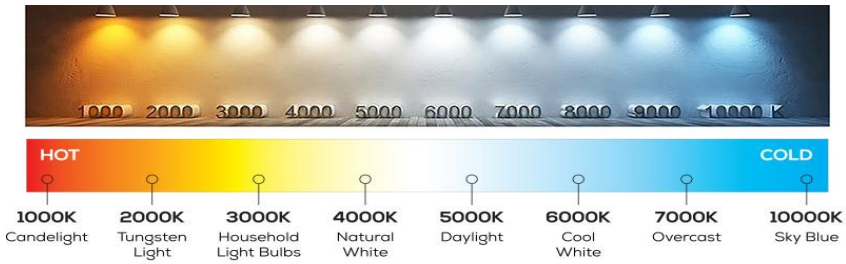


Fig: 2.3.: Different types of color temperature

Color Rendering Index (CRI): Color rendering index is a measure of how accurately a light source reveals the true colors of objects compared to natural sunlight. It is rated on a scale from 0 to 100.

A higher CRI (typically 80 or above) indicates that the light source renders colors more accurately, making them appear more vibrant and truer to life. Lamps with high CRI, as shown in fig 2.4, are preferred in environments where color accuracy is important, such as retail stores, art galleries, and medical facilities.

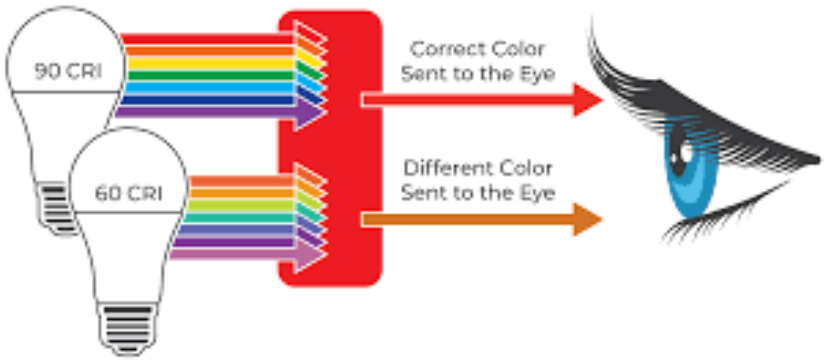


Fig: 2.4: Effect of variable CRI in human eyes

II. **Glare**: Glare is a visual sensation caused by excessive and uncontrolled brightness. It occurs when there's a significant contrast between the light intensity of an object and its background. Glare can be caused by various sources such as direct sunlight, artificial light sources, reflections, or even bright surfaces like snow or water [12][13].

There are two main types of glare:

1. Discomfort glare: This type of glare doesn't necessarily impair vision but causes discomfort or annoyance. It can make it difficult to see clearly and may result in squinting or averting the eyes.

2. Disability glare: This type of glare significantly impairs vision, making it difficult to see objects or details. It can cause temporary blindness or make it challenging to discern objects in the field of vision.

Glare can be mitigated through various means such as using polarized sunglasses, adjusting lighting levels, using anti-glare coatings on surfaces, or positioning objects to minimize direct light exposure. In architecture and design, considerations for glare are essential for creating comfortable and visually appealing environments.

III. **Average illuminance (E_{avg}):**

Average illuminance refers to the average level of light falling on a surface area. It is measured in lux (lx), which is the standard unit of illuminance in the International System of Units (SI).

To calculate average illuminance, typically measurement of the total luminous flux (the amount of light emitted) from all light sources within the area and divide it by the total area over which the light is distributed.

Average illuminance is important in lighting design as it helps ensure that a space is adequately lit for its intended purpose, whether it's for work, leisure, or safety. It's often used to determine lighting requirements for various environments such as offices, homes, outdoor spaces, and sports facilities [13].

IV. Overall uniformity (U_0):

Overall uniformity (U_0) in lighting design refers to the consistency of light distribution across a given area. It measures how evenly the illumination is spread throughout the space, considering variations in light intensity [13].

To calculate overall uniformity, as shown in equation(i), the illuminance level at the lowest point in the area is divided by the average illuminance level for the entire space. This ratio provides a measure of how evenly distributed the light is, with a higher value indicating better uniformity.

$$U_o = \frac{E_{min}}{E_{avg}} \quad \text{.....(eq.i)}$$

Achieving high overall uniformity is important in lighting design to ensure that there are no excessively bright or dim areas within a space. Uniform illumination contributes to visual comfort, reduces glare, and enhances the overall aesthetics and functionality of the environment. It is particularly crucial in applications such as workspaces, retail stores, and outdoor areas where consistent lighting is essential for safety and visual tasks. in lighting design refers to the consistency of light distribution across a given area. It measures how evenly the illumination is spread throughout the space, considering variations in light intensity.

V. Longitudinal uniformity (U_l):

A crucial factor in street and tunnel lighting design, is determined by the ratio of minimum luminance (L_{min}) to maximum luminance (L_{max}) along the lane axis. This calculation [8][9] is performed for each lane and holds significant importance. Insufficient uniformity, falling below the required threshold, becomes visibly apparent as alternating dark and bright stripes on the pavement, affecting overall lighting quality [12] [13].

VI. Unified Glare Rating (UGR):

Unified Glare Rating (UGR) is a metric used in lighting design to assess the level of discomfort caused by glare in indoor environments. Glare occurs when there is a significant contrast in brightness between different parts of the visual field, leading to visual discomfort and reduced visibility.

The UGR scale, shown in table:1, typically ranges from 10 to 30, with lower values indicating less glare and higher values indicating more glare. Lighting fixtures with a UGR below 19 are considered to provide minimal glare and are suitable for tasks that require high visual comfort, such as office workstations and educational facilities. By using UGR calculations, formula shown in fig:2.5, lighting designers can select appropriate luminaires and design lighting layouts that minimize glare, improve visual comfort, and enhance the overall quality of lighting in indoor spaces [13].

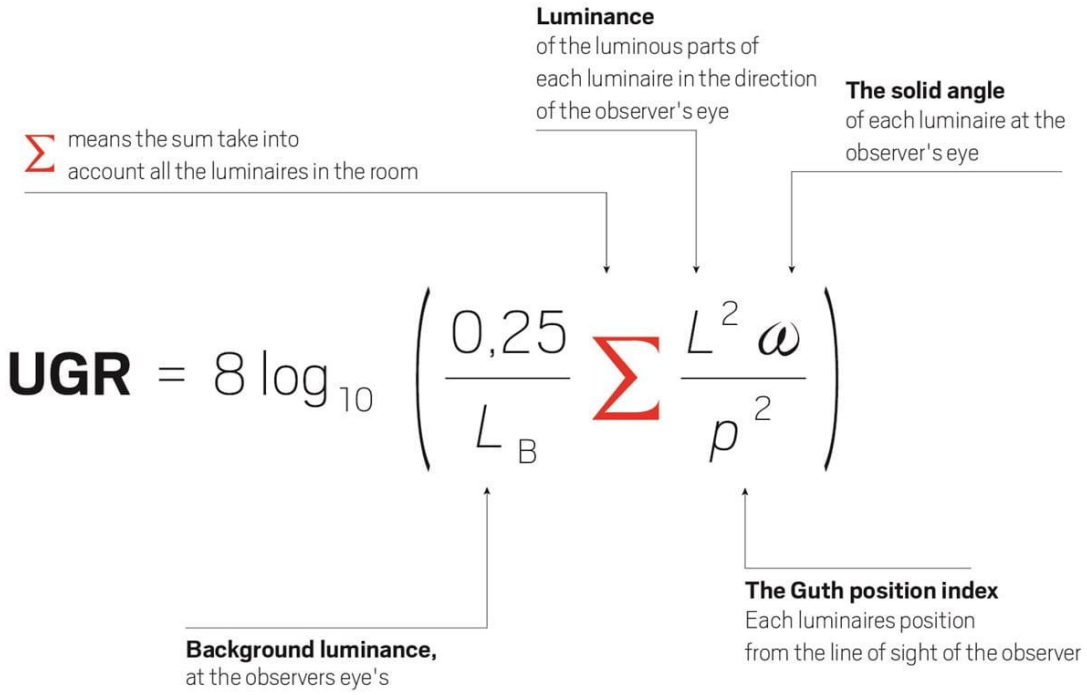


Fig: 2.5: Calculation of Unified glare rating

Table: 1: General overview of the glare rating with respective UGR levels

UGR	Discomfort Glare rating
10	Undetectable
13	Barely noticeable
16	Noticeable
19	Marginally tolerable
22	Not tolerable
25	Slightly uncomfortable
28	Discomforting

VII. Lighting Power Density (LPD)

- Lighting Power Density (LPD) [8][9][13] refers to the amount of power consumed by lighting fixtures per unit area in a given space. It is typically measured in watt per square meter (W/m^2) or watts per square foot (W/ft^2). LPD is used as a metric to assess the energy efficiency of lighting systems and to comply with building energy codes and standards.

Designers strive to optimize LPD by selecting energy-efficient light sources, implementing lighting controls, and utilizing natural daylighting strategies to reduce energy consumption and operating costs in buildings. Also, with the help of LPD, there is many important factors that needs to be highlighted through lighting design as shown in fig:2.6.

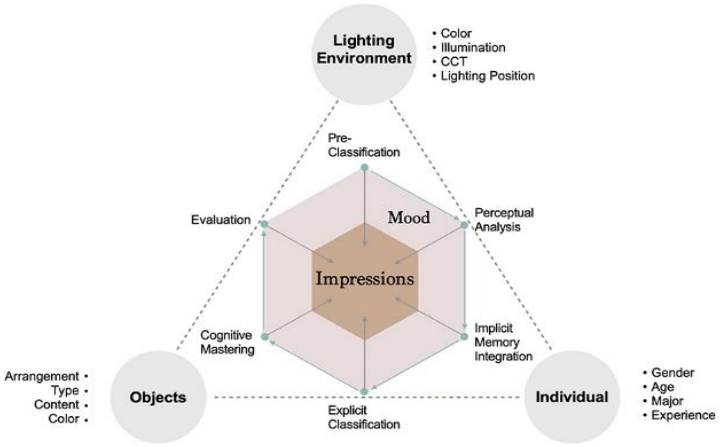


Fig:2.6: Important factors co-related with the lighting design process

2.4. Objectives of lighting design

Lighting Design encompass various goals and considerations, as shown in fig: 2.7, aimed at creating effective and aesthetically pleasing illumination for different environments. These objectives typically include:

- Functionality: Ensuring that the lighting design meets the practical needs of the space, such as providing adequate illumination for tasks, enhancing visibility, and supporting safety and productivity.
- Aesthetics: Enhancing the visual appeal of the space through lighting effects, accentuating architectural features, and creating a pleasant ambiance that complements the overall design scheme [10].
- Energy Efficiency: Minimizing energy consumption and environmental impact by selecting energy-efficient light sources, utilizing lighting controls, and optimizing the design to maximize natural daylighting wherever possible [8][9].
- Visual Comfort: Striving to create lighting environments that minimize glare, flicker, and other discomforts while promoting visual clarity and ease of perception.
- Flexibility: Designing lighting systems that are adaptable to different uses and activities within the space, allowing for adjustments in light levels and configurations to accommodate changing needs and preferences.
- Sustainability: Incorporating sustainable lighting practices, such as using recycled materials, selecting fixtures with minimal environmental impact, and designing for long-term durability and resource efficiency.
- Cost-Effectiveness: Balancing upfront installation costs with long-term operational savings by selecting lighting solutions that offer the best value over the lifecycle of the system, including maintenance and replacement considerations [9][10].

- Regulatory Compliance: Ensuring that the lighting design meets relevant codes, standards, and regulations related to energy efficiency, safety, accessibility, and environmental impact

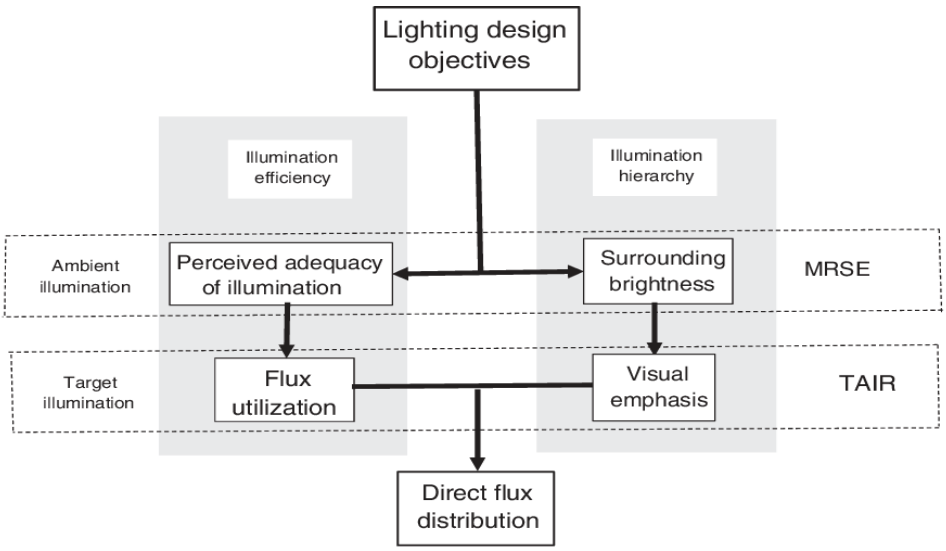


Fig: 2.7: Objectives of Lighting design at a glance

2.5. Lighting Designing Steps:

By addressing these objectives comprehensively, lighting designers can create lighting solutions that enhance the functionality, aesthetics, and sustainability of indoor and outdoor spaces while meeting the specific needs and preferences of users and stakeholders. Designing lighting, as shown in fig: 2.8 and 2.9, involves several steps to ensure that the lighting scheme meets the functional, aesthetic, and energy efficiency requirements of the space. Here's a general procedure for lighting design [9] [10]:

i. Understanding the Project Requirements: Begin by thoroughly understanding the purpose of the space and the activities that will take place within it. Consider factors such as the size and shape of the area, its function (e.g., residential, commercial, industrial), desired ambiance, and any specific lighting needs.

ii. Site Analysis: Conduct a detailed analysis of the site, considering natural light sources, architectural features, existing electrical infrastructure, and any potential obstacles that may affect lighting design [10].

iii. Establish Lighting Goals: Define specific objectives for the lighting design, such as providing adequate illumination for tasks, enhancing architectural features, creating ambiance, and minimizing energy consumption.

iv. Develop Lighting Concept: Based on the project requirements and goals, develop a conceptual lighting design that outlines the overall approach to lighting the space. This may include considerations such as the types of fixtures to be used, their placement, and the desired lighting effects [10].

v. Calculate Lighting Requirements: Determine the appropriate illuminance levels (measured in lux or foot-candles) needed for various areas within the space, considering factors such as the type of activity, visual tasks, and the age of occupants (if applicable).

vi. Select Lighting Fixtures: Choose fixtures that are suitable for the intended application and compatible with the design concept. Consider factors such as light output, color temperature, color rendering index (CRI), energy efficiency, and maintenance requirements [9] [10].

vii. Create Lighting Layout: Develop a detailed lighting layout that specifies the placement of fixtures, aiming angles, and lighting zones to achieve uniform illumination and desired lighting effects. Use lighting design software or manual calculations to optimize the layout for efficiency and performance.

viii. Address Lighting Controls: Determine the appropriate lighting control system (e.g., switches, dimmers, sensors, timers) to regulate the intensity, timing, and distribution of light based on occupancy, daylight levels, and user preferences. Integrate controls seamlessly with the lighting layout to maximize energy savings and user comfort.

ix. Evaluate Sustainability: Consider incorporating energy-efficient lighting technologies, such as LED fixtures, daylight harvesting strategies, and lighting controls, to minimize energy consumption and environmental impact over the long term.

x. Review and Refinement: Review the lighting design with stakeholders, architects, engineers, and other relevant parties to solicit feedback and make any necessary adjustments or refinements.

xi. Documentation and Specifications: Prepare detailed documentation and specifications that outline the lighting design, including fixture schedules, photometric data, control diagrams, installation instructions, and maintenance guidelines. Ensure that all relevant information is clearly communicated to contractors, suppliers, and other project stakeholders.

xii. Implementation and Commissioning: Oversee the installation of lighting fixtures and controls according to the approved design plans. Conduct thorough testing and commissioning to verify that the installed system performs as intended and meets the specified requirements for illumination, energy efficiency, and user comfort.

xiii. Post-Occupancy Evaluation: After the space is occupied, conduct a post-occupancy evaluation to assess the effectiveness of the lighting design in meeting the needs of users and identify any areas for improvement. Gather feedback from occupants and facility managers to inform future lighting projects and optimizations.

By following these steps [10], lighting designers can develop effective and efficient lighting solutions that enhance the visual environment, promote productivity and well-being, and contribute to the overall success of the project.

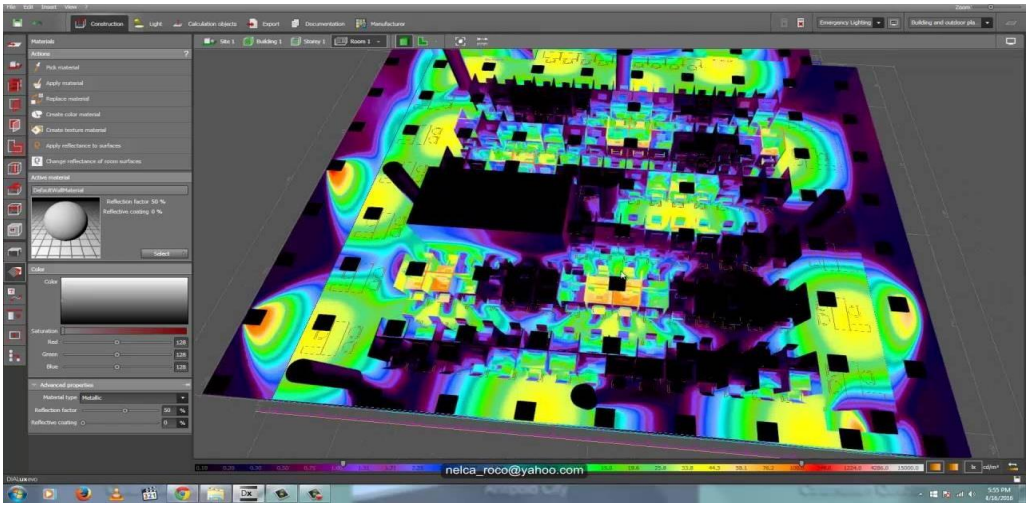


Fig: 2.8: DIALux software interface with false color on

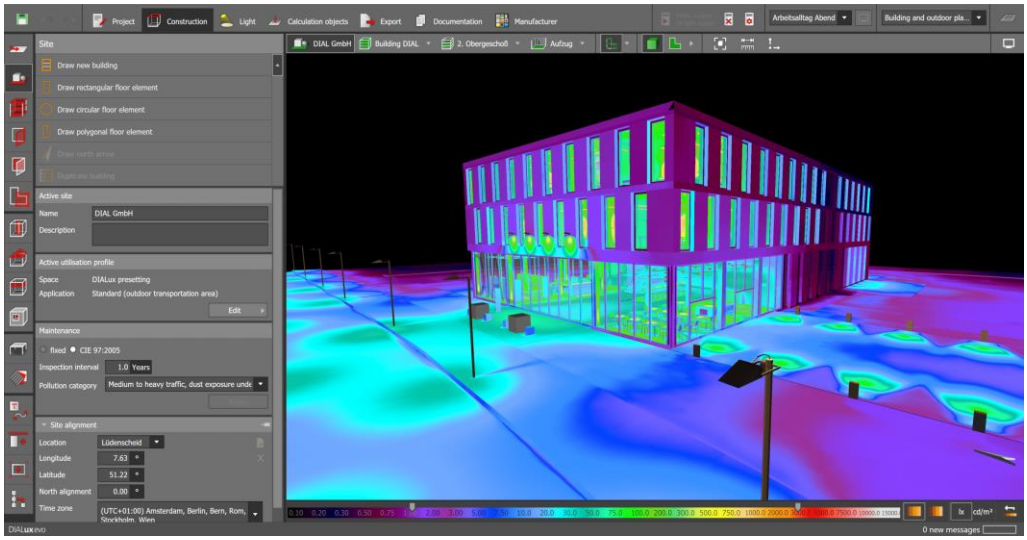


Fig: 2.9: DIALux software interface with false color on

2.6. Lighting Design Standard:

The 2010 National Lighting Code (NLC) encompasses several key areas:

a) It provides guidance on illuminating engineering practices tailored to different types of occupancies.

b) The code offers guidance on sound engineering practices for designing, selecting, installing, and maintaining both indoor and outdoor lighting systems.

c) It covers matters related to the science of illumination, including the physics of light, electric light sources, luminaires, and photometry.

d) The NLC addresses coordination aspects to consider when designing lighting systems, such as daylighting. [9] [10].

e) It includes aspects of energy management and conservation in lighting installations, providing design guidelines and best practices for efficient and effective use of light sources.

The primary objective of this code is to establish clear requirements for responsible social, commercial, and engineering conduct among lighting designers, manufacturers, and suppliers. Lighting technology plays a crucial role in achieving social safety and environmental goals. The code aims to promote good lighting practices and systems that minimize light pollution, glare, light trespass, and energy consumption while ensuring safety, security, utility, and productivity.

The lighting industry is characterized by fragmentation and relatively low technical barriers to entry. Despite its essential role in safety operations, it faces comparatively low levels of regulation. As a result, end users and consumers often lack accurate and reliable information regarding what constitutes a safe, reliable, and efficient lighting system. This code seeks to foster trust between the industry and its customers by integrating commerce and technology, providing reliable standards and guidelines.

Guidelines for Interior Illumination: Enhancing Workspace Efficiency and Visual Comfort

The Code of Practice for Interior Illumination (IS 3646(part1):1992) and IS3646-Part 2 (1966) is a standard set forth by the Bureau of Indian Standards, sanctioned by the Electro-technical Division council, following approval by the Illuminating Engineering and Luminaires sectional committee.

This standard serves as a comprehensive guide aimed at achieving effective lighting within interior spaces. Its primary focus lies on illuminating working environments such as factories, offices, commercial establishments, and public buildings, including hospitals and schools. The overarching goal of the code is twofold: to ensure clear visibility of tasks and to foster visually pleasing and conducive surroundings.

Effective lighting, as outlined in this code, is defined by its ability to provide both quality and quantity of light, catering to the needs of users while facilitating efficient visibility of crucial elements or details. These recommendations are applicable to artificial, natural, or hybrid lighting systems, underlining the importance of maintaining high lighting standards during building occupation, treating lighting provision as a service [9] [10]

While the conventional planning methods detailed in this code are continually under review, certain scenarios may necessitate a consideration of luminance patterns across the entire visual field. Therefore, a well-coordinated approach involving architects, consultants, and illumination engineers is imperative during the implementation of a robust lighting system. Collaboration among these stakeholders, exchanging lighting-related information from the planning phase through to installation, is essential for optimal outcomes [11][12] [13][14].

2.7 Guideline of Outdoor Lighting Design: Guidelines from the National Lighting Code (NLC) - 2010

The National Lighting Code (NLC) of 2010 offers comprehensive guidelines for exterior illumination, aimed at improving workspace efficiency and enhancing visual comfort in outdoor environments

These guidelines cover a wide range of aspects pertaining to outdoor lighting, including but not limited to:

- Illumination Requirements: The NLC delineates the necessary lighting levels and distribution patterns required for various outdoor workspaces, ensuring adequate visibility and safety.
- Energy Efficiency: The code emphasizes the importance of energy-efficient lighting solutions, promoting the use of sustainable technologies and practices to minimize environmental impact and reduce operational costs.
- Glare Reduction: Glare can impair visibility and cause discomfort. The NLC provides strategies for minimizing glare through proper luminaire selection, positioning, and shielding, thereby enhancing visual comfort for outdoor workers.
- Light Pollution Mitigation: Outdoor lighting often contributes to light pollution, which can have adverse effects on wildlife and human health. The NLC includes measures to mitigate light pollution, such as specifying appropriate lighting fixtures and implementing effective control strategies.
- Safety and Security: Adequate lighting is essential for ensuring the safety and security of outdoor workspaces. The code outlines requirements for illuminating pathways, parking areas, and other outdoor areas to deter crime and enhance visibility during nighttime operations.

By adhering to the guidelines outlined in the NLC-2010[9][12][13], stakeholders can create outdoor lighting solutions that not only meet functional requirements but also contribute to a more sustainable and visually appealing built environment.

2.8 Light Emitting Diode (LED):

Light Emitting Diode (LED) [15][16] lamps represent a solid-state, mercury-free lighting solution with instant switching and dimming capabilities, offering high energy efficiency and long service life. Laboratory-tested LEDs can provide over 200 lumens per watt, although average efficacy ranges from 20 to 60 lumens per watt, and they typically have expected lifetimes of around 50,000 hours. LEDs operate on direct current (DC) electrical power, requiring internal circuits to function from standard AC voltage, and incorporate heat management elements such as heat sinks and cooling fins to prevent damage from higher temperatures. The color of LED emission is determined by the energy bandgap of the semiconductor material used, and emitting white light can be achieved through either RGB-LEDs, which use multiple LED chips emitting different wavelengths to form a broad white light spectrum, or phosphor-converted LEDs. Advantages of LEDs include their suitability for both general and special-purpose lighting, offering multiple color options without the need for filters, long life expectancy, low energy use, and compact size, which provide flexibility in lighting fixture design. Additionally, LEDs are resistant to vibration and impact due to their rigid internal support structure and can be dimmed over a wide range with proper driver electronics design, without requiring a minimum current for operation. However, they face challenges such as a complex production process, relatively high price compared to traditional light sources, low-quality Color Rendering Index (CRI) typically below 75, efficiency decreases with temperature rises, and potential failure due

to poor-quality driver circuits. Initially used for indicators, signal lighting, and decorative purposes, LEDs are increasingly being adopted to replace fluorescent and CFL lamps in commercial settings.

2.8.1. History of LED:

Light-Emitting Diodes (LEDs), as shown in fig: 2.10, harness the principle of electro luminescence, where diodes emit light upon electrical stimulation. These devices consist of p and n regions with a junction akin to traditional diodes. When voltage is applied, electrons flow across the junction towards the positive charges in the p region. Upon recombination with positive ions, the electric potential energy converts into electromagnetic energy, resulting in photon emission.

The history of LEDs dates back to the early 20th century, with initial observations of electroluminescence in semiconductor materials. However, practical applications remained limited until the 1960s when the first practical LED was developed, primarily serving as low-intensity indicators [15][16].

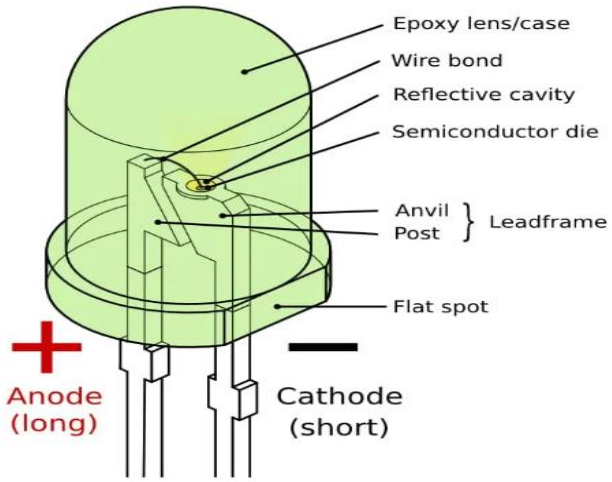


Fig: 2.10: Architecture of LED

Over subsequent decades, significant advancements in semiconductor technology paved the way for brighter, more efficient LEDs. By the late 20th century and into the 21st century, breakthroughs in epitaxy techniques, material science, and manufacturing processes propelled LEDs into the mainstream. These advancements enabled the creation of high-brightness LEDs capable of emitting white light, revolutionizing the lighting industry [15][16].

Today, LEDs are manufactured using various semiconductor materials, typically combinations of gallium, arsenic, and phosphorus, to achieve different colors and spectral characteristics. This versatility allows LEDs to be employed across a myriad of applications, from everyday lighting in homes and offices to specialty uses in automotive, signage, and display technologies.

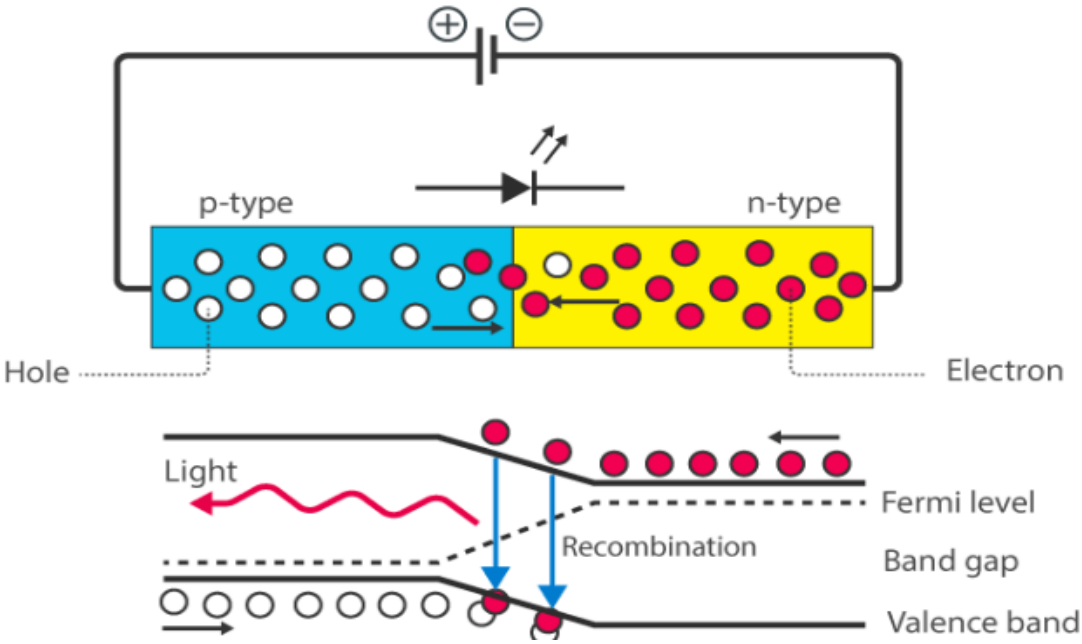


Fig: 2.11: P-N Junction

LEDs (Light Emitting Diodes) work using a principle called electroluminescence, which occurs in a semiconductor material when current flows through it [8] [9].

In an LED, a P-N junction, as shown in fig: 2.11, is created by combining a region with an excess of positively charged "holes" (P-type) and a region with an excess of negatively charged electrons (N-type). When a voltage is applied across the junction, electrons from the N-type region move across the junction to fill the "holes" in the P-type region.

When an electron fills a hole, it releases energy in the form of light. This is because the electron transitions to a lower energy state, emitting a photon of light with a specific wavelength characteristic of the semiconductor material.

So, in short, LEDs produce light when electricity passes through a semiconductor material with a P-N junction, causing electrons to release energy in the form of photons [15][16].

2.8.2. Advantages of LED:

LEDs (Light Emitting Diodes) outshine traditional lighting technologies like incandescent, fluorescent, and halogen bulbs with their efficiency, longevity, and versatility. Key advantages include [8][15][16]:

1. Energy Efficiency: LEDs use far less energy, offering significant cost savings.

2. Longer Lifespan: They last much longer, reducing replacement frequency.

3. Durability: Solid-state construction makes them robust against impacts.

4. Eco-Friendly: Free of toxic materials and fully recyclable.

5. Low Heat Emission: Safer to use and can lower cooling expenses.

6. Instant On: No warm-up time needed, with durability against frequent switching.

7. Dimmability: Offers adjustable lighting levels for energy savings and atmosphere.

8. Directional Lighting: Focuses light where needed, enhancing efficiency.

9. Color Rendering: Produces vibrant and accurate colors.

10. Cold Temperature Operation: Effective in low-temperature settings.

11. Design Flexibility: Small size allows for creative and compact designs.

These benefits make LEDs, as shown in fig: 2.12, the leading choice for a wide array of lighting applications, aligning with both performance and environmental sustainability.

Fig:2.12: Benefits of LED

2.8.3. Drivers of LED:

An LED driver is essential in LED lighting systems, acting as a specialized power supply that manages the power an LED or array of LEDs receives. Because LEDs need a consistent and specific input of power to operate efficiently—unlike traditional bulbs that work directly from mains power—the LED driver's role is to provide steady voltage and current according to the LED's requirements. This ensures optimal performance, longevity, and efficiency of the lighting system [8] [15][16].

Functions of an LED Driver:

Regulate Current: Ensures a constant current flow, critical for maintaining consistent brightness and preventing LED damage.

Convert Voltage: Transforms the incoming power supply to the voltage level suitable for the LEDs.

Enable Dimming: Offers the capability to adjust light output.

Provide Thermal Protection: Protects LEDs from overheating to preserve their lifespan.

Types of LED Drivers:

1. Constant Current Drivers:

These drivers, as shown in fig: 2.13, supply a fixed current, ensuring the LED emits a consistent light output. They're used when the application demands uniform brightness, and are ideal for single or series-connected LEDs [8].

Fig:2.13: Constant Current Drivers

2. Constant Voltage Drivers:

These kinds of driver seen in fig: 2.14, provide a fixed voltage, typically used with LEDs that are designed to operate at a specific voltage. They're suitable for parallel-connected LED setups, where each LED or strip requires the same voltage level but may draw different currents [15][16].

Understanding the distinction between these drivers is crucial for selecting the right one, as using the incorrect type can lead to inefficient operation or damage to the LED.

Fig:2.14: Constant Voltage Drivers

2.9. Beam angles:

Here are different types of lighting beams of luminaires commonly used in various applications [8] [9]:

- Spotlight Beam: This type of beam produces a narrow, focused light pattern with a high intensity, typically used to highlight specific objects or areas.
- Floodlight Beam: Floodlights create a wide, uniform illumination over a large area. They are often used for general lighting in outdoor spaces, sports fields, or architectural lighting.
- Narrow Beam: Narrow beams have a concentrated light spread, making them suitable for accent lighting or highlighting specific architectural features.
- Wide Beam: Wide beams provide a broader spread of light, useful for general area lighting or creating a softer ambient glow.

These different types of lighting beams, as shown in fig: 2.15, offer versatility in various lighting applications, allowing designers to achieve specific aesthetic or functional objectives [15][16].

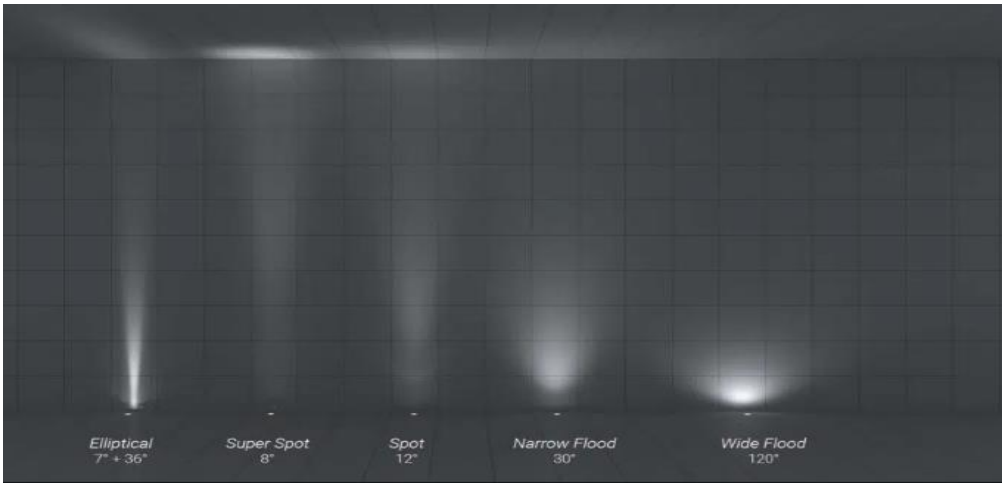


Fig: 2.15: Different types of lighting beams

2.10. Electrical layout and Dimming:

Electrical layout is a crucial aspect of building design, ensuring that electrical systems are strategically placed and interconnected to meet the functional and safety requirements of the space. This involves careful planning to determine the optimal placement of electrical components such as outlets, switches, junction boxes, circuit breakers, and panel boards. Factors such as building codes, safety regulations, accessibility, and user convenience are taken into consideration during the layout process [8] [9].

Moreover, electrical layout also involves the routing of electrical wiring and cables to connect various components and systems throughout the building. Proper routing minimizes the risk of electrical hazards such as short circuits, overloads, and fire hazards. It also facilitates ease of maintenance and future upgrades or expansions of the electrical infrastructure.

Dimming systems, refer to fig: 2.16, on the other hand, offer versatility and flexibility in controlling lighting levels within a space. They allow users to adjust the brightness of light fixtures according to specific needs, preferences, and activities. For instance, dimming lights can create ambiance in residential settings, enhance comfort and productivity in offices, and set the mood in hospitality venues [15][16].

There are various types of dimming technologies available, including traditional phase-cut dimmers, leading-edge dimmers, trailing-edge dimmers, and digital dimming systems. Each type has its unique features, compatibility with different light sources (such as incandescent, fluorescent, LED), and control options (such as manual, remote, or automated).

In addition to enhancing user comfort and energy efficiency, dimming systems offer benefits such as extending the lifespan of light bulbs by reducing the strain on them and lowering energy consumption by adjusting light levels based on natural daylight or occupancy sensing. They can also contribute to sustainability efforts by reducing overall energy usage and operating costs over time. As a result, integrating dimming systems into electrical layouts has become increasingly common in modern building designs [8] [9] [15][16].

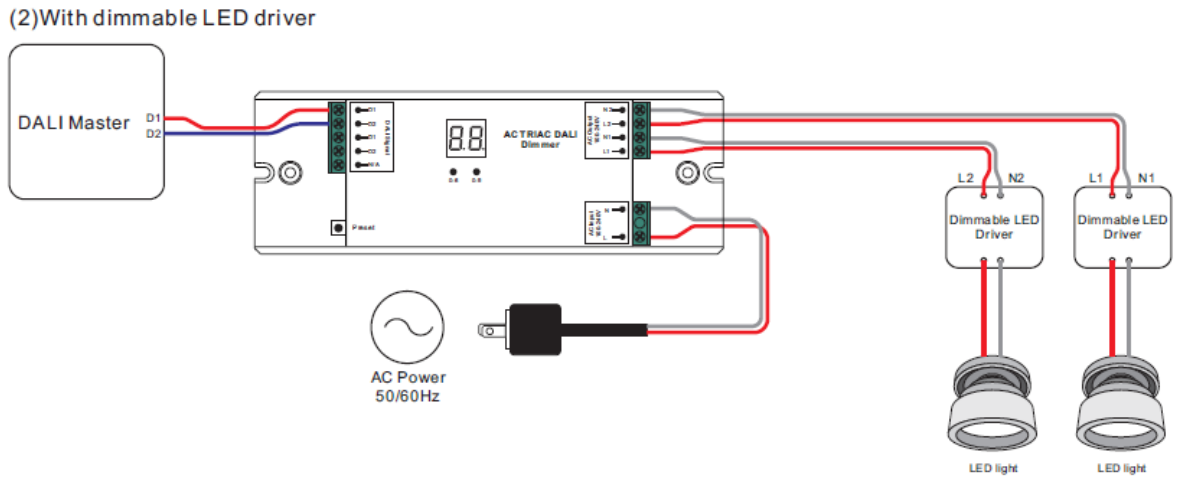


Fig:2.16: DALI circuit and connection

- In this project, looping diagram which also includes the electrical layout. As per the requirements, it was ensured that two lighting fixtures will be dimmed simultaneously via a single connection [8] [9].

- Additionally, directional lights will be dimmed separately using a dedicated line. This approach allows for efficient control and customization of lighting levels to meet specific needs and enhance the overall functionality and ambiance of the space.

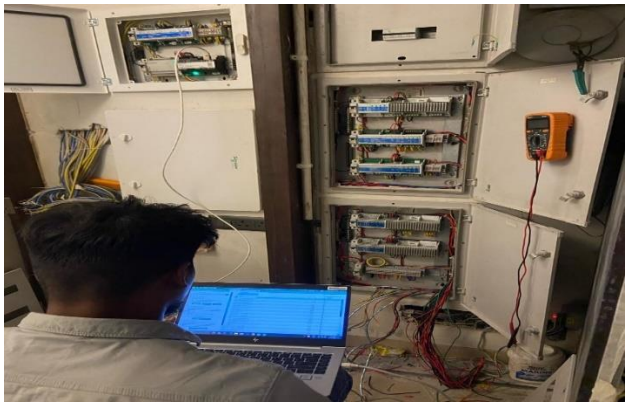


Fig:2.17: DALI[18] connection integration on actual site

- In this context, here DALI (Digital Addressable Lighting Interface*)* dimming technology is opted to ensure precise dimming control, as shown in fig: 2.17, for each individual light fixture. It is imperative to achieve long-lasting results to maintain the desired dimming levels effectively over time. This technology offers enhanced reliability and flexibility, allowing for tailored dimming settings that align with the specific requirements of the space. By leveraging DALI dimming technology, it is aimed to optimize energy efficiency, enhance user comfort, and prolong the lifespan of lighting systems, thereby maximizing the overall effectiveness and longevity of the dimming solution.

- **DALI (Digital Addressable Lighting Interface) dimming technology offers:**

  1. Individual control: Precise control of each fixture for tailored lighting schemes.

  2. Scalability: Suitable for small rooms or large buildings without compromising performance.

  3. Two-way communication: Real-time monitoring and feedback for advanced control strategies.

  4. Easy setup: Simplified commissioning and configuration, reducing installation time.

  5. Flexibility: Allows dynamic reconfiguration without rewiring, ensuring adaptability.

  6. Energy efficiency: Optimizes usage, reduces consumption, and extends lamp lifespan. Overall, DALI offers superior functionality, flexibility, and efficiency compared to traditional methods [18] [19].

2.11. Different types of Lighting scheme:

Architectural studio cum office like this usually demands a thoughtful selection of luminaires, influenced by several factors such as building design, tasks performed, room size, natural light exposure. A diverse range of light fixtures exists, each with unique characteristics and light distribution patterns. These include:

1. Recessed Lighting: Embedded within the ceiling, providing a sleek and unobtrusive lighting solution suitable for general illumination.

2. Pendant Lighting: Suspended from the ceiling, adding a stylish touch while offering focused illumination ideal for task areas or accent lighting.

3. Track Lighting: Featuring adjustable fixtures mounted on a track, allowing for flexibility in directing light to specific areas or objects.

4. Surface-Mounted Fixtures: Mounted directly onto the ceiling or wall, offering versatile options for general or task lighting depending on placement.

5. Desk Lamps: Providing localized illumination for individual workstations, offering adjustable features to cater to personal preferences.

Each luminaire type serves a distinct purpose, contributing to an efficient and visually appealing office environment tailored to the specific needs and aesthetics of the space [15][16]

- **Direct luminaires:**
  A direct luminaire, as shown in fig: 2.18, is a type of lighting fixture designed to emit light primarily downwards, focusing the illumination onto a specific area or surface below. These fixtures typically have reflectors or diffusers to direct the light in a specific direction, often used for tasks where focused illumination is needed, such as reading, writing, or working on a computer [15][16]
- **Indirect luminaire:**
  An indirect luminaire, as shown in fig: 2.19, is a type of lighting fixture designed to emit light upwards or towards the ceiling, with the light then reflected and diffused to illuminate the surrounding space. These fixtures are often used to create a soft, diffuse light that minimizes shadows and glare, providing a more comfortable and visually pleasing environment. Indirect luminaires are commonly employed in spaces where uniform ambient lighting is desired, such as offices, classrooms, and commercial buildings, as well as in architectural lighting applications to enhance the overall atmosphere of a space.
  Room surface lighting refers to the illumination of walls, ceilings, floors, and other surfaces within a space. Unlike traditional lighting fixtures that primarily focus on providing direct illumination for tasks or ambient lighting for overall brightness, room surface lighting is designed to enhance the visual appeal and atmosphere of a room by highlighting its architectural features and textures [15][16]

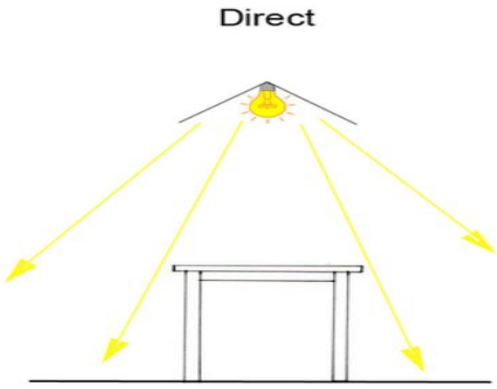


Fig:2.18 Direct Luminaire

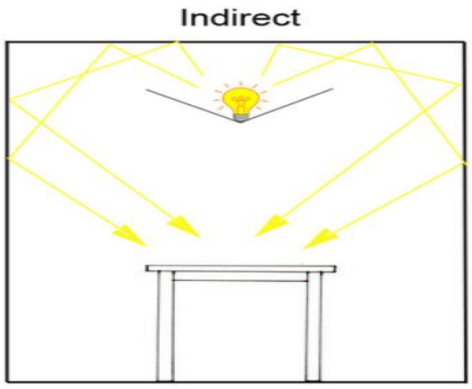


Fig:2.19: Indirect luminaire

- **Room surface lighting:**
  This type of lighting means good lighting, as shown in the fig: 2.20, can be achieved through various methods [15][16], including:

  - Wall Washers: These fixtures are mounted on walls or ceilings and emit a broad, uniform light that washes over the surface, highlighting textures and creating a visually pleasing effect.
  - Cove Lighting: Cove lighting fixtures are installed in recesses or ledges along the perimeter of a room's ceiling, casting a soft, indirect light upwards to illuminate the ceiling and create a warm, inviting ambiance.
  - Floor Up lights: Placed strategically along the baseboards or floor perimeter, floor up lights project light upwards to illuminate walls and accentuate architectural details, such as columns or mouldings.
  - Linear LED Strips: These versatile lighting solutions can be installed along surfaces such as walls, ceilings, or floors to create a continuous line of light, adding visual interest and enhancing the room's aesthetics.
  - Room surface lighting, plays a crucial role in interior design by enhancing the overall ambiance and visual appeal of a space. By carefully selecting and positioning lighting fixtures, designers can create dynamic lighting effects that transform ordinary surfaces into focal points, contributing to a more inviting and immersive environment.

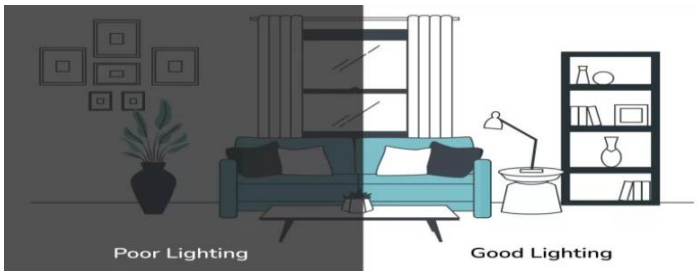


Fig:2.20 Difference between Poor lighting and Good lighting

2.12. Lighting design factors:

- **Reflection factor:**

The reflection factor [15][16]., also known as reflectance, measures how much light a surface reflects compared to the light it receives. It's typically expressed as a decimal or percentage, with 0 indicating complete absorption and 1 indicating total reflection. Understanding this factor is vital in lighting design, affecting light distribution and intensity in a space. Surfaces with higher reflection factors enhance brightness and uniformity, while lower factors lead to darker areas. In architecture and interior design, selecting materials with appropriate reflection factors is crucial for achieving desired lighting effects, visual comfort, and energy efficiency, ensuring optimal use of lighting resources for appealing and functional spaces.

As per the specifications outlined in the National Lighting Code of 2010, the reflectance values designated for significant interior surfaces are regarded as.

Type: Ceiling: 70%: Wall: 50%: Floor: 20%

- **Calculation surface consideration:**

The arrangement and elevation of tables and workstations play a crucial role in guiding the placement of luminaires and establishing the optimal height for the work plane. Typically, a standard height of 0.8 meters is adopted for office environments, aiding in efficient lighting design and workspace functionality [15][16]

- **Maintenance factor consideration:**

Maintenance factor quantifies the retained light output of a system over time, crucial in lighting design to maintain adequate illumination levels by accounting for factors like dirt accumulation and luminaire degradation, with values determined by environmental conditions and luminaire quality.

In the case of LED lighting systems, which are known for their longevity and relatively low maintenance requirements, a **commonly adopted maintenance factor is 0.85.** This value accounts for the minimal degradation of LED luminaires and ensures that sufficient light levels are maintained over the system's operational lifespan [15][16]

2.13. Lighting design part of architectural studio:

The architectural studio's lighting is vital for ambiance, function, and productivity. Here's why it matters:

1. Aesthetic Appeal: Well-designed lighting enhances architectural features, fostering creativity and innovation.

2. Task Efficiency: Proper lighting ensures architects can work comfortably without eye strain.

3. Mood Setting: Lighting sets the atmosphere for different activities, from meetings to focused work

4. Flexibility: Studios need adaptable lighting for various tasks throughout the day.

5. Energy Savings: Energy-efficient lighting reduces costs and environmental impact.

6. Well-being: Good lighting contributes to occupant comfort, productivity, and satisfaction.

7. Branding: Thoughtful lighting reflects a studio's identity and professionalism.

In short, lighting is crucial for studio design, influencing aesthetics, function, sustainability, and occupant well-being.

2.14. Designing outdoor lighting & Importance of it:

- **Purpose and Functionality:** Before diving into the design process, it's crucial to understand the purpose of the outdoor space and how lighting can enhance its functionality. Determining if the space is for relaxation, entertainment, security, or highlighting architectural features [17][18]

- **Types of Outdoor Lighting:**

  Task Lighting: Direct illumination for specific activities like cooking, reading, or working.

  Accent Lighting: Highlights architectural or landscape features, creating visual interest.

  Ambient Lighting: Provides overall illumination to create a comfortable and inviting atmosphere.

  Security Lighting: Deters intruders and enhances safety by illuminating paths, entrances, and dark corners.

  Decorative Lighting: Adds aesthetic appeal through decorative fixtures, lanterns, or string lights.

- **Layers of Lighting:** Effective outdoor lighting designs often incorporate multiple layers to create depth and visual interest.

  Primary Layer: Provides general illumination for the entire space.

  Secondary Layer: Adds accent and task lighting to highlight focal points or specific areas.

- **Lighting Techniques:**

  Up-lighting: Lights placed at ground level to illuminate trees, sculptures, or architectural elements from below.

  Moonlighting: Mimicking the soft, diffused light of the moon by placing fixtures high in trees to cast gentle shadows.

- **Fixture Selection:**

  Choose fixtures that complement the architectural style and aesthetic of the space.

  Select fixtures with adjustable features to customize light levels and beam angles.

- **Lighting Control Systems:**

Incorporate timers, motion sensors, or photocells for automated control and energy savings.

Integrate smart lighting technology for remote access and customization via smartphones or tablets.

- **Light Pollution and Dark Sky Compliance:**

  Minimize light pollution by directing light where it's needed and avoiding excessive glare.

  Follow dark sky principles to reduce light trespass and preserve the natural night-time environment.

- **Safety and Code Compliance:**

  Ensure compliance with local building codes and regulations regarding outdoor lighting installations.

  Prioritize safety by illuminating pathways, stairs, and potential hazards to prevent accidents and injuries.

  By considering these principles and techniques, outdoor lighting designs can enhance the beauty, functionality, and safety of any outdoor space [18].

2.15 Parameters of Outdoor Lighting Design:

i. **Uniformity(U_0):** Uniformity in outdoor lighting ensures consistent light levels across an area, vital for safety and aesthetics. It's measured using Utilization Factor (UF) and Uniformity Ratio (UR), with factors like fixture spacing, light distribution, and surface reflectance influencing it. Lighting design software helps optimize layouts. Recommended levels vary by application, with guidelines from organizations like the IES. Achieving uniformity enhances safety and creates visually pleasing environments [18]

ii. **Average lux level:** The average lux level in outdoor lighting measures the overall brightness and visibility across a space. It's crucial for safety and aesthetics. Factors like space purpose, activities, ambient light, and regulations affect it. Measurement involves using illuminance meters and calculating the average from multiple points. Designers optimize lux levels through fixture selection, spacing, and energy-efficient solutions to ensure uniform illumination and meet standards.

iii. **Longitudinal uniformity (U_l)**: Longitudinal uniformity (U_l) in outdoor lighting refers to the consistency of illuminance levels along a linear path, such as a road, sidewalk, or pathway. It measures the uniformity of light distribution in the direction of travel, ensuring adequate visibility and safety for pedestrians, cyclists, and drivers.

2.16 Parameters of Street Lighting Design:

i. **Boom angle:** The "boom angle", as shown in fig: 2.21, in street lighting refers to the angle at which a street light is mounted on a pole or boom arm. It's crucial for directing light onto specific areas like roads or sidewalks while reducing glare and light pollution. Adjusting this angle ensures proper light distribution for improved visibility and safety for pedestrians and drivers.

ii. **Boom length:** "Boom length" generally describes to the distance between the mounting point of the street light fixture and the point at which the light is emitted. It determines how far the light can reach and illuminate the surrounding area. A longer boom length allows the light to cover a larger area, while a shorter boom length concentrates the light in a smaller radius.

iii. **Overhang:** "Overhang" refers to the horizontal distance between the mounting point of the street light fixture and the edge of the road or sidewalk below. It's the extent to which the light extends beyond the support structure (such as a pole or boom arm). The overhang plays a significant role in determining the coverage area and uniformity of illumination on the ground [15] [17] [18].

iv. **Distance between the pole:** Distance between poles – describes the spacing or interval between individual light poles along a road or pathway.

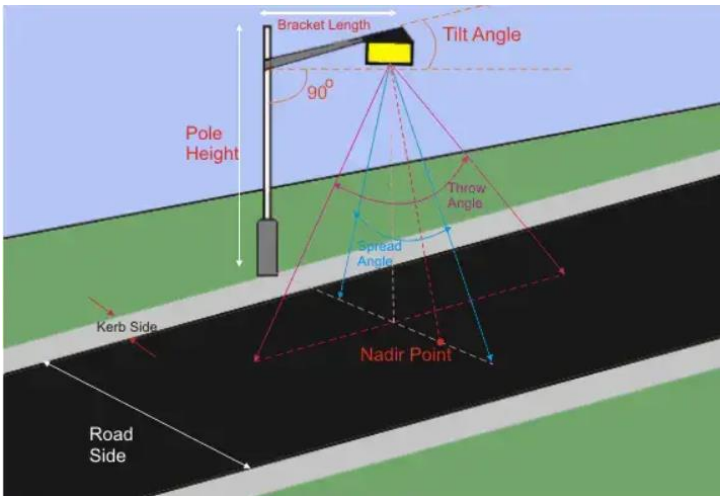


Fig: 2.21 Street lighting distribution

Chapter: 3

Lighting Design for Indoor

Architectural Studio cum Office

3.1. Areas of consideration:

- **Seating space**: In seating areas, various seating arrangements are placed according to the client's requirement. These layouts, as shown in fig: 3.1 and 3.2, can vary from structured geometric patterns to more organic circular designs, regardless of the style, whether it's a cozy family room or a formal sitting area, comfort and functionality are paramount. Hence, designing these areas to reduce the need for strenuous adjustments is essential. Addressing direct and reflected glare is also important. Reflected glare can be caused by bright surfaces reflecting light onto screens or occupants eyes.

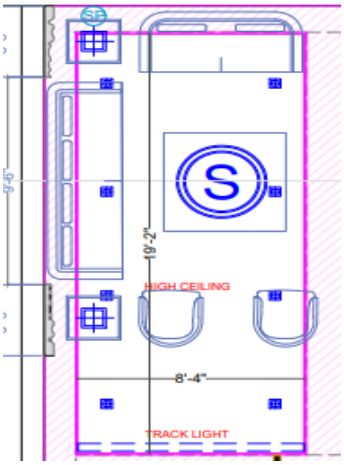


Fig: 3.1: CAD layout of Seating space

Fig: 3.2: Site view after Product Installment

- **Art gallery:** Art galleries, as shown in fig: 3.3 and 3.4, showcase diverse exhibits, in an open architectural studio like this. These galleries feature layouts ranging from structured displays with geometric patterns to more fluid arrangements fostering organic flow. Regardless of the gallery's atmosphere, whether intimate or grand, the primary focus remains on captivating visitors with artistic allure.

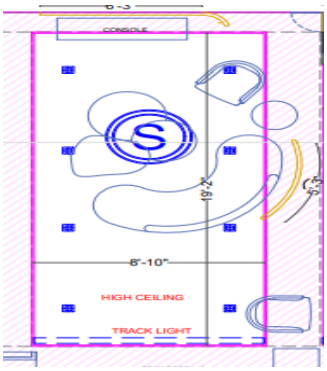


Fig: 3.3: CAD layout of Art gallery

Fig: 3.4: Site view after luminaire installment

- **Study area**: Designing lighting for study areas, as shown in fig: 3.5 and 3.6, involves navigating various challenges to foster an environment that promotes concentration and productivity. Key considerations include ensuring adequate task lighting without causing glare, balancing ambient lighting to avoid distractions, and offering adjustable lighting options to cater to individual preferences. Selecting appropriate color

temperatures, minimizing glare, integrating natural light thoughtfully, and prioritizing energy efficiency are also crucial factors. By addressing these challenges effectively, designers can create study environments that optimize lighting conditions, leading to improved focus, comfort, and overall productivity for users.

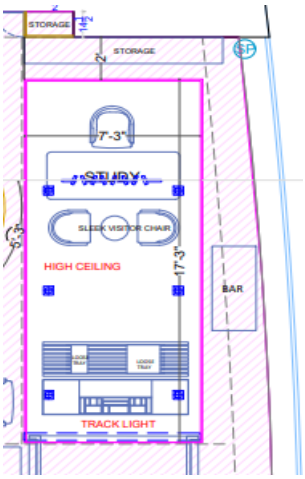


Fig: 3.5: CAD layout of Study area

Fig: 3.6: Site view after luminaire installment

- **Dining area:** Dining areas, as shown in fig: 3.7 and 3.8, involves overcoming various challenges to create an inviting atmosphere for enjoyable dining experiences and social gatherings. Alongside technical lighting, incorporating decorative fixtures like chandeliers or pendant lights can significantly enhance the aesthetic appeal and mood of the space. Careful consideration of style, size, and placement of these fixtures is essential to complement the overall design scheme and elevate the dining experience.

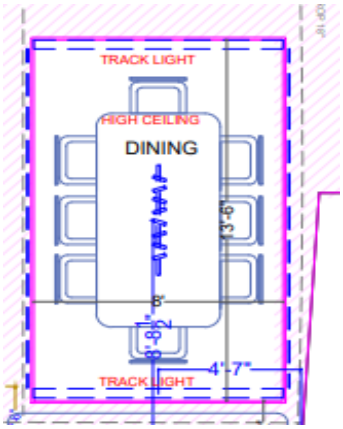


Fig: 3.7: CAD layout of Dinning area

Fig: 3.8: Site view after luminaire installment

- **Bedroom/wardrobe:** When designing bedroom lighting, as shown in the fig: 3.9 and 3.11, it's essential to consider various factors to create a tranquil and cozy atmosphere conducive to rest and relaxation. While simple dimmable lights play a key role in setting a comforting mood, additional elements contribute to enhancing the overall bedroom lighting design. Additionally, for wardrobe lighting, as shown in the fig: 3.10 and 3.12,

the use of directional light aids in locating items from different racks within the wardrobe. Incorporating a total warm tone in both the bedroom and wardrobe further enhances the overall experience, promoting a sense of comfort and intimacy throughout the space.

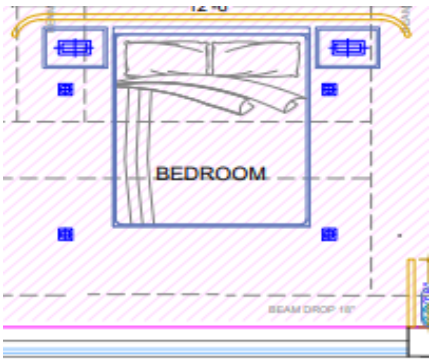


Fig: 3.9: CAD layout of Bedroom

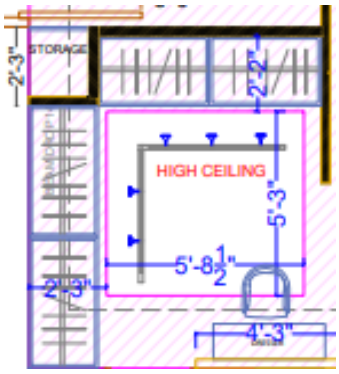


Fig: 3.10: CAD layout of Wardrobe

Fig: 3.11: Site view of Bedroom after luminaire installment

Fig: 3.12: Site view after luminaire installment

- **Living Room:** In the bustling living room as shown in the fig: 3.13 and 3.14, where diverse individuals gather for various activities, crafting the right ambiance is key. Adjustable lighting fixtures play a crucial role, but combining them with accent lighting and strategic placement of lamps adds depth and functionality. Warm-toned lighting enhances the inviting atmosphere, making it ideal for relaxation and socializing.

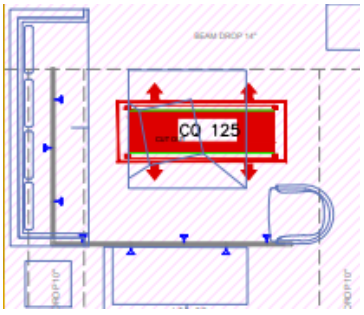


Fig: 3.13: CAD layout of Living area

Fig: 3.14: Site view after luminaire installment

- **Conference room:** Optimized lighting design of conference room, as shown in fig:3.15 and 3.16, is important to balance functionality and ambiance for productivity. Use overhead lighting to evenly illuminate the space, reducing shadows and glare. Incorporate adjustable fixtures for flexibility during presentations, discussions, or video conferences. Maximize natural light through windows or skylights to energize attendees. Smarts controls offer customization, enhancing comfort during long meetings.

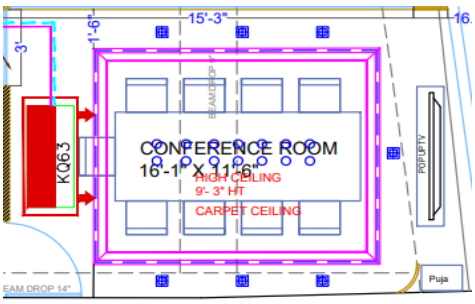


Fig: 3.15: CAD layout of Conference room

Fig: 3.16: Site view after luminaire installment

- **Reception:** Crafting reception lighting, as shown in fig: 3.17, involves balancing practicality and ambiance for an inviting and efficient space. Strategic overhead lighting minimizes shadows and glare, aiding tasks like paperwork and welcoming guests. Adjustable fixtures adapt to various activities, while natural light enhances openness and atmosphere. Smart controls offer personalized comfort, leaving a lasting positive impression on guests and ensuring seamless operations.

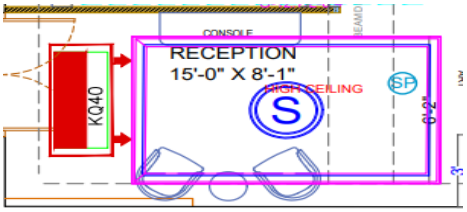


Fig: 3.17: CAD layout of reception

- **Project manager:** It's important to design lighting for a project manager's room, as shown in fig: 3.18 and 3.19, it's crucial to balance practicality and ambiance to create an inviting and efficient workspace. Strategic overhead lighting should be carefully placed to minimize shadows and glare, facilitating tasks such as paperwork and welcoming visitors. Adjustable fixtures provide flexibility to accommodate various activities throughout the day, while the incorporation of natural light enhances the room's atmosphere and sense of openness. Introducing smart lighting controls enables personalized settings tailored to individual preferences, ensuring comfort and leaving a lasting positive impression on guests. These considerations contribute to a workspace that promotes productivity and seamless operations for the project manager.

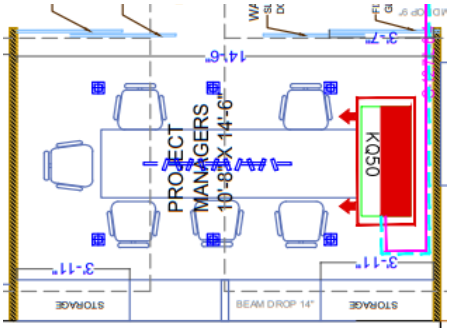


Fig: 3.18: CAD layout of Project manager room

Fig: 3.19: Site view after luminaire installment

- **Account and marketing manager room:** The account and marketing manager's room, as shown in fig: 3.20 and 3.21, involves prioritizing reality and comfort. Emphasizing the drafting area as the main workspace, strategic overhead lighting minimizes shadows and glare, ensuring clarity for analytical tasks and brainstorming.

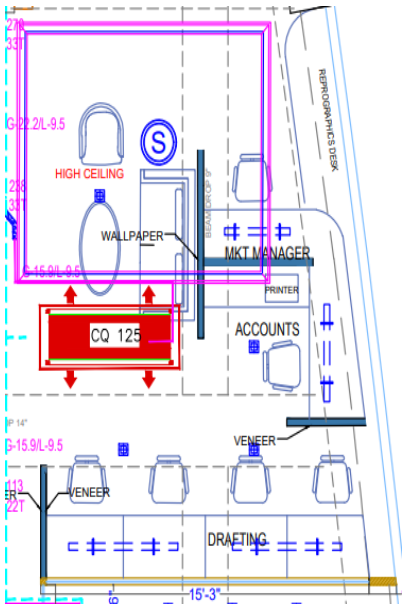


Fig: 3.20: CAD layout of Account and marketing manager room

Fig: 3.21: Site view after luminaire installment

- **Chamber & main chamber room:** In the chambers room, as shown in fig: 3.22 and 3.23, where crucial meetings unfold, meticulous attention is given to lighting design, balancing functionality with an ambiance conducive to decisive discussions. Overhead lighting is strategically placed to minimize shadows and glare, ensuring clarity and focus during important deliberations. Adjustable fixtures provide adaptability for various meeting formats, from presentations to brainstorming sessions, catering to the diverse needs of attendees. Natural light streams in through carefully positioned windows, infusing the space with a sense of openness and vitality

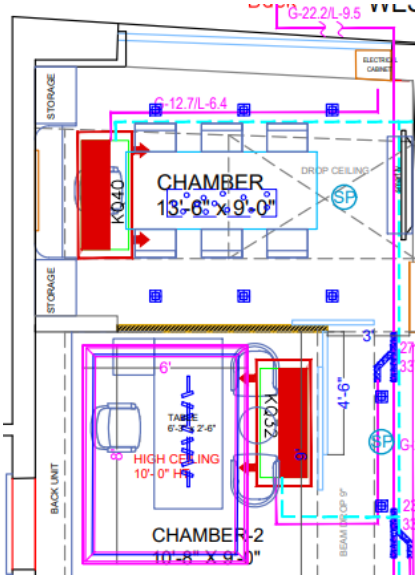


Fig: 3.22: CAD layout of Chamber & main chamber room

Fig: 3.23: Site view after luminaire installment

- **Bathrooms:** In bathroom design, as shown in fig: 3.24, main emphasis shifts to providing ample task lighting for grooming rituals, while also considering ambient lighting to foster relaxation. Through careful selection and placement of fixtures, a harmonious lighting environment is created, that not only enhances functionality but also elevates the aesthetic appeal of the space, ensuring a delightful and comfortable experience for all users.

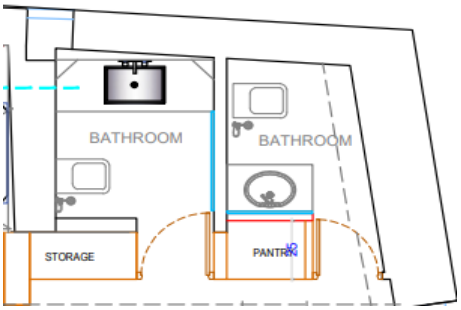


Fig: 3.24: CAD layout of bathroom

3.2 Required Values of Design Parameters:

The design standards, as shown in table: 3.1 outlined in (IS 3646(part1):1992) and IS 3646-Part 2(1966)[13][14] and the National Lighting Code (NLC) 2010 - address the general illumination needs and glare limitations for various indoor environments.

In accordance with the requirements and based on the occupancy age group, **300 lux** is considered appropriate. Since individuals from young to adult age groups will be present, this given value of lux requirement is required to achieved at this place.

Table: 3.1: Lighting standards as per IS3646: The prescribed illuminance and uniformity values:

Areas	Illuminance (Lux)	Uniformity
Office	300	>0.6
General Office	300	>0.6
Computer work stations	300	>0.6
Conference rooms, executive offices	500	>0.6
Reception	300	>0.6
Living area	300	>0.6
Dining area	300	>0.6

International standard for Indoor design:

According to EN 12464-1:2002 (European Standard) [20], the guidelines for indoor lighting design, including office environments, are detailed in Table 3.2.

Table: 3.2: International European standard

Areas	Illuminance (Lux)	Uniformity
Conference rooms	500	>0.6
Reception	300	>0.6

Writing, typing, reading, data processing	300	>0.6
General lighting	300	>0.6

3.3 Electrical looping diagram for dimming control:

The image used in Figure 3.25 represents the actual electrical looping diagram of the site. Utilizing this diagram, the automation control team manages the dimming of connections or luminaires at the final stage of luminaire placement.

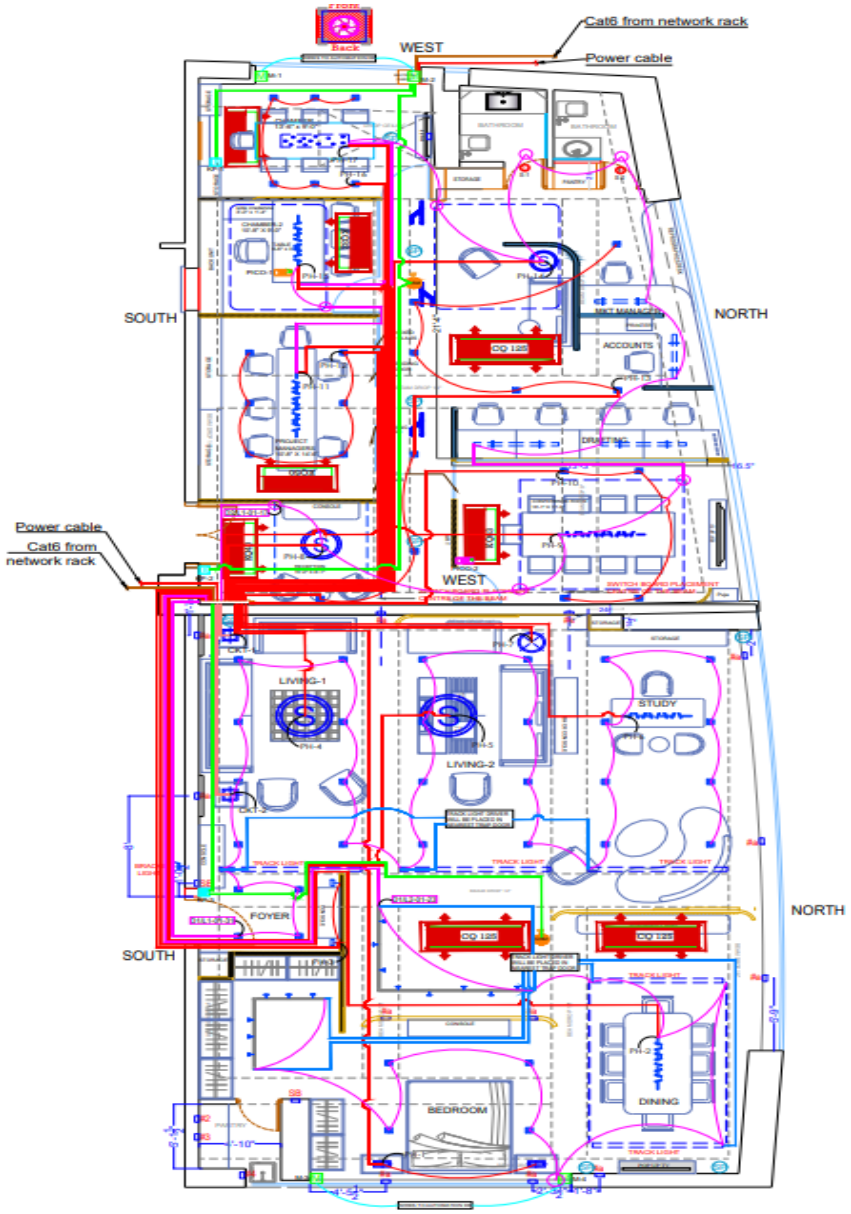
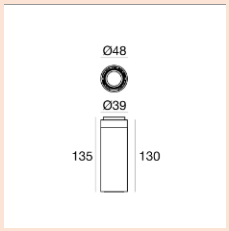
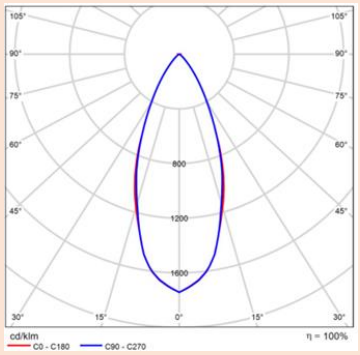
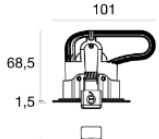
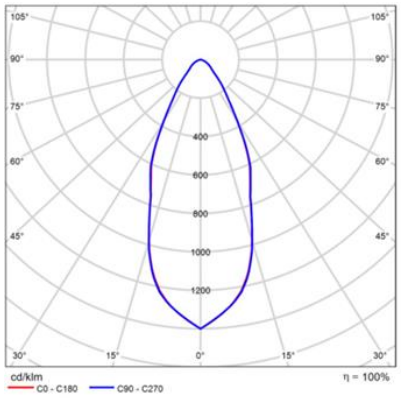


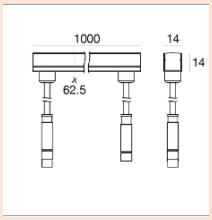
Fig:3.25: Electrical looping diagram

3.4. Types of Luminaire used:

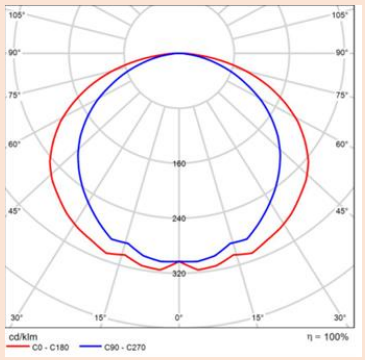
This comprises the entirety of the luminaires utilized in the design. The table provided delineates the luminaire characteristics alongside their respective distribution curves as shown in table 3.3.

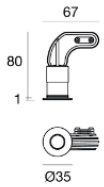
Table: 3.3: Luminaire details with Light distribution curve

Picture	Details of Luminaire Fixture	Light Distribution curve
 	Article No. 82004W60 P 6.0 W Φ_{Lamp} 391 lm $\Phi_{Luminaire}$ 391 lm η 99.93 % Luminous efficacy 65.2 lm/W CCT 3000 K CRI 92	
 	Article No. 97920N33 P 8.0 W Φ_{Lamp} 580 lm $\Phi_{Luminaire}$ 580 lm η 99.93 % Luminous efficacy 72.5 lm/W CCT 4000 K CRI 92	

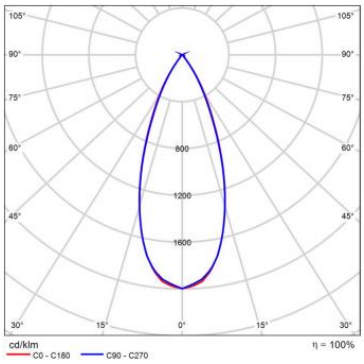


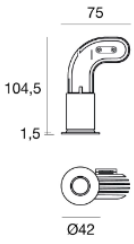
Article No.	80394
P	3.0 W
Φ_{Lamp}	136 lm
$\Phi_{Luminaire}$	136 lm
η	99.93 %
Luminous efficacy	45.3 lm/W
CCT	3000 K
CRI	85



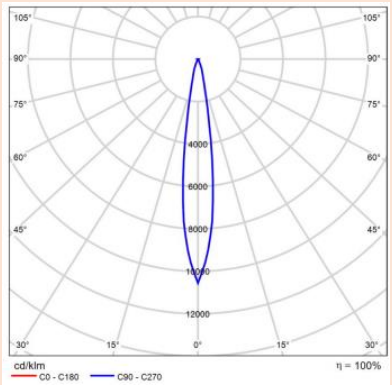


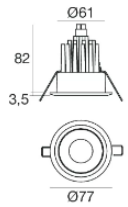
Article No.	90644W60
P	4.0 W
Φ_{Lamp}	152 lm
$\Phi_{Luminaire}$	152 lm
η	99.73 %
Luminous efficacy	37.9 lm/W
CCT	3000 K
CRI	80



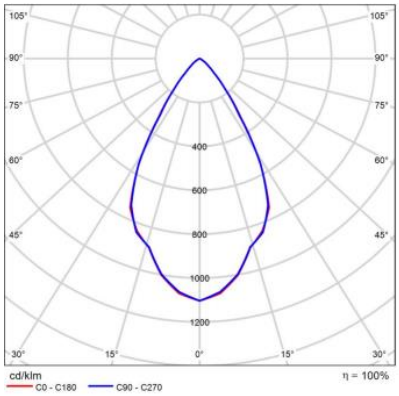


Article No.	90650M15
P	6.0 W
Φ_{Lamp}	301 lm
$\Phi_{Luminaire}$	301 lm
η	99.89 %
Luminous efficacy	50.1 lm/W
CCT	3000 K
CRI	92





Article No.	96635W60
P	8.0 W
Φ_{Lamp}	691 lm
$\Phi_{Luminaire}$	692 lm
η	99.93 %
Luminous efficacy	86.5 lm/W
CCT	3000 K
CRI	80



3.5. Diverse software utilization in the project:

- **DIALux EVO:** DIALux EVO is a powerful software, as shown in fig: 3.26, tool widely used in architectural lighting design, embraced by architects, lighting designers, and engineers for its ability to elevate the quality, sustainability, and user experience of illuminated spaces.
  Its user-friendly interface and advanced features enable efficient planning and execution of lighting designs with precision. Notably, DIALux EVO excels in generating accurate 3D models of indoor and outdoor environments, facilitating realistic visualization of lighting scenarios to aid decision-making.

  The software offers a comprehensive toolkit including lighting calculations, luminaire placement, daylight analysis, and rendering capabilities. This allows professionals to evaluate various design options, optimize lighting performance, energy efficiency, and visual comfort, while ensuring compliance with regulatory standards.

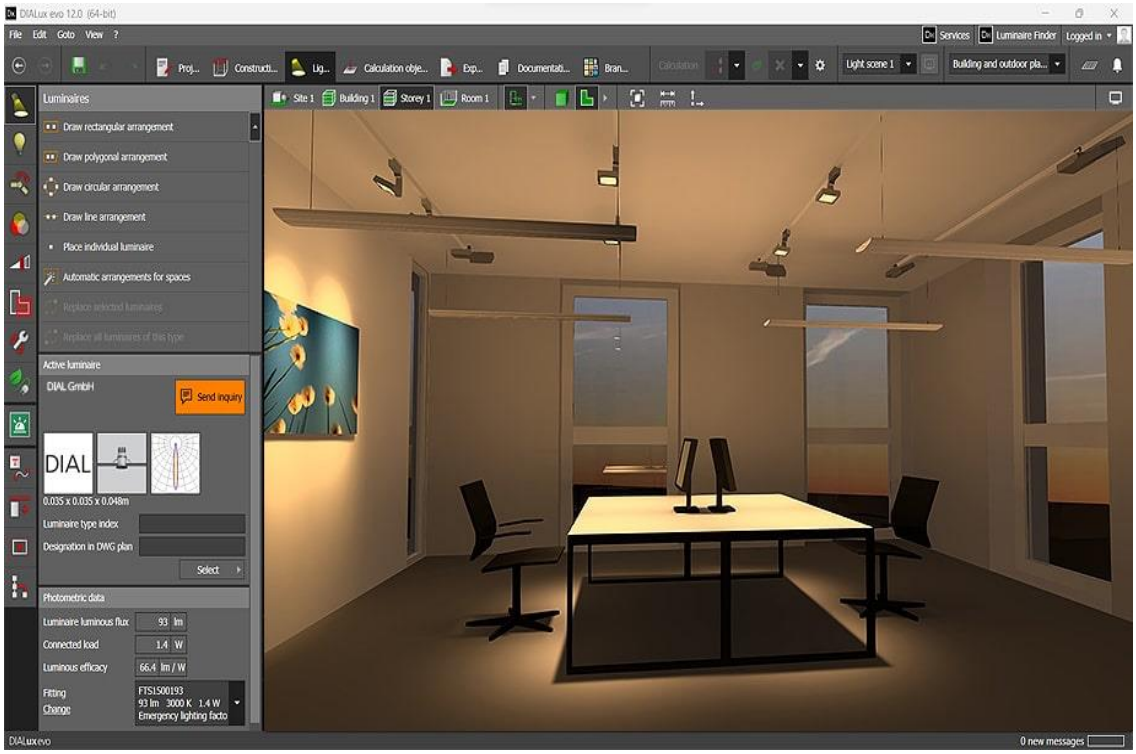


Fig:3.26: Software interface of DIALux EVO software

In essence, DIALux EVO empowers users to create lighting solutions that enhance both the aesthetics and functionality of spaces, contributing to sustainability and occupant well-being. Its role in informed decision-making and iterative design processes makes it indispensable in shaping illuminated environments to the highest standards.

- **AutoCAD:** AutoCAD is a widely recognized computer-aided design (CAD) software, as shown in fig: 3.27, developed by Autodesk. It serves as a powerful tool for architects, engineers, drafters, and designers across various industries to create precise 2D and 3D drawings and models. AutoCAD offers an extensive range of features and functionalities tailored to facilitate the design, drafting, and documentation processes. One of the key strengths of AutoCAD lies in its versatility. Users can generate detailed drawings of buildings, mechanical components, electrical circuits, and much more with utmost accuracy. The software provides an array of drawing tools, including lines, shapes, arcs, and text, allowing for the creation of intricate designs. Additionally, it supports parametric drawing, enabling users to maintain relationships between objects and easily make modifications.

  In addition to its design capabilities, AutoCAD facilitates efficient documentation and collaboration. Users can generate precise dimensions, annotations, and detailing to create comprehensive technical drawings and construction documents. Moreover, AutoCAD's compatibility with various file formats, including DWG (its native format), ensures seamless exchange of drawings with collaborators and stakeholders.

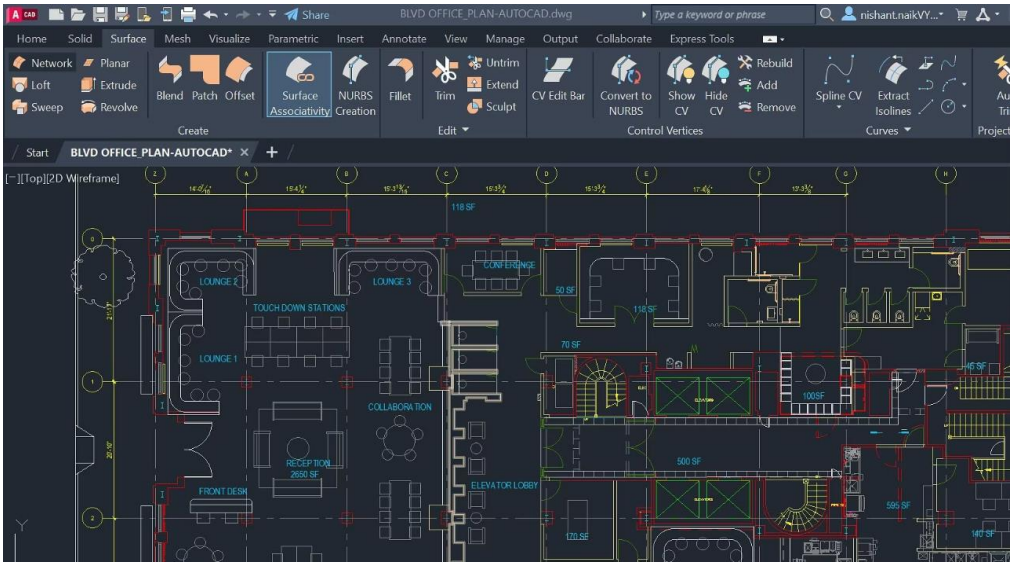


Fig:3.27: Software interface of AutoCAD software

Overall, AutoCAD stands as a cornerstone in the realm of computer-aided design, empowering professionals to translate their ideas into detailed, accurate, and visually compelling designs across diverse industries. Its robust features, flexibility, and interoperability make it an indispensable tool for design and engineering workflows.

3.6. Overview of Different Areas in an Indoor Design Project: [Architectural studio cum office]

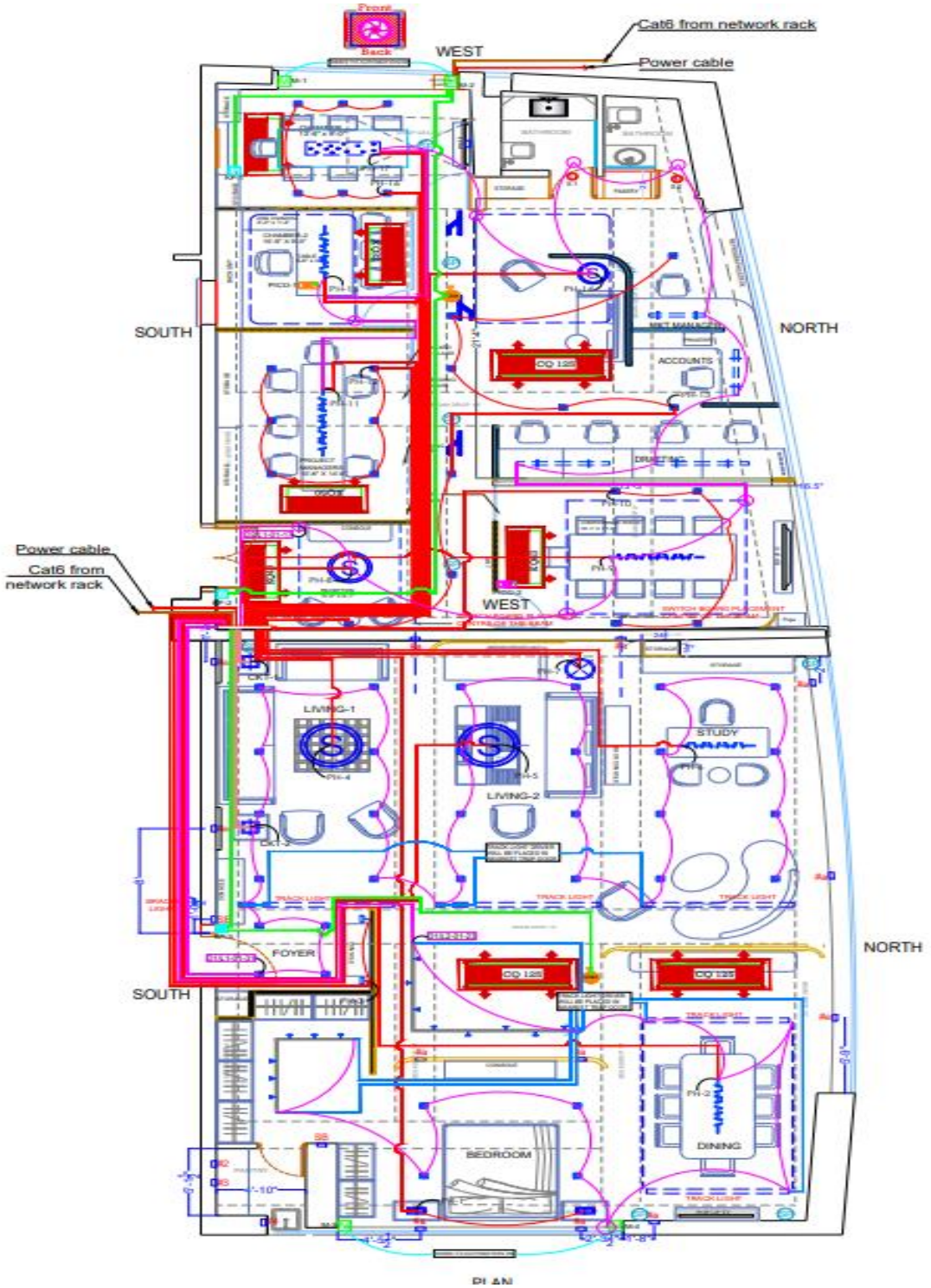


Fig:3.28: Full AutoCAD view of the site

3.7 Design Parameters and Considerations

In accordance with the layout specifications and client preferences, everything is meticulously designed for all indoor spaces, considering all pertinent factors outlined in Table 3.4

Table: 3.4: Design Considerations of the Project:

Consideration	Requirement
Room dimensions	As per AutoCAD drawing
Mounting height	2.790m for recessed luminaires & 2.570m for luminaire that are placed on false ceiling
Height of the work-plane & calculation grid	From floor level: 0.8m
Maintained average illuminance (E_{avg}) on work-plane	≥300 lux for Bedroom/ Living room/ Personal chamber, ≥150 lux for Bathrooms, ≥500 lux for Drafting area.
Overall maintained uniformity (U0) on table top	≥ 0.6

3.8. Details of design:

The lighting design for the 'architectural studio cum office' was custom-tailored to align with the client's specific requirements, incorporating all of their expectations. Comprehensive summaries of the design across various areas, as shown in fig: 3.28, have been furnished, encompassing vital input data such as room dimensions, light loss factors, reflectance factors, and work plane heights for precise illumination level calculations. Furthermore, the report includes output data such as average illumination levels, overall uniformity, and LPD values. Additionally, it features Isolux diagrams, which visually represent points of similar illuminance connected by contours. Detailed information regarding the luminaires utilized in the simulation is provided within the summary report, including luminaire coordinate lists that specify positions and mounting heights.

CAD-layout of the architectural studio:

The diagram illustrated in Figure 3.29 depicts the layout of the architectural studio.

Fig:3.29: AutoCAD view of architectural Studio

3.9 Areas of architectural studio with lighting calculations and design summary:

- **Area: 1 [Seating space]**

The area illustrated in Figure 3.30 represents the seating space of the entire architectural studio, as depicted in Figure 3.31.

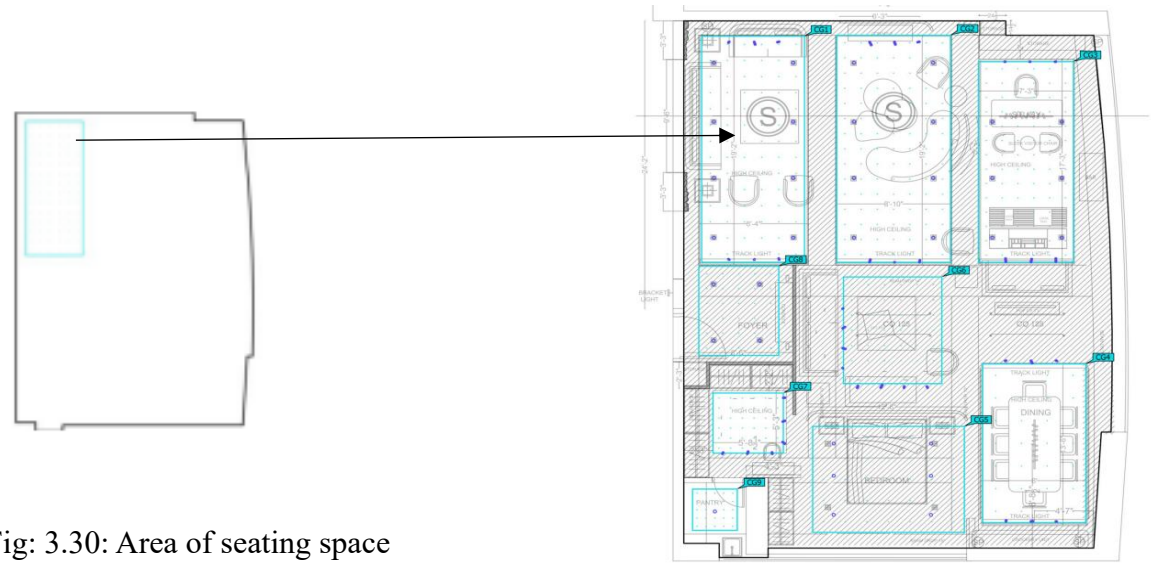


Fig: 3.30: Area of seating space

Fig:3.31: Architectural studio

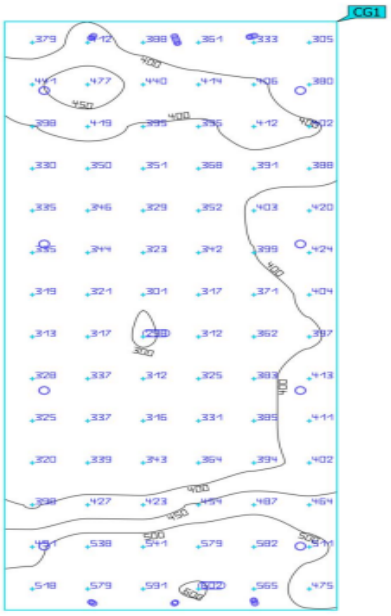


Fig:3.32: Lighting Calculation area of the seating space

Design summary:

In the design summary, respective figures clearly show the results after carefully followed the standards, as shown in fig: 3.33

Properties	$\bar{E}$	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation surface(Seating Space) Perpendicular illuminance Height: 0.800 m	397 lx	298 lx	602 lx	0.75	0.50	CG1

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Fig:3.33: DIALux report of the calculation surface

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 397 lux
- Overall Uniformity (U_0) = 0.75
- Lighting Power Density (LPD)/ Specific Connected Load = 4.11 W/m^2

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.34.

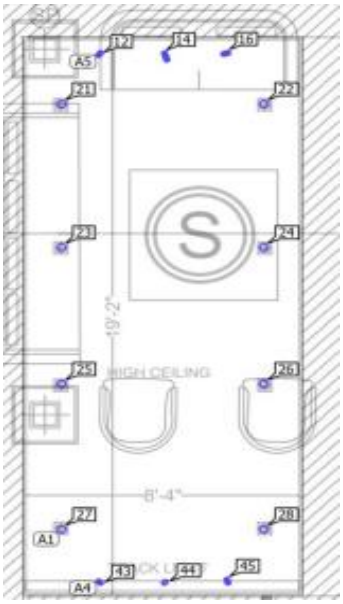


Fig:3.34: Luminaire layout of the seating space

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.35

3 x Linea Light Group Pound_S Projectors 6W DC

Type	Line arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	1.016 m / 12.494 m / 2.790 m	1.016 m	12.494 m	2.790 m	12
X-direction	3 pcs., Centre - centre, Distances not equal	1.574 m	12.494 m	2.790 m	14
		2.132 m	12.494 m	2.790 m	16
Arrangement	A5				

3 x Linea Light Group Pound_S Projectors 6W DC

Type	Line arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	1.016 m / 7.214 m / 2.790 m	1.016 m	7.214 m	2.790 m	43
X-direction	3 pcs., Centre - centre, Distances not equal	1.574 m	7.214 m	2.790 m	44
		2.132 m	7.214 m	2.790 m	45
Arrangement	A4				

8 x Linea Light Group Loro_R Downlight 8W DC

Type	Field Arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	0.674 m / 7.747 m / 2.790 m	0.674 m	11.984 m	2.790 m	21
X-direction	2 pcs., Centre - centre, Distances not equal	2.446 m	11.984 m	2.790 m	22
		0.674 m	10.557 m	2.790 m	23
Y-direction	4 pcs., Centre - centre, Distances not equal	2.446 m	10.557 m	2.790 m	24
		0.674 m	9.196 m	2.790 m	25
Arrangement	A1	2.446 m	9.196 m	2.790 m	26
		0.674 m	7.747 m	2.790 m	27
		2.446 m	7.747 m	2.790 m	28

Fig: 3.35: luminaire co-ordinates of the seating space

Visualization of Lighting Design:

Below images is the visualization of the site as shown in the fig: 3.36 and 3.37,

Fig: 3.36: View through lighting software

Luminaire placement at the site:

Fig: 3.37: After product instalment

- **Area: 2 [Art gallery]**

  The area illustrated in Figure 3.38 represents the art gallery of the entire architectural studio, as depicted in Figure 3.39

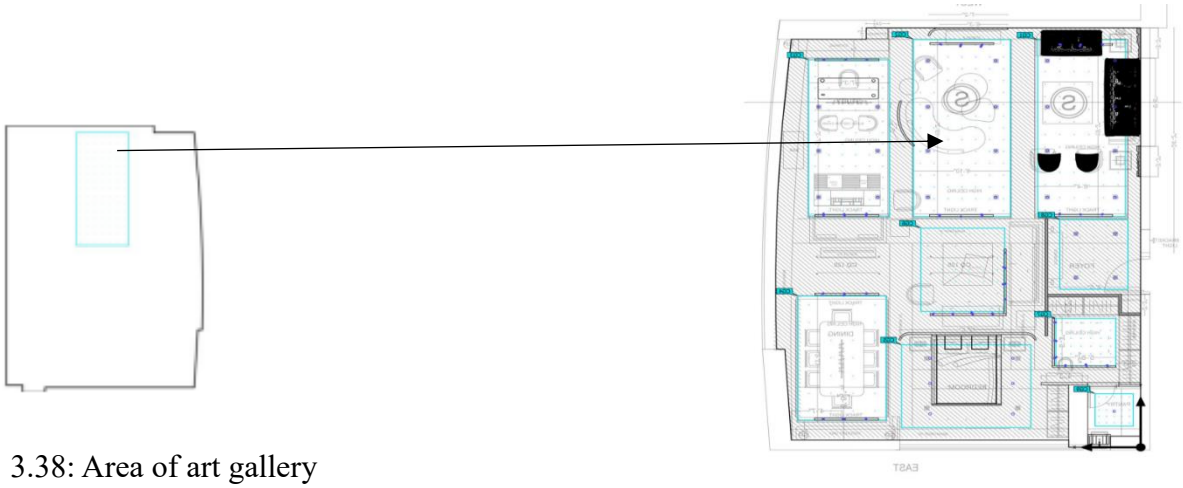


Fig: 3.38: Area of art gallery

Fig: 3.39: Architectural studio

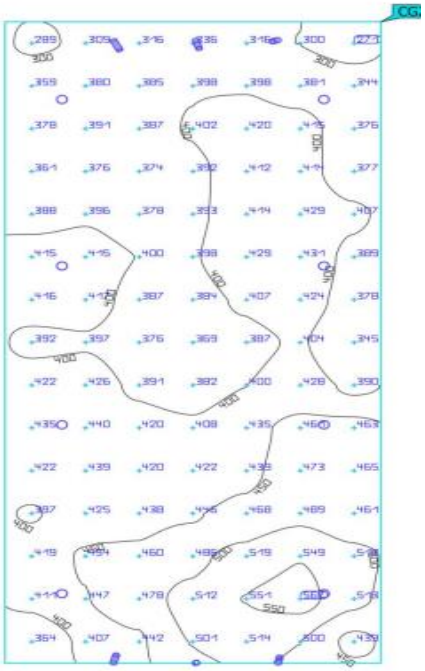


Fig: 3.40: Lighting Calculation area of the art gallery

Design summary:

In the design summary, respective figures clearly show the results after carefully followed the standards as shown in fig: 3.41

Properties	$\bar{E}$	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation Surface(Art gallery) Perpendicular illuminance Height: 0.800 m	415 lx	271 lx	567 lx	0.65	0.48	CG2

Fig: 3.41: DIALux report the area

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 415 lux
- Overall Uniformity (U_0) = 0.65

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.42.

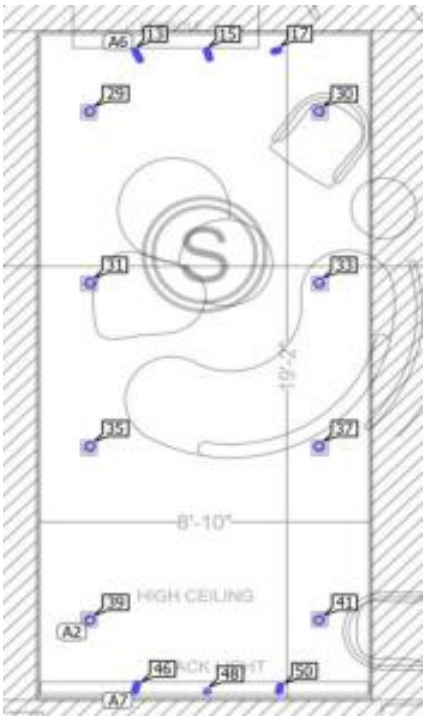


Fig: 3.42: Luminaire layout of the Art gallery

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.43

3 x Linea Light Group Pound_S Projectors 6W DC

Luminaire layout plan

Type	Line arrangement
1st luminaire (X/Y/Z)	4.152 m / 12.494 m / 2.790 m
X-direction	3 pcs., Centre - centre, Distances not equal
Arrangement	A6

X	Y	Mounting height	Luminaire
4.152 m	12.494 m	2.790 m	13
4.710 m	12.494 m	2.790 m	15
5.268 m	12.494 m	2.790 m	17

3 x Linea Light Group Pound_S Projectors 6W DC

Type	Line arrangement
1st luminaire (X/Y/Z)	4.152 m / 7.152 m / 2.790 m
X-direction	3 pcs., Centre - centre, Distances not equal
Arrangement	A7

X	Y	Mounting height	Luminaire
4.152 m	7.152 m	2.790 m	46
4.710 m	7.152 m	2.790 m	48
5.268 m	7.152 m	2.790 m	50

8 x Linea Light Group Loro_R Downlight 8W DC

Type	Field Arrangement
1st luminaire (X/Y/Z)	3.806 m / 7.747 m / 2.790 m
X-direction	2 pcs., Centre - centre, Distances not equal
Y-direction	4 pcs., Centre - centre, Distances not equal
Arrangement	A2

X	Y	Mounting height	Luminaire
3.806 m	11.984 m	2.790 m	29
5.578 m	11.984 m	2.790 m	30
3.806 m	10.557 m	2.790 m	31
5.578 m	10.557 m	2.790 m	33
3.806 m	9.195 m	2.790 m	35
5.578 m	9.195 m	2.790 m	37
3.806 m	7.747 m	2.790 m	39
5.578 m	7.747 m	2.790 m	41

Fig: 3.43: Luminaire co-ordinates of the Art gallery

Visualization after design:

Below images is the visualization of the site as shown in the fig: 3.44

Fig: 3.44: Visualization of the area though software

- **Area: 3 [Study area]**
  The area illustrated in Figure 3.45 represents the study area of the entire architectural studio, as depicted in Figure 3.46

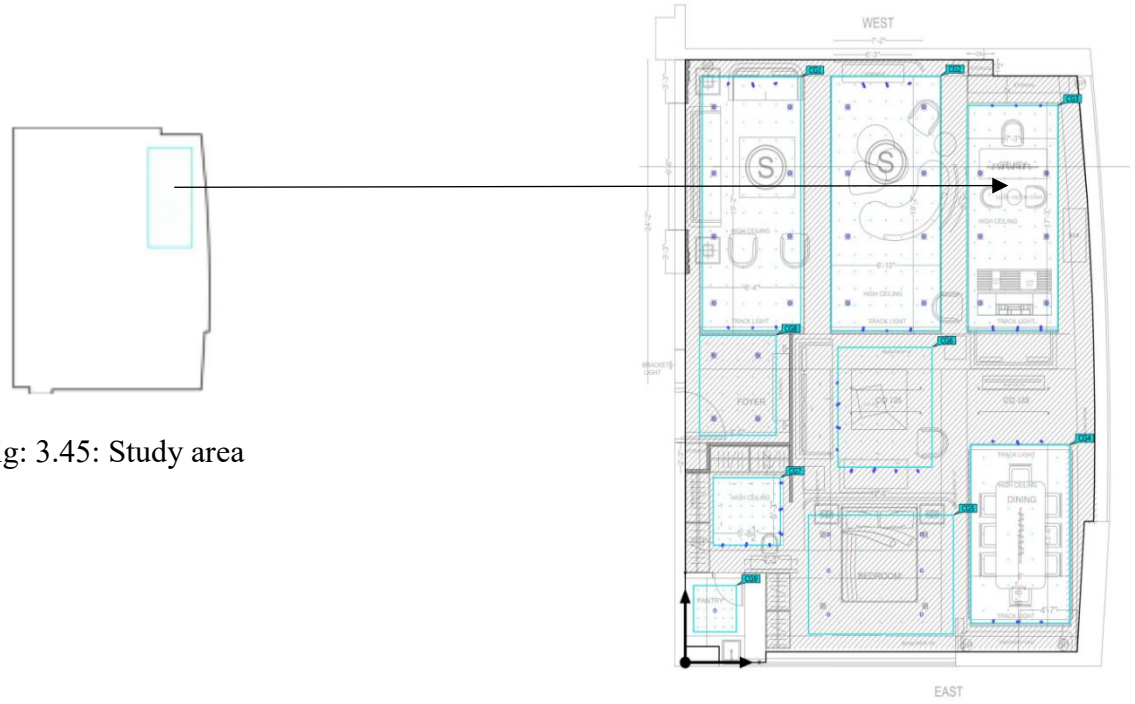


Fig: 3.45: Study area

Fig:3.46: Architectural studio

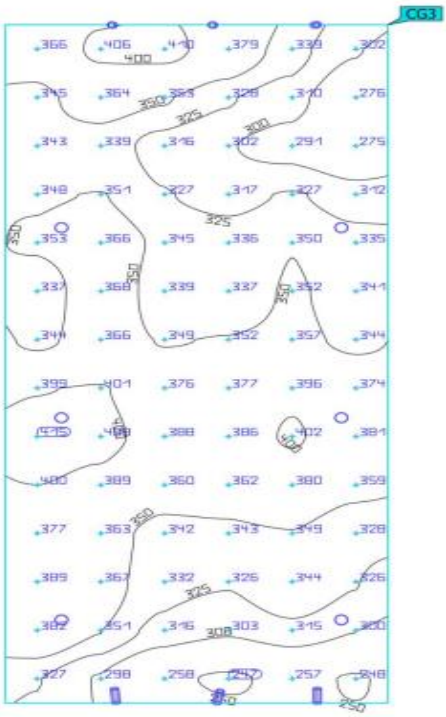


Fig: 3.47: Lighting Calculation of the Study area

Design summary:

In the design summary, as shown in fig: 3.48, respective figures clearly show the results after carefully followed the standards.

Properties	$\bar{E}$	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation Surface (Study Area) Perpendicular illuminance Height: 0.800 m	346 lx	247 lx	415 lx	0.71	0.60	CG3

Fig: 3.48: DIALux report the area

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 346 lux
- Overall Uniformity (U_0) = 0.71

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.49

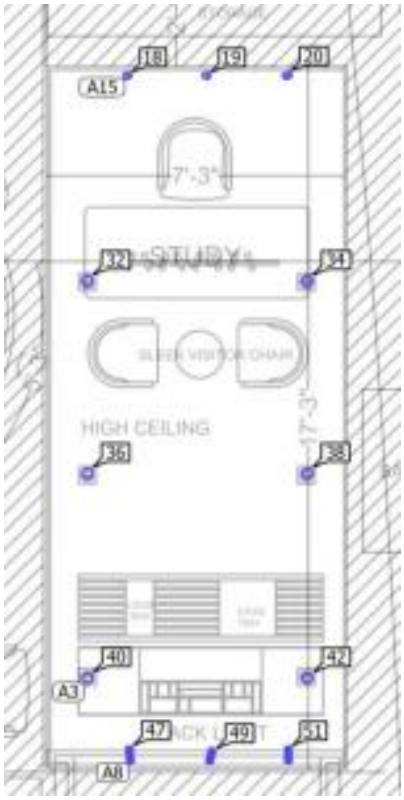


Fig: 3.49: Luminaire layout of the study area

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.50

3 x Linea Light Group Pound_S Projectors 6W DC

Type	Line arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	7.187 m / 12.008 m / 2.790 m	7.187 m	12.008 m	2.790 m	18
X-direction	3 pcs., Centre - centre, Distances not equal	7.745 m	12.008 m	2.790 m	19
		8.303 m	12.008 m	2.790 m	20
Arrangement	A15				

3 x Linea Light Group Pound_S Projectors 6W DC

Type	Line arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	7.204 m / 7.152 m / 2.790 m	7.204 m	7.152 m	2.790 m	47
X-direction	3 pcs., Centre - centre, Distances not equal	7.762 m	7.152 m	2.790 m	49
		8.320 m	7.152 m	2.790 m	51
Arrangement	A8				

6 x Linea Light Group Loro_R Downlight 8W DC

Type	Field Arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	6.900 m / 7.747 m / 2.790 m	6.900 m	10.557 m	2.790 m	32
X-direction	2 pcs., Centre - centre, Distances not equal	8.454 m	10.557 m	2.790 m	34
		6.900 m	9.195 m	2.790 m	36
Y-direction	4 pcs., Centre - centre, Distances not equal	8.454 m	9.195 m	2.790 m	38
		6.900 m	7.747 m	2.790 m	40
Arrangement	A3	8.454 m	7.747 m	2.790 m	42

Fig: 3.50: Luminaire co-ordinates of the study area

Visualization of the design:

Below images is the visualization of the site as shown in the fig: 3.51 and 3.52,

Fig: 3.51: Visualization of study area through DIALux software

After luminaire implementation:

Fig: 3.52: After product instalment.

- **Area :4 (Dinning area)**
  The area illustrated in Figure 3.53 represents the dining area of the entire architectural studio, as depicted in Figure 3.54

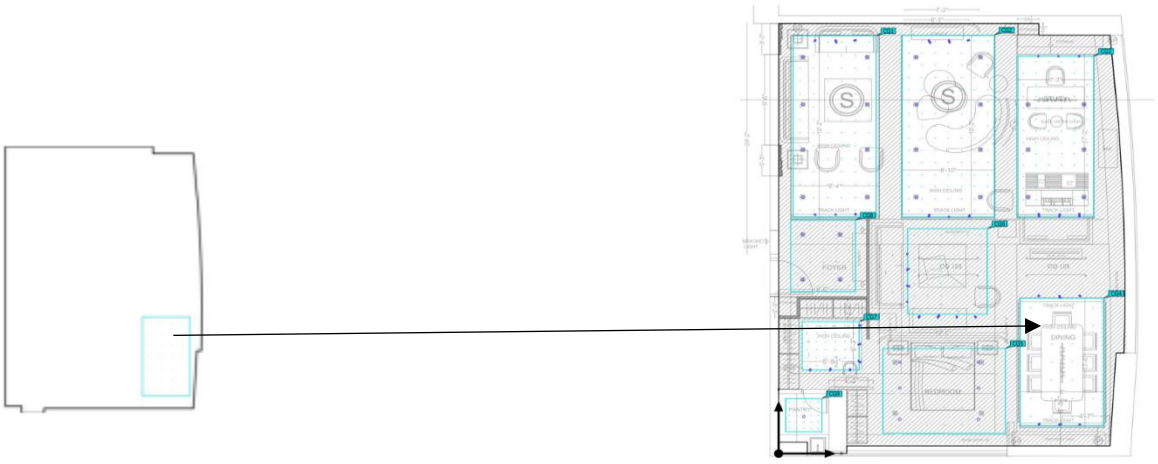


Fig: 3.53: Dinning area

Fig: 3.54: Architectural studio

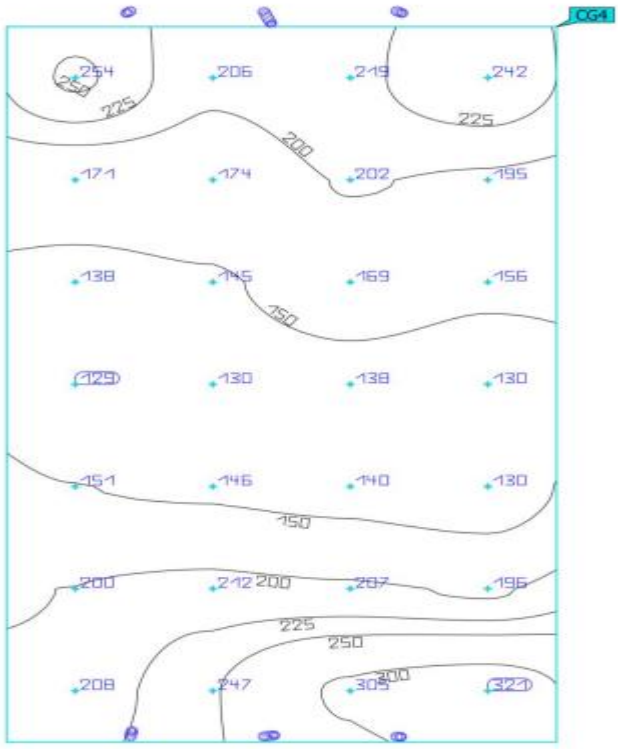


Fig: 3.55: Lighting Calculation of the Dining area

Design summary:

In the design summary as shown in fig: 3.56, respective figures clearly show the results after carefully followed the standards.

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation Surface(Dinning) Perpendicular illuminance Height: 0.800 m	188 lx	129 lx	321 lx	0.69	0.40	CG4

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Fig: 3.56: DIALux report the area

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 188 lux
- Overall Uniformity (U_0) = 0.69

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.57

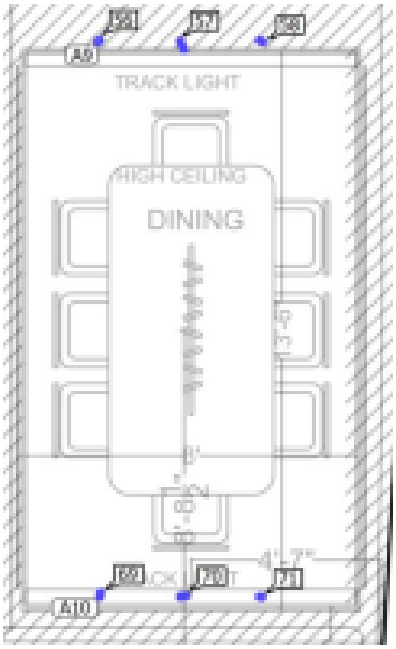


Fig: 3.57: Luminaire layout of the dining room

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.58

3 x Linea Light Group Pound_S Projectors 6W DC

Type	Line arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	7.204 m / 4.773 m / 2.790 m	7.204 m	4.773 m	2.790 m	56
		7.762 m	4.773 m	2.790 m	57

X-direction	3 pcs., Centre - centre, Distances not equal	X	Y	Mounting height	Luminaire
Arrangement	A9	8.320 m	4.773 m	2.790 m	58

3 x Linea Light Group Pound_S Projectors 6W DC

Type	Line arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	7.204 m / 0.875 m / 2.790 m	7.204 m	0.875 m	2.790 m	69
X-direction	3 pcs., Centre - centre, Distances not equal	7.762 m	0.875 m	2.790 m	70
		8.320 m	0.875 m	2.790 m	71
Arrangement	A10				

Fig: 3.58: Luminaire co-ordinates of the dining room

Visualization after design:

Fig: 3.59: Visualization of dining area through DIALux software

Area: 5 [Bedroom]

The area illustrated in Figure 3.60 represents the bedroom area of the entire architectural studio, as depicted in Figure 3.61

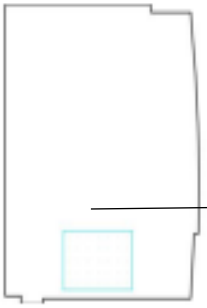


Fig: 3.60: Bedroom area

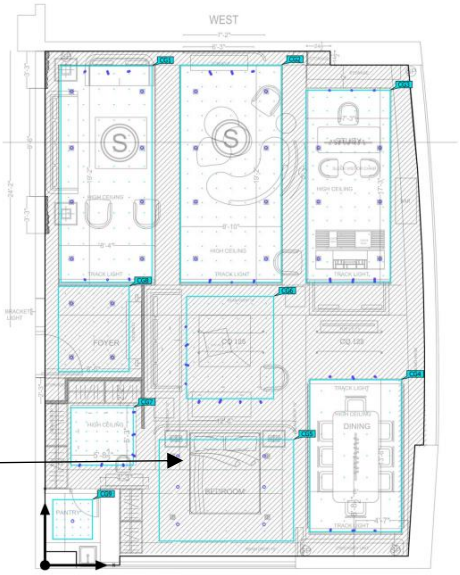


Fig: 3.61: Architectural studio

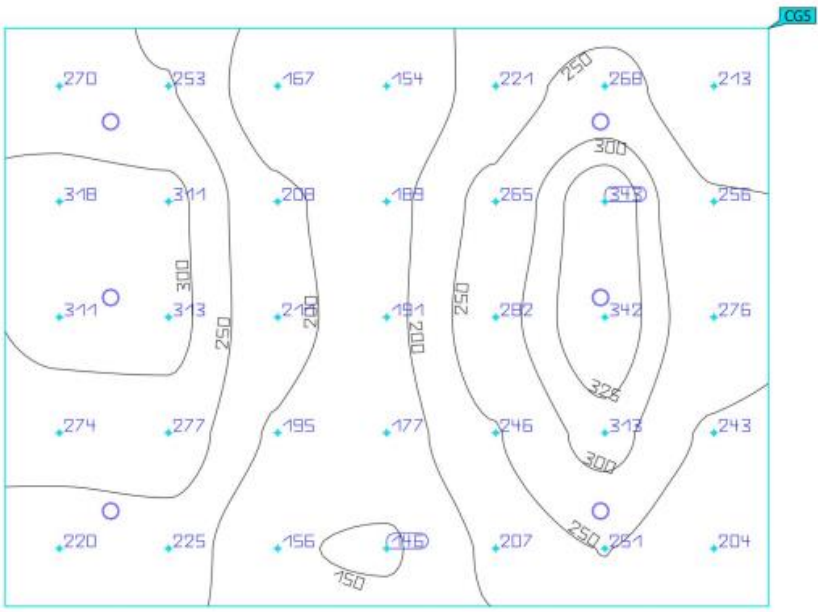


Fig: 3.62: Lighting Calculation of the Bedroom area

Design summary:

In the design summary as shown in fig: 3.63, respective figures clearly show the results after carefully followed the standards.

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Bedroom Perpendicular illuminance Height: 0.800 m	243 lx	146 lx	343 lx	0.60	0.43	CG5

Fig: 3.63: DIALux report the area

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 243 lux
- Overall Uniformity (U_0) = 0.60

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.64

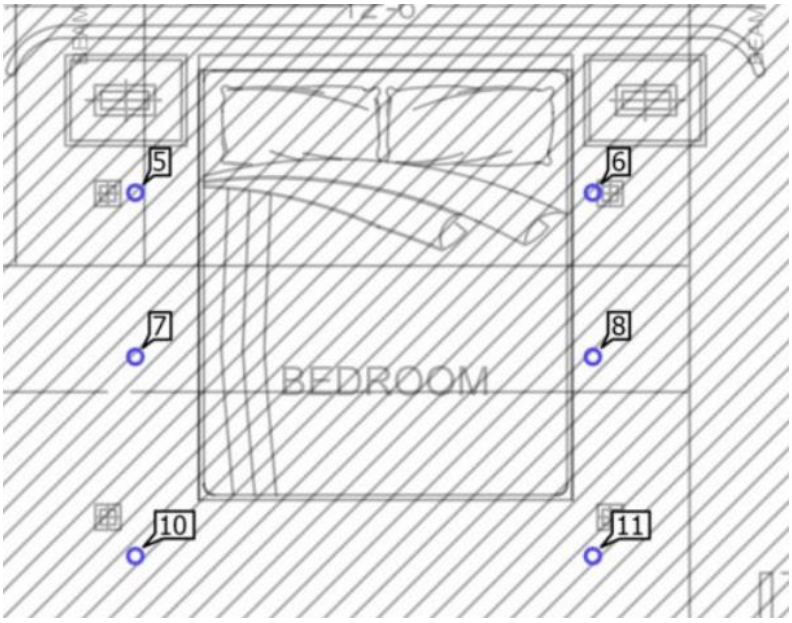


Fig: 3.64: Luminaire layout of the Bed room area

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.65

6 x Linea Light Group Loro_R Downlight 8W DC

X	Y	Mounting height	Luminaire
3.353 m	2.762 m	2.790 m	5
5.528 m	2.762 m	2.790 m	6
3.353 m	1.981 m	2.790 m	7
5.528 m	1.981 m	2.790 m	8
0.696 m	1.115 m	2.790 m	9
3.353 m	1.033 m	2.790 m	10
5.528 m	1.033 m	2.790 m	11

Fig: 3.65: Luminaire co-ordinates of the Bed room area

Visualization after design:

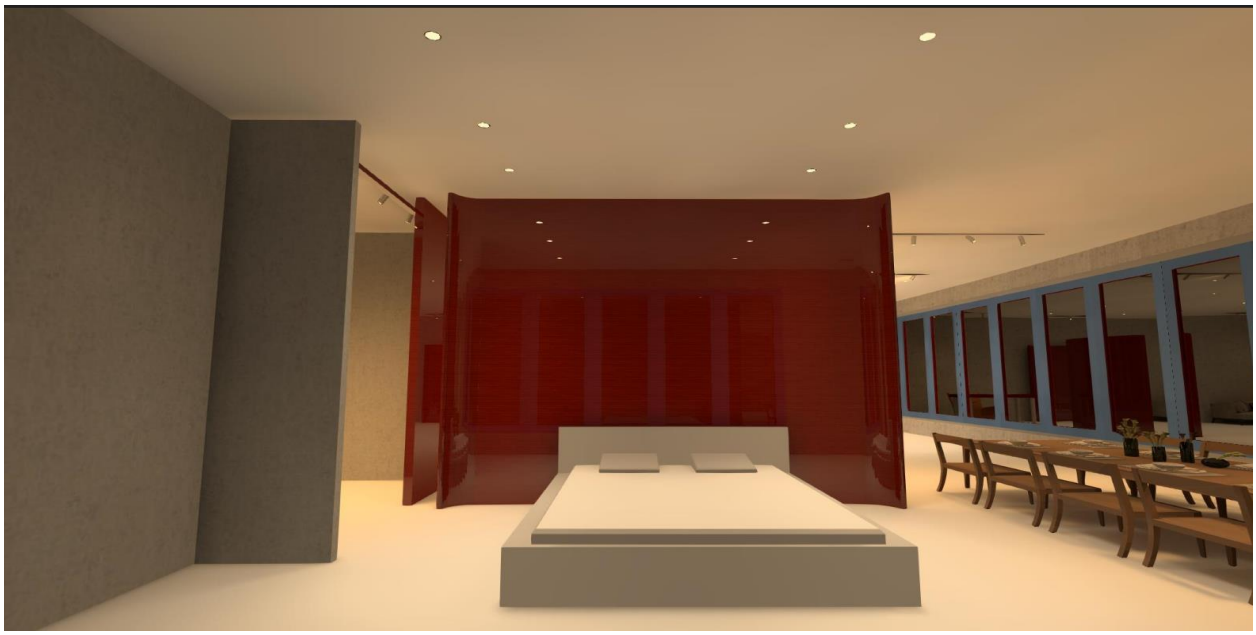


Fig: 3.66: Software view of the Bedroom area

- **Area: 6 [Wardrobe]**
  The area illustrated in Figure 3.67 represents the wardrobe area of the entire architectural studio, as depicted in Figure 3.68

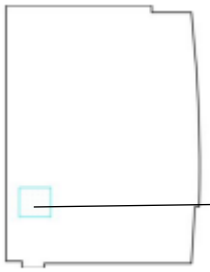


Fig: 3.67: Wardrobe area

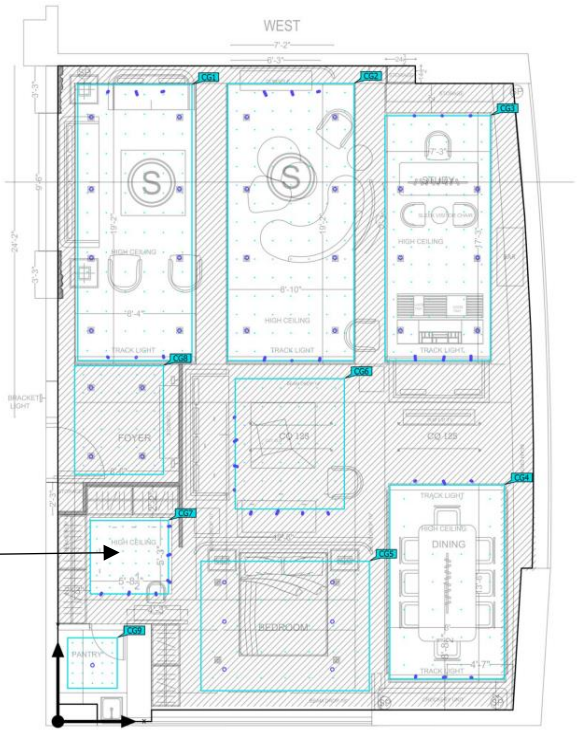


Fig: 3.68: Architectural studio

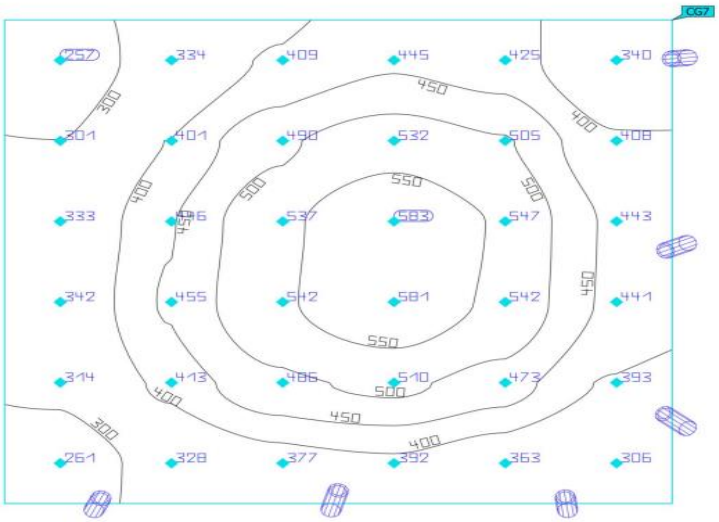


Fig: 3.69: Lighting Calculation of the wardrobe area

Design summary:

In the design summary as shown in fig: 3.70, respective figures clearly show the results after carefully followed the standards.

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation Surface(Walk-in-Closet) Perpendicular illuminance Height: 0.800 m	424 lx	257 lx	583 lx	0.61	0.44	CG7

Fig: 3.70: DIALux report the area

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 424 lux
- Overall Uniformity (U_0) = 0.61

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.71

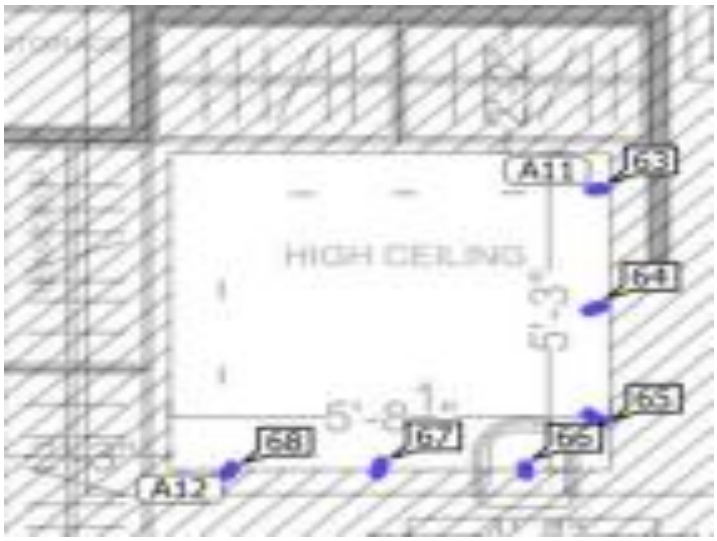


Fig: 3.71: Luminaire layout of the Wardrobe area

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.72

3 x Linea Light Group Pound_S Projectors 6W DC

Type	Line arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	2.263 m / 3.872 m / 2.790 m	2.263 m	3.872 m	2.790 m	63
X-direction	3 pcs., Centre - centre, Distances not equal	2.263 m	3.314 m	2.790 m	64
		2.263 m	2.756 m	2.790 m	65
Arrangement	A11				

3 x Linea Light Group Pound_S Projectors 6W DC

Type	Line arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	1.979 m / 2.510 m / 2.790 m	1.979 m	2.510 m	2.790 m	66
X-direction	3 pcs., Centre - centre, Distances not equal	1.421 m	2.510 m	2.790 m	67
		0.863 m	2.510 m	2.790 m	68
Arrangement	A12				

Fig: 3.72: Luminaire co-ordinates of the Wardrobe area

Visualization after the design:

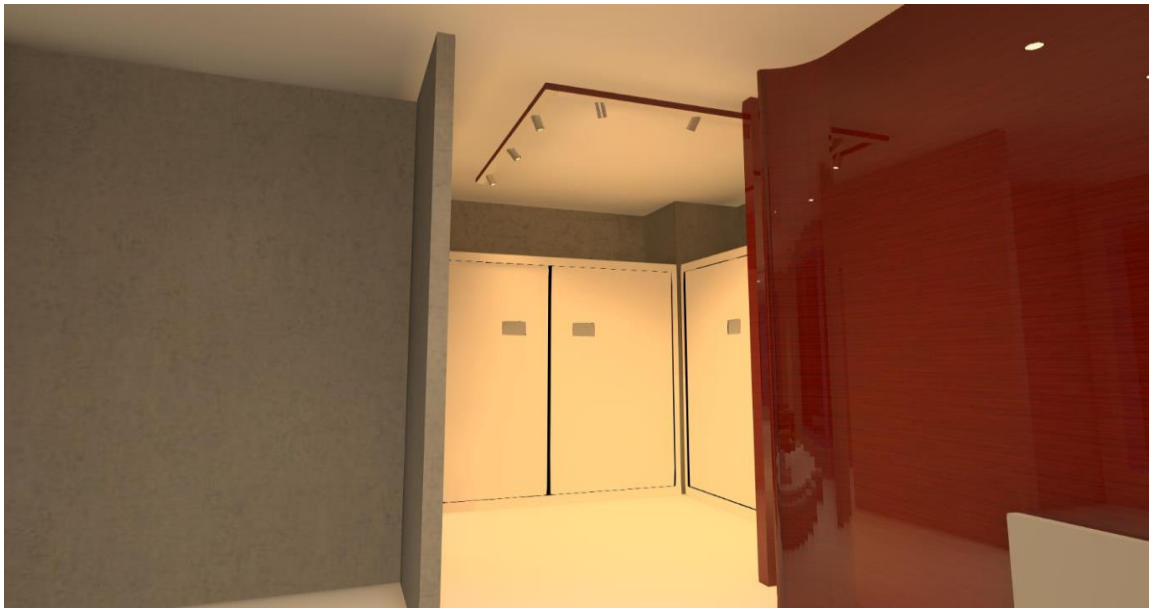


Fig: 3.73: Software view of the wardrobe area

- **Area: 7 [Entrance]**
  The area illustrated in Figure 3.74 represents the entrance area of the entire architectural studio, as depicted in Figure 3.75

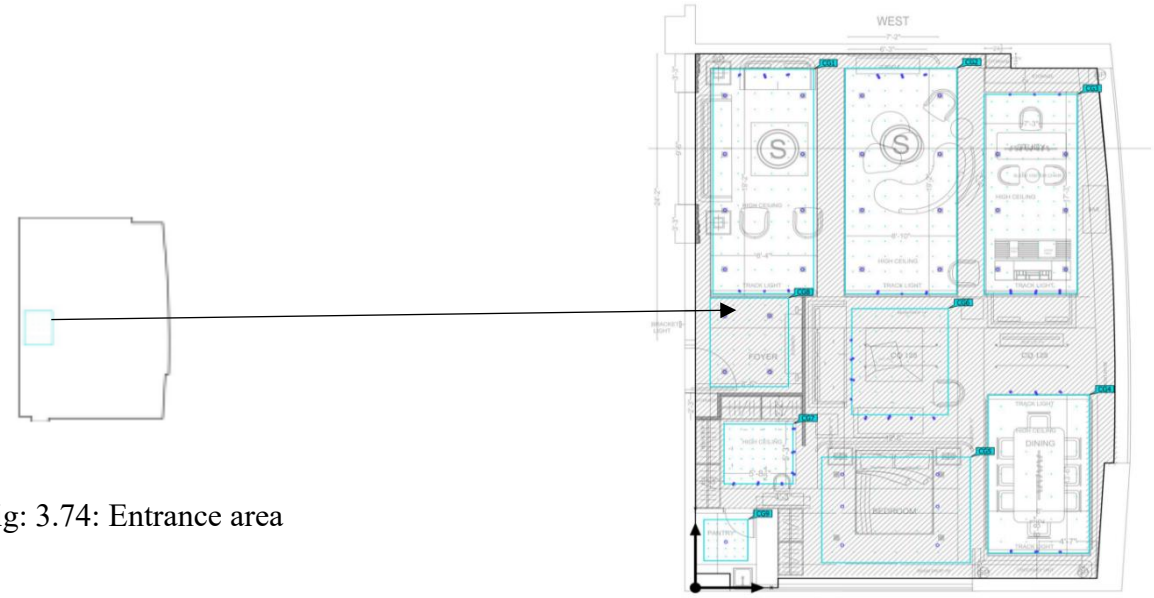


Fig: 3.74: Entrance area

Fig: 3.75: Architectural studio

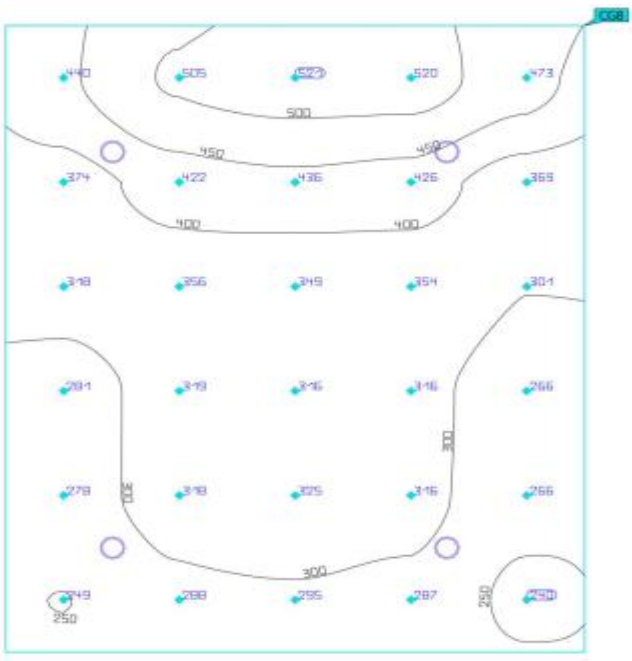


Fig: 3.76: Lighting Calculation of the entrance area

Design summary:

In the design summary as shown in fig: 3.77, respective figures clearly show the results after carefully followed the standards.

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation Surface(Entrance) Perpendicular illuminance Height: 0.800 m	351 lx	240 lx	521 lx	0.68	0.46	CG8

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Fig: 3.77: DIALux report of the calculation surface

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 351 lux
- Overall Uniformity (U_0) = 0.68

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.78

Fig: 3.78: Luminaire layout of the entrance

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.79

6 x Linea Light Group Loro_R Downlight 8W DC

Individual luminaires

X	Y	Mounting height	Luminaire
0.666 m	6.619 m	2.790 m	1
1.699 m	6.619 m	2.790 m	2
0.666 m	5.255 m	2.790 m	3
1.699 m	5.255 m	2.790 m	4

Fig: 3.79: Luminaire co-ordinates of the entrance

Visualization after design:

Fig: 3.80: Software view of the Entrance after design

3.10. Design analysis of the office area:

The diagram illustrated in Figure 3.81 depicts the layout of the office area.

Fig: 3.81: AutoCAD layout of the office area

- **Area: 1 [Reception]**

The area illustrated in fig:3.82 represents the reception area of the entire office area, as depicted in fig:3.83

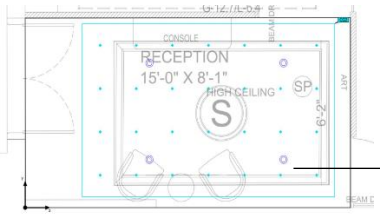


Fig: 3.82: Reception area

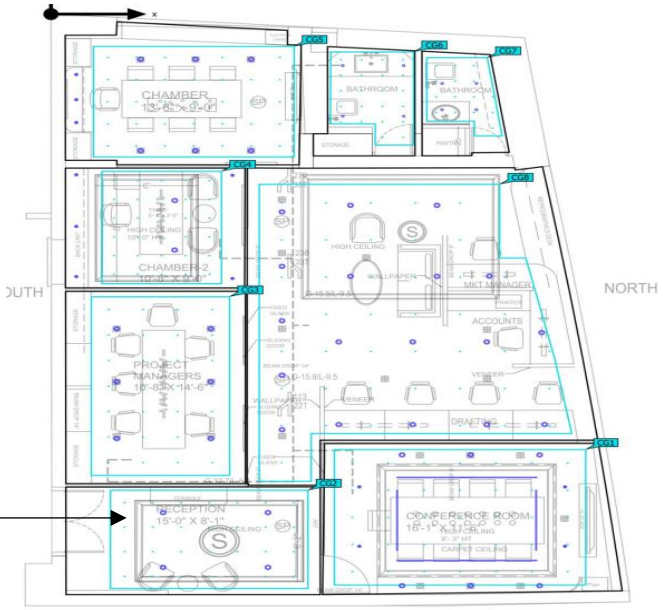


Fig:3.83: The office area

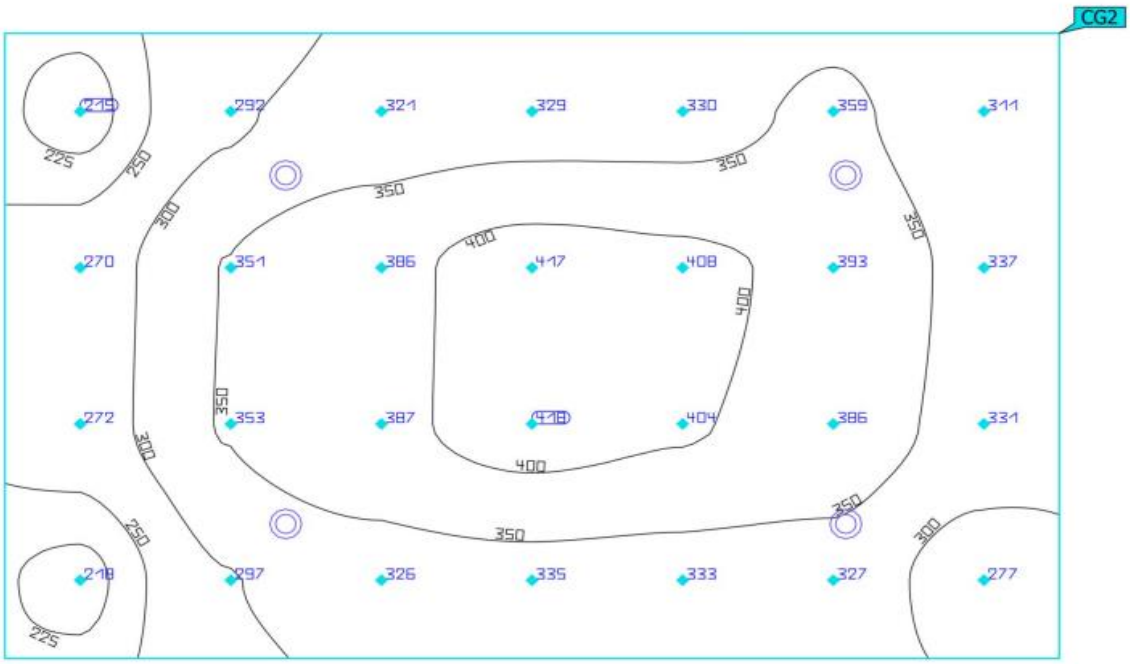


Fig:3.84:: Lighting Calculation of the reception area

Design summary:

In the design summary, as shown in the fig:3.85, respective figures clearly show the results after carefully followed the standards.

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation surface(Reception) Perpendicular illuminance Height: 0.800 m	335 lx	215 lx	418 lx	0.64	0.51	CG2

Fig: 3.85: DIALux report of the calculation surface

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 335 lux
- Overall Uniformity (U_0) = 0.64
- Lighting Power Density (LPD)/ Specific Connected Load = 5.43 W/m^2

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.86

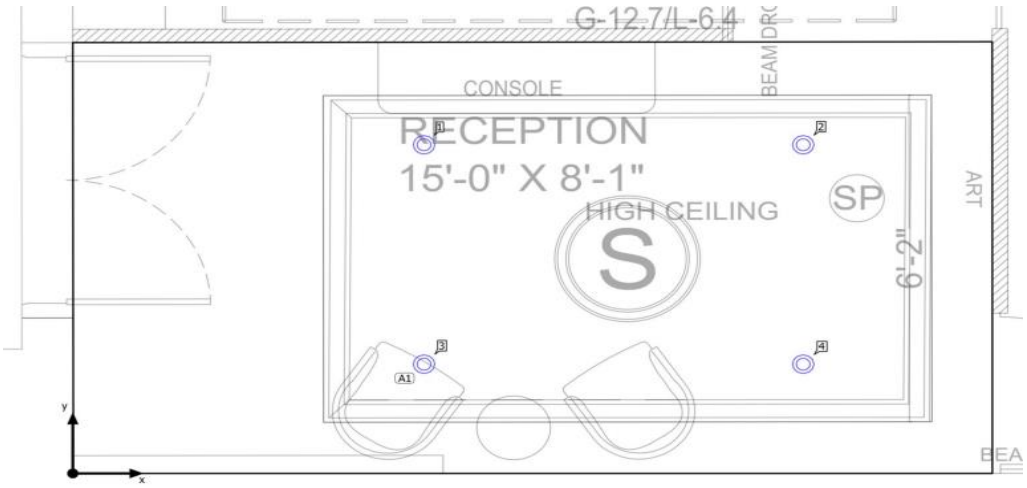


Fig:3.86: Luminaire layout of the reception

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.87

4 x Linea Light Group Anton R 8W

Type	Field Arrangement
1st luminaire (X/Y/Z)	1.260 m / 0.453 m / 2.570 m
X-direction	2 pcs., Centre - centre, Distances not equal
Y-direction	2 pcs., Centre - centre, Distances not equal
Arrangement	A1

X	Y	Mounting height	Luminaire
1.260 m	1.363 m	2.570 m	1
2.620 m	1.363 m	2.570 m	2
1.260 m	0.453 m	2.570 m	3
2.620 m	0.453 m	2.570 m	4

Fig:3.87: Luminaire co-ordinates of the reception

Visualization after the design:

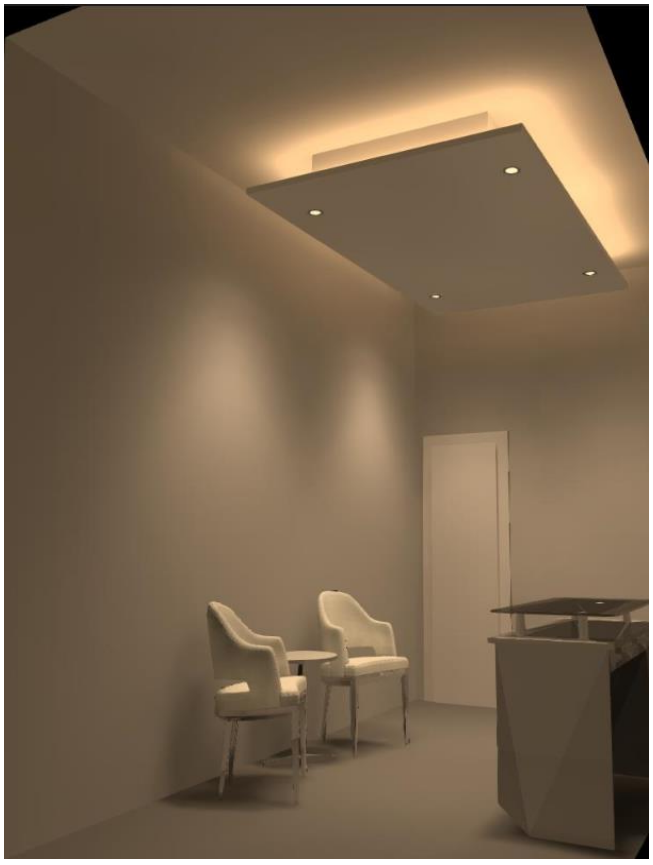


Fig:3.88: Software view of the reception

- **Area: 2 [Conference room]**
  The area illustrated in fig:3.89 represents the conference room area of the entire office area, as depicted in fig:3.90

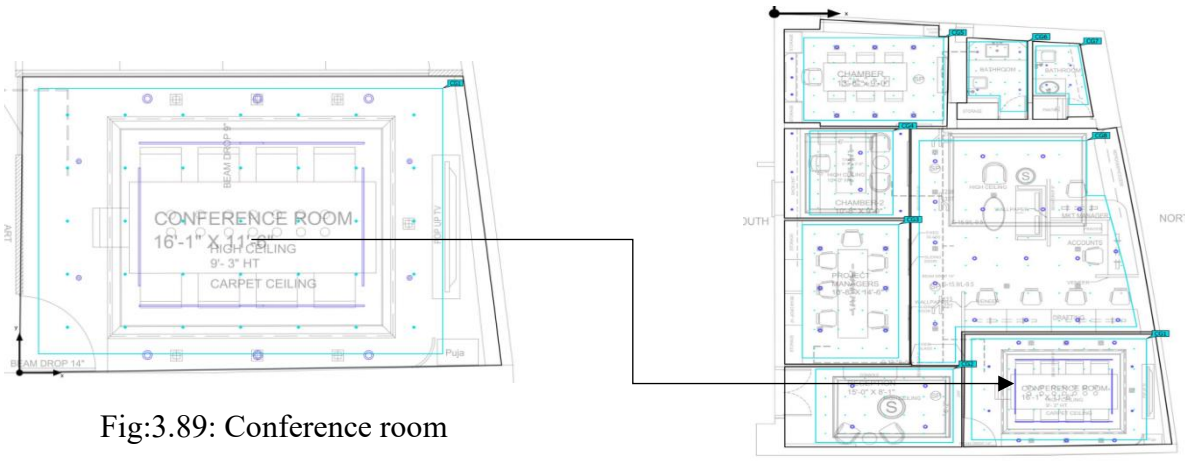


Fig:3.89: Conference room

Fig:3.90: The office area

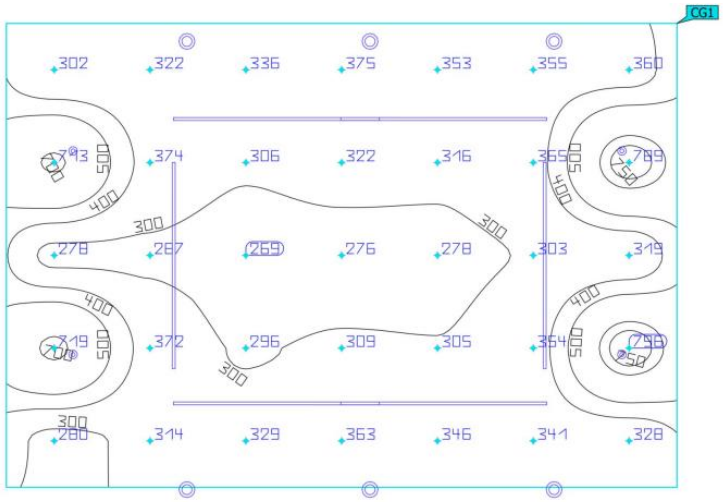


Fig: 3.91: Lighting Calculation of the Conference room area

Design summary:

In the design summary, as shown in the fig:3.92, respective figures clearly show the results after carefully followed the standards.

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation surface(Conference Room) Perpendicular illuminance Height: 0.800 m	373 lx	269 lx	796 lx	0.72	0.34	CG1

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Fig:3.92: DIALux report of the calculation surface

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 373 lux
- Overall Uniformity (U_0) = 0.72
- Lighting Power Density (LPD)/ Specific Connected Load = 9.75 W/m^2

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.93

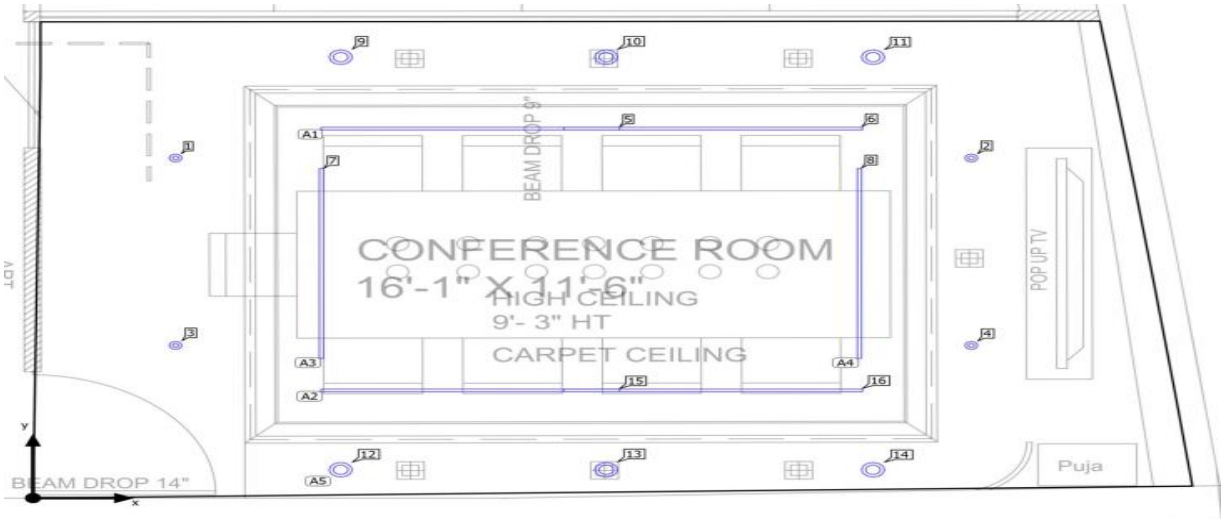


Fig:3.93: Luminaire layout of the conference room

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.94

6 x Linea Light Group Anton R 8W

Type	Field Arrangement
1st luminaire (X/Y/Z)	1.031 m / 0.149 m / 2.790 m
X-direction	3 pcs., Centre - centre, Distances not equal
Y-direction	2 pcs., Centre - centre, Distances not equal
Arrangement	A5

X	Y	Mounting height	Luminaire
1.031 m	2.323 m	2.790 m	9
1.920 m	2.323 m	2.790 m	10
2.815 m	2.323 m	2.790 m	11
1.031 m	0.149 m	2.790 m	12
1.920 m	0.149 m	2.790 m	13
2.815 m	0.149 m	2.790 m	14

2 x Linea Light Group RUBBER - Strip, White, IP65 - Mono-emission LED 10 W

Type	Line arrangement
1st luminaire (X/Y/Z)	1.465 m / 1.946 m / 2.628 m
X-direction	2 pcs., Centre - centre, 0.813 m
Arrangement	A1

X	Y	Mounting height	Luminaire
1.465 m	1.946 m	2.628 m	5
2.279 m	1.946 m	2.628 m	6

2 x Linea Light Group RUBBER - Strip, White, IP65 - Mono-emission LED 10 W

Type	Line arrangement
1st luminaire (X/Y/Z)	1.465 m / 0.567 m / 2.628 m
X-direction	2 pcs., Centre - centre, 0.813 m
Arrangement	A2

X	Y	Mounting height	Luminaire
1.465 m	0.567 m	2.628 m	15
2.279 m	0.567 m	2.628 m	16

1 x Linea Light Group RUBBER - Strip, White, IP65 - Mono-emission LED 10 W

Type	Line arrangement
1st luminaire (X/Y/Z)	0.967 m / 1.236 m / 2.628 m
X-direction	1 pcs., Centre - centre, 1.626 m
Arrangement	A3

X	Y	Mounting height	Luminaire
0.967 m	1.236 m	2.628 m	7

1 x Linea Light Group RUBBER - Strip, White, IP65 - Mono-emission LED 10 W

Type	Line arrangement
1st luminaire (X/Y/Z)	2.769 m / 1.236 m / 2.628 m
X-direction	1 pcs., Centre - centre, 1.626 m
Arrangement	A4

X	Y	Mounting height	Luminaire
2.769 m	1.236 m	2.628 m	8

Fig:3.94: Luminaire co-ordinates of the conference room

Visualization after design:

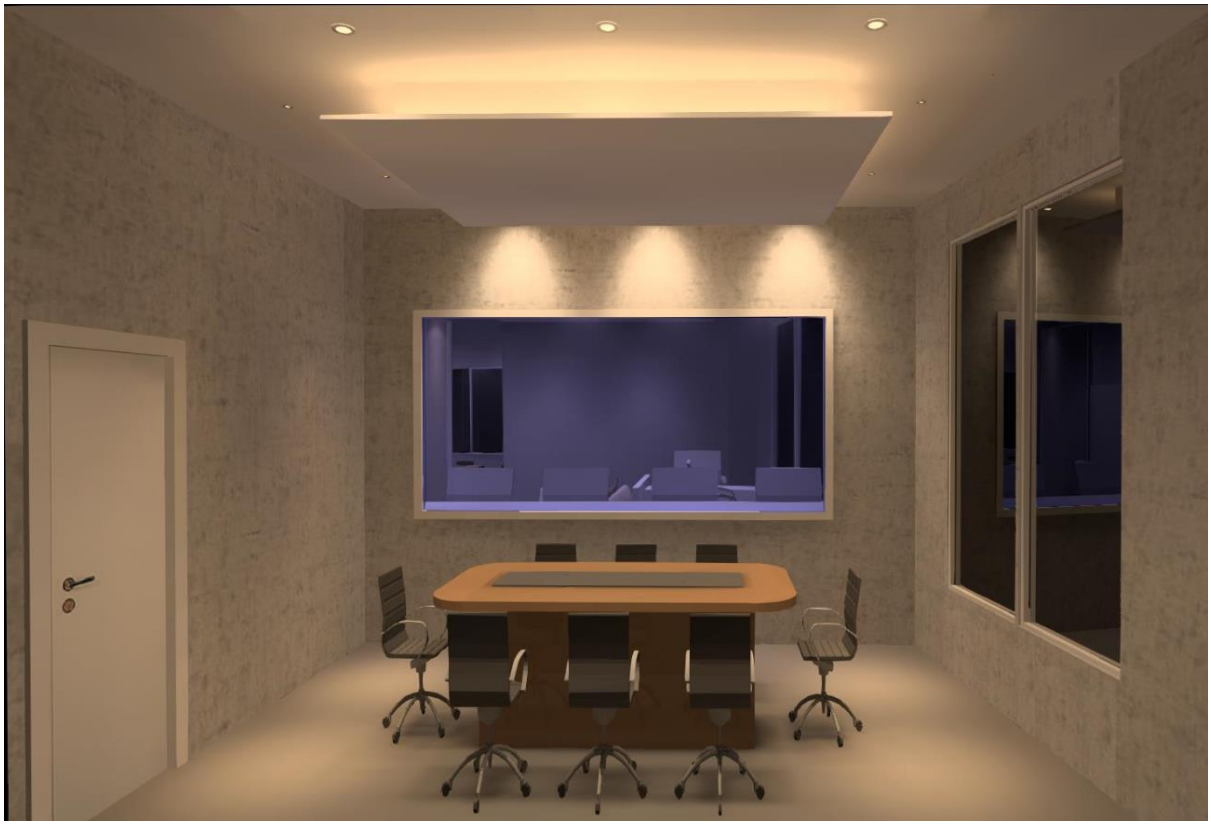


Fig:3.95: Software view of the Conference room after design

- **Area: 3 [Project Manager room]**
  The area illustrated in fig:3.96 represents the project manager room area of the entire office area, as depicted in fig:3.97

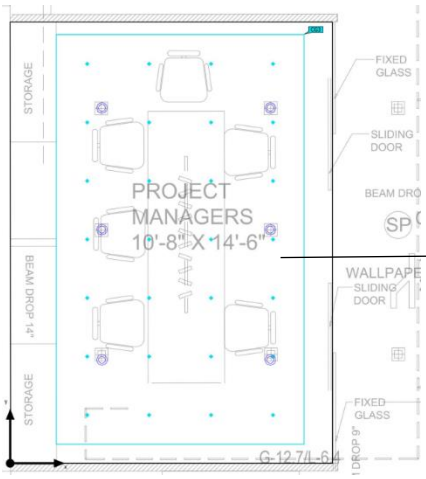


Fig:3.96: Project manager

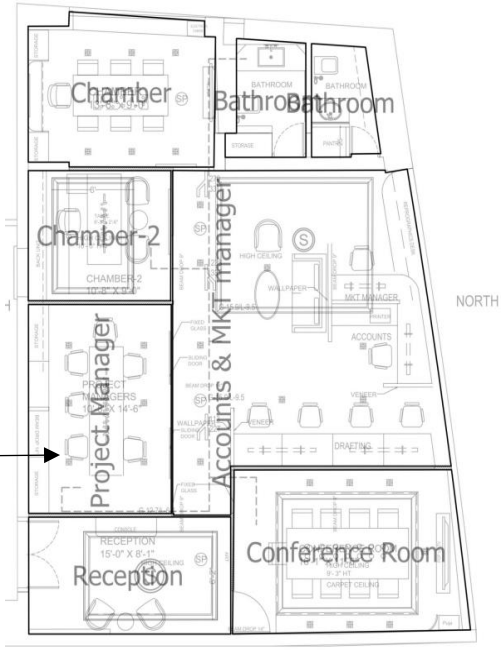


Fig: 3.97: The office area

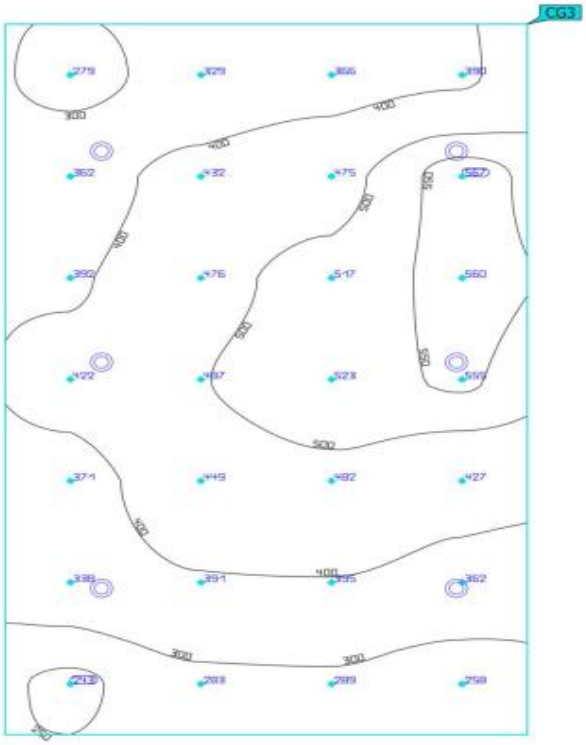


Fig: 3.98: Lighting Calculation of the Project manager room area

Design summary:

In the design summary, as shown in the fig:3.99, respective figures clearly show the results after carefully followed the standards.

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation surface(Project Manager Room) Perpendicular illuminance Height: 0.800 m	408 lx	243 lx	567 lx	0.60	0.43	CG3

Fig:3.99: DIALux report of the calculation surface

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 480 lux
- Overall Uniformity (U_0) = 0.60
- Lighting Power Density (LPD)/ Specific Connected Load = 6.45 W/m^2

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.100

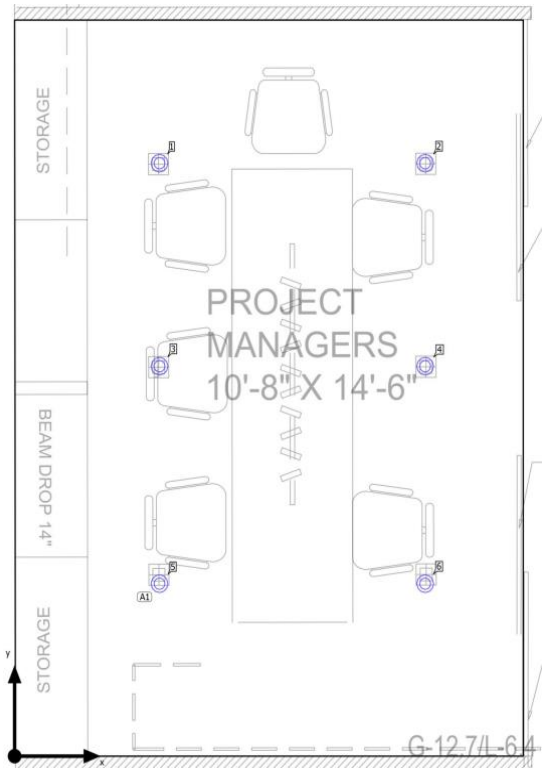


Fig:3.100: Luminaire layout of the Project manager room

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.101

6 x Linea Light Group Anton R 8W

Type	Field Arrangement
1st luminaire (X/Y/Z)	0.664 m / 0.748 m / 2.790 m
X-direction	2 pcs., Centre - centre, Distances not equal
Y-direction	3 pcs., Centre - centre, Distances not equal
Arrangement	A1

X	Y	Mounting height	Luminaire
0.664 m	2.573 m	2.790 m	1
1.882 m	2.573 m	2.790 m	2
0.664 m	1.692 m	2.790 m	3
1.882 m	1.692 m	2.790 m	4
0.664 m	0.748 m	2.790 m	5
1.882 m	0.748 m	2.790 m	6

Fig:3.101: Luminaire co-ordinates of the Project manager room

Visualization after the design:

Fig:3.102: Software view of the Project manager room after design

➢ **Area:4 [Accounts & Marketing manager room]**

The area illustrated in fig:3.103 represents the accounts & Marketing manager room area of the entire office area, as depicted in fig:3.104

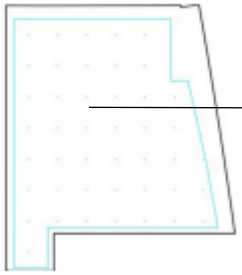


Fig:3.103: Accounts & Marketing manager room

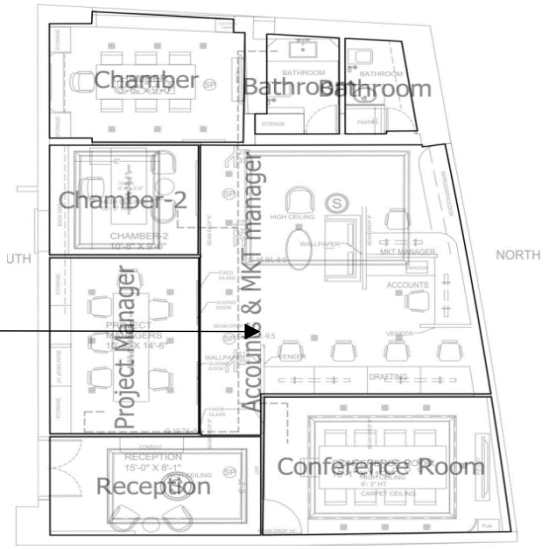


Fig:3.104: The office area

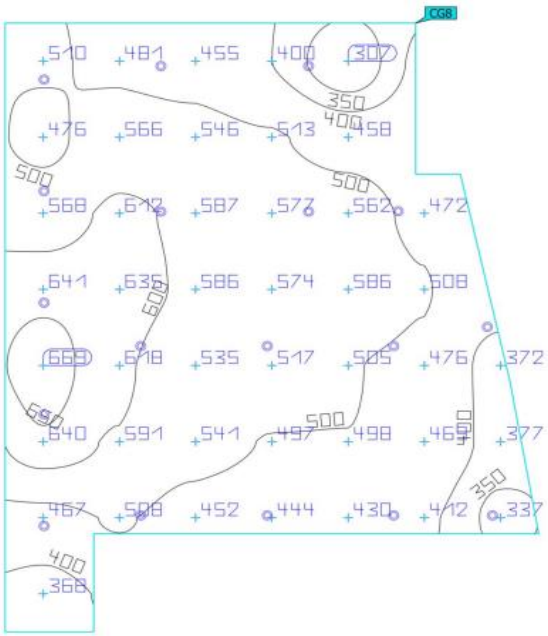


Fig:3.105: Lighting Calculation of the Accounts & Marketing manager room

Design summary:

In the design summary, as shown in the fig:3.106, respective figures clearly show the results after carefully followed the standards.

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation surface (Acc & Marketing dept room) Perpendicular illuminance Height: 0.800 m	508 lx	307 lx	669 lx	0.60	0.46	CG8

Fig:3.106: DIALux report of the calculation surface

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 508 lux
- Overall Uniformity (U_0) = 0.60
- Lighting Power Density (LPD)/ Specific Connected Load = 7.31 W/m^2

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.107

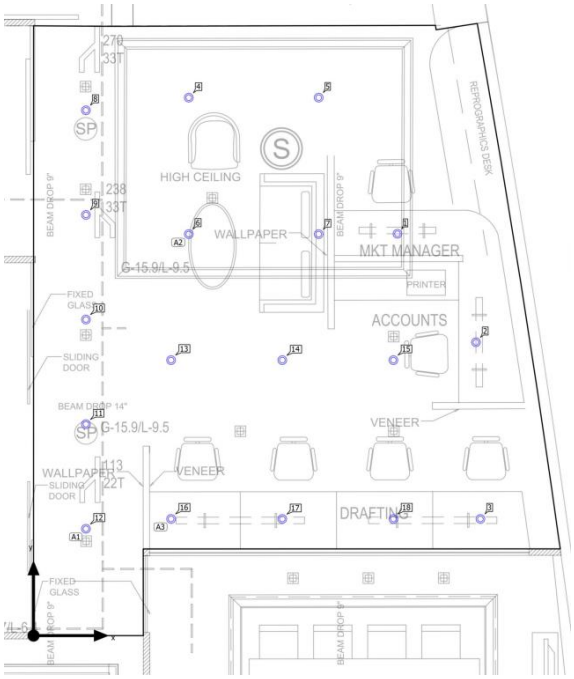


Fig:3.107: Luminaire layout of the accounts & Marketing manager room area

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.108

5 x Linea Light Group Anton R 8W

Type	Line arrangement
1st luminaire (X/Y/Z)	0.452 m / 4.541 m / 2.790 m
X-direction	5 pcs., Centre - centre, 0.904 m
Arrangement	A1

X	Y	Mounting height	Luminaire
0.452 m	4.541 m	2.790 m	8
0.452 m	3.637 m	2.790 m	9
0.452 m	2.732 m	2.790 m	10
0.452 m	1.828 m	2.790 m	11
0.452 m	0.923 m	2.790 m	12

4 x Linea Light Group Anton R 8W

Type	Field Arrangement
1st luminaire (X/Y/Z)	1.340 m / 3.471 m / 2.570 m
X-direction	2 pcs., Centre - centre, Distances not equal
Y-direction	2 pcs., Centre - centre, Distances not equal

X	Y	Mounting height	Luminaire
1.340 m	4.650 m	2.570 m	4
2.461 m	4.650 m	2.570 m	5
1.340 m	3.471 m	2.570 m	6
2.461 m	3.471 m	2.570 m	7

6 x Linea Light Group Anton R 8W

Type	Field Arrangement
1st luminaire (X/Y/Z)	2.147 m / 2.381 m / 2.790 m
X-direction	3 pcs., Centre - centre, Distances not equal
Y-direction	2 pcs., Centre - centre, Distances not equal
Arrangement	A3

X	Y	Mounting height	Luminaire
1.187 m	2.381 m	2.790 m	13
2.147 m	2.381 m	2.790 m	14
3.106 m	2.381 m	2.790 m	15
1.187 m	1.009 m	2.790 m	16
2.147 m	1.009 m	2.790 m	17
3.106 m	1.009 m	2.790 m	18

Individual luminaires

X	Y	Mounting height	Luminaire
3.141 m	3.474 m	2.570 m	1
3.818 m	2.536 m	2.790 m	2
3.857 m	1.009 m	2.790 m	3

Fig:3.108: Luminaire co-ordinates of the accounts & Marketing manager room area

Visualization after lighting design:

Fig:3.109: Software view of the accounts & Marketing manager room area

Fig:3.110: Software view after design

- **Area: 5 [Chamber room]**
  The area illustrated in fig:3.111 represents the Chamber room area of the entire office area, as depicted in fig:3.112

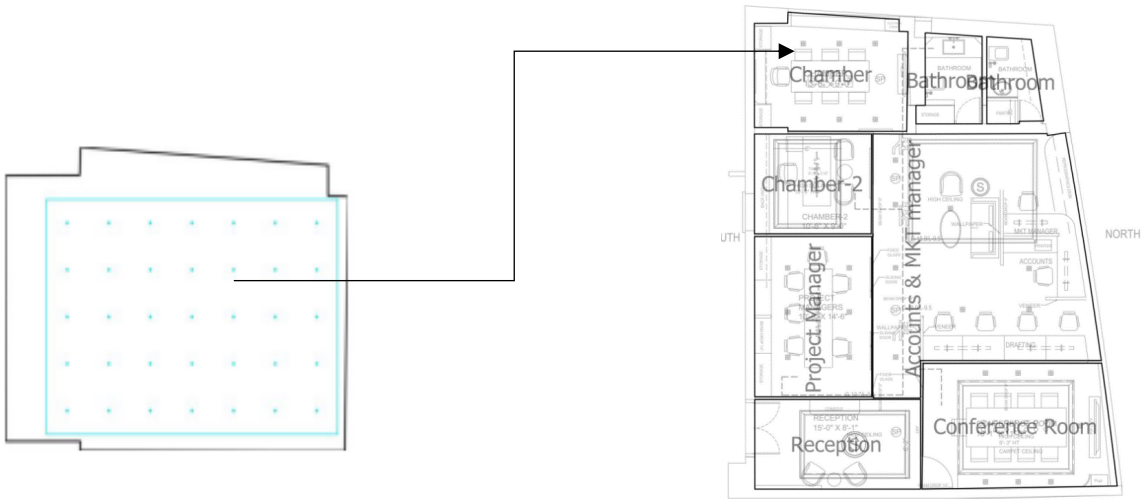


Fig:.3.111: Chamber room area

Fig:3.112: The office area

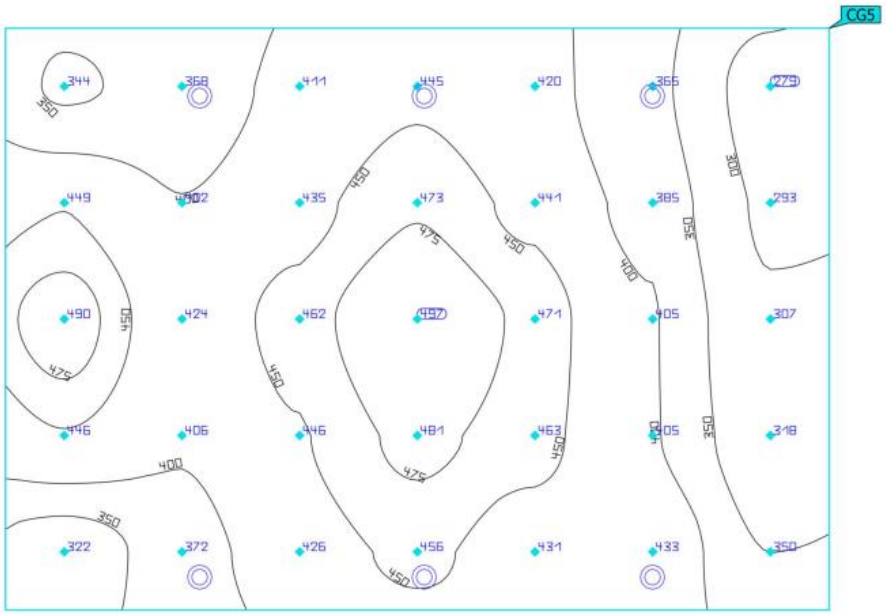


Fig:3.113: Lighting Calculation of the chamber room

Design summary:

In the design summary, as shown in the fig:3.114, respective figures clearly show the results after carefully followed the standards.

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation surface(chamber) Perpendicular illuminance Height: 0.800 m	409 lx	279 lx	497 lx	0.68	0.56	CG5

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Fig:3.114: DIALux report of the calculation surface

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 409 lux
- Overall Uniformity (U_0) = 0.68
- Lighting Power Density (LPD)/ Specific Connected Load = 9.69 W/m^2

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.115

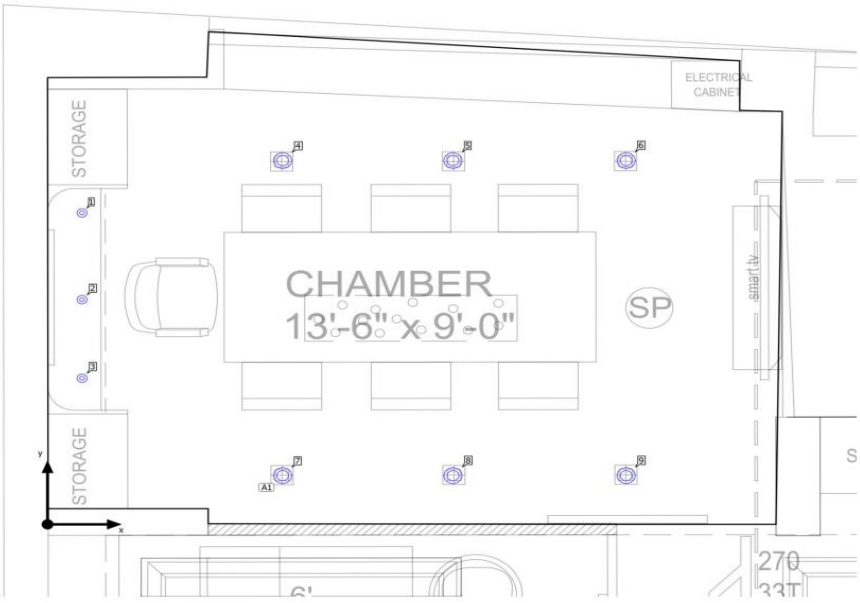


Fig:3.115: Luminaire layout of the chamber

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.116

Manufacturer	Linea Light Group	**P**	6.0 W
Article No.	90650M15	**$\Phi_{Luminaire}$**	301 lm
Article name	Vos_R Downlight 6W DC		
Fitting	1x LED-XHP007-SC		

Individual luminaires

X	Y	Mounting height	Luminaire
0.144 m	1.502 m	2.790 m	1
0.144 m	1.084 m	2.790 m	2
0.144 m	0.705 m	2.790 m	3

6 x Linea Light Group Anton R 8W

Type	Field Arrangement
1st luminaire (X/Y/Z)	0.979 m / 0.235 m / 2.790 m
X-direction	3 pcs., Centre - centre, Distances not equal
Y-direction	2 pcs., Centre - centre, Distances not equal
Arrangement	A1

X	Y	Mounting height	Luminaire
0.979 m	1.754 m	2.790 m	4
1.688 m	1.754 m	2.790 m	5
2.409 m	1.754 m	2.790 m	6
0.979 m	0.235 m	2.790 m	7
1.688 m	0.235 m	2.790 m	8
2.409 m	0.235 m	2.790 m	9

Fig:3.116: Luminaire co-ordinates of the chamber

Visualization after the design:

Fig:3.117: Software view of the chamber through design

- **Area: 6 [Secondary chamber/Chamber room -2]**
  The area illustrated in fig:3.118 represents the secondary chamber room area of the entire office area, as depicted in fig:3.119

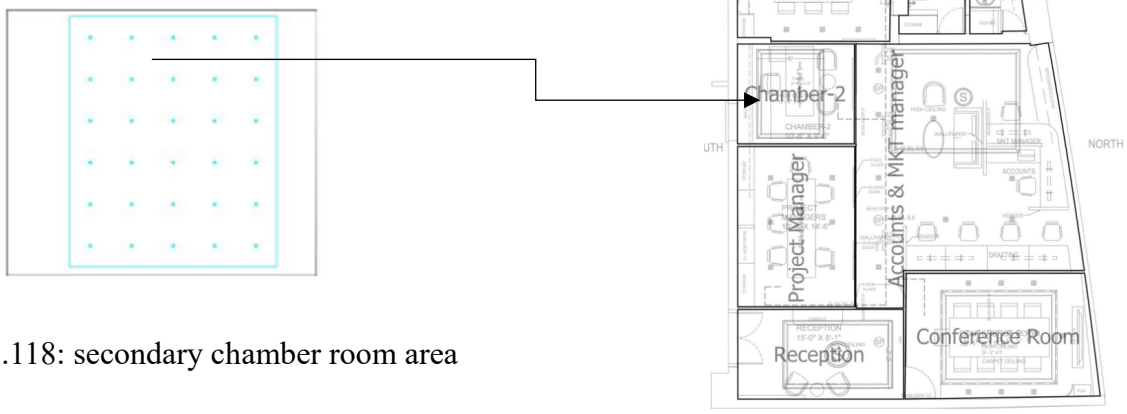


Fig:3.118: secondary chamber room area

Fig:3.119: The office area

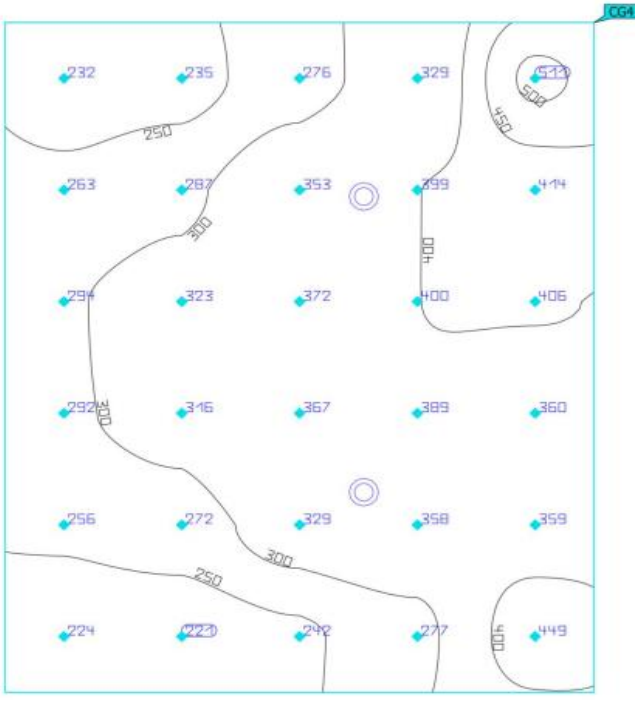


Fig:3.120:: Lighting Calculation of the secondary chamber room

Design summary:

In the design summary, as shown in the fig:3.121, respective figures clearly show the results after carefully followed the standards.

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation surface(Chamber 2) Perpendicular illuminance Height: 0.800 m	327 lx	221 lx	511 lx	0.68	0.43	CG4

Fig:3.121: DIALux report of the calculation surface

The values obtained throughout the room are as follows:

- Average Illuminance (E_{avg}) = 327 lux
- Overall Uniformity (U_0) = 0.68
- Lighting Power Density (LPD)/ Specific Connected Load = 9.94 W/m^2

Luminaire layout & Positions of the luminaire:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 3.122

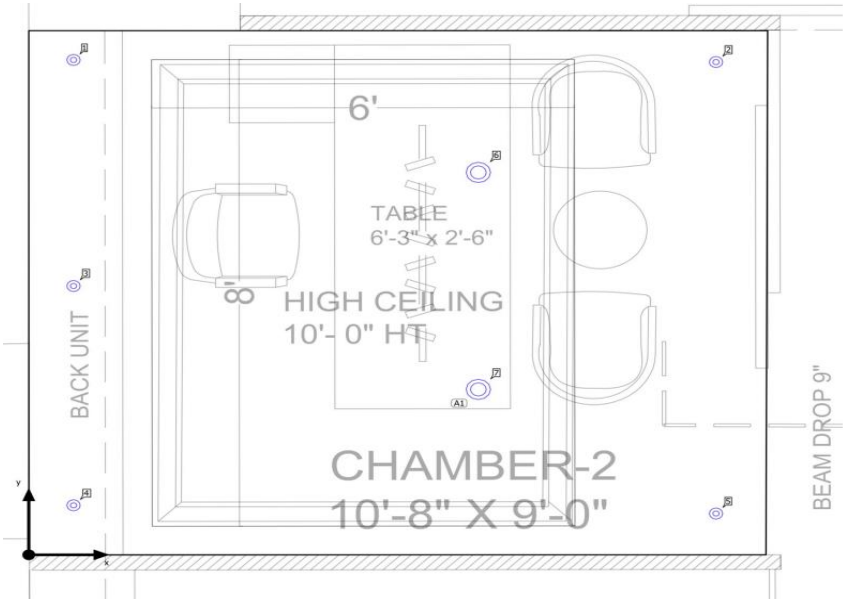


Fig:3.122: Luminaire layout of the secondary chamber room area

➢ The given data shows us the luminaire positioning on the actual site as shown in the fig: 3.123

Manufacturer	Linea Light Group	**P**	6.0 W
Article No.	90650M15	**$\Phi_{Luminaire}$**	301 lm
Article name	Vos_R Downlight 6W DC		
Fitting	1x LED-XHP007-SC		

Individual luminaires

X	Y	Mounting height	Luminaire
0.141 m	1.879 m	2.790 m	1
2.166 m	1.871 m	2.790 m	2
0.141 m	1.021 m	2.790 m	3
0.141 m	0.188 m	2.790 m	4
2.166 m	0.157 m	2.790 m	5

2 x Linea Light Group Anton R 8W

Type	Field Arrangement
1st luminaire (X/Y/Z)	1.417 m / 0.628 m / 2.570 m
X-direction	2 pcs., Centre - centre, Distances not equal
Y-direction	2 pcs., Centre - centre, Distances not equal
Arrangement	A1

X	Y	Mounting height	Luminaire
1.417 m	1.452 m	2.570 m	6
1.417 m	0.628 m	2.570 m	7

Fig:3.123: Luminaire co-ordinates of the secondary chamber room area

Visuals after lighting design:

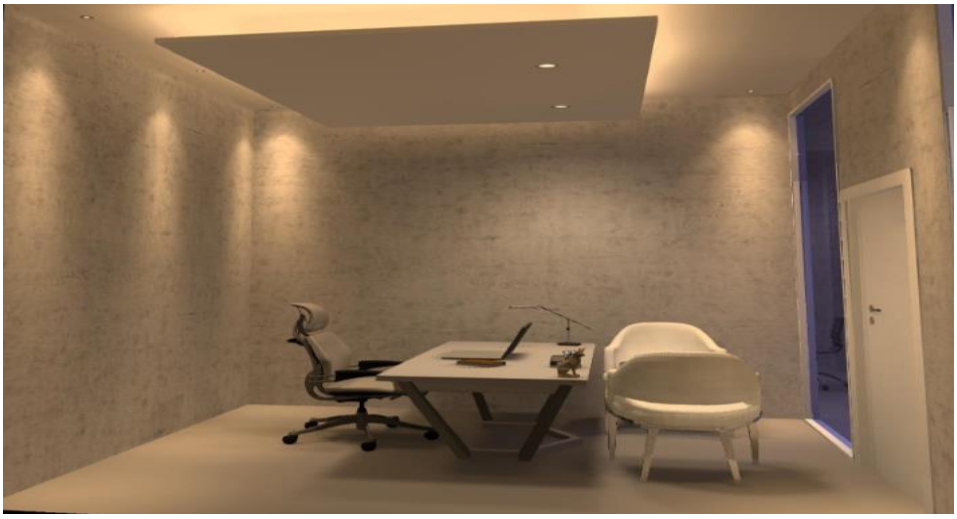


Fig:3.124: Software view of the secondary chamber room area

3.11. Result Analysis:

Indoor Lighting Design application area: Architectural Studio cum office lighting

Analyzing the simulation results obtained for various areas using latest LED options as previously discussed in the chapters, is done with a focus on:

1. **Average illuminance**
2. **Uniformity**
3. **Lighting Power Density (LPD)**

- The illuminance values achieved with LED light fixtures in the simulated area are compared, and the percentage variation in illuminance levels is determined for each case. These values are presented in the provided table, as shown in table: 3.5.
- This aims to demonstrate that the design of the simulated area using standard LED light fixtures complies with IS3646 standards.

➢ **Table: 3.5: Average Illuminance of Different Areas:**

Classification of Areas	Average illuminance of the Area (E_{avg} in lux)	Standard illuminance (in lux) value as per IS3646	Percentage of Changes (%)
Seating Space	397	300	32.33
Art Gallery	415	300	38.33
Study Area	346	300	15.33
Dinning	188*	300	37.33
Bedroom	243	300	19.00
Living Room	385	300	28.33

Classification of Areas	Average illuminance of the Area (E_{avg} in lux)	Standard value as per IS3646	Percentage of Changes (%)
Walk-in-Closet	424	300	41.33
Entrance	351	300	17.00
Pantry	162	150	8.00
Conference Room	373	300	24.33
Reception	335	300	11.66
Project Manager room	408	300	36.00
Chamber	409	300	36.33
Secondary chamber (Chamber - 2)	327	300	9.00
Account & Marketing Department room	508	500	1.6
Bathroom	136	100	36.00

Here is the representational chart, as shown in the fig:3.125, depicting the average lux levels of different areas in comparison to the respective standards.

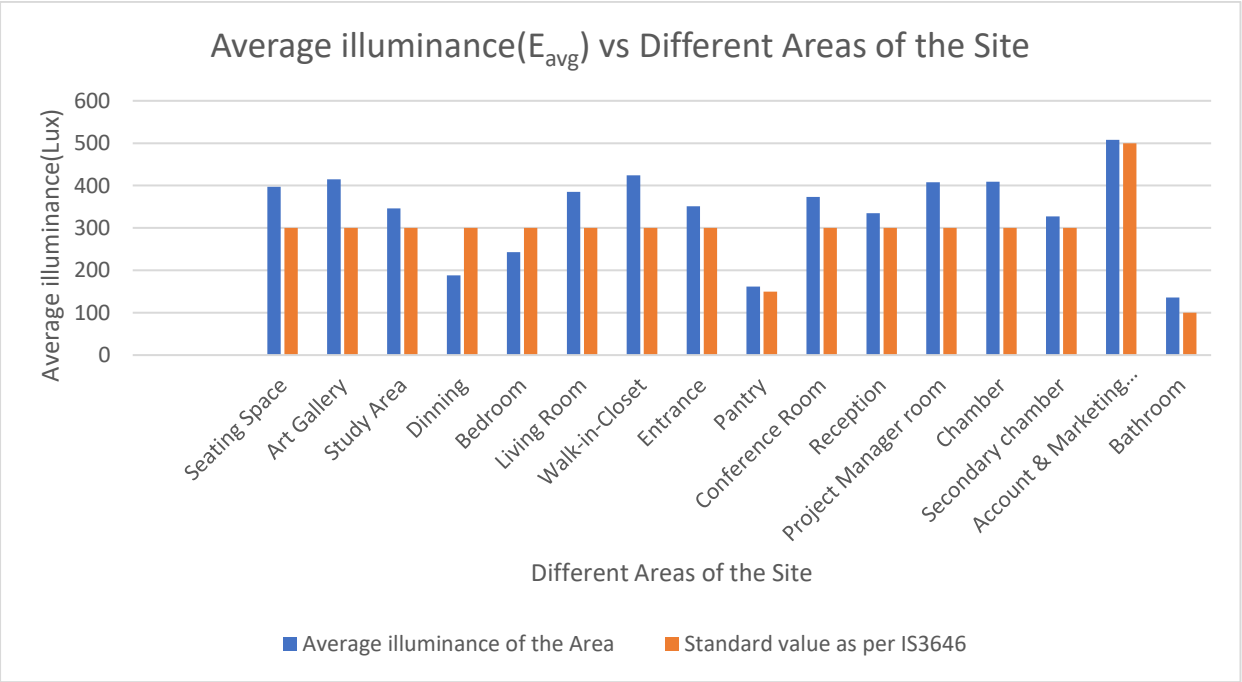


Fig: 3.125: Average illuminance vs Difference Areas of the site

Observation:

1. The recommended illuminance levels specified in IS 3646 have been met in all primary areas, with the exception of certain spaces (*such as the dining area), where decorative lighting plays a significant role in achieving the desired lux levels.
2. Given that all luminaires are equipped with dimming controls, the intensity of the lighting can be adjusted to create the desired mood and ambiance as needed.

➢ **Table 3.6: Uniformity of Different Areas of indoor space:**

Classification of Areas	Overall uniformity of the areas	Standard uniformity value as per IS3646	Percentage of Changes (%)
Seating Space	0.75	0.6 - 0.8	25
Art Gallery	0.65		8.33
Study Area	0.71		18.33
Dinning	0.69		15
Bedroom	0.60		0.00
Living Room	0.71		18.33
Walk-in-Closet	0.61		1.66
Entrance	0.68		13.33
Pantry	0.79		31.66
Conference Room	0.72		20.00
Reception	0.64		6.66
Project Manager room	0.60		0.00
Chamber	0.68		13.33
Secondary chamber (Chamber - 2)	0.68		13.33
Account & Marketing Department room)	0.60		0.00
Bathroom	0.69		15.00

Here is the representational chart, as shown in the fig:3.126, depicting uniformity of different areas in comparison to the respective standards.

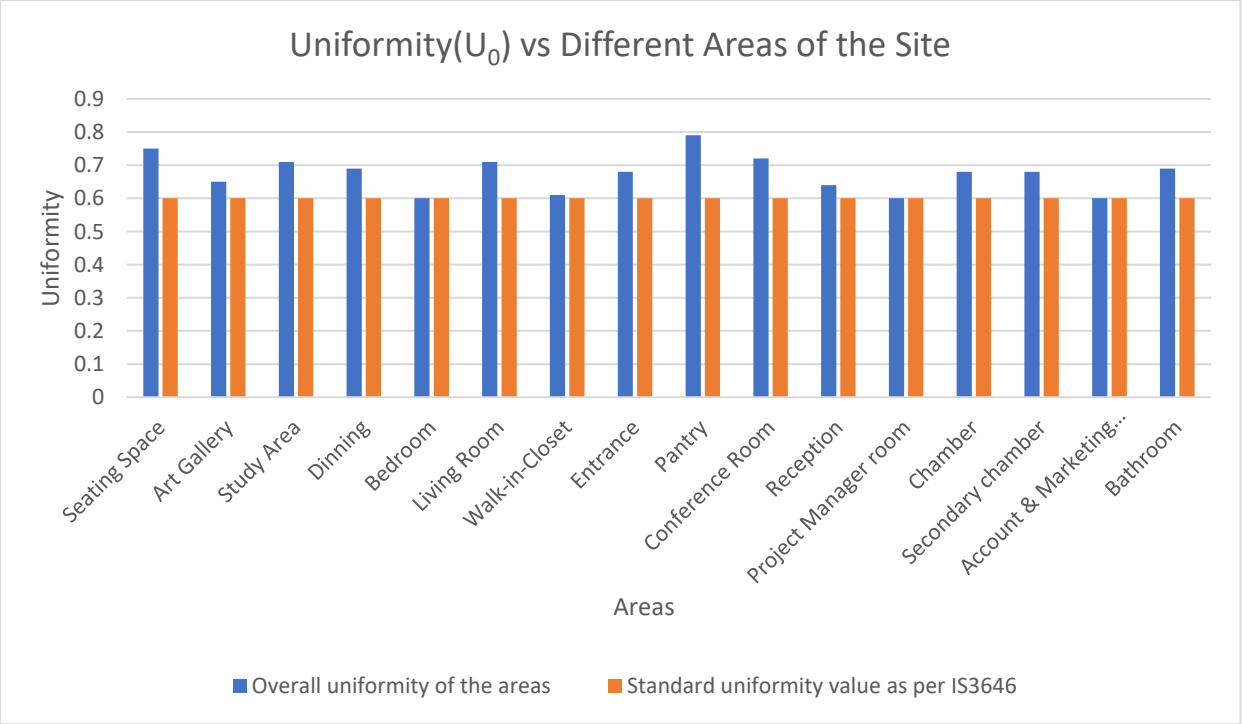


Fig: 3.126: Uniformity vs Different Areas of the sites

Observation:

1. By observing all the datapoints, as shown in the fig:3.126, regarding uniformity, it can be observed that uniformity is achieved as per standards for all the different areas.
2. For optimal results, it is better to maintain uniformity within the standard range of 0.6-0.8. In this context, it is used that 0.6 as a reference value, as shown in the table 3.6, to assess the change in uniformity after attaining the minimum level.

Table 3.7: Lighting Power Density of Different Areas

LPD values obtained with LED luminaire, as shown in table 3.7, for the simulated area are compared to standard benchmarks. This comparison highlights the potential energy savings achievable with LED lighting.

Types of Areas	As per ECBC standard LPD values in W/m^2	Achieved LPD values in W/m^2
Seating Space	10	4.11
Art Gallery	10	4.11
Study Area	10	4.11
Dinning	10	4.11
Bedroom	10	4.11
Living Room	10	4.11
Walk-in-Closet	10	4.11
Entrance	10	4.11

Types of Areas	As per ECBC standard LPD values in W/m^2	Achieved LPD values in W/m^2
Pantry	10	4.11
Conference Room	10	9.75
Reception	10	5.43
Project Manager room	10	6.45
Chamber	10	9.69
Secondary chamber (Chamber - 2)	10	9.94
Account & Marketing Department room	10	7.31
Bathroom	10	7.67

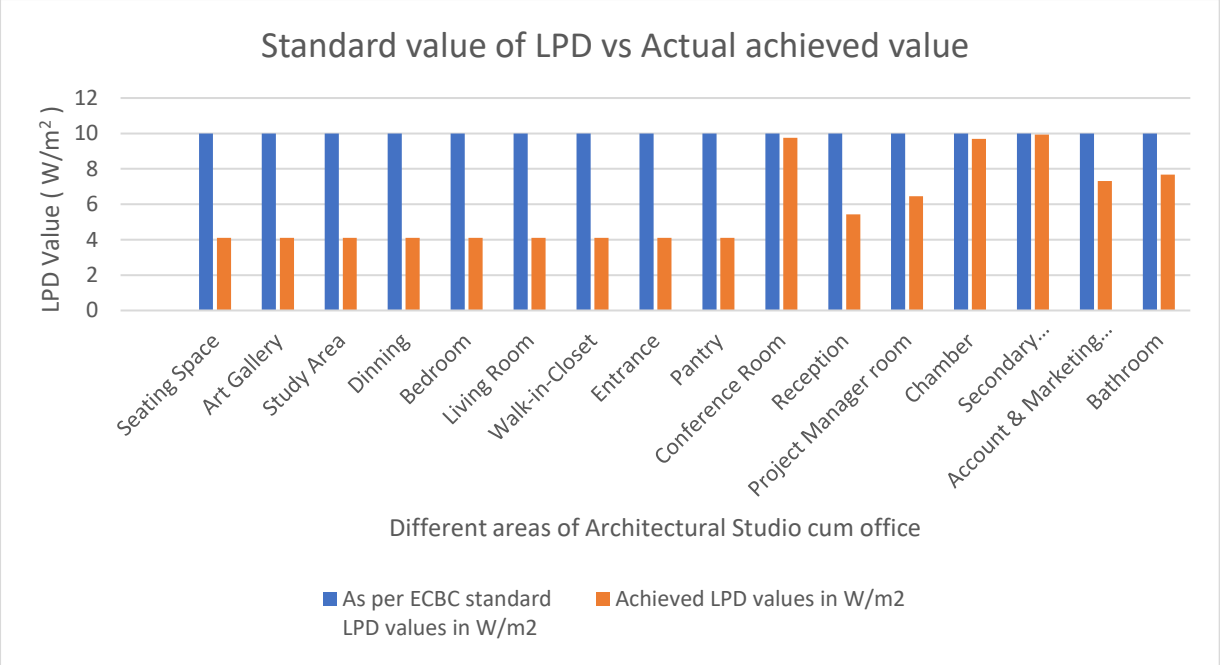


Fig: 3.127: Standard value of LPD vs Actual achieved value of LPD

Observation:

1. By observing all the datapoints, as shown in the fig:3.127, regarding LPD values, standard values that is ECBC[20] ,are compared with the achieved values for different areas.
2. For the architectural studio, since the entire area is treated as a single zone in the design, the LPD values remain consistent throughout. However, in the office area, different sections yield varying LPD values, as detailed in Table 3.7.

Chapter 4:
Outdoor Design Application:
Lighting Design of Car Parking area

4.1 Design of Car parking area using high mast:

The given design encompasses the entire car parking area, aiming to illuminate the space with the best possible solutions through an optimized design. After discussions with clients, the initial design concept of the entire area centred around the implementation of high mast lighting.

Requirement for the High mast-based lighting:

High mast-based lighting[15] is used for illuminating large outdoor areas such as highways, intersections, ports, and stadiums. To ensure effective and safe high mast lighting, several requirements must be considered:

1. Height and Structure:

Height: High mast poles typically range from 10 to 40 meters, depending on the area to be illuminated.

Structure: Poles must be robust and made of high-strength materials like galvanized steel to withstand environmental conditions, including high winds and corrosion.

2. Lighting Fixtures:

Type of Lamps: LED fixtures are preferred for their energy efficiency, long lifespan, and better light control. Metal halide and high-pressure sodium lamps are also used but are less common.

Number of Fixtures: The number of fixtures per pole varies based on the height of the pole, the area to be illuminated, and the light output of each fixture.

3. Light Output and Distribution:

Lumens: The total lumen output should be sufficient to provide the required illumination level for the specific application (e.g., highways, ports).

Uniformity: Light distribution should be even, minimizing dark spots and ensuring consistent illumination across the area.

Glare Control: Fixtures should be designed to minimize glare, improving visibility and safety.

4. Mounting and Maintenance:

Mounting: Fixtures should be mounted securely, and poles should be equipped with features like tilting mechanisms or winch systems for easy maintenance.

Access for Maintenance: Consideration for maintenance access, such as lowering devices or hinged poles, is important for safe and efficient servicing of the fixtures.

5. Electrical Components:

Power Supply: The electrical system must support the load of the high mast lighting, with appropriate circuit protection and control mechanisms.

Control Systems: Incorporation of smart controls for dimming, scheduling, and remote management can enhance efficiency and reduce operational costs.

6. Environmental and Safety Considerations:

Wind Resistance: Poles and fixtures must be designed to withstand local wind loads and other environmental factors.

Safety Features: Ensure compliance with safety standards and regulations, including grounding and lightning protection.

7. Installation and Foundation:

Foundation Design: A solid foundation is critical, designed according to soil conditions and structural requirements to ensure stability.

Installation Process: Professional installation following manufacturer guidelines and local regulations is essential for safety and performance.

8. Energy Efficiency:

Energy Consumption: opting for energy-efficient fixtures to reduce operational costs and environmental impact.

Renewable Energy Options: Consider integrating renewable energy sources, like solar power, to enhance sustainability.

By adhering to these requirements, high mast lighting systems can provide effective, reliable, and energy-efficient illumination for large outdoor areas.

Design criteria of high mast lighting: it involves several key criteria[15] to ensure effective illumination, safety, and efficiency:

1. Illumination Levels: Determine required lux levels based on the application, ensuring uniform distribution with a ratio of 0.4 to 0.6.

2. Pole Height and Placement: Choose heights from 10 to 40 meters and space poles 2 to 4 times the pole height.

3. Lighting Fixtures: Use high-efficiency LED fixtures, calculating the number based on lumen output, pole height, and beam spreads

4. Light Distribution and Control: Select appropriate beam angles, minimize glare, and incorporate dimming and smart controls.

5. Structural Integrity: Use high-strength, corrosion-resistant materials and design for wind load resistance.

6. Foundation Design: Design robust foundations based on soil conditions and secure pole anchoring.

7. Electrical System: Ensure reliable power supply with surge protection and appropriate wiring.

8. Maintenance and Accessibility: Design for easy maintenance with lowering devices and durable fixtures rated IP66 or higher.

9. Environmental Considerations: Minimize light pollution and optimize energy efficiency with renewable sources where feasible.

10. Regulatory Compliance: Comply with standards and safety regulations for lighting, structural design, and electrical systems.

Total area:

In the AutoCAD drawing, as shown in the fig: 4.1, the total area of the parking lot behind the car showroom is clearly delineated. Given the proximity of the national highway and airport to the parking area, good amount of attention has been paid to incorporating these factors into the design.

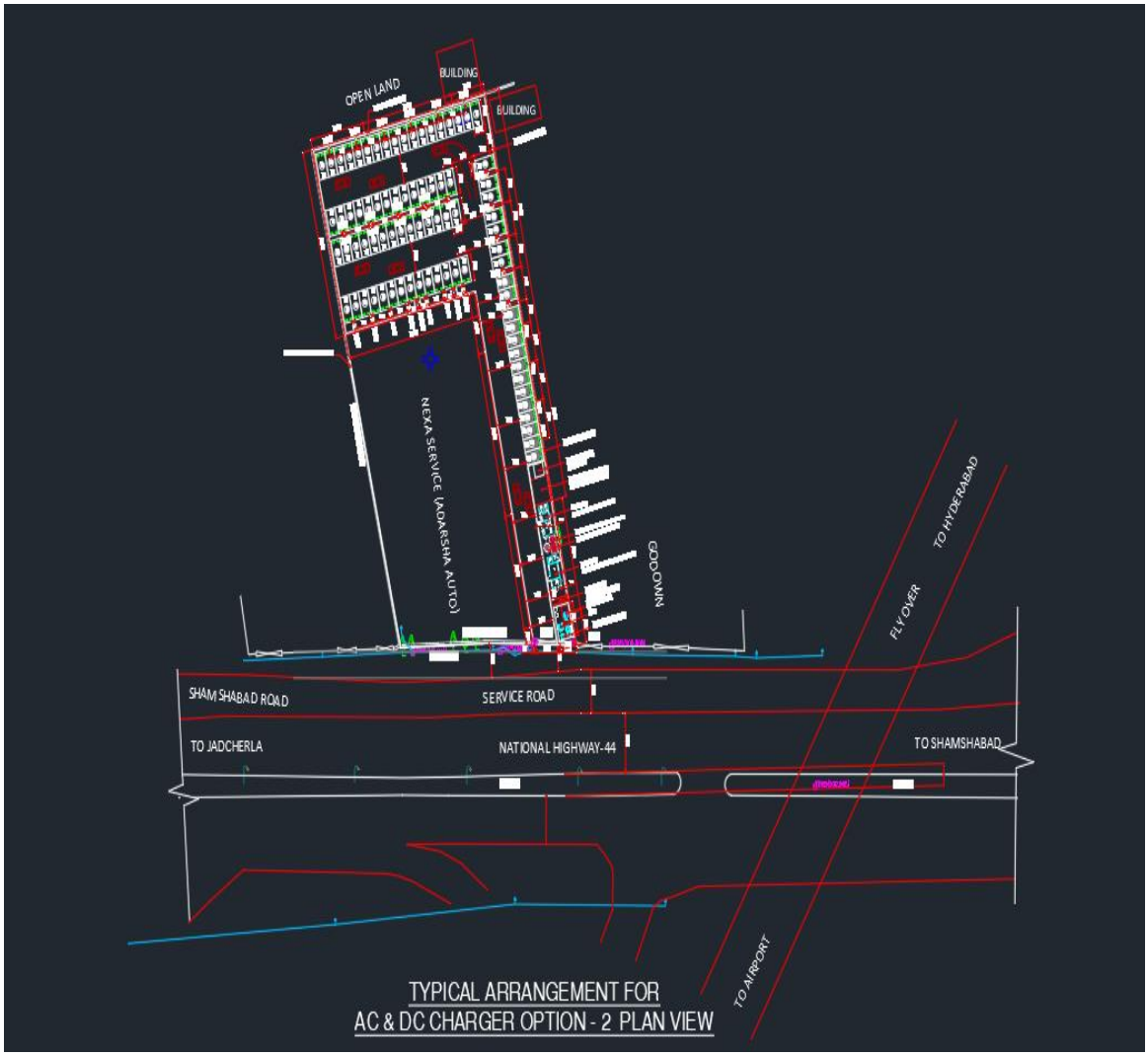


Fig: 4.1: Total area of the Car parking with CAD view of national highway

Total area of consideration for design:

The area illustrated in Figures 4.2 and 4.3 is identified as the main section requiring more optimized lighting solutions.

Fig:4.2: Total car parking area

Fig:4.3: Entrance of the car parking area

4.2. Design criteria and analysis using High-Mast Lighting:

- Details of luminaires:
  Below are the details of the luminaire, as shown in the fig: 4.4 and 4.5, that are used for the high mast-based lighting for the car parking area.

Fig:4.4: Goldmedal High mast Luminaire

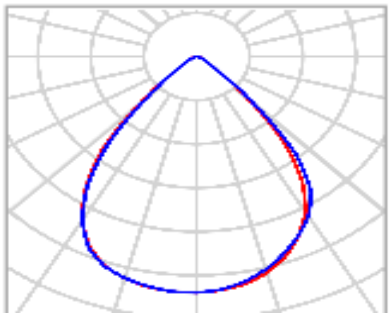


Fig: 4.5: Light distribution curve of the Luminaire

- **Characteristics of the floodlight for High mast-based lighting**:

- PDC Aluminium housing with Fresnel lenses.
- IP66 (Water and Weather proof).
- Rated Life: Up to 25000 hrs.
- Instant start and energy efficient light source.
- Suitable for outdoor application.

Design analysis:

As shown in Fig: 4.6 and 4.7, the depicted area represents the total space considered for the lighting calculation.

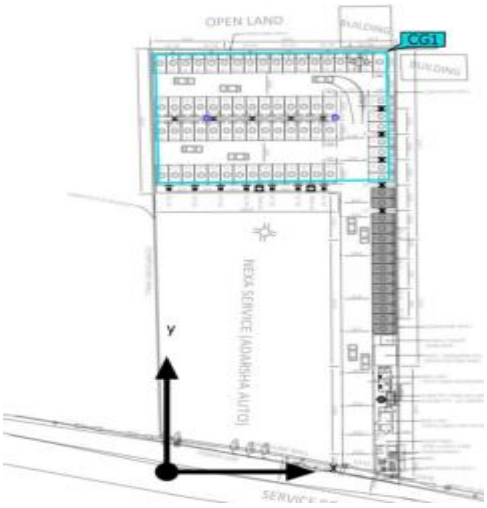


Fig:4.6: Considered area for lighting calculation

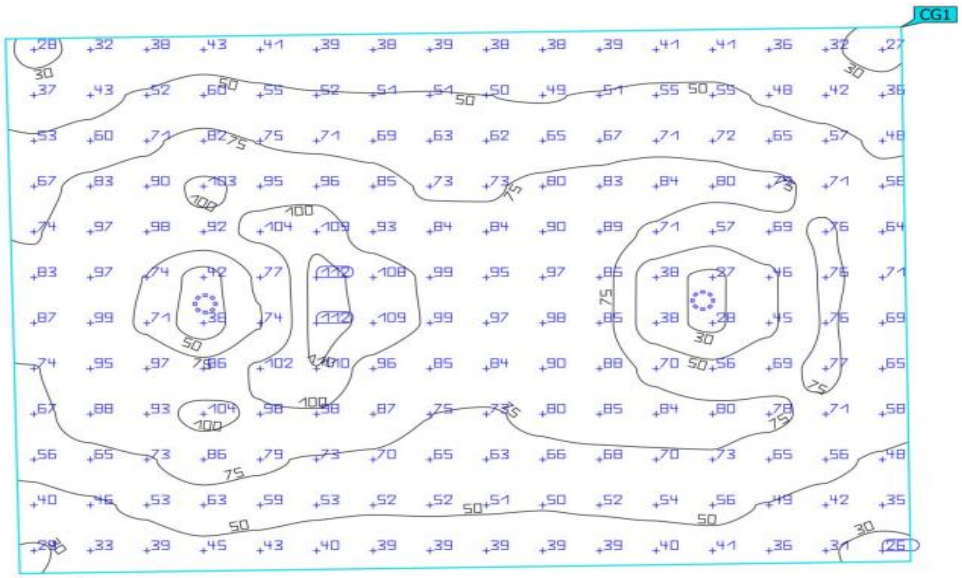


Fig: 4.7: Lighting Calculation area for the Parking area

Top-view of the calculation grid:

The area illustrated in Figure 4.8 demonstrates the distribution of lux levels throughout the main area.

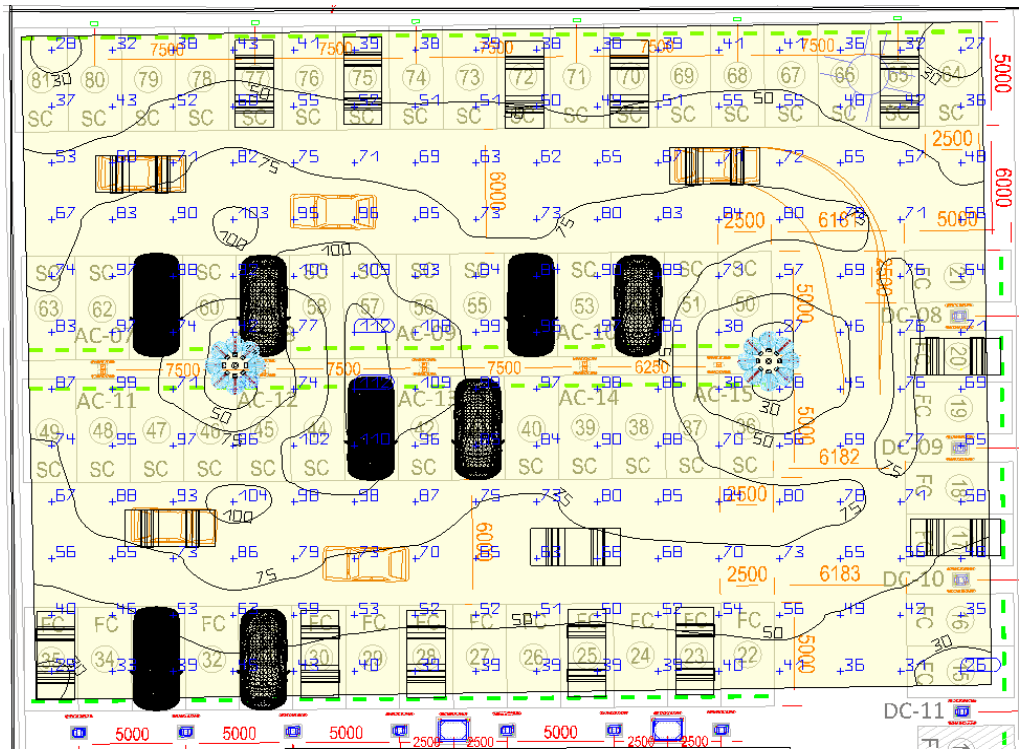


Fig: 4.8: Value chart view of the Considered area

Design summary:

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	U_o (g_1)	g_2	Index
Calculation surface(Parking) Perpendicular illuminance Height: 1.000 m	66.0 lx	26.4 lx	112 lx	0.40	0.24	CG1

Fig: 4.9: DIALux report for the calculation area

- Average illuminance (E_{avg}) = 66 Lux
- Uniformity(U_0) = 0.40

Luminaire layout & Positions:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 4.10

Fig: 4.10: Luminaire layout of the High mast-based lighting design

Positions:

- The given data shows us the luminaire positioning on the actual site as shown in the fig: 4.11

8 x Not yet a DIALux member Goldmedal Electricals Flood Light IP65 120W

Type	Circle Arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	8.200 m / 88.089 m / 12.017 m	8.054 m	87.736 m	12.017 m	9
Arrangement	A1	7.700 m	87.589 m	12.017 m	10
		7.346 m	87.736 m	12.017 m	11
		7.200 m	88.089 m	12.017 m	12
		7.346 m	88.443 m	12.017 m	13
		7.700 m	88.589 m	12.017 m	14
		8.054 m	88.443 m	12.017 m	15
		8.200 m	88.089 m	12.017 m	16

Type	Circle Arrangement	X	Y	Mounting height	Luminaire
1st luminaire (X/Y/Z)	33.100 m / 88.288 m / 12.017 m	32.954 m	87.934 m	12.017 m	1

Arrangement	A2	X	Y	Mounting height	Luminaire
		32.600 m	87.788 m	12.017 m	2
		32.246 m	87.934 m	12.017 m	3
		32.100 m	88.288 m	12.017 m	4
		32.246 m	88.641 m	12.017 m	5
		32.600 m	88.788 m	12.017 m	6
		32.954 m	88.641 m	12.017 m	7
		33.100 m	88.288 m	12.017 m	8

Fig:4.11: Luminaire co-ordinates of the High mast-based lighting design

Visualization after design:

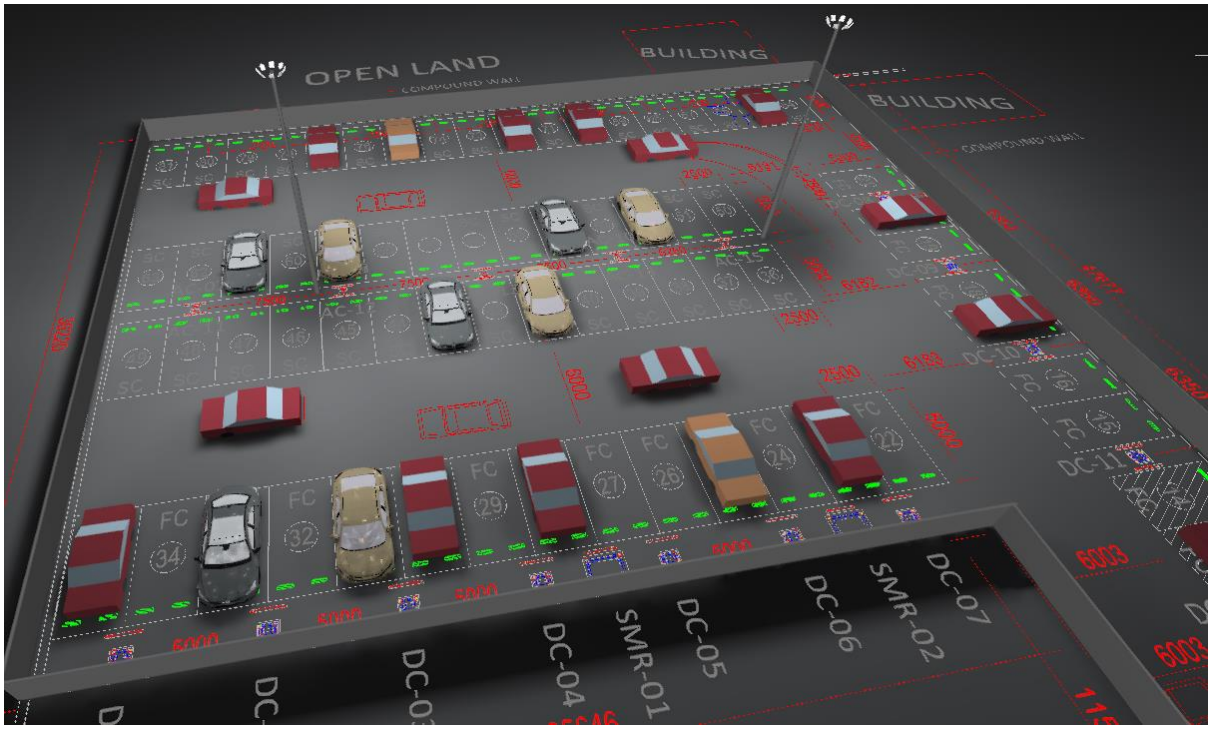


Fig: 4.12: Software view of the high mast lighting

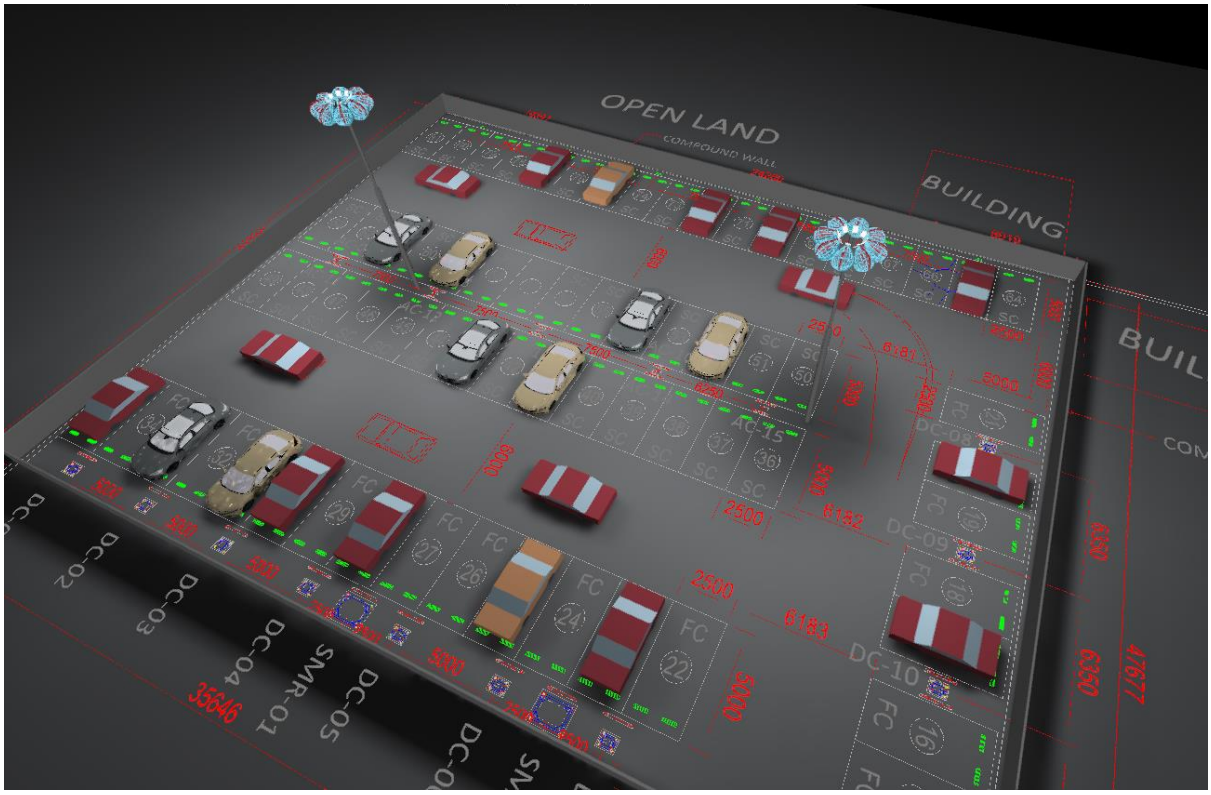


Fig:4.13: Software view of the high mast lighting

- **Case study of using street light over high mast lighting for Parking area:**

After conducting a thorough observation and analysis of the car parking area, it becomes evident that the primary objective of illuminating the space was not achieved, due to the various factors. Despite multiple discussions with the clients, it is apparent that there are several factors that need to be accurately analysed to provide an optimized design for this area.

As progressed in analysis, deeper analysis will help that how strategic street lighting design can significantly enhance all parameters, thereby optimizing the functionality and aesthetics of this area to a higher degree.

4.3. Car parking area lighting using the street light:

Incorporating street lighting into the design approach expands our focus beyond the parking area, enhancing visibility and safety while contributing to the ambiance of the entire space. Strategically placed lights, along with considerations like distribution and energy efficiency, create a welcoming environment. Smart technology and sustainability ensure lasting benefits for clients and the community.

Lighting Standard:

i. As per lighting standard, the parking area should achieve the necessary lux level as the National Lighting Code (NLC-2010).
ii. Given the standard, the average lux level which should be maintained that is 50 lux, as shown in the fig: 4.14 and 4.15, with the uniformity of 0.4.
iii. As per client's requirement, the minimum level of lux level that to be maintained is 25 lux.

Table 3 Lighting Recommendations for Different Road Types — IS Classification
(*Clause* 8.1.4)

Sl. No.	Classification of Lighting Installation	Type of Road	Average Illuminance on Road Surface	Uniformity Ratio E_{min}/E_{av}	Transverse Uniformity (E_{min}/E_{max})
(1)	(2)	(3)	(4)	(5)	(6)
i)	Group A1	Important traffic routes carrying fast traffic	30	0.4	0.33
ii)	Group A 2	Other main roads carrying mixed traffic like main city streets, arterial roads and throughway roads	15	0.4	0.33
iii)	Group B 1	Secondary roads with considerable traffic like principal local traffic routes and shopping	8	0.3	0.2
iv)	Group B 2	Secondary roads with light traffic	4	0.3	0.2

NOTE — Transverse uniformity: Ratio of E_{min} and E_{max} across the road.

Fig:4.14: Street lighting classifications [21] (IS1944)

9 LIGHTING LEVEL REQUIREMENTS

9.1 Public Areas

Sl. No. (1)	*Areas* (2)	*Average Maintained Illuminance (lux)* (3)
i)	Private/Public Parking Areas	50
ii)	Entrance/Exit (Public Assembly)	300
iii)	Train Display/Reservation Checking	300
iv)	Ticket Counters	300
v)	Platform	200
vi)	Platform Edges	250
vii)	Concourse	300

NOTE — 30 percent of the above illumination will be catered by luminaires on essential supply.

Fig:4.15 Street lighting lux level standards [21] (IS1944)

Design analysis:

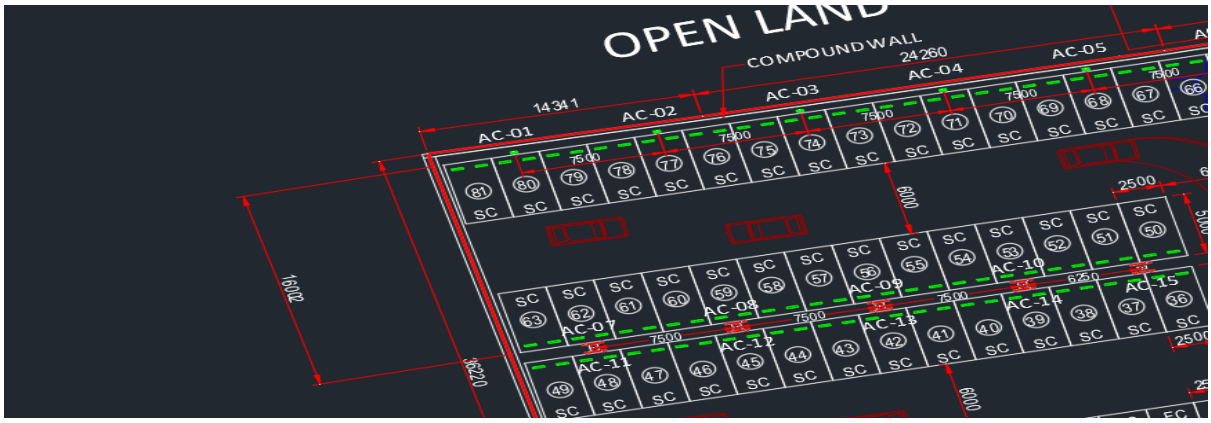


Fig:4.16: Distance in between two car parking area

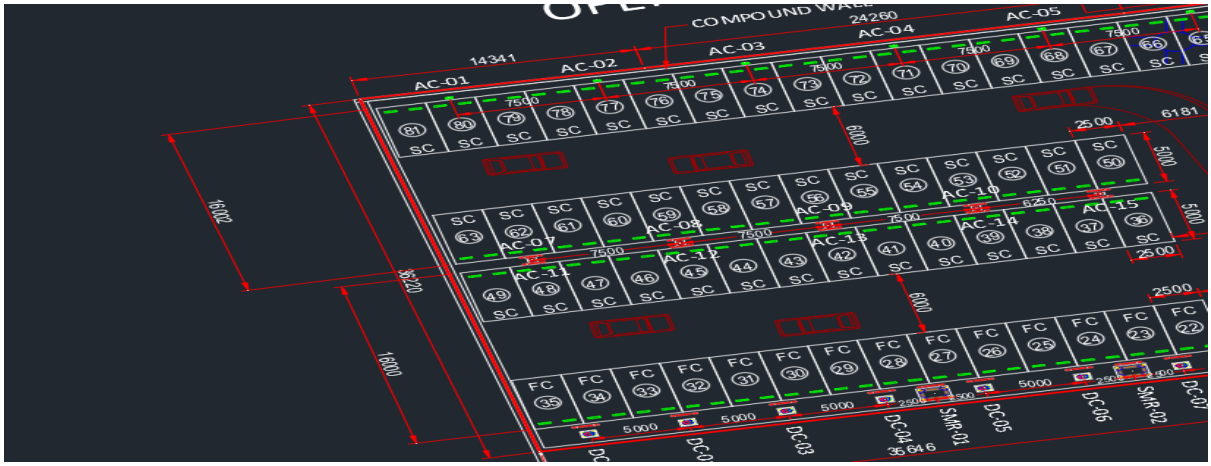


Fig:4.17: Total area

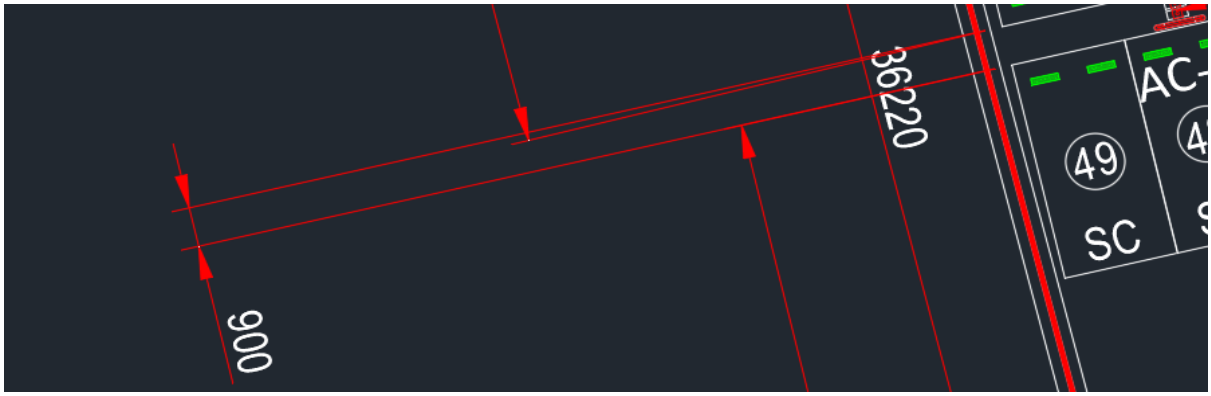


Fig:4.18: Poll placement in the middle

In above picture, as shown in fig: 4.16, 4.17, 4.18, the length of each parking area is given. Given the measurement, the same measurement used to design the area with street lighting arrangements.

Here, the arrangement is two carriageways of 17 meter with median of 0.9m is taken to design the area with the principal of street lighting concept.

Luminaire position & details:

The general arrangement and positioning of the luminaires are depicted in the corresponding figures as shown in fig: 4.19

Goldmedal SL 120W 48LED 5050 PB 70 140 LENS 5 5 DEG.IES (Median, 2 per pole)

Pole distance	15.000 m
(1) Light spot height	7.000 m
(2) Light point overhang	1.050 m
(3) Boom inclination	15.0°
(4) Boom length	1.526 m

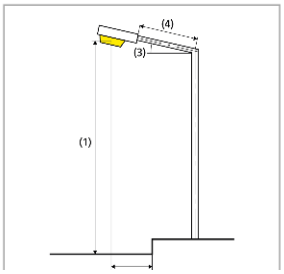


Fig:4.19: Pole arrangement and Luminaire details

- **Product details:**

1. **Pole height**: 7 meters
2. **Distance between polls:** 15 meters
3. **Boom length:** 1.5 meter
4. **Boom angle:** 15 Degree
5. **Wattage:** 120W
6. **Lumen efficacy:** 12000 Lumen/W

- In the fig: 4.20 and 4.21, The product and the light distribution curve is shown of the luminaire that is used in this project as street light.

Fig:4.20: Street light

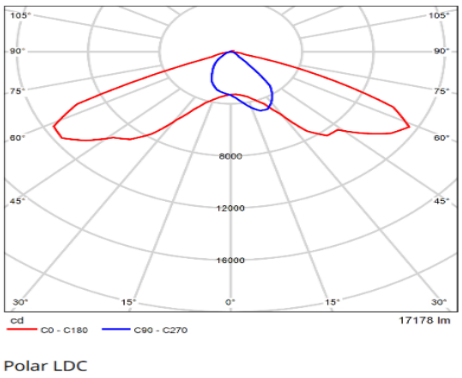


Fig:4.21: Light distribution curve of the luminaire

Calculation grid & Isolines: [For main parking area]

As shown in the fig:4.22,4.23,4.24, and 4.25 – tells us the way the distance between poll of 15 meters and calculation is done for the main car parking area.

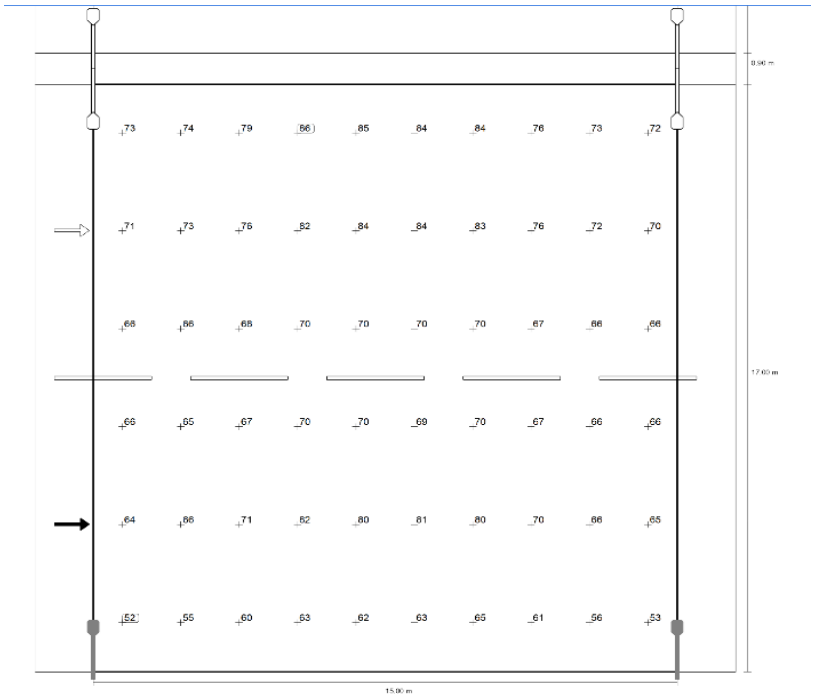


Fig: 4.22: Value chart of the considered calculation area (One side)

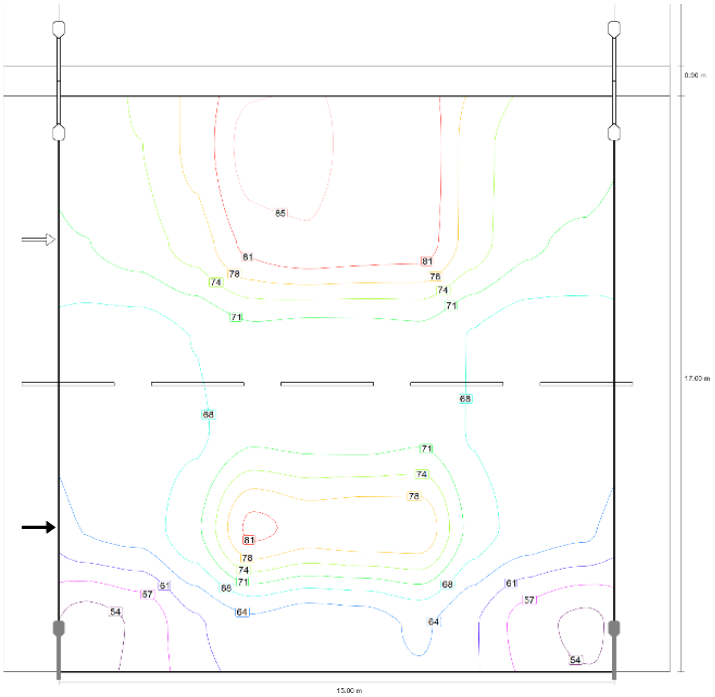


Fig:4.23: Isoline distribution of the considered calculation area (One side)

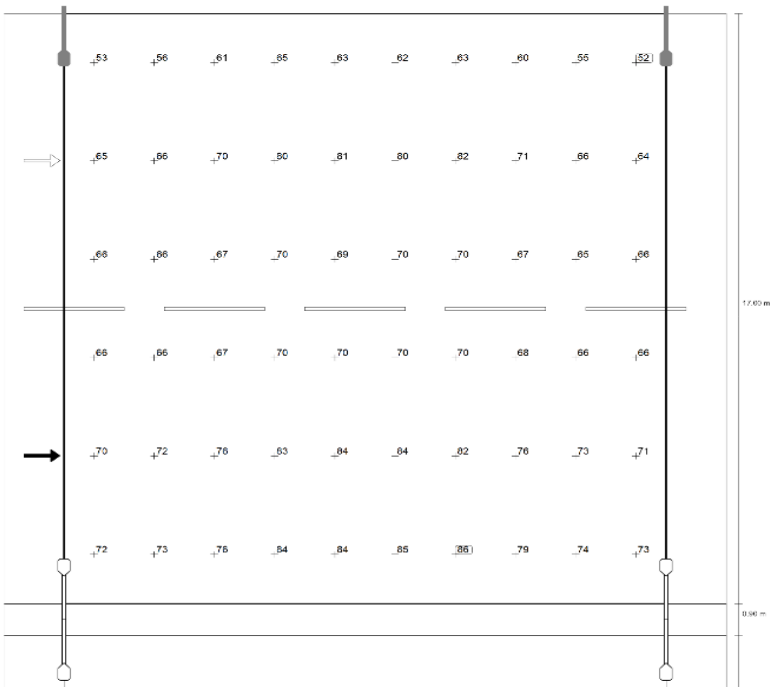


Fig:4.24: Value chart of the considered calculation area (Other side)

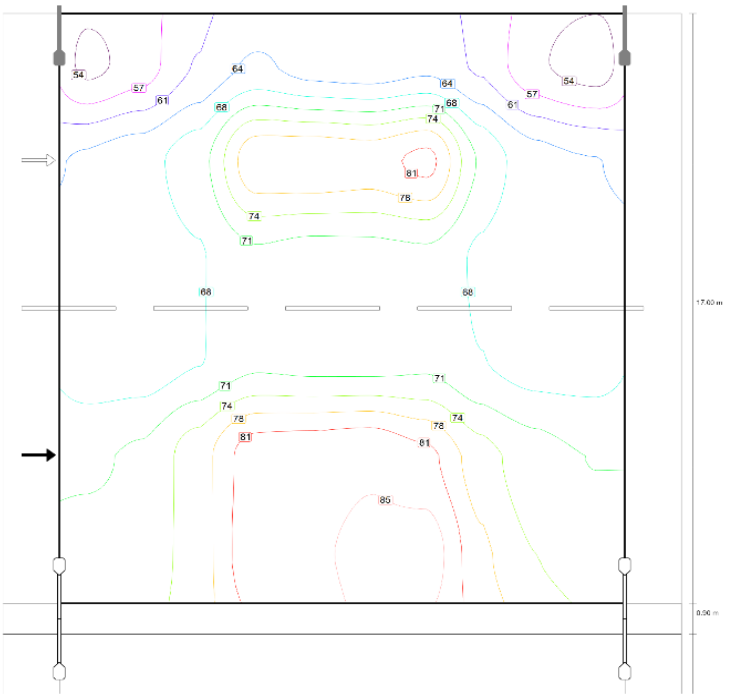


Fig:4.25: Isoline distribution of the considered calculation area (Other side)

Design summary:

The area illustrated in Figure 4.26 and 4.27, demonstrates the distribution of lux levels throughout the car parking area.

For road (1)

	E_{av}	E_{min}	E_{max}	U_o (g_1)	g_2
Maintenance value, horizontal illuminance	70.5 lx	52.4 lx	86.4 lx	0.74	0.61

Fig:4.26: DIALux report of the considered calculation area (One side)

For road (2)

	E_{av}	E_{min}	E_{max}	U_o (g_1)	g_2
Maintenance value, horizontal illuminance	70.5 lx	52.4 lx	86.4 lx	0.74	0.61

Fig: 4.27: DIALux report of the considered calculation area (Other side)

- Average illuminance: 70.5 lux
- Minimum illuminance: 52.4 lux
- Uniformity: 0.74

Result for observer: (For road :1 & 2)

A maintenance factor of 0.85 was used for calculating for the installation.

	Symbol	Calculated	Target
Roadway 2 (M4)	L_{av}	4.43 cd/m²	≥ 0.75 cd/m²
	U_o	0.62	≥ 0.40
	U_l	0.77	≥ 0.60
	$TI^{(3)}$	–	≤ 15 %
	R_{EI}	0.18	≥ 0.30
Roadway 1 (M4)	L_{av}	4.43 cd/m²	≥ 0.75 cd/m²
	U_o	0.64	≥ 0.40
	U_l	0.77	≥ 0.60
	$TI^{(3)}$	–	≤ 15 %
	R_{EI}	0.18	≥ 0.30

Fig:4.28: Observing results at a glance for car parking area

Design analysis of the entrance of the parking area:

The entrance area, as shown in fig:4.29, is considered is in the same way as for the main parking area. Total carriageway is taken into consideration that is 11 meters.

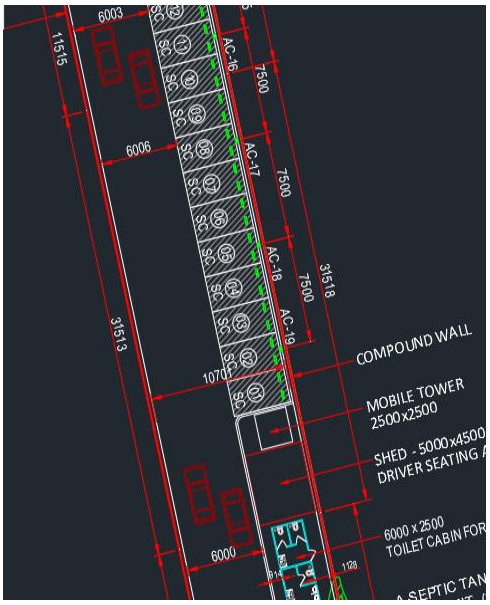


Fig:4.29: CAD layout of the Entrance area

Design summary:

The area illustrated in Figure 4.30,4.31, and 4.32, demonstrates the distribution of lux levels throughout the car parking area.

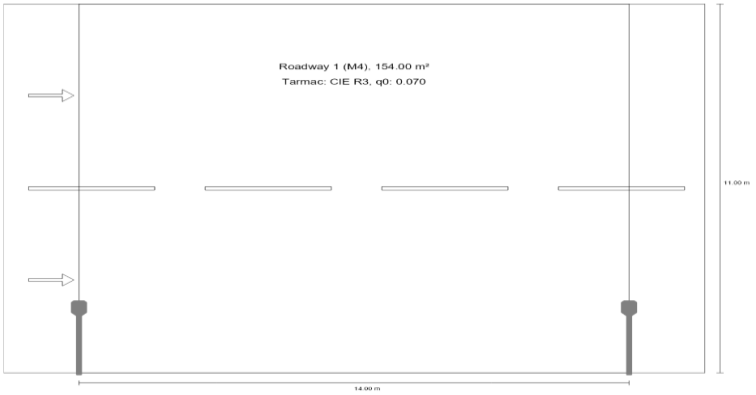


Fig: 4.30: Distance between two polls

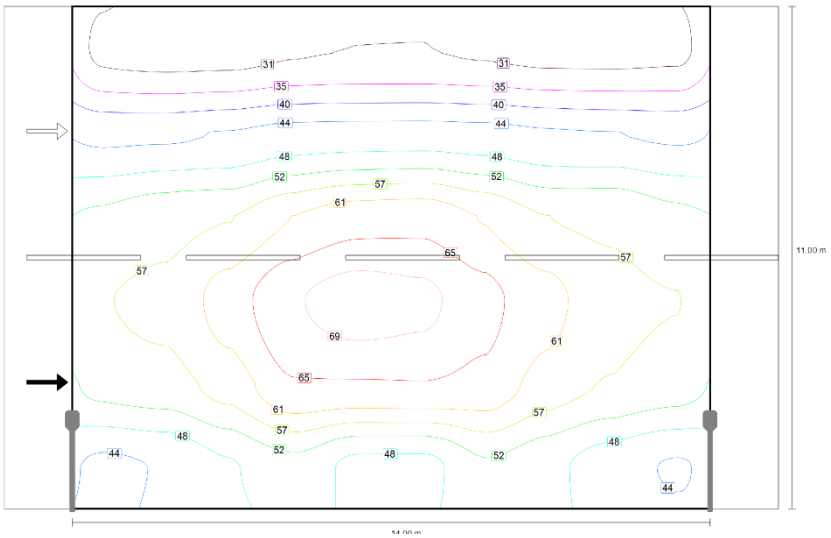


Fig:4.31: Isoline distribution of the considered calculation area (Entrance)

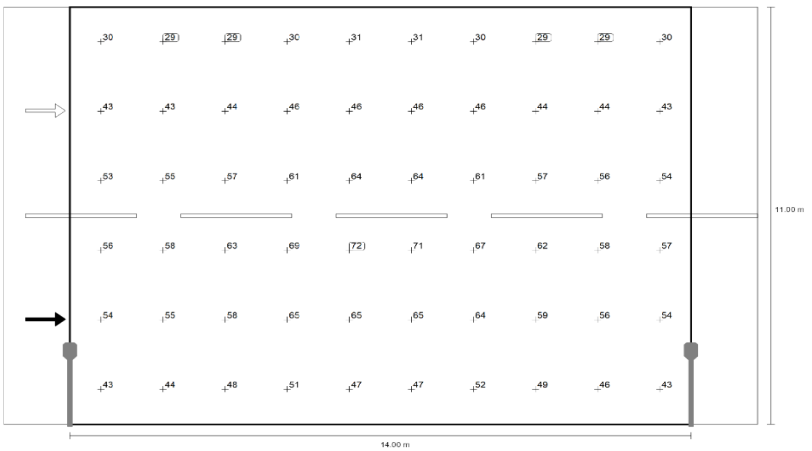


Fig:4.32: Value chart of the considered calculation area (Entrance)

Calculation results:

With the distance between poll of 14 meters, calculation, as shown in fig: 4.33, is done for the entrance pathway.

	E_{av}	E_{min}	E_{max}	U_o (g_1)	g_2
Maintenance value, horizontal illuminance	50.3 lx	28.8 lx	71.6 lx	0.57	0.40

Fig 4.33: DIALux report for the entrance area

- Average illuminance: 50.3 lux
- Minimum illuminance: 28.8 lux
- Uniformity: 0.57

Table: 4.1: **LPD values of the Outdoor design**

Types of Luminaire based design	**As per ECBC standard LPD values in W/m^2**	**Achieved LPD values in W/m^2**
High mast lighting	1.6	0.806
Street lighting design	1.6	0.907

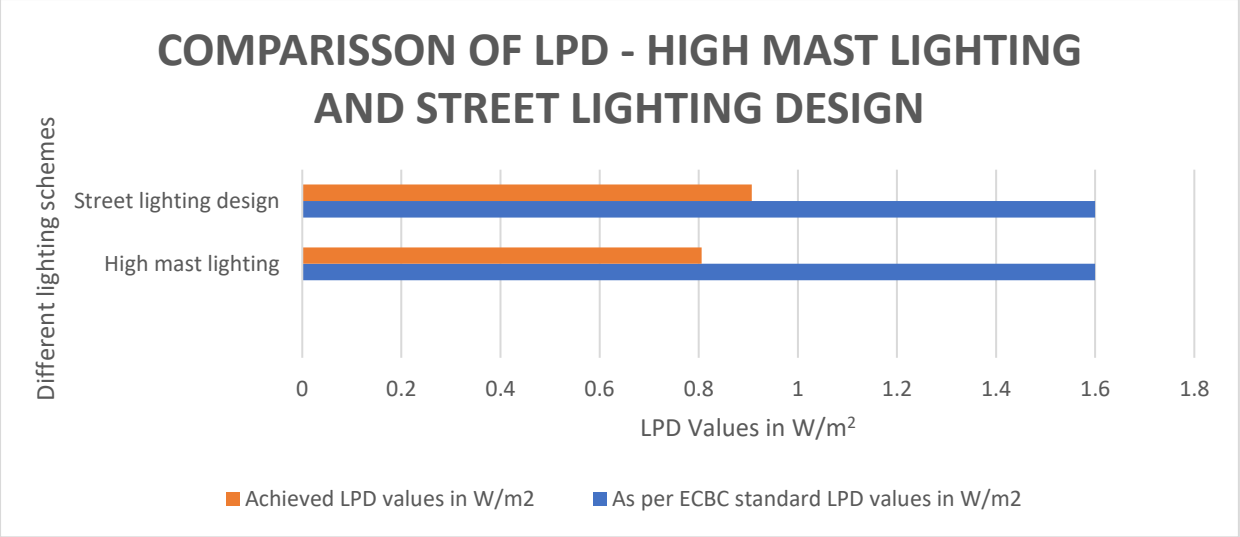


Fig: 4.34: Comparison of LPD - High mast lighting and Street Lighting Design

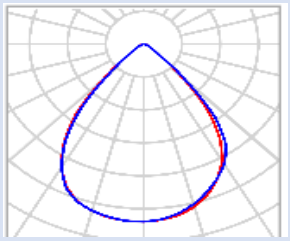
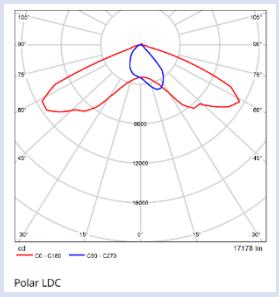
Observation:

1. Analysing the LPD across different lighting design schemes, as shown in the fig: 4.34 and: table:4.1, using various luminaires shows that the LPD values remain within the standard range of ECBC [21].

2. Both high mast lighting and street lighting have low LPD values, with the primary difference between them being the project cost which will be discussed later.

4.4 Comparative Analysis: High-Mast Lighting vs. Street Light Design for a Car Parking area

Sl.no	Characteristics	High mast Based Lighting Design	Street Light Based Lighting Design
1	Mounting Height	12 meters	7 meters
2	Quantity of Luminaires	16	15
3	Product Details	Goldmedal Insta 100W Floodlight (IP65)	Goldmedal City light 120W Streetlight (IP66)

4	Design Parameters	Eavg:66 lux Emin: 26.4 lux Uniformity: 0.4	Eavg: 70.4 Emin: 51 lux Uniformity: 0.51
5	Costing	Total no of pole(a): [₹100000 * 2] = ₹200000/- Total luminaire cost(b): [₹3500 * 16] = ₹56000/- **Total cost (a+b)** = ₹2,56,000/-	Total no of pole cost(c): [₹ 5850 * 15] = ₹ 87750 /- Total luminaire cost(d): [₹2500* 15] = ₹37500/- **Total cost (c+d)** = ₹1,25,250/-
6	Reference Picture of the Product for this Project		
7	Light Distribution Curve		
8	Conclusion	High-mast lighting presents itself as a good solution for achieving extensive illumination over vast distances while necessitating a restrained number of poles. However, when assessing the project's overall cost from the client's viewpoint, it becomes apparent that the expenses associated with this option tend to be elevated.	Street lighting stands out as an excellent option due to its efficient coverage of car parking areas. There exists potential for augmenting the number of poles for street lighting, with the added advantage of relatively lower costs per pole compared to alternative types.

Chapter 5:
Conclusion & Future scope

5.1 Conclusion:

This thesis work focuses on examining the processes and activities within both an architectural studio and office space, as well as the car parking area. The primary objective is to implement energy-efficient lighting solutions, ensuring maximum energy savings while maintaining compliance with all relevant standards. Emphasis is placed on achieving a high success rate across various areas. Additionally, careful consideration is given to the visualization aspect of all spaces throughout the process to ensure optimal outcomes.

The comprehensive study of the proposed designs presented in the preceding chapter underscores the potential for significant energy savings through the utilization of modern LED luminaires. Typically, the initial investment for installation or replacement is recouped within 6 to 7 years through reduced energy expenses.

By embracing energy-efficient lighting technologies and integrating intelligent lighting solutions (DALI system), considerable energy conservation can be realized within lighting design. Overall the study concludes a well and optimized design and its implementation throughout the process.

5.2 Future scope:

In the design shown in the previous chapters, all the luminaires used in the design, help in satisfying the illuminance criteria as per the IS 3646:1992. But in many areas, as directional luminaire is used as primary lighting, the average lux level is more or some cases less than the standard value. As a result, they fail to limit the lux level. So as per the standard suggesting that a more careful design of the luminaires should be considered so as to limit the standard lux level for each area.

However, a significant challenge emerges due to a lack of environmental awareness among specific societal groups, leading to excessive glare-causing lighting in various areas. As here, everything is done in accordance with the client's requirements, the work has been completed, with providing an optimized design. Consequently, a dimming system has been installed to reduce the excessive light intensity.

To mitigate glare, adjustments can be made to the intensity distribution of the luminaires, such as employing direct and indirect intensity distribution or using improved diffusers. This helps to minimize glare effectively. Similarly, achieving standard uniformity and lux levels with directional spot luminaires may require design modifications in the near future. Furthermore, in areas where the lux level exceeds the desired threshold, adjustments will be necessary.

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